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Methods and tools to support New Product Development tasks

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Even youths grow tired and weary, and young men stumble and fall; but those who hope in the Lord will renew their strength. They will soar on wings like eagles; they will run and not grow weary, they will walk and not be faint. (Isa 40:30-31)

I giovani si affaticano e si stancano; i più forti vacillano e cadono; ma quelli che sperano nel Signore acquistano nuove forze, si alzano a volo come aquile, corrono e non si stancano, camminano e non si affaticano. (Isa 40:30-31)

Summary

During the last decades a multitude of methods has been developed with the aim of supporting New Product Development tasks. Most of these approaches focus on the final steps of the design process aimed at improving technical solutions and detail aspects. However, a growing interest is also paid towards early phases that result crucial in determining the successful achievement of innovation initiatives.

The first phase of design process, generally known as Product Planning, allows analysing the reference market and planning a differentiation strategy capable to fulfil customer needs. New product and service ideas identified in this phase will be the driver for the following design tasks.

Despite its strategic role, a deep analysis of the literature shows that methods and tools developed to support such phase failed in pursuing this objective, since they only partially meet companies' needs. Starting from the evidences of this survey, the research activity performed in this doctorate was aimed at defining a method and a set of tools to effectively support Product Planning. The Thesis describes the developed approach and its implementation in various industrial fields.

The methodology is a systematic approach that supports all the activities of Product Planning, from information gathering up to the selection of a new product idea that will be developed in the following design phases. Two exemplary applications are described in order to clarify the application of the whole approach and four further tests have been carried out with the aim of assessing one of the original tool developed to support the idea generation task. All these experiments allow understanding the effectiveness of developed method and tools in different industrial sectors.

The contents are organized in 7 main Sections. Chapter 1 introduces the scientific context of the Thesis and describes the pursued methodological objectives. In Chapter 2 a critical review of literature tools and methods to support Product Planning and an analysis of companies' demands, is presented. Chapter 3 is dedicated to the description of the methodological proposal, by providing for each step of Product Planning the suitable (original and existing) tools to carry out that activity. Chapter 4 illustrates the application of the method to two case studies. Chapter 5 describes the experiments carried out in order to test an original tool developed to support the idea generation phase. In Chapter 6 discussions are presented about the effectiveness of original method and tools, the achievement of the methodological objective and possible future research activities that can be developed starting from the results obtained by this research. Eventually in Chapter 7 the conclusions are presented.

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Acronyms List

APS: Accessory Products and Services
BOS: Blue Ocean Strategy
B2B: Business-to-Business
B2C: Business-to-Customer
CAD: Computer-aided design
CEO: Chief Executive Officer
CRs: Customer Requirements
DIY: Do It Yourself
FFE: Fuzzy Front End
GDs: General Demands
HCI: Human-Computer Interaction
HF: Harmful function
ICT: Information and Communications Technology
LCs: Life Cycle phases
LCSO: Lifecycle System Operator
MS: Master Science
NPD: New Product Development
NVP: New Value Proposition
PCM: Profile Cost Matrix
PDM/PLM: Product Data Management/Product Lifecycle Management
QFD: Quality Function Deployment
RES: Resource
R&D: Research and Development
SAPPhIRE: State Action Part Phenomenon Input oRgan Effect
SHs: Stakeholders
SMEs: Small and Medium-sized Enterprises
SYS: System
TRIZ: Teoriya Resheniya Izobretatelskikh Zadach (Theory of Inventive Problem Solving)
UF: Useful function
VAM: Value Assessment Metrics
VI: Value Index
VoC: Voice of the Customers

Basic definitions

Design space: space of opportunities that can be potentially identified during New Product Development tasks.

Needs: customer requirements that have to be satisfied in order to generate satisfaction and potentially achieve market success.

Product attributes: existing, emerging or unspoken needs perceived by the customers and satisfied through the benefits generated by the product features. Attributes include tangible (e.g. quickness and speed in performing the functions, ergonomics, storability) or intangible (e.g. aesthetics, fun and adventure, ethics) characteristics of a product that generate value for the customer.

Product features: product engineering (technical) requirements.

Product Planning: first phase of the design process aimed at identifying new product attributes capable to fulfil customer expectations. One of the main outputs of Product Planning is the list of product requirements, which has to be taken into account in the subsequent design phases for defining, selecting and developing the most valuable technical solutions.

Product profiles: bundle of attributes associated with their matching offering levels to be transformed into an original product architecture.

Stakeholders: actors that interact with the product during its life cycle.

Systems: different levels of detail related to the product, from the external environment in which it is situated along its life cycle up to its parts, components and accessories.

Value: capability of designed product properties to engender customer satisfaction, satisfy needs and generate benefits for users. A value proposition strategy pursues the objective of differentiating the company's offer from the industrial standard, with the attempt of developing new products and services that enhance customer satisfaction through additional benefits and unprecedented experiences.

1 Introduction to the Thesis

This Chapter describes the context of the research with the aim of providing an overview of its scientific motivations and objectives.

Section 1.1 illustrates most diffused schemes of New Product Development (NPD) processes, focusing on the early phases that result crucial in achieving successful initiatives.

Section 1.2 contextualizes and analyses in depth the Product Planning phase within NPD cycles, as well as its activities and potentialities. In addition, the Section highlights the different definitions of the term “Product Planning” identified in literature.

Eventually, Section 1.3 highlights critical issues of the Product Planning phase and clarifies the objectives of the Thesis aimed at overcoming these limits.

1.1 Context of the research

The capability to innovate the commercial offer is becoming a key aspect for the survival of companies due to the high competitiveness of the market.

Among the tasks to be accomplished by an organization, design activities belonging to the NPD process undoubtedly represent an important ring in the value generation chain, which gives rise to successful products and services complying with customers’ expectations (Pahl and Beitz 2007). Therefore, firms should carefully analyse and continuously improve their NPD activities, in order to design something that will not only work from a technical point of view, but will also make business sense (e.g. Schilling 2008; Cantamessa et al. 2013).

Actually, several schemes of the product development process exist (e.g. Pahl and Beitz 2007; Shinno et al. 2006; Ulrich and Eppinger, 2011; Guo 2012); however, even though quite different terminologies are used, all of them can be represented through the overall model shown in Figure 1.1.

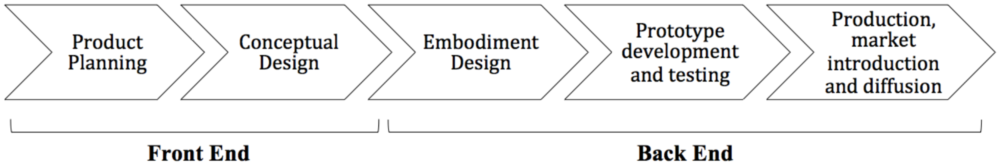

Figure 1.1 phases of the product development process

The first two phases of the product development process, i.e. Product Planning and Conceptual Design, generally constitute the so-called Front End. This initial part of the design process is often referred as "Fuzzy Front End" (FFE); the term has been first popularized by Smith and Reinertsen (1991). The adjective "fuzzy" has been attributed to Front End phases, because they typically involve random process and "ad hoc" decisions based on intuition, observations, discussions or accidents (Stasch et al. 1992; Montoya-Weiss and O'Driscoll 2000; Flint 2002).

Conceptual Design is acknowledged as a fundamental step towards the definition of original, novel and sustainable technical solutions (Al-Hakim et al. 2000). Product Planning consists in the identification of customer needs, the analysis of current lacks in the market and the definition of new product characteristics capable to fulfil customer expectations (Pahl and Beitz 2007). Therefore, the outcome of this phase constitutes the product idea on which the company will concentrate design efforts and resources (Montagna 2011). The research described in this Thesis focus on this first critical phase of the design process.

As shown in Figure 1, the Back End ranges from Embodiment Design to those activities oriented to the introduction of new artefacts in the marketplace.

A growing interest is paid towards those tasks that result crucial in determining the successful achievement of innovation initiatives. In this sense, the literature witnesses a significant role played by Front End activities (Kim and Wilemon 2002; Reid and de Brentani 2004; Riel et al. 2013). Indeed, several scholars highlight that a great percentage of product failures is ascribable to inefficient planning activities (Cooper 1999; Shinno and Hashizume 2002; Haig 2011). Moreover, Ulrich and Eppinger (2011) estimate that up to 80% of the forthcoming cost of a product is committed by the decisions undertaken in the initial phases, as well as, according to Achiche et al. (2013), expenditures for revising these decisions drastically increase as the product development process progresses. Furthermore, managers and researchers claim that improvements in the management of the Front End phases are capable to produce benefits far exceeding those resulting from enhancements concerning later stages (Zhang and Doll 2001).

The careful accomplishment of the activities at the beginning of design cycles strongly reduces problems in the subsequent product development tasks (Cagan and Vogel 2001; Flint 2002), drives revenues and increases firms' profitability (Dahl and Moreau 2002; Reid and de Brentani 2004; Alam 2006; Kahn 2011). In brief, well-managed initial design phases are the prerequisite for creating successful new products (Kim and Wilemon 2002; Ernst 2002; Guo 2012). However, despite some decades of research focused on NPD processes, those attempts have not obtained the expected results (Koen et al. 2001; Flint 2002; Soukhoroukova et al. 2012), especially from the viewpoint of introducing formal practices and methodologies in industry with the aim of guiding the fruitful execution of the whole product development cycle (Pahl and Beitz 2007). This situation is even more remarked for Product Planning: despite its strategic role, surveys about the most diffused and acknowledged design methods (e.g. Tomiyiama et al. 2009) highlight that a major attention is actually paid towards the final steps of NPD, aimed at improving technical solutions and detail aspects.

1.2 Insights about Product Planning

In the literature, the term "Product Planning" has been adopted to define different design activities. Some scholars (Lee et al. 2010; Li et al. 2012) affirm that the main activity of Product Planning is the translation of identified client wishes into product technical requirements, using the Quality Function Deployment, QFD (Akao 2004). Other authors claim that the main objectives of the Product Planning are the assessment and selection of alternative product concepts (Jetter and Sperry 2013). Kahn (2011) defines the Product Planning as the process of envisioning, conceptualizing, developing, producing, testing, commercializing, sustaining and disposing of organizational offerings, i.e. he considers the whole product life cycle. Besides these definitions, it is widely accepted (Shinno et al. 2006; Pahl and Beitz 2007) that the main objective of Product Planning is the identification of new product features capable to fulfil customer expectations, in order to exploit new market opportunities. With this meaning, one of the main outputs of Product Planning is the list of product requirements, which has to be taken into account in the subsequent design phases for defining, selecting and developing the most valuable technical solutions. Such a concept of Product Planning, which is the most popular, will be employed in the residual of the thesis.

By referring to customer expectations, Product Planning has to take into consideration the benefits generated by both physical goods and intangible services (Flint 2002; Alam 2006). For the sake of brevity, the term "product" will be diffusedly use the in this thesis for indicating any commercial offer or deliverable of industrial processes that includes characteristics pertaining to both products and services (thus physical artefacts, pure services, mixes of tangible products and related services). According to the needs satisfied by technical features they will be indicated in this manuscript with the term "product attributes". Hence, attributes can represent both tangible (e.g. quickness and speed in performing the functions, ergonomics, storability) and intangible (e.g. aesthetics, fun and adventure, ethics) characteristics of a product that generate value for the customer.

The main activities forming the Product Planning process are currently the generation of ideas about the new product to be developed and the subsequent selection of alternatives. Additional operations are sometimes included in Product Planning. Tables 1.1-1.3 present the reference literature sources devoted to discuss Product Planning, revealing the fundamental concepts about idea generation, idea selection and the other activities. More specifically, they present scholars' views (sometimes partially conflicting) on:

- the characteristics of, functions accomplished in and role played by idea generation (Table 1.1);
- the features and the effects of idea selection (Table 1.2);
- the additional activities to be performed within Product Planning (Table 1.3).

The idea generation, sometimes called Opportunity Identification stage (Cagan and Vogel 2001; Achiche et al. 2013), allows identifying attributes, features or general ideas of the product to be developed. For this reason, some scholars consider idea generation the basic task of Product Planning and a primary source of commercial success. However, many companies do not allocate sufficient resources to carry out this stage accurately, since it is perceived as a random process. As a result, even recent proposals about structuring the FFE disregard the ideation process; (Riel et al. 2013) is among the exceptions.

Idea generation usually gives rise to several options. Hence, this divergent activity must be followed by a convergent idea selection task (Rietzschel et al. 2006). The idea selection, named Opportunity Analysis stage in some sources (e.g. Koen et al. 2002), constitutes the decision-making phase of the Product Planning that allows choosing the alternatives to be further developed. Also this activity is supposed to be insufficiently supported.

The other activities, beyond idea generation and selection, play a not negligible role in the commencing stages of product development, by supporting the management of available resources. However, all these tasks are out of the scope of the present work, because they mostly concern the general management of innovation projects.

	Concepts about idea generation					
	Idea generation plays a key role in the NPD process	Creativity stimulation holds a high relevance in idea generation	There is a strong correlation between idea generation and commercial success	Not sufficient resources are allocated by companies to perform the idea generation accurately	Companies perceive idea generation as a random process	It is important to structure the ideation activity in the NPD process
Feldman and Page 1984				•		
Sowrey 1990				•		
Rochford 1991	•					
Stasch et al. 1992					•	
Ayers et al. 1997			•			
Ernst 2002			•			
McAdam and McClelland 2002		•				
Alam 2006	•			•	•	
Pahl and Beitz 2007					•	•
Riel et al. 2013	•					•

Table 1.1 literature sources discussing the characteristics, the role and the practices concerning idea generation

	Concepts about idea selection				
	Companies lack coherent or formal process for selecting ideas	Companies have difficulties to distinguish lucrative from poorly beneficial alternatives	Long time and vast human resources are currently dedicated to fulfil idea selection (due to the great number of ideas to be assessed)	Difficulties lie in assessing radical innovative ideas (due to greater uncertainties about potential market results)	There is a strong correlation between idea selection and commercial success
Johne and Snelson 1988				•	
Mishra et al. 1996				•	
Song and Perry 1996					•
Ayers et al. 1997					•
Ernst 2002					•
Rietzschel et al. 2006		•			
Toubia 2006			•		
Barczak et al. 2009	•				
Cascini 2012			•		
Soukhoroukova et al. 2012	•		•	•	

Table 1.2 literature sources discussing the role and the practices regarding idea selection

	Additional Product Planning activities			
	Monitoring the financial position of the company	Allocating resources and planning timing	Analysing existing and potential new technologies	Identifying legal regulations and patents
Verma and Fabrycky 1997				•
Shinno et al. 2006	•		•	
Agouridas et al. 2008				•
Gausemeier et al. 2009	•		•	
Montagna 2011	•	•	•	
Ulrich and Eppinger 2011		•	•	

Table 1.3 literature sources individuating additional activities to carry out Product Planning

1.3 Critical issues and research objectives

In order to understand the main critical issues of Product Planning, it is useful to consider the Front End of the product development process as a whole. Indeed, as shown in Section 1.1, several scholars and practitioners face Product Planning and Conceptual Design together, because these phases have much in common.

Many professionals and researchers do not judge FFE as a structured process because of its intrinsic fuzziness, ambiguity and uncertainty (Koen et al. 2001; Kim and Wilemon 2002; Alam 2006). This circumstance partially motivates the fact that many companies have neither adopted a structured approach to follow, nor do they entrust formal methodologies (Reid and de Brentani 2004; Achiche et al. 2013) but they carry out FFE through intuitive approaches (Shinno et al. 2006; Pahl and Beitz 2007). This fact is also confirmed by a recent survey, performed by the author's research group (see Chapter 2 for more details) with the aim of mapping enterprises' demands concerning Product Planning and identifying issues that limit the diffusion of existing methods in industrial environments.

On the contrary, a great number of organizations focus their attention on Back End activities, for which acknowledged methods are more diffused, by primarily aiming at reducing manufacturing errors. According to Cagan and Vogel (2001), this strategy is however hazardous, because the disregard of the FFE can lead to product failures or anyway to great expenditures for revising decisions, which dramatically increase as the design process progresses. Figure 1.2 illustrates this situation in a graphical way, by combining the representations included in (Kim and Wilemon 2002) and (Cousineau et al. 2004).

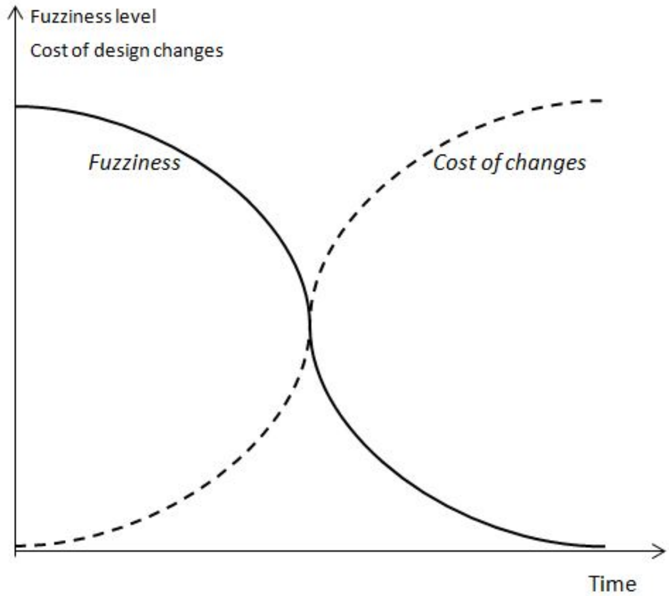

Figure 1.2 cost of changes vs. fuzziness in the NPD process

In order to reduce the "fuzziness" of early product development stages and contextually support design decisions in these phases, several scholars (Koen et al. 2001;

Cagan and Vogel 2001; Riel et al. 2013) developed formal and comprehensive procedures for supporting the Front End activities in a more systematic way. Proposals to better manage the FFE include organizing teams swivelling on FFE activities (Kim and Wilemon 2002), managing in different ways the fuzziness related to customers, technology and competitors (Zhang and Doll 2001), focusing on the available resources of the company (Achiche et al. 2013). Besides, ICT tools are claimed to speed up the commencing part of NPD processes, reduce costs, increase collaboration, improve decision quality and knowledge management, reduce risks and enhance overall creativity (Monteiro et al. 2010).

Notwithstanding a not negligible amount of contributions attempting to overcome uncertainties and ambiguities inherent to the FFE, the goal of effectively performing the ideation of new products and their implementation into technical solutions is still far from being reached. On the one hand, computer applications require additional and more specific empirical researches, because the benefits they should provide have not yet been rigorously studied (Hüsig and Kohn 2009; Monteiro et al. 2010). On the other hand, many suggested procedures explain the required activities to be performed, but lack to individuate appropriate tools for accomplishing FFE tasks, especially those pertaining to Product Planning. Promising strategies to manage the FFE have not yet received up to now ample evidence or currently require too much information to work correctly. In each case, the cited proposals have overall a poor orientation towards the products to be developed and the valuable characteristic to be fulfilled. In other words, many success factors of the product development process do not pertain to what is directly designed, manufactured and marketed.

In this sense, some scholars (Flint 2002; Alam 2006; Soukhoroukova et al. 2012) suggest that the FFE can become much less "fuzzy", if customers are involved in the initial stages of NPD. This thought is however not shared by other authors (e.g. Ulwick 2002), who argue that customers fundamentally focus on already fulfilled needs and consequently the opportunities potentially emerging from the exploration of new market domains get lost.

Besides, the studies about the management of the early stages of NPD cycles (Adams et al. 1998; Ramesh and Tiwana 1999; García et al. 2008) and the strategic positioning of development projects (Balachandra and Friar 1997; Henard and Szymanski 2001) have already brought to clear evidences. According to these sources, key aspects to achieve commercial success lie in internal collaboration between different units of the company, the attention dedicated to manifold organizational issues, trust in fostering cross-functional integration, R&D effectiveness, managers' experience.

On the contrary, few efforts have been devoted to analyse those activities that directly involve the product and its distinguishing features. In this perspective, major knowledge should be acquired about best practices and means for carrying out Product Planning. An effort in this sense can provide a key of reading with regards to the limited implementation of formalized Product Planning approaches and guide the development of new methods that overcome these limits.

With these premises, the objectives of the Thesis concern:

- investigation of current problems encountered by industrial subjects in these critical design activities;
- comparison of perceived needs of companies with respect to Product Planning activities and the benefits offered by techniques described in the literature;
- definition of requirements of an ideal approach to support Product Planning;
- development of an original method to effectively support firms during the whole Product Planning process.

The second Chapter of the Thesis provides an overview of methods and tools aimed at supporting designers during the Product Planning phase, shedding light on their strengths and weaknesses. In addition, Product Planning practices in the industrial context have been investigated in order to highlight industrial demands. Both surveys allowed eliciting requirements of an ideal Product Planning method and constraints for its implementation. Subsequently, the third Chapter illustrates an original approach to support Product Planning activities, developed according to the requirements identified in the previous phase. The fourth Chapter shows two illustrative applications of the method applied to real case studies. Chapter five illustrates further experiments performed to test an original tool developed to support the idea generation activity. The sixth Chapter presents an overall discussion about developed method and tools to support the planning of product innovation strategies. Eventually, seventh Chapter closes the Thesis by recalling the main achievements of the work and indicating future research opportunities.

2 Product Planning methods vs. industrial needs: requirements of an ideal approach

In this Chapter both methods proposed in the literature and current industrial practices have been analysed with the aim of identifying the requirements of an ideal Product Planning approach.

The research methodology can be schematized in the following steps:

1. state-of-the-art analysis of methods and tools dedicated to support Product Planning. This survey sheds light on strengths and weaknesses of the approaches available in literature and supports the identification of the main features currently offered by the proposed tools (Sections 2.1-2.3);
2. survey and analysis of the information gathered from a sample of firms, which have been interviewed and observed during the accomplishment of tasks ascribable to the Product Planning phase. This investigation allows understanding how these companies execute the idea generation and idea selection activities and highlights the needs that are currently satisfied or unfulfilled (Sections 2.4-2.7);
3. comparison of what is expected by the companies and what is offered by the literature to address the Product Planning phase (Section 2.8).

Eventually, Section 2.9 highlights requirements that an ideal Product Planning method should have and constraints for its implementation.

2.1 Literature review of Product Planning methods

Literature reviews have already been carried out dealing with several aspects of NPD tasks (Krishnan and Ulrich 2001; Ernst 2002; van Kleef et al. 2005). However, these works are not particularly recent or do not examine in detail the contributions intended to develop and choose product ideas. Therefore, the author decided to deepen the review of existing methods explicitly intended to support Product Planning with the specific aim of providing an overview about the main characteristic of existing approaches to perform idea generation and selection.

The criteria to perform the research are described in Section 2.2, which clarifies which results are considered relevant for the scopes of the survey. Section 2.3 introduces a general distinction among the various kinds of approaches to perform Product Planning, i.e. responsive and proactive (as widely accepted by the scientific arena) in addition to a new cluster (hybrid), which merges peculiarities of the former and the latter. With respect to said categorization, Subsections 2.3.1-2.3.4 describe the investigated methods and the way they support Product Planning activities by pointing out their main strengths and weaknesses, which emerge from literature sources or are inferred by the author as a result of clear evidences.

2.2 Research criteria

With the aim of deepening the literature survey about Product Planning, the author focused on its basic activities, i.e. idea generation and selection, which are more closely connected with intrinsic characteristics of innovative products. Thus, the review does not comprehend studies which emphasize the importance of the corporate image (e.g. Fombrun 1996), brands (e.g. Park et al. 1986), advertising (e.g. Drumwright 1996), retailing (e.g. Grewal et al. 2010), pricing (e.g. Nagle and Holden 1995). The review includes methodologies that support planning activities besides idea generation and selection, but just their contribution to the recalled basic tasks will be discussed. In addition, the author have not considered generic approaches for representing and monitoring the design process, e.g. Stage-Gate (Cooper 1990), or tools that support the management and the description of the outputs originating from the Product Planning, e.g. business model canvas (Osterwalder and Pigneur 2010), strategy canvas (Kim and Mauborgne 2005).

The analysis comprises formal methods, i.e. more or less systematic procedures, and software tools to support Product Planning. The scrutinized methods can be distinguished into those with an initial focus on general product ideas and approaches that consider customer requirements as a starting point for innovation initiatives. Product attributes can be subsequently articulated in order to create an innovative product profile, i.e. a bundle of attributes associated with their matching offering levels to be transformed into an original product architecture. Conversely, turning general product ideas into a list of product characteristics is extremely helpful into the subsequent design phases.

To be thorough, the survey has been limited to those methods that support the user in defining the list of competing factors (or in identifying the basic information to intuitively obtain it), which consequently allow carrying out product development cycles in the industrial practice. Such features include both current product characteristics and new attributes, commonly introduced to satisfy emerging or unspoken needs. In the remainder of the paper, the author will indicate with the term “latent needs” the complex of unprecedented customer requirements that are discovered, stimulated or aroused.

Furthermore, just contributions demonstrating the applicability of the proposed methods in industry or documenting real case studies have been considered for the scope of the research.

The literature search has been essentially oriented to literature sources within engineering design and more in general to innovation management, yet with a focus relevant for a discussion from an engineering design perspective. More in details, the survey has included different research sectors dealing with Product Planning and considered different jargons according to scholars’ field of expertise. Besides “Product Planning”, the main drivers for performing the research follow, indicating reference works that extensively use the matching terms:

- Fuzzy Front End (Guo 2012; Riel et al. 2013);
- New Product Development (Pahl and Beitz 2007; Ulrich and Eppinger 2011);
- New Value Proposition (Kim and Mauborgne 2005);

- customer needs and satisfaction analysis (Urban and Hauser 1993; Kano 1995);
- company general planning (Kahn 2011; Cooper 2011);
- product innovation (Cagan and Vogel 2001; Tripsas 2008);
- analysis of product success factors (Ayers et al. 1997; Ernst 2002);
- idea generation (Alam 2006; Soukhoroukova et al. 2012).

2.3 General approaches to perform Product Planning

It is well acknowledged that the key to achieve organizational goals is to be more effective and efficient than competitors in identifying and satisfying the needs of target markets (Narver et al. 2004; Kotler 2007), developing and delivering products that are valued by customers (e.g. Kim and Mauborgne 2005; Atuahene-Gima et al. 2005). According to this objective, two main categories of approaches can be identified in literature: responsive and proactive methodologies (Narver et al. 2004; Atuahene-Gima et al. 2005).

The former consider the industrial standard as a reference for identifying lacks in the offered product features and in the delivered performances. Responsive methods swivel on marketing surveys whose results are used as input information to define a new product idea. Hence, the task of pointing out desired improvements is almost entirely entrusted to the end user, who becomes the factual decision-maker. For this reason, the term "market (or demand) pull" is often used to define this kind of strategies (Schön 1967; Chidamber and Kon 1994; Brem and Voigt 2009; Di Stefano et al. 2012), while the innovation strategy implemented through these approaches is mainly based on the fulfilment of expressed needs. Therefore, the team in charge of the Product Planning task has to collect, analyse, interpret the customers expressed needs and translate them into product requirements. The marketing professionals typically manage the first three activities, whereas the fourth one is often delegated to designers.

Proactive methods attempt to capture unspoken wants of customers or even induce new needs for end users. They aim at developing product ideas radically different from the industrial standard. Therefore, these methods do not involve the end user in the investigation of the aspects that could represent potential innovation opportunities. Benchmarking analyses, usually performed by marketing experts, are used to analyse the market context, while the decisions about the definition and the selection of the most promising product ideas are totally in charge of design teams. This category of methods includes the so-called "technology push" strategies (Chidamber and Kon 1994; Rohrbeck et al. 2008; Brem and Voigt 2009; Di Stefano et al. 2012), in which emerging technologies can be exploited as driving forces for disruptive innovations (Wall et al. 2013). However, the use of a new technology is not generally sufficient to ensure the market success (Leinsdorff 1995; Flint 2002; Haig 2011). Therefore, a balanced R&D-marketing coordination is strongly recommended to carry out proactive approaches (Gupta et al. 1986; Leinsdorff 1995).

Besides the recalled typologies of methods, the survey proposed in this paper has revealed the existence of contributions that merge, as a matter of fact, peculiarities of both responsive and proactive approaches. They essentially try to discover and fulfil customers' latent needs by involving the end users of the product or recipients of the service in the idea generation process. Indeed, the users are asked to provide feedback about the new product ideas that are generated by the design team and/or collaborate in proposing new ones. Due to this evidence, the author decided to introduce a further category of contributions, named

"Hybrid", through which to classify all the methods that present both responsive and proactive characteristics.

The following Subsections 2.3.1-2.3.3 are articulated according to the distinction between responsive, proactive and hybrid methods. Each of them includes the description of the collected contributions and highlights their strengths and weaknesses. Eventually, Subsections 2.3.4 summarizes the main features of Product Planning strategies.

2.3.1 Responsive Methods

Responsive methods focus on the analysis of the Voice of the Customers (VoC), which is generally taken through questionnaire surveys. Many scholars (Anderson et al. 1992; Urban and Hauser 1993; Woodruff and Gardial 1996; Bruce and Cooper 2000; Cagan and Vogel 2001; Kärkkäinen et al. 2001; Kärkkäinen and Elfvengren 2002; Whyte et al. 2003; Agouridas et al. 2008; Cooper 2011; Ulrich and Eppinger 2011) claim that bringing the VoC into an organization is a key process of the Front End of product development. In this context, the main efforts of the scientific community are devoted to the development of data analysis tools aimed at supporting the identification of the main customer preferences. The survey allowed to identified several methods based on responsive Product Planning strategies (Reynolds and Gutman 1988; Anderson et al. 1992; Woodruff and Gardial 1996; Woodruff, 1997; Flint 2002; Kotler 2007; Ulrich and Eppinger 2011), but, according to the criteria described in Section 2.2, a subgroup of contributions has been chosen as a sample to be analysed in detail within the scope of the present review. More explicitly, the examined contributions include non-trivial VoC surveys providing indications about the product requirements to be fulfilled with the highest priority. The surveyed proposals include the original Kano model and its developments, as well as some representative decision support tools, which match customer opinions and other factors to select the most beneficial product characteristics.

Kano model (Kano et al. 1984) is a well-known tool, which constitutes the core of several methodologies extensively applied in different industrial contexts (Matzler and Hinterhuber 1998; Tan and Shen 2000; Nilsson-Witell and Fundin 2005) and its developments still represent a hot topic, especially within Total Quality Management context (Luor et al. 2012). It allows analysing the relationship between the offering level of product attributes and the consequent customer satisfaction through the employment of ad-hoc questionnaires. The model provides an effective approach to help understanding the potentiality of each product attribute (Matzler and Hinterhuber 1998; Tan and Shen 2000) by emphasizing the asymmetric relationship between performance and perceived satisfaction and highlighting the different effects of poorly fulfilled customer requirements. In addition, Kano (2001) has explained the possible dynamics of the customer preferences, as widely discussed by Löfgren et al. (2011). By providing additional information about the transformations occurring to the perception of customer requirements, guidelines have been proposed to support the planning of new products. These emerging indications have been experimented by other scholars (Nilsson-Witell and Fundin 2005; Zhao and Dholakia 2009; Sakao, 2009). However the dynamics of the customer preferences can change according to the type of product (Nilsson-Witell and Fundin 2005), the market context (e.g. Japan, USA, China) and the customer experiences (Kano 2001), thus limiting the applicability of Kano model (Borgianni and Rotini 2013). Furthermore, whereas the theory and its developments contribute to stress which product attributes or features to invest on, a lack of Kano-based methodologies stands in the poor capability to help the individuation of new valuable product attributes.

Liberatore and Stylianou (1995), as well as Matsatsinis and Siskos (1999), have suggested a set of statistical tools to combine the inputs coming from customer surveys, market and financial analysis, expertise of internal personnel, in order to generate a list of the most beneficial product requirements. These instruments have been implemented in computer-aided systems and tested through an industrial case study in companies involved in flooring industry (Liberatore and Stylianou 1995) and agriculture (Matsatsinis and Siskos 1999). Even if a single test cannot constitute a proof of reliability and general applicability, the tool developed by Matsatsinis and Siskos (1999) seems to be ready-to-use in different industrial fields, because it uses a generic formulation that makes the approach adoptable for variegated products. Furthermore, it integrates a forecasting tool that supports the analysis of customer preferences dynamics. Such a characteristic results useful for responsive methods (Kärkkäinen et al. 2001) because customer surveys often involve time-consuming activities, thus customers' preferences can change in the meanwhile. The two methods need both marketing and technical competencies in order to respectively support the analysis of the VoC and the definition of product requirements. Their main strength concerns the competitors' analysis that provides the design team a clear market vision. On the other hand, the main weaknesses are related to the statistical analysis that requires significant data samples and subjective experts' opinions, viable to jeopardize the reliability of the results.

Chan and Ip (2011) have proposed a method that follows a different procedure, if compared to the previous contributions. The design team has to assess, on the basis of experience, the most beneficial product attributes and features for the end user. The emerged characteristics are submitted to several samples of potential end users to analyse the purchasing behaviour through questionnaires. Then, the obtained data are matched and the best set of product features is identified. This method provides also a forecasting analysis to take into account the dynamic behaviour of the customer preferences. The scholars applied the method in an industrial context (power tool industry) obtaining encouraging results. However, also in this case, a single test is not sufficient to fully assess its reliability. Furthermore, the considered approach shares some weaknesses with those previously cited, because it needs to collect and analyse significant data samples and requires subjective inputs. However, subjectivity issues are better managed, since the comparison among surveys can highlight the presence of incongruities.

Liao et al. (2008) have proposed an original method of data analysis that investigates the relationships among customer demands and product characteristics. The method analyses the outcomes of customer surveys including target information (e.g. gender, age, purchase habits) and customer preferences, expressed in terms of most interesting product features. The data are combined with the aim of identifying specific needs of groups of customers and developing appropriate offers to certain market segments. Therefore, this approach provides a complete picture of the customer demand, which can be used to support all decisions in the Product Planning phase. The scholars applied the method in cosmetics industry and claimed that their approach can be generalized and employed in different fields; however, no application is currently documented in other industrial contexts. In addition, also this method requires significant data samples in order to obtain reliable results.

Generally speaking, the improvements in the management and exploitation of customer surveys supports the thought of some researchers (e.g. Bonner 2005; Atuahene-Gima et al. 2005; Tsai et al. 2008), who claim that responsive approaches can reduce the level of uncertainty related to the market response towards new products ideas. The interest in monitoring the dynamics of consumers' tastes helps in overcoming an acknowledged lack of responsive methods, which are supposed to be characterized by their inability to capture the shifts in customer needs and market conditions (March 1991; Kärkkäinen et al. 2001; Narver et al. 2004; Atuahene-Gima et al. 2005). Indeed, it has to be noted that the execution of massive customer surveys requires a considerable amount of time for interviewing consumers and analysing data (see e.g. the resources committed by Liao et al. 2008). Besides representing a problem in the perspective of shortening the time-to-market, long times are supposed to alter customers' tastes and then to drastically reduce the validity of surveys, especially in the volatile markets of the 21st century (Chong and Chen 2010). On the other hand, the illustrated methods reflect the weaknesses that are generally attributed to responsive approaches. By entrusting customers' feedback, highly responsive firms may be unable to differentiate themselves from their competitors, due to the low interest in new knowledge and alternative development directions (Tsai et al. 2008). This can be considered a consequence of the fact that many organizations are not capable to gather important customer information, because they lack awareness of which kind of data result the most valuable, the required skills, formal processes to perform the surveys (Flint 2002). Eventually, responsive methods cannot provide useful aids to explore new features and market contexts, whose exploration is hindered by relying on customers' requests (Berthon et al. 1999; Christensen and Bower 1996; Hamel and Prahalad 1994; Ulwick 2002). Indeed, several authors (O'Conner 1998; Kärkkäinen et al. 2001; Flint 2002; Haig 2011) have argued that customers are not able to conceive the benefits of radically innovative products. Therefore, anticipating what customers will value cannot be achieved uniquely by gaining their preferences, experiences and goals (Flint and Mentzer 2000; Flint 2002).

2.3.2 Proactive Methods

Proactive methods support the development of breakthrough product ideas without involving the end user in the Product Planning phase. A growing body of research (Reinertsen 1999; Dahl and Moreau 2002; Montoya-Weiss and O'Driscoll 2000; Alam 2006) suggests the use of proactive strategies in the NPD to boost the chances of developing successful innovations. In this field, the scientific community has focused its main efforts on the development of tools supporting the analysis of the reference market and the discovery of the end users' latent needs. Proactive approaches, as those analysed in detail in the present Subsection, leverage individuals' creativity to generate superior value for customers.

Lateral thinking (De Bono 1968; 2010) is a well-known technique with a considerable diffusion in industrial contexts (Coates et al. 1997) that can support the generation of new product ideas. This approach, unlike logical "vertical" thinking, pushes individuals to think from different perspectives, overcoming their psychological inertia and generating as many new ideas as possible. Several methods and tools can be used to support this task, e.g. Mind Maps (e.g. Buzan and Buzan 1996; Hüsig and Kohn 2009), Delphi method (Linstone and Turoff 1975) and Six Thinking Hats (De Bono 2009). The last one can support idea selection too and it can even be used to make forecasting analysis (e.g. to support the analysis of customer preferences dynamics). The main weaknesses of lateral thinking stand in its low systematic level and inefficiency (Li et al. 2007). Indeed, the approach is considerably based on subjective inputs and random processes.

The Blue Ocean Strategy (BOS) fine-tuned by Kim and Mauborgne (2005) is a mind-set aimed at supporting NPD initiatives, which is observing a growing consensus in industry in the last years (Lindič et al. 2012). It provides thinking tools intended to discover possible radical modifications of current industrial standards. Starting from a benchmarking analysis, the designer identifies a new product profile by the application of guidelines empirically obtained through the careful analysis of past market successes. Unfortunately, although these tools seem to have a general validity, their reliability has still to be demonstrated. Moreover, the BOS toolkit offers only mere qualitative indications that are not sufficiently systematic to support the designer during the whole Product Planning process (Aspara et al. 2008).

In this sense, research has been conducted to facilitate the individuation of most promising design options, since methods swivelled on creativity can lead to a great quantity of ideas. Borgianni et al. (2013) developed selection criteria (named Value Assessment Metrics, VAM), obtained through the analysis of past market successes and failures. This tool can assess the success chances of a new product, according to the attributes and features that deviate from the market standard, as suggested for instance by the BOS. In order to illustrate the applicability of this method, the scholars show a theoretical case study on an innovative lipstick design and an industrial case study on a concealed hinge. Besides the claimed capability of selecting the most promising alternatives among a set of already conceived ideas, the proposed metrics need to be further validated.

Differently from previous proposals, Lee et al. (2010) have developed a procedure that supports all the basic activities of Product Planning. The method involves a design team striving to identify the potential user needs and product requirements through a scenario-based analysis. This practice aims at reflecting upon most likely product use scenarios and alternative future developments. Scenario-based techniques are already diffused in industrial environments as a means for identifying new products ideas, giving rise to satisfying results (Woodruff and Gardial 1996; Flint 2002; Kahn 2011). The following selection of the most profitable set of product attributes is performed according to a criterion based on a benefit-cost analysis. The proposal has been tested through an industrial case study (i.e. the development of a tangible user interface) obtaining good results. A remarkable limitation is constituted by the need of a large design team since the members have to confront each other during idea generation and selection to obtain reliable results.

Ultimately, although the individuation of the proper user factors to be considered in order to provide greater value remains an open issue (Boztepe 2007), efforts have been made to discern good from bad business opportunities. Anyway, the surveyed proposals diffusedly reflect the outcomes resulting from the analysis of proactive methods performed by Ulwick (2002), which shows how proactive approaches might guide the designer towards product ideas resulting too distant from customer preferences. As a matter of fact, many firms lack formal processes for anticipating unspoken customer needs (Flint 2002), making the employment of proactive strategies extremely hazardous. In addition, some scholars (Reid and de Brentani 2004; Soukhoroukova et al. 2012) claim that this kind of strategies, as opposed to responsive methodologies, are quite complex and produce radical innovations whose market results are markedly uncertain. Eventually, Levinthal and March (1993) claim that the overall expenditures occurring during proactive Product Planning are usually higher than tasks carried out through responsive practices.

2.3.3 Hybrid Methods

As previously claimed, hybrid methods merge characteristics of responsive and proactive approaches. These methods can involve the customer:

- in an active way, with the aim of collaborating in the generation of new product ideas;
- in a passive way, with the aim of obtaining preliminary judgments about new ideas.

The active involvement of the users represents a distinguishing factor of the well-known Brainstorming method, originally developed by Osborne (1953). This approach is extensively used in the industrial practice (Geschka 1996; Coates et al. 1997), because it can be easily and intuitively implemented, even if in most cases it is implemented in a naïve way, not fully aligned to the original Osborne's recommendations. A group constituted by end users, guided by a moderator, discusses about new product ideas. At the end of the procedure, the design team analyses the results and compares the collected ideas and their feasibility. Several practices and techniques to support brainstorming sessions have been experimented in several decades, e.g. Synectics (Gordon 1961), Brainwriting (VanGundy 1984), Mind Maps (Buzan and Buzan 1996), Bodystorming (Oulasvirta et al. 2003), and so on. However, companies often develop their own customized technique, according to their needs. Brainstorming can support, in principle, both the main Product Planning activities. Nevertheless, some authors (Simonton 2003; Rietzschel et al. 2006) highlight that brainstorming participants seem to be unable to distinguish valuable from poor ideas.

Osborne stressed the importance of focusing on the quantity rather than on the quality of the ideas, by claiming that the abundance of hints results in greater chances of achieving successful outcomes. However, too many alternatives create considerable problems in the selection phase and the scarce quality of the outputs can lead to not lucrative results. In addition, whereas Brainstorming advocates claim that such method is more effective than entrusting idea generation to a plurality of individuals working separately, other studies (Diehl and Stroebe, 1991; Rochford 1991; Furnham 2000; Rietzschel et al. 2006) assess that groups employing Brainstorming produce a smaller quantity of ideas (besides less feasible).

In the last years, several software tools to support brainstorming have been developed, as surveyed by Hüsig and Kohn (2009), giving rise to the so-called "electronic brainstorming" (Aiken et al. 1994). Some researchers (Nunamaker et al.1991; Cooper and Gallupe 1993; Rangaswamy and Lilien 1997) claim that these tools can improve both the efficiency of idea generation (e.g. number of ideas per participant) and the effectiveness of the ideas (e.g. ideas viable to be successfully implemented). According to (Valacich et al. 1994; Rangaswamy and Lilien 1997), the most advantageous strategy is allowing thinking groups to work together supported by electronic brainstorming, rather than collecting the ideas generated by single human-computer interactions.

The Lead user method, finalized by Von Hippel (1986; 2005), does not consider all the potential customers, but only pioneer users (lead users) of a product. Pioneers have spent more time in using the product with respect to the rest of the customers, hence they probably have experienced needs still latent for many potential clients (Kano 1995). Thus, the company has to identify the lead users, e.g. through Internet searches, and involve them in the Product Planning phase. Such users are asked about new potential product features or original product ideas. Von Hippel's method supports only the idea generation phase, is quite intuitive, but the results based on users' ideas might result unfeasible for the company.

A more systematic contribution is proposed by Büyüközkan and Feyzioğlu (2004), which exploits an Internet database to collect new product ideas within a specific industrial context. Ideas are then generated not only by company designers or product managers, but also by customers and employees. It can be observed that many organizations disregard the opportunity of consulting with employees (Van Dijk and Van den Ende 2002; Burt 2004; Soukhoroukova et al. 2012), although they are a free and quick source of ideas for the company (Bhide 1994). The developed database includes also an internal system where product managers can introduce proposals based on competitors' products and benchmarking reports. The selection of the most promising idea is supported by a computer-aided tool, which uses a historical database collecting successful and unsuccessful product cases and a set of company's constraints. The application of this approach to an industrial case study in a toy-manufacturing firm has demonstrated its capability to speed-up the Product Planning process. Moreover, the researchers claim that each type of firm can adopt this tool. Nevertheless, it is worth to notice that the proposed method can be employed only if a great number of new product ideas are stimulated, being it based on neural networks. Moreover, a great limitation of the approach lies in the inconsistent results generated without the availability of an updated historical database, as claimed by the same scholars.

Kansei Engineering (Nagamachi 1995) has been developed in order to obtain customers' inclinations about product alternative ideas, which are previously collected by designers who analyse existing artefacts and/or conceive new ones. The method allows studying the emotional reactions of the customers up against descriptions, images, prototypes of new or existing products, their components and features. The focal belief stands in the assumption that products need to evoke the right emotions within the user, to distinguish themselves from those of competitors. Customers are generally asked to assess the proposed product ideas through questionnaires, which permit therefore to reveal the most promising alternatives. Hence, the method foresees a passive, although custom, involvement of the end users. The usability of the approach is enforced by a systematic 4-step procedure (Schütte et al. 2004) that exploits Kansei Engineering capabilities. One of the advantages of Kansei consists in its general applicability, since it can be used for any product, service or component, as witnessed by a plurality of even recent employments in variegated industrial fields (e.g. Yang 2011; Oztekin et al. 2013). Expert systems and computer application implementing the principles of Kansei Engineering are likewise diffused (e.g. Zhai et al. 2009; Wang 2011). On the contrary, one of the main weaknesses is related to the development of the questionnaire, since it is very tricky to find the right expressions by which to render the customer emotional reactions. Furthermore, cultural factors can play a misleading role in turning emotions to be aroused into product requirements to be fulfilled (Hartono et al. 2012), as well as different peoples' mind-set and typologies of industries require adaptations of Kansei Engineering outside Asian countries (Barnes et al. 2010).

Chen and Yan (2008), as well as Kimita et al. (2009), illustrate methods that support the designer in the process of generation and selection of product and service ideas, benefitting of customer surveys. As in Kansei, the end users are passively involved in the planning phase and provide feedback about ideas developed by the designers, who attempt to hybridize existing products features and identify new and existing services attributes through a brainstorming session. In addition, the method developed by Chen and Yan (2008) can forecast customer preferences by performing a trend analysis of historical data that have been accumulated over time by means of user surveys. Both the proposed approaches can totally support the Product Planning phase. Anyway, Chen and Yan show only a theoretical case study on cellular phone design to illustrate its applicability, therefore the usability of the method has to be fully demonstrated. On the other hand, the method proposed by Kimita et al. (2009) had already been successfully tested a computer-aided tool (Arai and Shimomura 2004), analysing domestic in-flight services. Although they obtained encouraging results, the scholars affirm that in some cases the outcomes could not be considered reliable, due to the possible disregard of relevant services features. Thus, the idea generation phase should be supported by more systematic methods in order to obtain more reliable results.

The proliferation of interconnectivity and interactivity through Internet-based technologies has fostered the introduction of new methods that might support NPD (Dahan and Hauser 2002; Klein and Spiegel 2013) and especially the idea generation phase (Von Hippel 2005; Soukhoroukova et al. 2012). A common characteristic of these new methods is the use of distributed knowledge through the interconnection of ideas from a vast number of participants (Toubia 2006; Soukhoroukova et al. 2012). Among these proposals, Füller and Matzler (2007) have demonstrated the key role of virtual interaction tools that allow companies to gain valuable input from customers about new product ideas. The scholars illustrate the exploitation of Internet capabilities to support Product Planning in an industrial application. The users are asked to assess and modify, according to their needs and creativity, new product general ideas, or product features developed by designers. This process is iterative and the cycle terminates with a feasible product idea that meets customer needs. The novelty of this method, compared to conventional market surveys analyses, is that customers are not only asked about their opinions, wants and needs. Indeed, they are invited to contribute to the real development of the product, adding value to all stages of the innovation process, as claimed by Füller and Matzler (2007). However, the development of the Internet platform and the interaction with customers involve a great amount of time and resources and, likely, just big enterprises own the capabilities to use this tool. Furthermore, this method implicates issues about the secrecy of NPD projects (due to the easy access to many Internet sources), so that competitors can take advantages from the obtained information.

One of the new frontiers in hybrid methods concerns the identification of customer latent needs analysing end users' psychological responses through the use of brain scanning and other technologies for measuring physical activities (Lindstrom 2008). However, these noteworthy techniques cannot be considered still thoroughly reliable, due to their very early stage of development.

Ultimately, the presented analysis highlights that hybrid methods merge together not only the positive aspects of both proactive and responsive strategies but, sometimes, also their disadvantages.

2.3.4 A brief recap of main Product Planning strategies

Each category of methods and tools that support Product Planning shares several pros and cons, as summarized in Table 2.1. On the one hand, responsive methods support the development of products that fulfil expected customer needs, reducing the uncertainty related to the market response. Consequently, these approaches are not suitable to support NPD initiatives aimed at breaking up the competition, as they do not take into account the exploration of new market domains. On the other hand, proactive methods are potentially capable to support the development of breakthrough products, since the search of new product ideas is performed by leveraging the creativity of designers and manifold sources of information, which however do not include customers' opinions. Potential consumers are indeed supposed to direct innovation processes towards products slightly differing from the existing commercial offer, being not capable to conceive new needs to be satisfied.

Nevertheless, proactive methods result much less reliable than responsive approaches since the risk of developing products too distant from customer expectations and/or unfeasible is high. Eventually, hybrid methods can support the development of innovative products with a low level of market uncertainty, because they involve the customer in the Product Planning phase, but they generally require a great amount of time to obtain reliable results.

	Pros	Cons
Responsive Methods	• Low level of uncertainty related to the market response towards new products ideas.	• Hindered exploration of new market domains; • Inability to adapt quickly to shifts in customer needs and market conditions; • Great amount of time and resources required, in order to obtain reliable results.
Proactive Methods	• Supported development of breakthrough products with unique benefits.	• Product ideas resulting too distant from customer preferences; • High level of risk and uncertainty due to the absence of customer feedback.
Hybrid Methods	• Supported development of innovative products with a low level of uncertainty related to customer feedback.	• Great amount of time and resources required in order to obtain reliable results.

Table 2.1 pros and cons of responsive, proactive and hybrid methods for Product Planning

2.4 Investigation of Product Planning practices in the industrial context

Despite the supposed relevance of initial design stages, the reasons of the scarce implementation of Product Planning tools in the industry are poorly analysed, as well as not much is documented about the ways enterprises carry out this task in reality. With respect to such an issue, literature sources just report some insights about the organization and the execution of NPD early stages. In brief, it is claimed that:

- Product Planning activities are commonly carried out by multidisciplinary teams constituted by marketing and technical experts (Pahl and Beitz 2007); however, recent investigations show how the specific industrial sector heavily influences the kinds of expertise employed for ideation activities (Eckert et al. 2014);
- whereas technicians and marketing experts cooperate in the Product Planning tasks, such interaction results problematic due to different mind-sets (Song et al. 1998; Leenders and Wierenga 2002);
- marketing teams own the main responsibilities in identifying the business opportunities to pursue and the core competing factors of new products (Krishnan and Ulrich 2001).

As an evidence, available information results too scarce and insufficiently reliable to understand the implementation problems of Product Planning methods. In this sense, the author's research team opted to obtain additional information by investigating Product Planning practices in firms available to share such a kind of information.

In order to perform this survey, a "sample of convenience" constituted by six companies has been identified. The quantity of involved firms is clearly insufficient to draw statistically significant conclusions about the difficulties encountered by organizations during Product Planning. Nor the sample can be considered representative of the variety of enterprises, which can potentially benefit of methods and tools for Product Planning. In compliance with the available resources of the research group, three main reasons motivate the choice of analysing in-depth few companies, rather than obtaining basic information from a greater number of firms:

- a detailed (and consequently time consuming) analysis of a focus group of enterprises can provide more valuable results if compared with quick questionnaires administered to a large sample of industrial subjects, as inferable from the discussion about investigation methods included in (Ulrich and Eppinger 2011);
- companies often highlight their strengths and hide their weaknesses (Bell 2008), therefore the use of questionnaires without interacting with the firms and/or observing how they act can provide unreliable results;
- the relationship of trust with the selected firms, due to frequent partnerships with author's research team, is supposed to provide a good understanding about their point of view with respect to Product Planning, as well as the actual strengths and weaknesses of their strategies. Other industrial partners have been not included in the investigation, because of their lack of autonomy in undertaking decisions concerning the FFE, minor degree of mutual trust, supposed hurdles in sharing the intended concept of Product Planning due to fully unstructured and rather haphazard design processes. The lower reliability of the outcomes provided by other companies, although available to participate to the survey, could potentially lead to misleading conclusions.

Despite the limited number of participants, the firms are characterized by a huge variety (see Table 2.2) in terms of:

- industrial sectors: from traditional mechanics to electronic products and ICT;
- the reference market: from mass market products to niches;
- the size of the firms: from few tens of employees (companies 1,2, 3 and 5 are SMEs) up to branches of multinational corporations (firms 4 and 6);
- the level of the turnover: from few to thousands of Mio. Euros.

Besides, all the involved enterprises have developed large market networks that allow them selling their products worldwide; as a result, they have matured a wide vision about threats of opportunities in their industrial sector. With respect to the recalled variety and the entrepreneurial capabilities of the involved industrial subjects, the author believes that the survey can disclose a first set of not negligible needs concerning Product Planning practices. In other words, although an exhaustive sample of firms' desiderata cannot be extracted, it is deemed that the emerged pressing needs are shared with many other companies.

	Industrial field	Turnover (about)	European classification according to the number of employees	Business strategy (B2B = business to business; B2C = business to customer)
Company 1	Electronic systems	3 Mio. €	Small Enterprise	B2B
Company 2	ICT	3 Mio. €	Medium Enterprise	B2B
Company 3	Audio systems	30 Mio. €	Medium Enterprise	B2B/B2C
Company 4	System providers for food and energy processes	5000 Mio. €	Big Enterprise	B2B
Company 5	Glass System Technology	5 Mio. €	Small Enterprise	B2B/B2C
Company 6	Powered appliances for kitchen, cleaning and outdoor use	15000 Mio. €	Big Enterprise	B2C

Table 2.2 main features of interviewed companies

The research approach and surveyed basic aspects are described in Section 2.5. Section 2.6 briefly illustrates methods used in these companies in order to carry out Product Planning processes. Eventually, Section 2.7 resumes main results obtained through firms' analysis.

2.5 Research approach

The survey has been conducted starting with an interview driven by a questionnaire (see Appendix D.4), but intentionally left open to digressions and examples. Furthermore, Product Planning activities have been directly observed. The first task allowed understanding companies' strategies and their basic needs in this design phase. The second activity examined in-depth actual demands, observing strengths and weaknesses of the Product Planning processes.

More in details, the survey allowed disclosing the following basic aspects:

- frequency and attributed importance of Product Planning activities;
- repeatability and systematic level of companies' implemented approaches;
- satisfaction level concerning the used methods;
- firms' knowledge of literature methods and their implementation weaknesses;
- main features that idea generation and idea selection activities should have according to companies' view point;
- hurdles in implementing Product Planning methods developed in the academic world, still according to firms' point of view.

The information described in next Sections, which originates from the industrial investigation, is illustrated without making reference to its extrapolation from the questionnaires or direct observations of the author's research team.

2.6 Brief description of surveyed companies' Product Planning approaches

In company 1, the Product Planning phase is entrusted to a multidisciplinary innovation team, specifically devoted to manage this task. At first, the team analyses customer needs, identified through social networks, Internet portals, industry trade fairs and professional associations. At the same time, the team pays a considerable attention to new emerging technologies. Both market and technical information is collected and examined through a software tool. After idea generation, the most promising product development option is selected according to team's experience and company available resources (assets and know-how). Eventually, the company drafts a document, namely *business model*, which summarizes the new idea, the required technologies and includes a market analysis.

Unlike the previous firm, company 2 involves all the employees in Product Planning phase. Indeed, managers think that rigid organizational structures (e.g. teams or departments) could limit the identification of new business opportunities. With the aim of identifying new product and service ideas, the company exploits a wide sample of approaches tailored to its industrial field. The participation to the idea generation task is stimulated through brainstorming sessions, company inner contests and thematic workshops. The identified ideas are than tested and improved through virtual interaction tools (Internet platforms) that allow the company gaining valuable feedbacks from potential customers. The ideas are subsequently improved and selected according to customer preferences; eventually, they are structured through the *business model canvas* (Osterwalder and Pigneur 2010). This tool is a visual chart through which the firm describes its new offer, the resources required for the development of the idea and the potential customers. The final version of the document represents then the output of the Product Planning phase.

In the company 3, the Product Planning is entrusted just to the technical department. The engineers identify the main opportunities through the analysis of the VoC and try to satisfy emerging requirements, by implementing the desired features into new products. Even if the firm understands that such a kind of strategy cannot bring to breakthrough products, it deliberately opts for an approach that reduces the risks of failure. In addition, the company owns a group of loyal customers and it is less affected by the competition, due to the seeded trust.

Company 4 is a large enterprise with several divisions in Europe and it organizes inner innovation contests in order to collect new product ideas from all local groups and then select the most promising ones. The innovation teams use a technology push strategy, primarily based on patent analysis, in order to support the idea generation phase. In addition, they perform benchmarking analyses and study customer preferences dynamics with the aim of supervising competitors' offers and trying to anticipate future consumers' needs. The central European board of managers selects the best ideas according to the expected development costs and efficiency of new products. Hence, the winning team receives the financial resources to finalize the design of the proposed idea.

In company 5, the engineers identify new product ideas through industry trade fairs, web searches and primarily from the VoC (customers, suppliers and contractors). In addition, they carry out extensive analyses of competitors and patents, in order to deepen the knowledge of the reference industry. On the other hand, the idea selection phase is mainly entrusted to the CEO and it is based on expected product development costs and his experience. Throughout the Product Planning phase, the firm makes frequent meetings to assess partial results. Although this activity slows down the design process, the firm prefers to minimize risks of failure.

Eventually, company 6 manages the Product Planning phase with a market driven Stage-Gate approach (Cooper 1990). The idea generation activity, namely opportunity assessment phase, is entrusted to market analysts that study customer behaviour and trends of preferences. In addition, marketing experts benchmark competitors' products, by monitoring sales, features and performances. Hence, the identified opportunities are compared with competitors' deliverables in order to select a subgroup of promising innovative ideas. Eventually, the company develops prototypes and tests them with a sample of potential customers. If a product obtains positive feedbacks, its development will be completed.

All these approaches show distinguishing traits of identified Product Planning strategies. Indeed, companies 3 and 5 implement responsive strategies primarily based on the fulfilment of explicit user needs, enterprises 1 and 4 essentially use proactive (technology push) approaches and the residual firms implement hybrid procedures that involve the customer in the idea selection phase (as resumed in Table 2.3).

Company	Product Planning strategy	Kind of approach
Company 1	General approach based on the VoC	Responsive
Company 2	Virtual interaction	Hybrid
Company 3	General approach based on the VoC	Responsive
Company 4	Scenario technique	Proactive
Company 5	General approach based on the VoC	Responsive
Company 6	Scenario technique and selection approach similar to Kansei	Hybrid

Table 2.3 approaches used by analysed companies

2.7 Main results of companies' survey

The performed survey partially confirms the generally shared vision in the literature that Product Planning is often entrusted to intuition and experience of few decision makers. However, the author's research team also identified several attempts of the companies to reduce managers' discretion (e.g. through customer surveys or customer preferences analysis). The research confirms that, in larger companies, the tasks are commonly supported by conjoint activities involving multidisciplinary teams, as recommended also by Pahl and Beitz (2007). However, interviewed SMEs use this synergic strategy too. Indeed, it is useful for both types of enterprises to take customer needs and technological capabilities into sufficient consideration, even in the early stages of the innovation process, as suggested by Rubenstein (1994), so that they can minimize both uncertainties about market results and problems related to the technical feasibility of products.

The problem raised in (Song et al. 1998; Leenders and Wierenga 2002) concerning difficulties in interfacing technical and market experts have been not observed in the surveyed enterprises. In addition, the survey has not highlighted the propensity of entrusting marketing teams the main responsibilities concerning the identification of business opportunities to pursue and the core competing factors of new products, as pointed out by Krishnan and Ulrich (2001). Indeed, technical experts are always involved in these activities. This aspect deserves to be deepened, since it could mean a growth of competencies of engineers involved in the FFE of NPD cycles, a shift of responsibilities over time from marketing departments to technical units, or, otherwise, the sample of the survey could result heavily biased in terms of the strong technological orientation of the investigated industrial fields.

Eventually, although it is widely acknowledged in the literature that companies allocate many more resources to perform Back End activities of the design process, just two interviewed SMEs clearly confirmed this general tendency.

As shown in Table 2.4 most of the surveyed companies are not very enthusiast of their current Product Planning approach and they are quite inclined to test new approaches, even if they do not know further methods. However, the survey highlighted organizational constraints that imply difficulty to introduce modifications of the current approach because of well-established organizational structures.

Company	Level of satisfaction for the used approach	Knowledge of literature methods	Inclination to test new approaches	Ease of introducing new approaches in the firm (structural limits)
Company 1	Medium	No	Medium	Medium
Company 2	Low	No	High	High
Company 3	Low	No	Medium	Low
Company 4	Medium	No	Medium	Medium
Company 5	High	No	Low	Low
Company 6	Medium	No	Medium	Low

Table 2.4 summary of some basic results emerging from companies' survey

The most pressing exigencies related to Product Planning activities expressed by at least half of the surveyed firms (as shown in Table 2.5) are:

1. *Quickness and easiness of the method/tool*: easy, quick and intuitive methods reduce the companies' committed resources;
2. *Development of computer applications*: those methods that have been implemented in a computer-aided tool accelerate and make easier the Product Planning phase;
3. *Effective support in the individuation of latent needs*: the discovery and fulfilment of latent needs supports the development of breakthrough products and allows avoiding head-to-head competition;
4. *Integrated competitors' analysis*: the analysis of the reference industry can help to individuate the competition factors and to seek a differentiation strategy;
5. *Consideration of customer preferences dynamics*: those methods that consider the variations in the time of the customers' preferences and tastes support the development of the right offer at the right time. Indeed, it can happen that long NPD cycles determine the market launch of products that are not valued anymore by customers, due to alterations of priority needs to be fulfilled;

6. *Reliability of the approach*: Product Planning methods are considered reliable, whereas, regardless their way of functioning, many practical implementations are documented leading to successful new products. The repeatability of positive outcomes within different industrial sectors has to be considered as an extreme demonstration of methods' reliability;
7. *Support in selecting the most beneficial product idea*: it is fundamental to support the last decision-making phase of the Product Planning, because it evaluates which product idea has the greatest chances to be turned into a potential market success;
8. *Independence from inputs subjectivity*: it refers to the limited employment of personal judgments or uncertain inputs, which can alter the final results of the Product Planning. Such feature influences to a considerable extent the robustness and repeatability of the method or tool;
9. *Possibility of involving customers in the Product Planning activities*: this need is strictly related to the possibility of minimizing the risks related to the development of new products.
10. *Possibility of entrusting the Product Planning phase to multidisciplinary teams*: this demand starts with the assumption that multidisciplinary teams can provide more point of views, supporting the development of innovative products.
11. *Possibility of formally schematizing the identified ideas*: this need is related to the demand of formalizing, saving and sharing generated ideas.

Companies needs	**Firm 1**	**Firm 2**	**Firm 3**	**Firm 4**	**Firm 5**	**Firm 6**
1. Quickness and easiness of the method/tool	•	•	•	•	•	
2. Use of computer applications	•	•		•	•	
3. Effective support in the individuation of latent needs	•	•				•
4. Integrated competitors' analysis	•	•		•	•	•
5. Consideration of customer preferences dynamics	•	•		•		•
6. Reliability of the approach			•	•	•	•
7. Support in selecting the most beneficial product idea		•		•		•
8. Independence from inputs subjectivity	•	•		•		•
9. Possibility of actively involving customers in the Product Planning activities		•	•	•	•	•
10. Possibility of entrusting the Product Planning phase to multidisciplinary teams	•			•	•	
11. Possibility of formally schematizing the identified ideas	•	•			•	

Table 2.5 companies' shared needs during Product Planning activities

This set of diffused companies' needs together with further features identified through literature review have been used to compare what industrial subjects demand and what literature methods claim. This analysis will be described in the next Section.

2.8 Obtained results vs. problems claimed in the literature

Besides shared companies' demands, collected in the previous Section, literature review allowed to identify two further features that distinguish existing methods:

12. *Initial focus on products attributes*: customer requirements are the starting point for innovation initiatives. In this case, product attributes can be subsequently articulated in order to create an innovative product profile;
13. *Initial focus on general product ideas*: general product ideas will be later turned into a list of product characteristics. This is extremely helpful into the subsequent design phases. The capability of framing a general product idea from the very beginning of the design process avoids the need to reconcile single and potentially conflicting customer requirements.

The identified set of 13 features has been used to compare literature-reviewed methods. The author used the information provided by the scholars and/or further indications achievable from the literature in order to classify the approaches. Table 2.6 shows the comparison among the reference methods and tools, indicating their reference to responsive, proactive and hybrid approaches. The assigned names of the properties are not reported, but the numeration of list is exploited. A trivial dichotomous system (i.e. yes/no) is insufficient to describe all the methods according to each property, because, in some circumstances, the surveyed contributions fulfil just partially certain requirements. The superscripts in the cells of Table 2.6 clarify not straightforward association of the properties to the methods and add further details; they have to be read as follows:

1) the information has been extrapolated, by considering potentially time-consuming activities such as the collection of customer/stakeholders interviews and the elaboration of the extracted data;
2) the instrument is not readily usable if historic information is not available; using it from the beginning requires customer interviews conducted in different years;
3) creative sessions using these tools can have very different durations;
4) the method requires potentially long-lasting iteration cycles due to multiple interactions between the company and its customer;
5) elucidated attractive customer requirements can be considered as uncovered latent needs;
6) lead users are expected to individuate latent needs also with respect to other customers' wants;
7) the number of practical case studies reported in the literature cannot be considered sufficient to infer a significant reliability of the methods across various industrial domains; some methods suffer from a development performed outside of the industrial environment and subsequent adaptations to face companies' challenges;
8) subjective inputs are required, but the use of statistical instruments allows estimating which evaluations can be considered sufficiently reliable.

Kind of approach	Methodology	Property #												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Responsive	DSS for Customer Satisfaction Assessment	N	Y	N	Y	N	P[7]	Y	P[8]	N	N	N	Y	N
	SW for Marketing Surveys Analysis	N[1]	Y	N	Y	Y	P[7]	Y	P[8]	N	N	N	Y	N
	DSS based on Experts and Customer Surveys	N	Y	N	N	Y	P[7]	Y	P[8]	N	N	N	Y	N
	Marketing Survey with Persona Model	N[1]	Y	N	N	N	P[7]	Y	P[8]	N	N	N	Y	Y
	Kano Model (classic)	N[1]	N	Y[5]	N	N	P[7]	Y	P[8]	N	N	N	Y	N
	Kano Model Evolution	N[2]	N	Y[5]	N	Y	P[7]	Y	P[8]	N	N	N	Y	N
Proactive	Scenario model	P[3]	N	Y	N	N	P[7]	Y	N	N	Y	N	Y	N
	Blue Ocean Strategy	P[3]	N	Y	Y	N	P[7]	N	N	N	N	Y	Y	N
	Lateral thinking	Y	Y	Y	N	N	N	Y	N	N	Y	N	Y	Y
	Value Assessment Metric	Y	N	Y	Y	N	P[7]	Y	Y	N	N	N	Y	N
Hybrid	Brainstorming	Y	Y	Y	N	N	N	N	N	Y	Y	N	Y	Y
	Lead Users Method	Y	N	Y[6]	N	N	N	N	N	Y	N	N	Y	Y
	Selection from New Product Ideas Database	N[1]	Y	Y	Y	N	N	Y	N	Y	N	N	N	Y
	Kansei Engineering	N	Y	Y	N	N	P[7]	Y	P[8]	Y	N	N	Y	Y
	System for product conceptualization and customer surveys	N	N	N	N	Y	P[7]	Y	P[8]	Y	Y	N	Y	N
	Customer value model for service design	N[1]	N	Y	N	N	P[7]	Y	P[8]	Y	Y	N	Y	N
	Virtual Customer Integration	N[4]	Y	Y	N	Y	P[7]	Y	P[8]	Y	N	N	Y	Y

Table 2.6 comparison of the collected methods according to the distinguishing properties of Product Planning tools. Superscripts refer to the explanations of the assigned judgments. The labels Y, N and P stand for Yes, No and Partially, respectively

Figure 2.1 provides a quick view of obtained results. Approaches that can not or only partially satisfy ideal properties have been summed up. Features have been sorted in decreasing order of number of methods that can not support and/or only partially satisfy ideal properties, in order to highlight the main gap that should be filled to support the Product Planning phase.

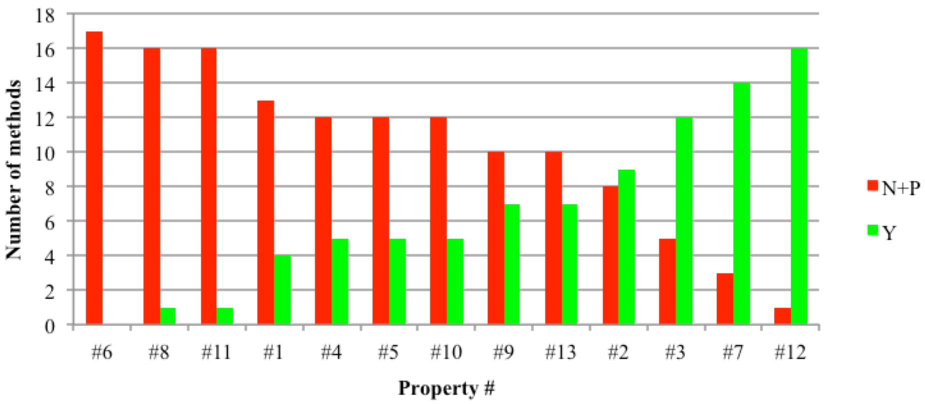

Figure 2.1 number of methods that support each property. Ideal features have been sorted from less supported ones. Red blocks refer to the sum of methods that do not support or partially supported each feature. Green blocks concerns approaches that satisfy ideal properties. The labels N+P and Y stand for Not or Partially supported and Yes (supported), respectively

Figure 2.1 shows that the most diffused weaknesses of collected methods concern overall their scarce reliability, subjectivity of the inputs and the impossibility of formally schematizing the identified ideas. The first problem is mainly due to the focus on specific application fields and to the limited quantity of industrial case studies shown so far. On the one hand, it is worth noting that the development of some approaches has not started with the objective of directly supporting industrial tasks, but they rather aim at fostering people's creativity regardless the final scope of idea stimulation. On the other hand, significant enhancements are expected for the examined methods, especially because most of them lie in the early development stage and own an algorithmic structure that might be implemented in computer-aided tools. Hence, in order to achieve more consistent feedback, the most recent methods are worth of being further tested. The subjectivity of the inputs is connected with the widespread use of experts' judgments, as a main driver to define and assess new product ideas. The methods that exploit statistical analyses are less affected by this problem, because they analyse a wide sample of data and provide therefore a more general view of the opinions expressed by experts and decision makers. However, they imply the commitment of a great amount of time and resources in order to obtain a reliable sample of data. Eventually, the literature search highlighted a tool, namely Strategy Canvas (belonging to BOS) that effectively allows schematizing new product ideas in the Product Planning phase, showing attributes and related performance that designers plan to offer.

Besides these three most diffused weaknesses, few methods can support the user in a quick and easy way, they rarely integrate analysis of competitors and barely monitor customer preferences dynamics. In addition, few approaches entrust the Product Planning phase to multidisciplinary teams and hybrid methods are the unique techniques that (by definition) involve customers in the process.

The disregard of intuitiveness affects especially responsive and hybrid methods, since they require individuating new needs to fulfil and performing customer surveys. Such a matter can potentially hinder, in industrial contexts, the diffusion of reliable techniques developed in academics.

According to the analysis of the competitors, it has to be underlined that, whereas this kind of investigation is made, it is commonly not aimed at providing a clearer picture of the competitiveness in the industry, but it basically provides inputs and factors needed for exploiting the methods themselves.

The most diffused properties include the development of computer applications (more than half of collected methods), effective support in the individuation of latent needs (proactive and hybrid methods) and in selecting the most beneficial product idea. Eventually, a large majority of the collected methods starts focusing on products attributes, rather than considering general product ideas. In each case, most of the hybrid methods have the capability to take into account both the validity/feasibility of general product ideas and the role played by product attributes. It might be inferred that such kind of methods, which involve the customer in variegated stages of the Product Planning, own a higher level of versatility for the designer.

This comparison between industrial demands and properties of Product Planning methods highlights a good fit between research trajectories and companies' expectations. However, we can remark how certain relevant properties are fulfilled just partially or by a small subset of methods. The lack of industrial validation of Product Planning methods, implying their scarce reliability, can be considered as a significant weakness in the landscape of academic research on the topic. Indeed, many surveyed companies have underlined the perception of the uncertainty about efficiency and efficacy of what is developed in the academics. This leads to the fact that no analysed enterprise is aware of the specific methods that have been illustrated in Section 2.3.

More in particular, still according to the viewpoint of interviewed firms, the main reasons of the unsuccessful industrial implementation of methods developed in the academics can be summarized in:

- scholars' "dogmatic" approach;
- communication problems;
- insufficient promotion of research results (several firms do not know scholars' works);
- cultural problems;
- distance from the business world and its needs;
- supposed unsuitability of the methods' outcomes in certain industrial fields.

According to this vision, scholars should start advertising their works and reinforcing the links with industry. In this way, they could have a major understanding of firms' needs and develop more suitable methods and tools.

2.9 Elicited requirements of an ideal Product Planning method and constraints for its implementation

The main evidences of the comparison between emerging needs from industrial subjects and the claimed benefits of methods proposed in the literature, as described in the previous Sections, are summarized here in the followings.

With regards to the main properties of Product Planning tools originating from academia it can be highlighted that:

- the quickness of Product Planning processes is a basic feature for the firms, but it is not adequately addressed by the available methods;

- software tools for the Product Planning phase are deliberately demanded, so that more efforts should be paid in order to implement literature methods into ICT applications;
- the effective support in the individuation of customer latent needs is important for the companies and some literature methods can support this task;
- the analysis of the competitors is absolutely required in the industry, but the reviewed methods hardly support this activity;
- the analysis of customer preference dynamics is not supported by most of literature methods, but a large part of interviewed firms highlighted this need;
- the reliability of the approach to be followed is explicitly requested and adequately addressed by literature methods, according to what is claimed; nevertheless, more efforts should be paid in order to demonstrate the validity of the proposed tools;
- idea selection represents undoubtedly a fundamental task for companies and most of literature methods support this activity;
- the limitation of subjectivity issues is required by companies and sufficiently satisfied by literature approaches, but more efforts need to be addressed in this direction, since firms' practices diffusedly conflict with the intentions of undertaking well-supported decisions;
- active involvement of customers in the Product Planning activities is widely required by companies in order to reduce risks concerning new products. Therefore hybrid approaches can be preferred even if, as seen above, they require more time and resources than proactive methods;
- the need of entrusting the Product Planning phase to multidisciplinary teams has been highlighted by part of interviewed firms however only some literature approaches clearly suggest this mode of use;
- possibility of formally schematizing identified ideas is quite required but supported by only one of collected literature approaches (BOS);
- the focus on general product ideas or single product attributes arouses little interest in the interviewed companies that do not show a well-defined strategy, nor preferences are expressed towards one of the two approaches. Indeed, firms employ a mix of both strategies, focusing on general ideas characterized by new distinguishing attributes that product should include.

According to these outputs an ideal Product Planning method should implement the features collected in Table 2.5 and new research efforts have to be addressed toward those requirements not already included in most of existing approaches (Table 2.7).

Requirements of an ideal Product Planning method not already included in most of literature approaches
Quick and easiness of the method/tool
Integrated competitors' analysis
Independence from inputs subjectivity
Possibility of formally schematizing the identified ideas

Table 2.7 requirements of an ideal Product Planning method not already included in most of literature approaches

However, as seen above, there are constraints to the implementation of new methods concerning the difficulty to change well-established procedures and/or organizational structures. In order to overcome these limits an ideal Product Planning approach should be easily implementable and it should not require specific skills to use it. Indeed, organizational structures often cannot be changed and there is no time to learn how to use new approaches.

Both ideal features and identified constraints have been used with the aim of developing a new method to support the designer in Product Planning process.

3 Methodological proposal

In this Chapter the approach developed to support designers during Product Planning is described.

According to methodological objectives, introduced in Chapter 2, the proposed method supports the identification of innovative product or service ideas, providing as output main design objectives. The proposal allows planning a differentiation strategy based on the introduction of new product features and on radical changes of currently offered performance.

Methodological proposal include both original and existing tools to support various tasks of the Product Planning process. The research activity that has led to the development of new tools has been reported in the Appendix D.1, D.2 and D.3 while in this Chapter they are presented only for application purposes.

In the following Sections logic and steps of the proposed roadmap are introduced, as well as tools that support each step.

3.1 Overview of the methodological proposal

As shown in Table 3.1, the roadmap is constituted by three main steps, i.e. information gathering, idea generation and idea selection. Table shows the list of steps, their main activities, partial results and supporting tools. Such procedure ranges from the analysis of the as-is scenario in a reference market to the choice of a new product profile that a company decides to develop. Here in the following the main features of the approach are described, while in the next sections each phase and the involved tools are presented in detail.

The analysis of as-is scenario is a preliminary task to understand what is currently offered in a reference market. Moreover, the identification of new product ideas is the key activity to define a differentiation strategy aimed at providing new benefits to the customers. Eventually, the selection phase is fundamental to choose the most promising idea among the others generated in in the previous step. The activities showed in Table 3.1 should not be considered as a strict series of tasks, indeed some of these activities could be repeated in an iterative way during the Product Planning phase. For instance, information could be gathered during whole process.

As a whole, the proposed method try to supports all the activities of Product Planning and allows facing the process in a systematic way.

Step	Main activities	Partial results	Supporting tools
1. Information gathering	Data mining	• Competing factors • Offered performance	**Guidelines to support the search of information**
	Definition of the industrial standard/s	Industrial standard/s	**Algorithm to identify the industrial standard**
	Representation of the as-is scenario	Value curves	Strategy canvas
2. Idea generation	Generation of new ideas	• New product attributes • New product ideas	• CRs Check List • LCSO • Six Paths framework • **APS Check List** • **iDea**
	Selection of new ideas to be assessed	Sub-group of identified ideas	Likert scale
	Differentiation strategy	New value propositions (that have to be assessed)	• Consistency with selected ideas • Four Actions framework • New value Proposition guidelines • **Graphic analysis of Strategy Canvas**
3. Idea selection	Benefits' analysis	Potential success of assessed profiles	VAM
	Costs' analysis	Potential cost (feasibility) of assessed profiles	**Profile Cost Matrix**
	Product profile's choice	Selected profile	• **Success-cost chart** • Value index

Table 3.1. roadmap of developed method. It is constituted by 3 main steps: for each step main activities, partial results and supporting tools are summarized. The tools in bold are the original ones developed to support the related task

The developed approach follows an abstraction-synthesis process (see Figure 3.1), in order to reduce the psychological inertia that often hinders the generation of innovative products (e.g. Altshuller 1984; Adams et al. 1998; Godkin and Allcorn 2008). Indeed, most of the information about the as-is offer, collected through the first step of the approach, is often related to technical features (e.g. battery life). According to the author view, the identification of needs satisfied by these features (e.g. possibly of using a device for a long time) allows to break away from existing solutions (e.g. long lasting batteries) and supports the designer both highlighting new needs (e.g. possibility of having a devices that works only when I need it) and identifying new ways to satisfy a demand (e.g. integrating an automatic on-off switch). Indeed, the abstraction process leads to a more general analysis of *what* generate value for the customers. As a result of this generalization from product features to needs it is easier to find new ways to satisfy existing and new customer demands, without focusing on specific solutions. In other words, designer should first of all understand *why* existing products offers a certain set of features (which needs do existing features try to satisfy?) and *what* customer actually want (do customers perceive these needs? What does he/she demand?). Later he/she can try to identify *how* to answer to these needs through a new set of product features.

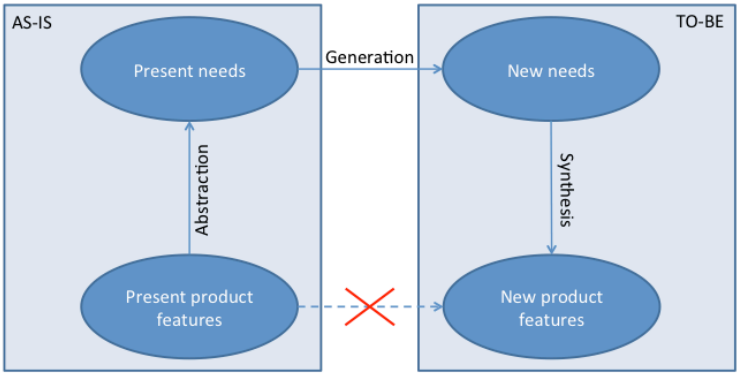

Figure 3.1 the abstraction-synthesis process limits issues related to psychological inertia. Existing features are abstracted to present needs. The idea generation activity is performed at this level and new product features can be obtained starting from new identified needs

3.2 Description of the method

In this Section the three step of the approach are described highlighting objectives, implementation and partial results. For each step the tools selected and/or developed to support various activities are described.

3.2.1 Step 1: Information gathering

Objectives

The aim of the first step is to collect information about existing products or services, allowing the analysis of as-is scenario in a reference market. This preliminary activity is fundamental to understand the current offer and plan differentiation strategies based on customer value. Such an exploration supports even another demand, i.e. avoiding the development of existing solutions (especially in case of exclusive rights protected by patents).

In order to satisfy these objectives, the information gathering phase requires performing the following activities:

1. *Data mining*: such activity is aimed at extracting and collecting all the information related to the current offer in a reference market. This task allows identifying competing factors and related performances offered by competitors and/or alternative products that satisfy analogous needs.
2. *Definition of the industrial standard*: this task is aimed at identifying the main categories of existing products, allowing clustering the data collected in the

previous activity. In addition, it can support the identification of further product and/or service categories not considered during the first task.

3. *Representation of the as-is scenario*: this activity is aimed at depicting the data collected and clustered in the previous tasks in graphical form. The drawn value curves that show attributes and performances offered by industrial standard(s) constitute the strategic framework that supports the planning of differentiation strategies.

Step implementation

1. Data mining

The data mining task is an essential activity (Pahl and Beitz 2007) that allows collecting information about a certain product or service, competitors' offers and alternative goods (that satisfy analogue needs). Even if most of the information are collected in a preliminary phase, this task can be repeated several times during Product Planning because further information can be required carrying on with the process.

This activity can be carried out involving customers and/or taking in consideration several information sources that nowadays can be mostly found on the web. However, taking part to fairs, workshops, visiting stores, consulting experts and testing existing products or services can provide useful information too.

The literature search highlighted no rules to collect data in the Product Planning phase and, according to the author's research team experience, each company has its own approach. However, in order to accelerate this task the main types of sources (and some illustrative websites) have been summarized in Table 3.2 and a possible roadmap is shown in Figure 3.2.

Type of sources	**Illustrative sources**	**Illustrative websites**
Technical sources	Thesis, lecture notes, documents made by experts and/or enthusiasts, encyclopaedias, etc.	www.wikipedia.org www.madehow.com www.slideshare.net www.openthesis.org etc.
Technical-commercial sources	Catalogues, companies' websites, resellers' websites, fairs' websites, online auction, (virtual) leaflets, price comparison shopping sites, etc.	www.ebay.com www.amazon.com www.pricegrabber.com etc.
Scientific sources	Books, scientific journals, conference papers, workshops, etc.	www.scholar.google.com www.scirus.com www.scopus.com etc.
Patents	Innovation patents, design patents, utility models	www.espacenet.com www.uspto.gov www.wipo.int/patentscope www.google.com/patents etc.
Reviews made by customers and/or experts	Video reviews, blogs, forums, online communities, social networks, FAQs, etc.	www.youtube.com www.ciao.com www.amazon.com etc.

Table 3.2 list of main available sources that can be analysed during the Product Planning phase. The Table provides some illustrative websites too

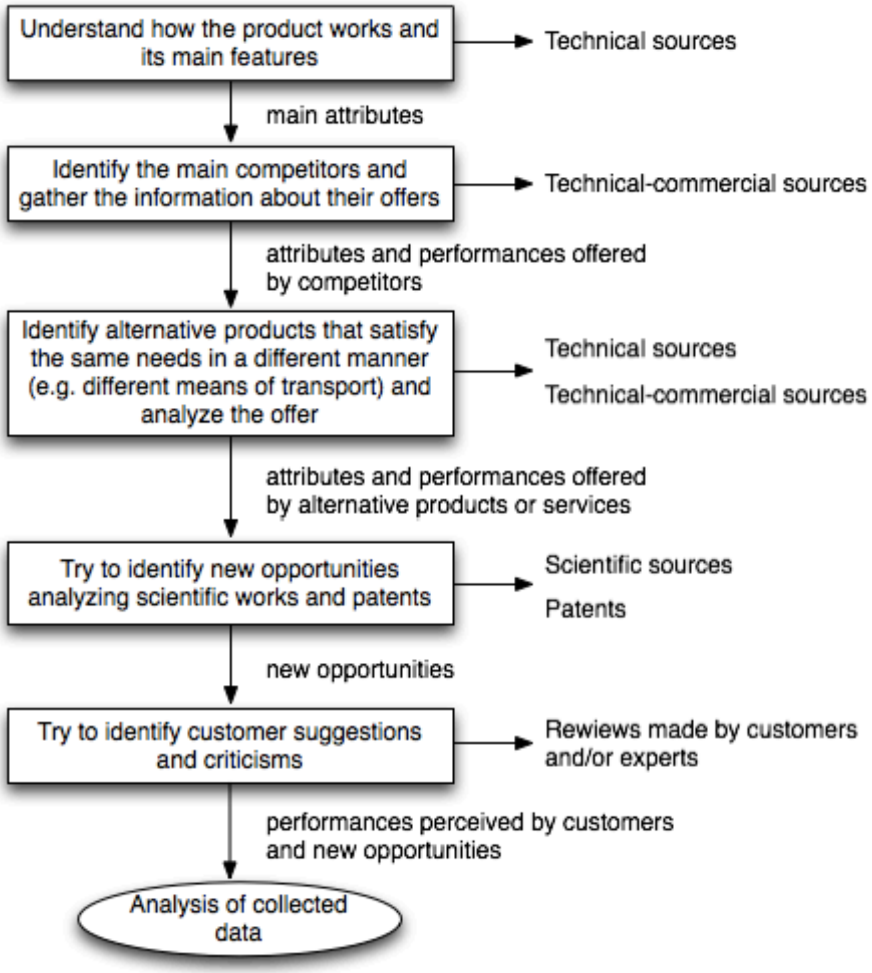

Figure 3.2 possible roadmap to support the data mining activity. For each task the useful sources are showed on the right and main outputs are inserted under each block

In case the type of product is new to the firm a preliminary search has to be carried out in order to understand how the product works and its main features. After that, competitors have to be identified. Usually companies already know the actors that operate in the reference market, anyway some hints to identify competitors can be:

- searching on Internet (e.g. focusing on resellers' websites, online auction, etc.);
- participating in trade fair (or looking at fairs' websites);
- asking to stakeholders (e.g. commercial agents, technicians, customers, etc.) which brands they know and/or prefer;
- going to distribution channels (if product is sold in stores), looking at marketed brands and/or asking to assistants, which are the best (or most sold) products.

Besides the analysis of competitors' offer, products/services that satisfy the same needs in a different manner can be analysed in order to create a complete picture of the as-is scenario.

The information that has to be highlighted from collected sources concerns competing factors and related performances currently offered. According to the approach showed in the previous section all technical features have to be expressed in terms of product attributes. For instance, Table 3.3 shows this abstraction process, starting from the specifications of a dishwasher identified on a company's website.

Technical features	Product attributes	Notes
Dimensions (cm): 82x59x57	Minimal amount of space	Another attribute can be related to the compatibility with kitchen cabinets
Energy efficiency class: A+++	Energy saving	This attribute could be split into ethics and cheapness demands
Standard cycle water consumption (lt): 11	Minimal consumption of water	This attribute could be split into ethics and cheapness demands
Number of programmes : 8	Versatility of use	Each program can be expressed as the possibility of satisfying specific needs.
Place settings : 13	Maximum capacity	
Sound Power (dB(A)) : 49	Noiselessness	
Salt refill indicator light	Ease of managing salt refill	

Table 3.3 illustrative conversion of product features into product attributes for a dishwasher. Some notes to provide clarification, if necessary, have been provided

It is important to express all the attributes in a positive manner (as shown in Table 3.3), i.e. the raise of performance has to improve the customer satisfaction and vice versa. Indeed, it allows having a homogeneous set of attributes that simplify the analysis of as-is scenario and the following differentiation strategy. For instance, according to Table 3.3, if designer uses a set of attributes that includes "noise" (instead of "noiselessness"), "occupied space" (instead of "minimal amount of space"), "versatility of use" and "ease of managing salt refill" the raise of attributes' performances produces different effects for the first two and the last two factors, i.e. the reduction and increase of customer satisfaction, respectively.

Three kinds of performance can be identified according to the type of attribute:

- quantitative (e.g. cheapness, quickness, etc.);
- qualitative (e.g. aesthetics, ease of use, etc.);
- present/absent (e.g. water resistant, possibility of use in the dark, etc.).

It is quite easy to identify information about quantitative and present/absent attributes using most of sources collected in Table 3.2, on the other hand the performance of qualitative attributes are quite difficult to identify/assess. The most useful sources to gather information about this latter type of attributes are the reviews made by costumers and/or experts. However, they can state subjective experiences that are not generalizable.

Some hints to find and conveniently assess these sources are presented here in the following:

- Consumer and online-shopping portals (e.g. www.ciao.com, www.amazon.com) allow identifying both comments and "statistics" about existing product attributes (see Figure 3.3). These "statistics" are based on one or more customer reviews. Hence, the first information that has to be checked is the number of reviews, in order to understand if data can be generalizable.
- Consumer forums provide lots of information about product attributes and perceived performances. However, only widely shared visions have to be collected, neglecting comments based on specific needs or that are radically different from the others. Sometimes these feedbacks can be also used to identify new opportunities (e.g. developing a product for disabled persons, professionals, etc.).
- Frequently Asked Questions (FAQs), available on several technical-commercial sources (see for instance Figure 3.4), allow understanding the main demands of customers. According to these questions and related answers, the user can infer if and how some product attributes are offered. For instance, if a question is: "Why my dishwasher does not clean dishes completely?" and the answer is: "It can happen with persistent dirt, you should manually remove it", the cleaning efficacy of the product is surely not high.

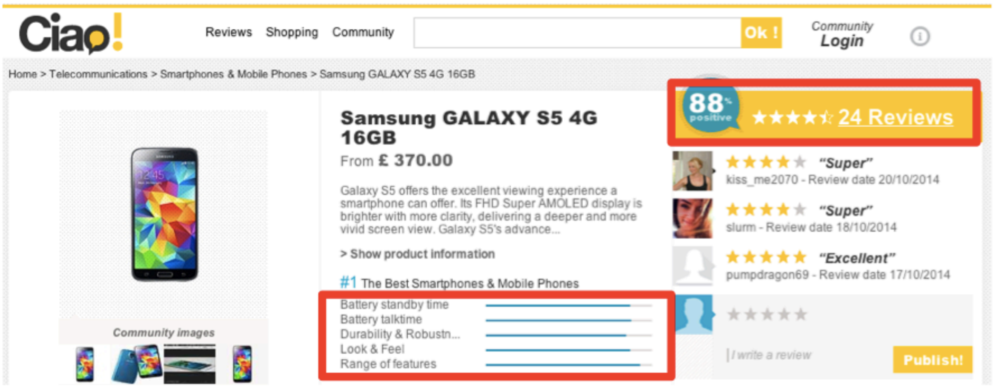

Figure 3.3 screenshot of a web page of www.ciao.com. It shows 24 reviews about a smartphone, providing both an average assessment of the product and of 5 attributes/features (as highlighted in red boxes)

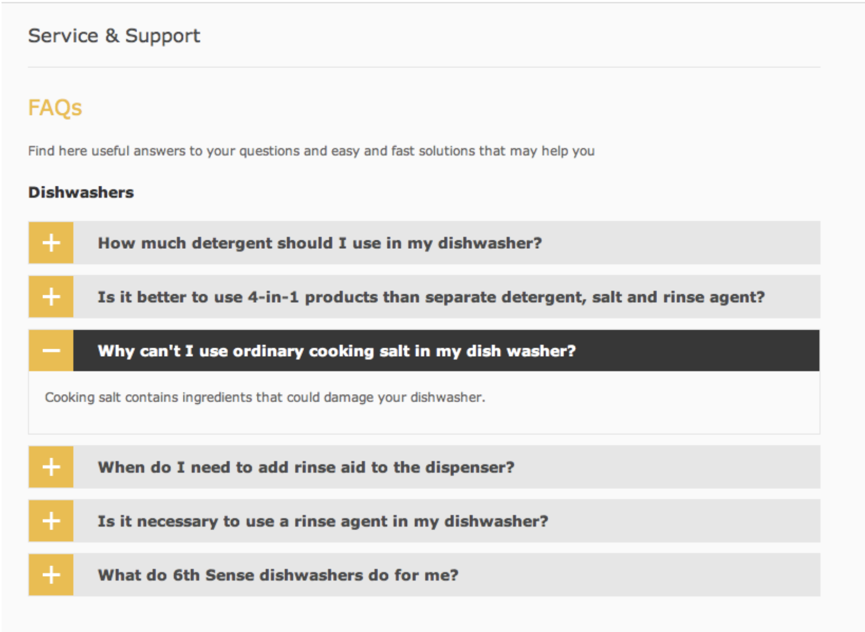

Figure 3.4 screenshot of a FAQs web page (source www.whirlpoolindia.com)

In addition, this kind of sources can be used to understand if currently offered performances outstrip customers' demands or barely satisfy their expectations. For instance, customers that agree with the statement: "the product provides too many functionalities" allow understanding that the number of functionalities (or the versatility of the product) should be reduced. Vice versa if customers claim that a product is too much noisy, the noiselessness could be improved in new products.

Besides the analysis of as-is scenario, data mining activity can even support the identification of new opportunities in terms of not widespread product attributes, completely new technologies and/or solutions that are typical of different industrial field. The sources that mainly allow identifying this kind of information are scientific works (e.g. scientific papers, books, etc.) and patents. Even if it is not the main goal of this task, these data could be particularly useful during the following phases of product development process. Therefore, the author decided to provide a quick overlook of main literature techniques that support the analysis of new technologies. Here in the following diffused methods are briefly described:

- Laws of technical system evolution: they are the most diffused evolution trends for technical systems discovered by Altshuller (1984) analysing thousands patents. These low can be used to forecast new technologies (Cascini et al. 2011);
- Delphi method: it is an intuitive forecasting method, which involves a panel of experts who anonymously reply to questionnaires about new technological opportunities and subsequently give feedback of collected solutions. After this first round the process repeats itself more times. The goal is to identify an opportunity that is closer to expert consensus (see Dalkey and Helmer 1963 for more details).

- Biomimetics (or biomimicry): it concerns the analysis of natural systems with the aim of identifying new technologies inspired by solutions (Rosa et al. 2011; Baldussu and Cascini 2015). The search can be facilitated by available databases (e.g. www.asknature.it);
- Patent analysis: the search of information in patent databases allows to identify useful technologies currently applied in fields that are different from the analysed one and technological trends (Campbell 1983). Text mining (Yoon and Park 2004; Cascini and Russo 2007) and statistical (Basberg 1987; Lee et al. 2012) tools can accelerate this kind of analysis.

As a whole, in the end of this first activity the gathered information should include:
- existing technical features (that have to be converted into product attributes);
- existing product attributes (i.e. features already expressed in terms of benefits);
- offered performances (qualitative, quantitative and present/absent);
- attributes with offered performances that outstrip customers demand;
- attributes with offered performances that barely satisfy customers;
- attributes that are not widespread and do not constitute competing factors yet;
- new technologies and technical solutions (useful for the Conceptual Design phase).

This activity cannot generally support the identification of radically new ideas, however in some cases customers (e.g. Von Hippel 2005) can provide useful hints to support the planning of a differentiation strategy.

2. *Definition of the industrial standard*

Such task is aimed at supporting the identification of main product categories in a reference market and allows considering alternative product or services that satisfy analogue needs (e.g. pen and paper are an alternative to word processors). This activity can be carried out together with the first task and it can be useful to address the search of information. Indeed, designer can focus on specific product categories reducing the exploration space.

In order to support this task a flow diagram, namely Industrial Standard Chart, has been developed (Figure 3.5).

According to the type of product that a company want to develop a reference market generally exist. However, sometimes companies can even identify completely new market spaces. In this case, different products or services that satisfy similar needs can be used as reference industrial standards. For instance, the first bulb could be compared with candles, or the first television could be compared with the radio market. Rarely, the product cannot be compared with other goods or services, however, if it happens, the main objective is understanding if an actual need exists and if possible competitors could appear from different industrial field.

Often companies already have one or more products in a certain market and their objective is the development of a new product's model. In this case they can decide to consider only their product(s) or perform a competitors analysis. However, the first choice is not recommended, unless the companies have a monopoly or are government institutions, because useful information can be lost.

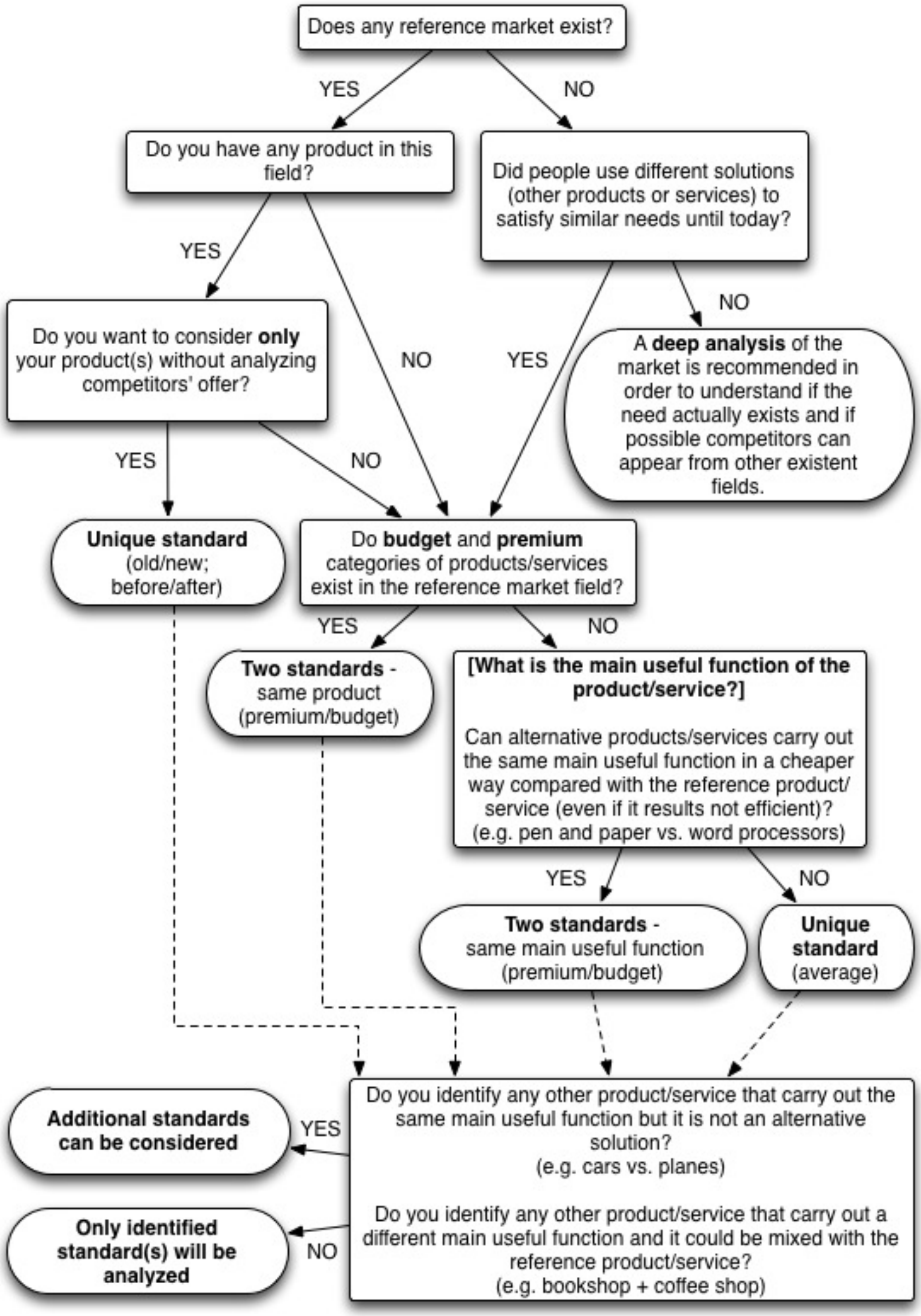

Figure 3.5 industrial standard chart. It supports the identification of the standard(s) in a reference market. Dotted arrows suggest elective tasks

Because of the strong growth of emerging countries, in most of the markets two main categories of products can be identified:

- *budget*: cheap products with generally low quality performances;
- *premium*: quite expensive products with high quality levels.

In order to understand if these two categories exist in a certain market, the main factor that has to be analysed is the price (i.e. the cheapness attribute). If a considerable gap between products' prices can be observed, it can be assumed that the above mentioned standards have been identified. However, there is also another factor that support this task, i.e. the analysis of distribution channels. Indeed, for instance, a product distributed through large retailers and another one sold in boutique can respectively belong to budget and premium categories.

As seen above, there could be different products that satisfy the same main useful function, requiring low investments but providing a low efficiency level too. In this case there are two different product types that provide the same benefits and can be assimilated to budget/premium categories.

Eventually, if in a certain market domain only one category of product can be identified and the offered performance are comparable, the industrial standard can coincide with the average offer. However, if there are significant differences among various offers, they should be analysed separately.

The industrial standard chart provide two further hints (highlighted by dotted line in Figure 3.5) to extend the search including alternative not substitutive products (e.g. cars vs. plans) and different product that could be mixed with the analysed one (e.g. bookshop and coffee shop), as suggested by the BOS (Kim and Mauborgne 2005). These further data can support the differentiation strategy, but they have not to be necessarily collected and/or analysed in depth.

More details about the use of the industrial standard chart can be found in the next Chapter that illustrate two case studies, in which this tool has been applied.

Hence, the information about competitors' offer (and/or alternative product/services), gathered during the first activity of the process, can be clustered using the identified standards. It allows to order the collected data, understand the segmentation of the reference market and start planning differentiation strategies.

3. *Representation of the as-is scenario*

Once the information about competitors' offers has been collected and industrial standards have been identified, a useful representation of gathered data can be obtained through the employment of a widely diffused technique: the Strategy Canvas (Kim and Mauborgne 2005).

This tool is the most appropriate technique, identified in the literature that satisfies the needs of proposed general approach. Indeed, Strategy Canvas allows to formally schematizing both current offer and new product ideas in the Product Planning phase and it satisfies most of the ideal properties collected in Chapter 2:

- it turned out to be quick and easy to use (integrating some practical guidelines);
- it can be easily drawn and modified using commercial software (e.g. Excel);
- it has been developed to support both competitors' analysis and graphic representation of new identified ideas;

- it can be considered a reliable tool because it has been widely tested in several industrial fields. In addition, the integration of some practical guidelines (introduced by the author) allows to make the tool more repeatable;
- the employment of collected information leaves no room for personal judgment;
- it can be potentially used by multidisciplinary team and customers can be involved (even if no literature examples have been found);
- it focuses on product attributes and curves provide a quick image of general product ideas.

This graphical tool consists in a two dimensional map where in the abscissa there are product attributes (sometimes called competing factors), while in the ordinate the performance at which each product attribute is delivered to the customer is reported. This tool allows representing both the as-is scenario and new offers that will be ideated in the second step of Product Planning. The curves drawn in Strategy Canvas are usually called Value Curves and they represent the so-called product profiles. In Figure 3.6 an example of Strategy canvas is shown.

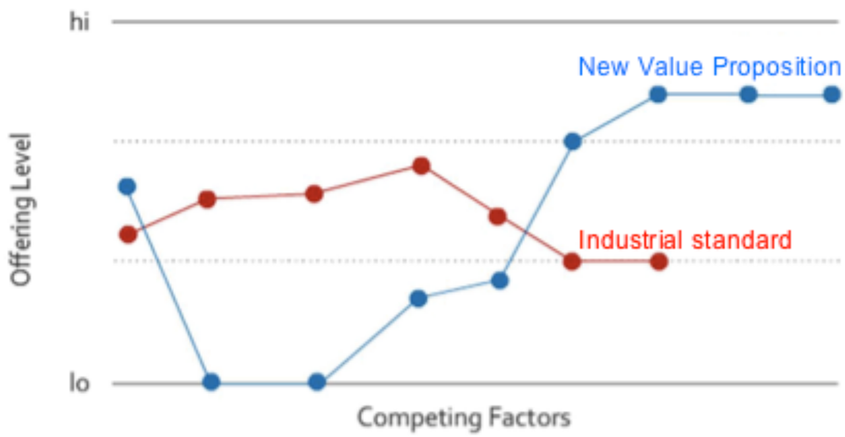

Figure 3.6 Strategy canvas. In the abscissa there are the product attributes (competing factors), while in the ordinate the performance at which each product attribute is delivered to the customer is reported. Such graphical representation allows depicting as-is scenario and supports differentiation strategy

No rules have been identified in the literature to support the use of Strategy Canvas. Indeed, curves are generally drawn in a qualitative way in order to provide a quick picture of the as-is scenario (average curves) and new offers. Therefore, the author has introduced some practical guidelines with the aim of:

- making the use of the tool more repeatable;
- simplifying the analysis of the curves, limiting the number of intersections;
- making qualitative and quantitative attributes comparable.

Collected information can be managed implementing the following steps:

- divide the ordinate into five levels: null, low, medium, high, very high/ideal;
- link the qualitative attributes to these performances' levels;

- analyse the quantitative performance and try to normalize data in a range 0-1 (where 1 represents the maximum performance that is, or could be, obtained with existing, or future, technologies);
- move data normalized in the previous point to the nearest level (assuming null=0; low=0,25; medium=0,5; high=0,75; very high/ideal=1). For instance, a normalized performance of 0,45 will be assumed as 0,5 (medium) and a performance of 0,8 will be moved to 0,75 (high);
- link present/absent attributes respectively to ideal and null performances.

In order to have a Strategy Canvas that can be easily read the number of curves cannot be too high. Hence, if more than 3-5 curves have to be drawn, more than one Strategy Canvas should be used. For instance, a Strategy Canvas could be used to compare the main competitors and another one to shows the offer of alternative products. In addition, if some curves coincide or are very similar can be simplified in a unique representative curve. The industrial standards should support this simplification process too. For instance, the curves belonging to the budget and/or premium categories can be drawn with a unique average curve, if they have similar shape (i.e. similar level of performance). When simplification cannot be done, but it is required, only main competitors and/or alternative products have to be considered in the Strategy Canvas. All the other neglected data could be anyway used to make strategic decisions.

Eventually, data in Strategy Canvas should be ordered with the aim or providing a map that is ease to read. According to this objective there are no general rules to support the task, however an easy procedure consists of selecting a profile and ordering its attributes according to their performances' levels, from the lowest to the highest one. In this way, at least one curve will be ease to read and it generally allows making easier the analysis of other curves too.

Partial results

The results obtained through the execution of the first phase of the method are summarized as it follows:

1. *Overview of the as-is scenario in a reference market*: market segmentation (i.e. industrial standards) and two dimensional map summarizing the value proposition of products available in the reference market (competing factors and offered performance).
2. *Useful information to support differentiation strategies*: customer feedback about current offers (in terms of provided performances) and new opportunities coming from both customers and scientific works.
3. *Useful information about technologies and technical solutions*: this kind of information can be used in the following design phases, in order to accelerate the product development process.

According to ideal properties collected in Chapter 2, general approach and techniques illustrated in this step satisfy the need of integrating competitors' analysis in the Product Planning phase. In addition, proposed tools are quick and ease to use, even if the search of information can take long time (according to the level of detail the user want to obtain). Approach is independent from inputs subjectivity, it can involve both multidisciplinary teams and customers and it can start focusing on product attributes or general ideas.

3.2.2 Step 2: Idea generation

Objectives

The idea generation, sometimes called Opportunity Identification stage (Cagan and Vogel 2001; Achiche et al. 2013), allows identifying attributes, features or general ideas of the product to be developed (Michaud and Llerena 2006; Alam 2006; Riel et al. 2013). Besides the identification of new opportunities, this task allows to plan a differentiation strategy based on radical changes in the level of currently offered performance too (Kim and Mauborgne 2005). All these activities allow delivering new benefits to existing customers, or generating new offers to attract non-customers. Original product profiles, defined in this phase, will be assessed in the last step of the method.

In order to carry out these tasks, the idea generation phase includes the following activities:

1. *Generation of new ideas*: such activity is aimed at identifying new opportunities in the reference market. It allows identifying new product attributes or general ideas (that will be converted in a list of attributes). This task represents the creative phase of the Product Planning process.
2. *Selection of new ideas to be assessed*: this activity is aimed at reducing the number of ideas generated in the previous task. It allows simplifying and accelerating the following steps of the method.
3. *Differentiation strategy*: this task is aimed at defining new product profiles, according to ideas generated and selected in the previous tasks. In addition, it allows taking into consideration possible differentiation actions, starting from the as-is scenario depicted in the first step of the method.

Step implementation

1. Generation of new ideas

The generation of new product ideas can be considered the basic task of Product Planning and it has been widely investigated in the product development literature (Rochford 1991; Alam 2006). Creativity stimulation plays a key role for the scopes of this activity (McAdam and McClelland 2002) and several techniques and tools have been developed to support this task, as seen in the previous Chapter. Here in the following, three quite systematic literature methods will be briefly described and two original approaches will be presented. More details about existing approaches and commercial tools are included in Appendix D.2 and D.3.

Within Blue Ocean Strategy (Kim and Mauborgne 2005), the most useful tool to support the designer during the idea generation process is the so-called Six Paths framework (Borgianni et al. 2012). The instrument is articulated in six suggestions (i.e. look across alternative industries, look across strategic groups within industry, redefine the industry buyer group, look across to complementary product and service offerings, rethink the functional-emotional orientation of the product, participate in shaping external trends over time) that can support the exploration of new opportunities. The main limit of this tool is that it offers only mere qualitative indications (Aspara et al. 2008) that could not be sufficient to effectively support the designer during idea generation activity.

Within the book *Re-engineering of Products and Processes* (Rotini et al. 2012), two tools are presented to support the generation of new product ideas. The first one, namely

Customer Requirements (CRs) Check List allows to identify new opportunities analysing a record of hints tailored to elicit the widest diffused kinds of product attributes. The other one, namely Lifecycle System Operator (LCSO), supports the idea generation task taking into account two aspects that participate to the delivery of the value for the customer, i.e. the circumstances that may occur along the different stages of the existence of the product (from the launch to the end of life) and different levels of detail (accessories/parts, product in general and external environment) that impact the investigated product under various operating contexts. Both these tools can even support the identification of existing attributes, not identified in the previous step, completing the analysis of as-is scenario.

All these literature appoaches are quick and ease to use, they support the individuation of latent needs, they can potentially involve multisciplinary teams and/or customers (even if no experiments have been found) and they focus on product attributes. User is guided in the identification of new opportunities through more (CRs Check List and LCSO) or less (Six Paths framework) specific hints and he/she can decide to make a combined use of these three techniques.

According to the above mentioned Six Paths framework one of the hints provided by the tool is looking across to complementary product and service offerings. This search can support both the identification of new accessories/services that can be offered together with the product and new useful features that can be directly integrated in the products. For instance, cleaning accessories can be included in product's box, in order to raise customer satisfaction, or they could even suggest the "possibility of self-cleaning" as a new product attribute. With the aim of supporting the identification of complementary products and services, the author developed a checklist, namely Accessory Products and Services (APS) Check list, starting from the international (Nice) classification of goods and services (www.wipo.int) used for the registration of marks. This list of products and services has been conveniently modified according to the objectives of idea generation activity. It can be used like the CRs Check List, systematically guiding the search of new accessories and/or attributes. Table 3.9 shows an excerpt of the tool, while the complete list can be found in Appendix A.

APS Check List
PRODUCTS • **Kits:** travel kit, hobby kit, vehicle kit, product care kit, body care kit, first aid kit, repair kit, tool kit, survival kit, educational kit, needle kit, etc. • **Gadgets:** key chains, pens, t-shirts, hats, watches, office accessories, stickers, etc. • **Product for colouring or changing colour:** paints, varnishes, lacquers, adhesive films, covers, cases, boxes, interchangeable parts, etc. • **…**
SERVICES • **Management services:** business management, business administration, financial affairs, real estate affairs, personal issue management, advertising, website, catering, etc. • **Research and development services:** customized solutions, identification of best solutions, prototype development services, information search services, surveys and data analysis services, etc. • **Installation/building services:** assembly services, test services, etc. • **…**

Table 3.4 excerpt of APS Check List. It supports the identification of new attributes considering complementary product or service offerings. The first half suggests new products and the second half new services that can be offered/included with/in the main product

In order to scan the mare magnum of possible product features to be implemented in new deliverables, the author identified a taxonomy categorizing the potential sources and circumstances viable to provide value for customers. According to this classification the exploration of design space can be carried out considering specific needs (General Demands, GDs) to be fulfilled in order to delight specific customers (Stakeholders, SHs) in certain circumstances (Life Cycle phases, LCs), which involves different levels of interaction with the developed system (SYS). Here in the following these four ways of characterizing designed benefits (Dimensions onwards) will be briefly described:

- General Demands (GDs): they are meant as distinct typologies of benefits, which can be provided by correctly designing a new product. They can broadly refer to kinds of existing, emerging or unspoken needs, otherwise defined as "value opportunities" (Cagan and Vogel 2001), "utility levers" (Kim and Mauborgne 2005) or "customer perceived value evaluation factors" (Lee et al. 2010) on which Product Planning tasks are set. They represent the basic characterization of product attributes that specifies the met needs or wants (Ulrich and Eppinger 2011) referable to both functional and emotional perception of value.
- Stakeholders (SHs): they include all the subjects that interact with the product, extracting value from the artefact or, generally speaking, are aroused of some interest as a result of the existence of the system. As claimed by Martin and Hanington (2012), design processes require individuating the reference actors standing for the key constituents of projects. With this meaning, SHs include the individuals that participate to the design task and the company that organizes innovation initiatives to generate turnover. On the other hand, product attributes are planned to satisfy needs of subjects that interact with the deliverables of design and manufacturing processes. From this viewpoint the relevant SHs to classify product features include all the actors that are influenced by the artefact in the lifecycle phases following its market launch. In each case, the concept of "customers", which has been traditionally employed, is extended from buyers to users, beneficiaries, service recipients and outsiders, with the aim of identifying new opportunities to increase the delivered value. As underlined by Cantamessa et al. (2013), buyers and users might be different individuals (e.g. parents and children) and the actor(s) that will ultimately benefit from the product might be different from either the buyer or the user (e.g. patients in a hospital).
- Life Cycle phases (LCs): they concern the circumstances that may occur along the different stages of product existence. Coherently with the observation advanced for SHs, the relevant domain to categorize product attributes starts with the market introduction, thus ranging from this moment to the end of product functioning (Cantamessa et al. 2013). By analysing the possible situations to be faced, scenarios where different SHs may perceive value can be identified (Rotini et al., 2012). A correct scrutiny of LCs is deemed crucial to avoid focusing only on the phase of product's use (Aurich et al. 2010), losing opportunities to identify sources of value. Not surprisingly, the correct examination of LCs is traditionally deemed critical within the correct definition of product specifications in engineering tasks (Tseng and Jiao 1998; Weissman et al. 2011).
- Systems (SYSs): this Dimension suggests analysing the product at different levels of detail, including the "super-system" in which the product is situated, as

indicated by classical TRIZ nine-screen scheme (Altshuller 1984) to individuate valuable suggestions for product development. The design of the product taking into account different hierarchical levels of the systems (SYSs), from the external environment to parts and components, is viable to guide the individuation of business opportunities (Sheu and Lee 2011). Besides, the literature reports examples concerning the exploitation of products' hierarchical and functional decomposition to deliver customer needs (McAdamset al. 1999) and to generate concepts (Tay and Gu 2002; Chen and Yan 2008).

In the literature, some scholars suggest approaches that support the idea generation task combining some of these Dimensions (see Appendix D.1 and D.3 for more details). However, nobody developed approaches that consider all of them. Hence, author has proposed an original algorithm to support this task. In addition, the tool has been also implemented in a computer application, namely iDea, in order to accelerate and simplify this critical activity.

The task of stimulating new ideas by contextually considering the four Dimensions requires to individuate objects referred to each of them to be favourably combined. Therefore the author decided to employ available schemes supposed to provide an exhaustive picture of the terms and the concepts representative for each Dimension. The items constituting the Dimensions were organized in terms of Elements, i.e. abstract concepts representing large categories of the matched cluster, and Specifications, i.e. concrete examples of common characteristics linked with the mentioned Elements. With respect to GDs, an available list of objects was found in the work of Borgianni et al. (2013), whereas a catalogue of needs was employed to estimate the success chances of innovative products. Given the large number of listed typologies of customer requirements, the sample was used to denote GDs' Specifications, subsequently grouped into a set of Elements. On the other hand, the Elements pertaining to SHs, LCs and SYSs were extracted from the representation provided by Cantamessa et al. (2013), the relevant objects reported in (Ward et al. 2003) and the mentioned TRIZ nine-screen framework, respectively. Specifications for the indicated Dimensions were elaborated by the author' research team on the basis of empirical observations of innovative aspects shown in successful products. Tables 3.5-3.8 show an excerpt of collected Elements and Specifications (the complete lists are presented in Appendix A).

Elements	**Specifications**
Fulfilled needs	• Quality of the expected outcomes; • Quantity or extent of the expected outcomes; • etc.
Versatility of use/ adaptability	• Suitability of the product according to different demands; • Adaptability of the product in diverging conditions with respect to the designed preferred ones; • etc.
Reliability/ safety	• Controllability of the system in order to obtain the expected outcomes; • Integrity of the product itself, its resistance to planned or accidental stress or collisions, the strength against wear or corrosion; • etc.

Ease	• The reduction of the information and skills to be gathered during the product life cycle; • The ease of acquiring the product, due to market penetration and distribution policies; • etc.
Aesthetics/ style/ethics	• Customize the product or certain properties; • The possibility of benefitting of the product (or its parts) for different employment after the end of its life; • etc.
Quickness	• The reduction of time to be waited before the functioning of the product delivers the expected outcomes; • The limitation of the time required to perform operations.
Cheapness	• The reduction of the consumption of parts, components or consumables; • The limitation of the required energy (or human power) needed for the product during its lifecycle; • etc.
Comfort/ ergonomics	• The absence of bother for the people; • The comfort of use, the ergonomics, the manageability; • etc.

Table 3.5 excerpt of elements and corresponding Specifications belonging to the Dimension "General Demands"

Elements	Specifications
Buyers	• Manager, decision maker • Parents or tutor • etc.
Users	• Teacher/trainer • Worker, employee • etc.
Beneficiaries	• Community, citizenry • Children • etc.
Outsiders	• Maintenance technicians or helpers • Third party developers • Assistants • etc.

Table 3.6 excerpt of elements and corresponding Specifications belonging to the Dimension "Stakeholders"

Elements	Specifications
Purchasing, choice and access activities	• Identifying the product on the web • Identifying the product on leaflets, brochures • etc.
Before use operations	• Shipping • Carrying • etc.

Utilization time	• Switching on/off • Handling • etc.
Elapsed time before further exploitations	• Exploiting the outcomes of the product utilization • Maintaining • etc.
End of the functioning	• Reselling the product and its accessories • Recycling or disposing of the product • etc.

Table 3.7 excerpt of elements and corresponding Specifications belonging to the Dimension "Lifecycle phases"

Elements	Specifications
Environment in which the product is situated	• Weather conditions • External environment • etc.
Product or service level	• Product in general • Service in general
Parts, components and accessories	• Case • Engine and transmission • etc.

Table 3.8 excerpt of elements and corresponding Specifications belonging to the Dimension "System hierarchies"

The manners of linking the Dimensions were preliminarily evaluated in a positive way in terms of the ratio between the benefits in employing the matching mode and the time spent to carefully consider the emerging combinations. It is worth noticing that matching all the Elements and/or Specifications composing the Dimensions would give rise thousands of combinations, whereof many of them could result meaningless in the majority of industrial contexts. In order to drastically reduce the number of combinations, the author opted not to consider all the four Dimensions contextually. The combination modes swivel on GDs, seen as a fundamental characterization of product attributes, to which the contents of the other Dimensions are associated to generate ideas. In other words, two concepts are matched simultaneously, whereas one of them refers to GDs' Dimension. More in details, three different combination procedures (to be exploited separately) are proposed:

- *quick*: any benefit (without indicating any particular content of GDs) with the Elements of SHs, LCs and SYSs. The user will exploit these Elements like a check list to identify new benefits that can be provided to different types of SHs, in various LCs and involving different SYSs;
- *standard*: Elements of GDs with the Elements of the other Dimensions. The user will focus on each type of benefit and tries to identify new opportunities for different SHs, in various LCs and at different hierarchical levels;
- *detailed*: a subset of the Specifications of GDs with particular Specifications of the residual Dimensions, as shown in (Appendix A). This kind of association is grounded on the observation of GDs' Specifications, which can vary with respect to particular Specifications (e.g. the customization of a product according to different exigencies of different stakeholders). Said Specifications

correspond to all the items included in a certain Dimension (indicated with “all” in Appendix A) or in tailored subsets.

The developed computer-aided application supports the task in terms of easing the combination of the items and the management of the generated ideas, making the developed method more usable. Any interested reader can freely download the iDea tool from the Internet at the web address: http://goo.gl/AwzZHF. In addition to the automatic execution of the above combination options, the prototype software allows selecting and customizing subgroups of Elements and/or Specifications in order to better fit the requirements of the industrial context in which the designer operates. Figure 3.7 presents the algorithm implemented in said ICT tool, shedding light on the possibility to select the contents of the Dimensions to be exploited and to switch between the three combination alternatives. A guide reporting the main functions of the software tool is included in the software application, downloadable from the above link and the code can be found in Appendix C.

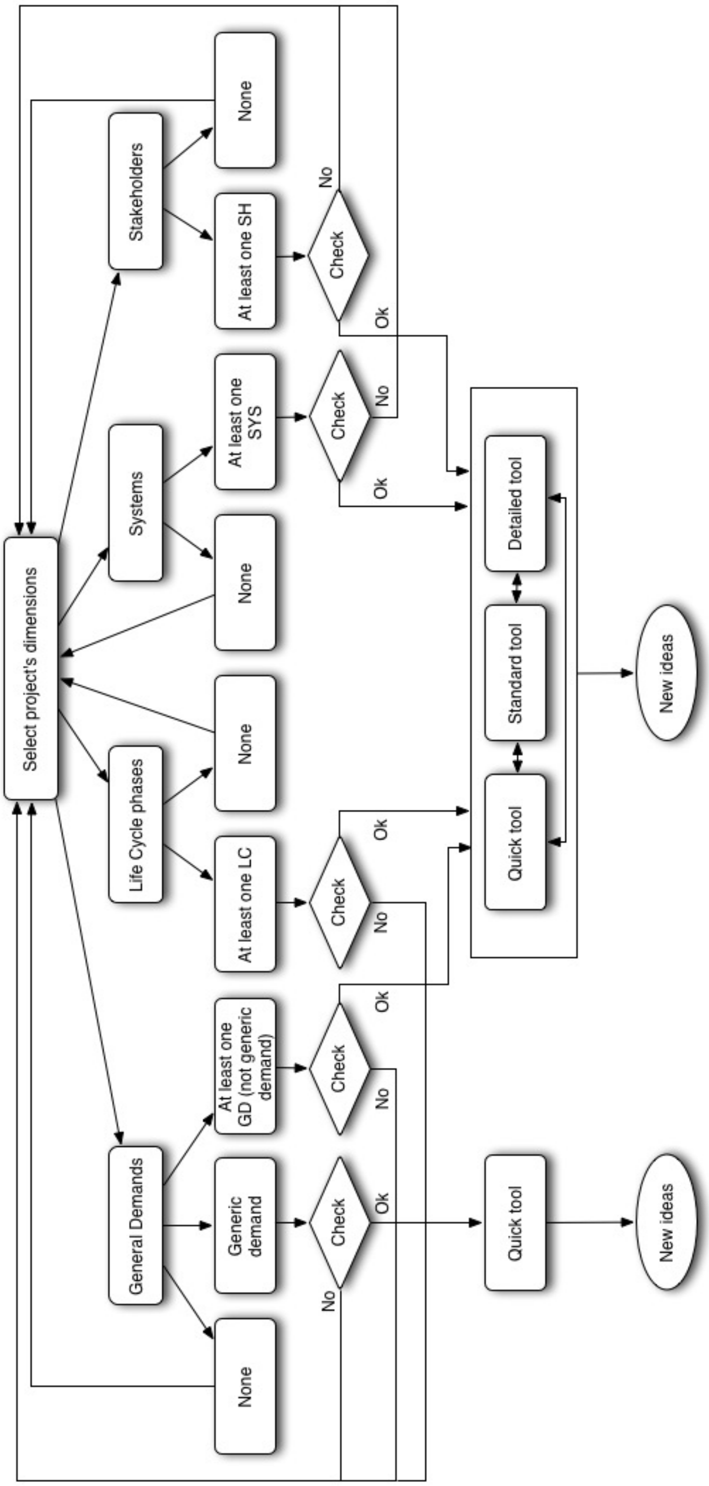

Figure 3.7 working flow of the prototype software aimed at stimulating ideas by combining concepts organized according to the developed taxonomy of product attributes

2. *Selection of new ideas to be assessed*

The previous phase can support the generation of lots of new ideas, therefore a preliminary selection could be useful to accelerate the following activities of Product Planning. This facultative task can be carried out using several decision-making techniques (e.g. Figueira et al. 2005), however a quick and simple way to assess generated ideas is the use of Likert scales. Hence, companies can score ideas (e.g. using a 1-5 scale, where 1 is the lowest score and 5 the higher one) according to their experience and preference (Figure 3.8). In order to simplify this task some evaluation criteria can be defined. For instance, the user can assess ideas' expected success, supposed technical feasibility and accordance with the company's core business (Figure 3.9) and then choose the most promising ideas (e.g. adding up partial scores).

Ideas	Poor	Fair	Average	Good	Excellent
Idea 1	1	X	3	4	5
Idea 2	1	2	3	X	5
...	...	...	...	...	...
Idea n	1	2	X	4	5

Figure 3.8 Likert scale (1-5) used to assess n ideas. The cross mark highlights the choices

Ideas	Expected success (1-5)	Technical feasibility (1-5)	Accordance with the company's core business (1-5)	TOT
Idea 1	4	1	2	7
Idea 2	2	5	3	10
...	...	...	...	...
Idea n	1	3	4	8

Figure 3.9 Likert scale (1-5) used to assess n ideas through three criteria: expected success, technical feasibility, and accordance with the company's core business. The scores can be added up obtaining a total score

The selection can be made using a threshold score. For instance, all ideas with a score greater than 3 can be mantained. If the number of selected ideas turns out to be excessive the threshold can be increased and/or the sub-group can be assessed again, trying to differentiate scores.

Discarded ideas should not be definitively eliminated, because they could be reconsidered in future NPD projects. Therefore, they can be clustered and archived. For instance, a possible classification is:

- promising but not feasible ideas: the current limits concern company's available (or preset) resources or inner policies. However, these ideas are interesing and could be reconsidered in future projects;
- not promising ideas: perhaps customer needs could change in the future and these ideas could be reconsidered.

3. *Differentiation strategy*

In order to define differentiation strategies, identified ideas (or sub-group of ideas selected through the previous activity) have to be expressed in terms of product profiles. Indeed, they will be compared with industrial standard(s) and strategic moves will be planned.

This activity can be carried out through the following steps:

1. Selection of a reference industrial standard;
2. Identification of new product attributes in generated ideas;
3. Analysis of existing attributes with their related performances and definition of differentiation moves, according to new identified ideas;
4. Check of planned differentiation strategies.

Among the industrial standards identified in the first step of the process a reference product profile has to be selected. This choice can be taken according to the objectives of the company. For instance, if the objective of an enterprise concerns the development of a premium product, the offer of "leader" (most important) firm in that field can be selected. As an alternative the average curve of competitors' premium offers can be drawn. In this case the performance levels of attributes should be similar, otherwise different offers have to be excluded and used only in the end of the process as further comparison curves to assess the planned differentiation strategy.

Innovative ideas identified in the previous activity have to be split into attributes. New product profiles will include completely new attributes and existing ones with varied (or maintained) levels of offered performance.

Four actions allow carrying out a differentiation strategy (Kim e Mauborgne 2005):

- *Eliminate*: remove existing attributes;
- *Reduce*: reduce the performance of existing attributes;
- *Raise*: improve the performance of existing attributes;
- *Create*: introduce new attributes.

"Maintain" action does not contribute to the differentiation process. However it cannot be omitted because it highlights attributes that products must have and it is essential in the following phases of the design process.

These strategic moves can be defined according to identified ideas. New attributes are linked to the action *Create*, the performance of existing features can be reduced, raised or maintained coherently with new objectives and attributes that are not essential (or have no sense) for new offer can be eliminated.

If idea generation task does not allow identifying clear ideas and/or a check of defined strategic moves is required, one or more of the following approaches can be used:

- Four actions framework (Kim and Mauborgne 2005): it provides four hints (related to the above mentioned four actions) to support the identification of favourable moves. The first one recommends companies to consider eliminating factors that have long competed on. Often those factors are taken for granted even though they no longer generate value for customers. The second hint suggests determining whether offered products features have been overdesigned and, in case, reducing their performance well below the industry's standard. Indeed, often companies focus on beating the competition and neglect real customer needs. The third advice pushes to eliminate the compromises industry forces customers to make, raising the performance of these factors well above the industry's standard. Eventually, the fourth hint exhorts to discover entirely new sources of value for the customers and create new demand.

- Graphical analysis of strategy canvas: differentiation moves can be planned and/or checked observing empty areas in strategy canvas, i.e. the levels of performance not offered by competitors. This approach can only provide some quick hints but it should not be used in a systematic way. Indeed, new ideas should have well-drawn objectives and cannot be a random mix of attributes/performances.
- New Value Proposition Guidelines (Borgianni et al. 2012): these hints derived from a study focused on the analysis of successful case studies and market failures. Attributes of these products and services have been classified into three main categories (functional features):
  - UF (Useful Function): attributes related to the delivery of useful functions, meant as the direct benefits perceived by the recipients for whom the product or service has been designed;
  - HF (Harmful Function): measures to attenuate or avoid the inconvenience due to undesired/harmful side effects;
  - RES (Resource): efforts aimed at mitigating the consumption of resources from the viewpoint of any stakeholder.

Classified attributes have been then analysed through the lenses of the four differentiation moves acted by companies, in order to identify repeatable patterns. According to this analysis advices shown in Table 3.9 have been provided.

Most favourable actions	Actions to be maximally avoided
Create RES	Reduce RES
Create UF	Eliminate HF
Raise HF	
Raise RES	

Table 3.9 summary of New Value Proposition guidelines

- Combination of graphical analysis of strategy canvas and New Value Proposition Guidelines can be used in order to identifying opportunities (differentiation moves into empty areas) and verify if those actions related to given attributes can be consistent with guidelines.

All these techniques start focusing on product attributes and they are quick and ease to use, independent from input subjectivity and support the selection of most beneficial product ideas.

Partial results

The results obtained through the execution of the second phase of the method are summarized as it follows:

1. *New product ideas*: new attributes, features and/or general product ideas aimed at generating value for the customers.

2. *Industrial standard*: reference as-is value curve that represents the starting point to plan a differentiation strategy.
3. *Differentiation strategies*: set of strategic moves planned according to generated new product ideas, in order to act differentiation strategies from the reference industrial standard.

According to ideal properties collected in Chapter 2, general approach and techniques illustrated in this step satisfy the need of supporting the individuation of latent needs and formally schematize identified ideas. In addition, proposed tools are quick and ease to use, can potentially involve both multidisciplinary teams and customers and they can focus on both product attributes and general ideas. Eventually, an original computer application to support idea generation activity has been developed.

3.2.3 Step 3: Idea selection

Objectives

The idea generation phase usually gives rise to several options. Hence, this divergent activity must be followed by a convergent idea selection task (Rietzschel et al. 2006). The idea selection, sometimes called Opportunity Analysis stage (e.g. Cagan and Vogel 2001; Koen et al. 2002; Achiche et al. 2013), constitutes the decision-making phase of the Product Planning that allows choosing the alternatives to be further developed.

Both benefits and feasibility limits of identified ideas are assessed in this step in order to support comparison and final choice of the most promising one.

The main output of this task is a New Value Proposition (NVP), i.e. the list of product attributes and related performance that should be used as a guide for designing and developing new products.

This step includes the following activities:

1. *Benefits' analysis*: such activity is aimed at assessing the potential success of ideas (or sub-group of ideas) identified in the previous phase.
2. *Costs' analysis*: this activity is aimed at assessing the feasibility of new identified ideas, according to various points of view (e.g. economic investment, requested time, requested skills, etc.).
3. *Product profile's choice*: this activity is aimed at selecting the most promising idea, comparing benefits and costs of new product profiles.

Step implementation

1. Benefits' analysis

In order to select the most promising product idea, mere subjective assessments should be avoided. The analysis of benefits can be carried out through a repeatable and reliable tool introduced in the second Chapter, i.e. VAM (Borgianni et al. 2013). It allows estimating the potential market appraisal of a new artefact through a balance of its functionalities with respect to the alternatives existing in the market. The metrics have been defined through an induction process from a large collection of successful innovations and market failures. Therefore, this tool is completely independent from subjective assessments.

The tool requires as input product attributes classified according to the four differentiation moves and functional features (described in the previous step) and gives as output success percentages ranging from 0 to 100% of each product profile. The VAM formula is:

$$VAM(\%) = \frac{1}{1+e^{-z}} \times 100 \quad (1)$$

Where *z* can be obtained through the following formula:

$$\begin{aligned} z = &-3{,}19 + 3{,}44\times UF/Create + 1{,}32\times HF/Create + 2{,}87\times RES/Create \\ &+ 0{,}97\times UF/Raise + 1{,}75\times HF/Raise + 0{,}41\times RES/Raise \\ &- 0{,}84\times UF/Reduce - 0{,}27\times HF/Reduce - 1{,}78\times RES/Reduce \\ &- 0{,}46\times UF/Eliminate - 9{,}49\times HF/Eliminate \\ &- 1{,}65\times RES/Eliminate \quad (2) \end{aligned}$$

Each term characterized by *functional feature/differentiation move* concerns the number of product attributes classified in that manner. For instance, in formula (2) *UF/Create* will be equal to 3 if product profile would include three radical new attributes related to the delivery of useful functions. In order to use this tool, it is important that all the attributes are expressed in a positive manner because, as seen above, the raise of performance improves the customer satisfaction and vice versa.

If VAM results in the range 0-50% the product is expected to fail, vice versa the range 50-100% suggests a commercial success. However, VAM is affected by uncertainty because of the nature of the approach used to develop this tool. Each weight of formula (2) varies according to a normal distribution characterized by a given mean value and a standard deviation. Therefore, the author introduced an approach to assess the uncertainty range:

1. Pick *n* (e.g. 5000) random weights from each normal distribution;
2. Calculate *n* VAM using the collected weights;
3. Supposing a normal distribution of obtained data, identify the mean value and standard deviation of VAM data. Latter index will be useful to consider the uncertainties on the mean value of VAM.

Obviously these calculations required an automatic system and a Java app (see Appendix C for the code) has been developed. A screenshot of the tool is shown in Figure 3.10. The app requires as input the number of attributes classified according to the two taxonomies and automatically calculate the VAM and the uncertainty on that value.

According to the ideal properties collected in Chapter 2, VAM allows to satisfy the following ones:

- it supports the selection of most beneficial product idea;
- it is quick and ease to use;
- it has been implemented by the author in a computer application;
- it has been improved in terms of reliability, integrating a method to assess the uncertainty of the outputs;
- it is independent from inputs subjectivity;
- it focuses on product attributes.

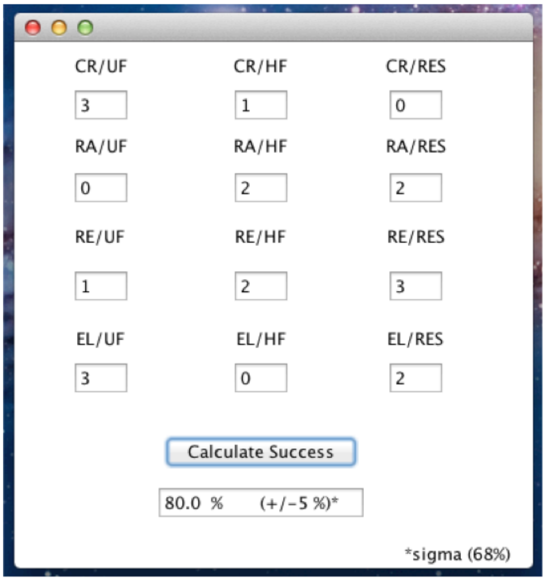

Figure 3.10 screenshot of the tool developed to calculate VAM. The labels CR, RA, RE, EL, UF, HF, RES stand for Create, Raise, Reduce, Eliminate, Useful Functions, Harmful Functions and Resources respectively

2. *Cost's analysis*

Feasibility of a product can depend from several factors. In addition, it is very difficult to assess costs in early phases of NPD process. Therefore, a flexible tool, namely Profile Cost Matrix (PCM), has been developed in order to guide this activity according to specific companies needs and priorities like: expected economic investment, requested time to design and develop the product, reputation risks, etc.

As shown in Figure 3.11 in PCM companies' demands are prioritised assigning a weight, w_j (e.g. from 0 up to 5), and attributes (with their related strategic moves) are linked to company's demands through correlation factors, a_{ij} (e.g. Null=0, N; Low=1, L; Medium=3, M; High=9, H). High correlation means that a certain action made on a product attribute could have a great impact on a specific need. In other words it entails a reduction of feasibility of product idea.

		Company's Needs/Risks				
		Need 1	*Need 2*	…	*Need m*	
	Weight	w_1	w_2	…	w_m	***Attribute's Cost***
Product Attributes - Differentiation moves	*Attribute-move 1*	a_{11}	a_{12}	…	a_{1m}	*Cost* A_1
	Attribute-move 2	a_{21}	a_{22}	…	a_{2m}	*Cost* A_2
	…	…	…	…	…	…
	Attribute-move n	a_{n1}	a_{n2}	…	a_{nm}	*Cost* A_n

Figure 3.11 Profile Cost Matrix

The cost of each attribute (A_i) can be calculated through the following formula:

$$Cost\ A_i = w_i a_{i1} + w_i a_{i2} + \cdots + w_i a_{im} = \sum_{j=1}^{m} w_i a_{ij} \quad (3)$$

Hence, the feasibility of a new idea can be obtained summing up the costs of the attributes related to that product profile (P_k):

$$Cost\ P_k = \sum Cost\ A_{i(P_k)} \quad (4)$$

1. Product profile's choice

After identifying both potential benefits and costs of new product profiles, the final step of the process concerns the selection of most promising one.

As advanced by Miles' Value Engineering (Miles 1949), firms usually want to maximize the ratio between the profitability of the delivered products and the costs pertaining its design and development. Therefore, the ratio between VAMs and feasibility costs (5), namely Value Index (VI), can be used to rank different product profiles.

$$VI = \frac{Benefits}{Costs} = \frac{VAM}{Cost\ P} \quad (5)$$

Using this approach the selection task could be computerised and the output would be independent from subjective assessments.

However, it could be useful to have a wide picture of alternative profiles in order to make a well-founded decision. Therefore, a benefits-costs (success-costs) chart can be used to represents both potential success and feasibility of alternative ideas (Figure 3.12).

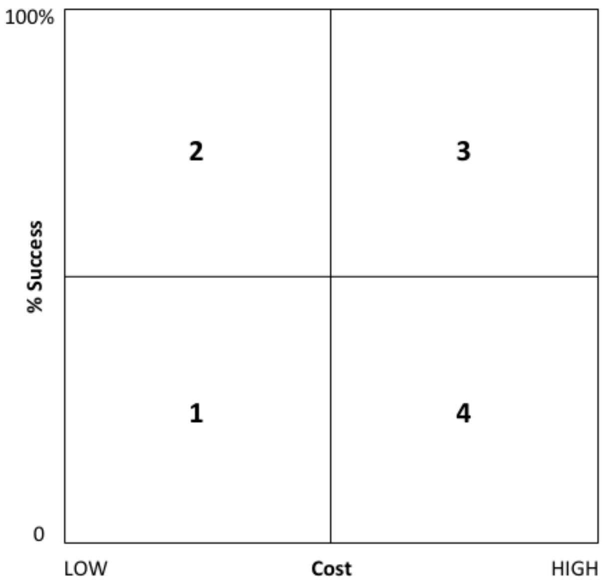

Figure 3.12 success-costs chart

The chart can be divided into four areas:

1. *low cost-low success*: here the feasibility is high but potential success is less than 50%;
2. *low cost-high success*: this is the most promising area because the feasibility of profiles is high and ideas are expected to achieve a commercial success;
3. *high cost-high success*: in this area high success require high costs;
4. *high cost-low success*: this is the less promising area because both feasibility and potential success are low.

The minimum cost can be added on the left side of x-axis, while the maximum one on the right side. In this way all the other costs can be distributed on the span. To simplify this process smallest and biggest values can be assumed equal to 0 and 100, respectively, and other values can be normalized as it follows:

$$Cost_i(\%) = \frac{(Cost_i - Cost_{min})}{(Cost_{max} - Cost_{min})} \times 100 \quad (6)$$

Observing the chart, companies can decide which product profile they want to develop, according to their propensity to risk and available resources.

In the end of the process the selected product profile, i.e. the list of attributes and related differentiation moves, will constitute the target objectives of the following design phases.

Partial results

The results obtained through the execution of the final step of the method are summarized as it follows:

1. *Benefits of product profiles*: potential success of new product profiles;
2. *Costs of product profiles*: potential cost (feasibility) of new product profiles;
3. *Selected product profile*: most promising product profile that company want to develop in the following phases of the design process.

According to ideal properties collected in Chapter 2, general approach and techniques illustrated in this step satisfy the need of supporting the selection of most beneficial product idea. In addition, proposed tools are quick and ease to use, they can potentially involve multidisciplinary teams, they allow to formally schematize identified ideas and they focus on product attributes. Eventually, an existing tool (VAM) has been implemented in a computer application, improving both quickness of use and reliability (adding an analysis of uncertainties of output data).

4 Illustrative application of the method

In this Chapter two illustrative application of the proposed approach will be presented. These case studies have been carried out through a collaboration with an Italian glass accessories firms and concern components for point-fixed curtain wall (Figure 4.1a) and glass staircases (Figure 4.1b).

The application of the method will be described step-by-step, showing how described tools have been applied and providing the main obtained outputs. A separate discussion for the iDea tool will be presented in Section 5, illustrating specific tests developed to highlight its potentialities and limits.

Figure 4.1 a) Point-fixed curtain wall; b) Glass staircases

4.1 Glass accessories: components for point-fixed curtain wall and glass staircases

Both components for point-fixed curtain wall and glass staircases have had a wide diffusion in the last decades. Because of the commercial success of these products, companies have only tried to maximize the ratio between quality and cost, without looking for differentiation strategies up to now. However, the capability to innovate the commercial offer in this field is becoming a key aspect for the survival of the firms, as claimed by the industrial partner, because developing countries increasingly succeed in providing good low-cost products.

Components for point-fixed curtain wall are currently constituted by two main systems: spider and rotules. Spiders (Figure 4.2a) are blocked to load-bearing structure of the building and they have to support the glass facade. Rotules (Figure 4.2b) join the glass panels to the spiders. For the sake of brevity, the term "spider" will be used to pertain combination of the two systems.

Figure 4.2 a) Spider; b) Rotule

On the other hand, components for glass staircases have to support steps and often balustrade/railings (Figure 4.3). These artefacts, like spiders, have a main structural body matched with rotules (or screws) that joint support to the step, wall and balustrade/railings.

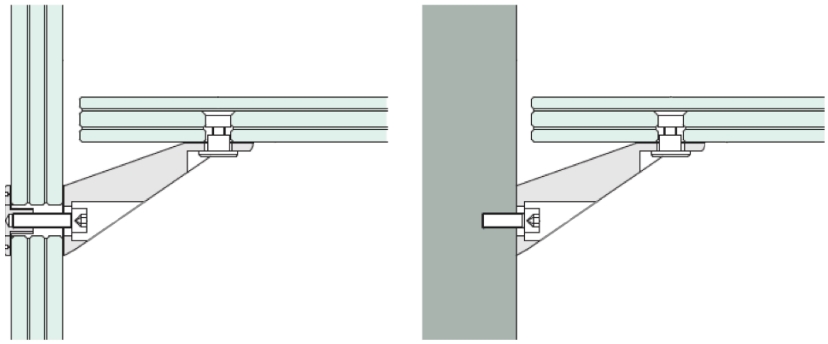

Figure 4.3 components for glass staircases in two configurations: stair joint to glass balustrade and stair joint to the wall

As seen above both products are quite simple and design efforts have been focused only on their mechanical strength and adaptability to various configurations (e.g. not linear facade, winding staircase) up to now. Both simplicity and competitive market make these products ideal case studies to test the developed method.

Here in the following each step of the approach will be applied to the case studies starting with the information gathering activity, following with the idea generation step and ending with the selection of most promising ideas that could be developed by industrial partner in the near future.

4.2 Step-by-step application of the method

4.2.1 Step 1: Information gathering

Both components for point-fixed curtain wall and glass staircases have had a wide diffusion in the last decades. Because of the commercial success of these products, companies have only tried to maximize the ratio between quality and cost, without looking for differentiation strategies up to now. However, the capability to innovate the commercial offer in this field is becoming a key aspect for the survival of the firms, as claimed by the industrial partner, because developing countries increasingly succeed in providing good low-cost products.

A preliminary search has been carried out in order to collect basic information about how the two products work and their fields of application. In this first phase, besides the information collected talking with industrial partner, technical (especially online available university lecture notes) and technical-commercial (especially companies' websites) sources have been consulted. Table 4.1 collects the main type of sources analysed during the tests and provides an excerpt of analysed sources.

Type of sources	**Illustrative identified sources**
Technical sources	www.wikipedia.org (curtain wall); www.arch.virginia.edu (lecture about glass and structures); etc.
Technical-commercial sources	www.loglimassimo.it; www.faraone.it; www.crlaurence.com; www.aliexpress.com; etc.
Scientific sources	Martins, Delgado and Camposinhos (2012) *Spider Glass Behaviour Under Seismic Action*. In WCEE 15, Lisboa 2012; Kooymans and Shafik (2008) *Free Span Structural Glass Staircase*. In Challenging Glass: Conference on Architectural and Structural Applications of Glass, Delft 2008; etc.
Patents	EP1882789; CN2013282892U; DE20062003497U; etc.

Table 4.1 examples of sources collected and analysed during information gathering step

The following activity focused on the definition of industrial standards. Industrial Standard Chart guided to the identification of two main categories (i.e. premium and budget) and additional standards (alternative/combinable products), as shown in Figure 4.4.

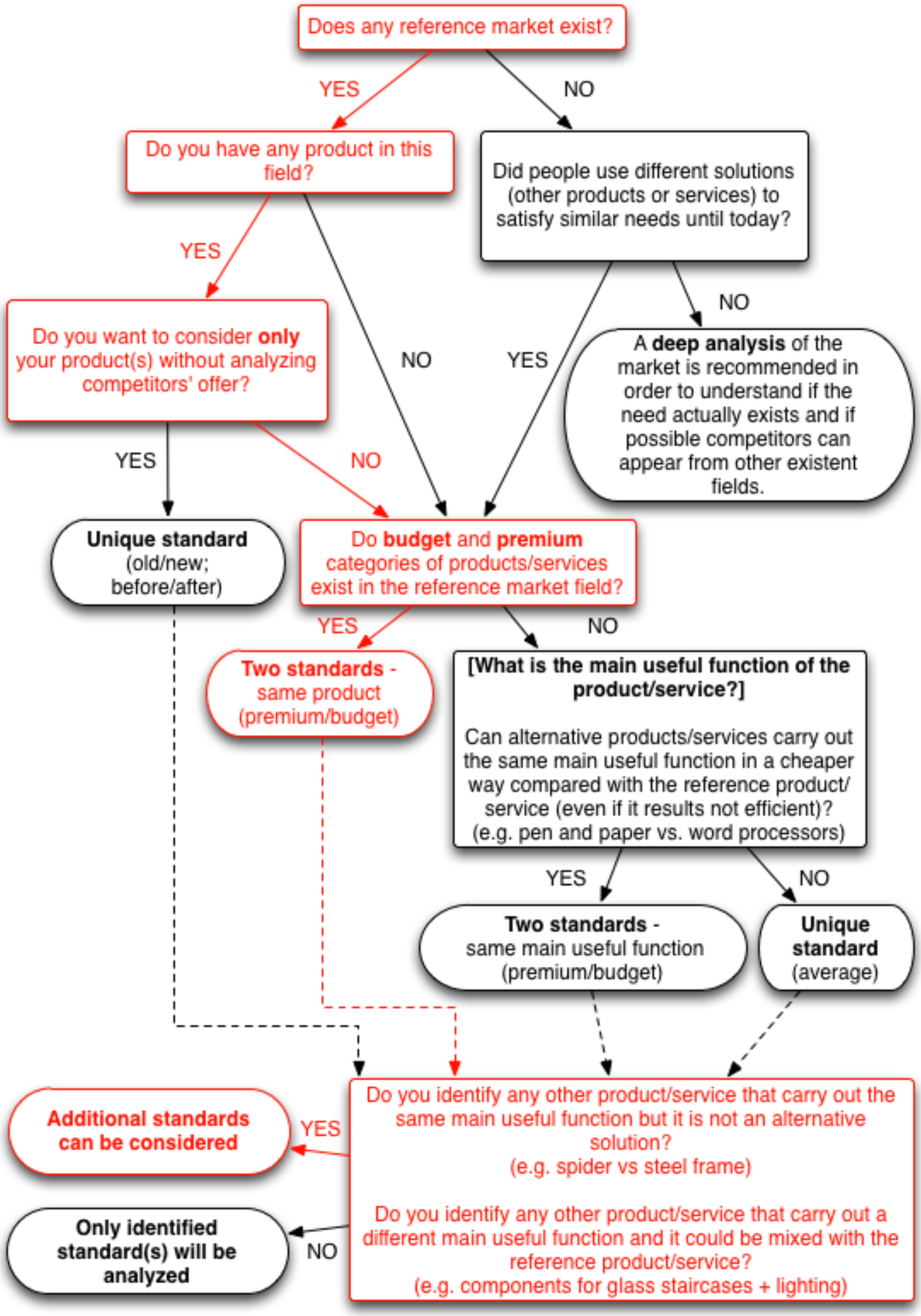

Figure 4.4 industrial Standard Chart. Red boxes and arrows show the path traced for both case studies

The industrial partner belongs to the premium category, in which three additional competitors can be found (for both types of product). Budget category is crowded by companies (especially established in Asia) that offer cheap products characterized by quite low quality standards.

In premium category we decided to maps the offer of each competitors, while in budget category a mean curve have been drawn because of the high similarity among companies' offers. Additional standards have not been in depth analysed and drawn in the strategy canvas because industrial partner want to mainly focus on premium competitors offers. However, alternative products/services were useful in the following idea generation phase. Indeed, they provided useful hints and were not neglected during the definition of differentiation strategies.

Analysis of companies websites and technical-commercial sources, available on the web, allowed to identify 107 attributes in the spider field and 111 attributes related to components for glass staircases. These attributes concern both products features and related services offered by the companies. For each attribute the performance offered by premium competitors and a mean value provided by the budget category has been identified analysing collected sources. In order to depict these performances we choose a range from 0 (not provided attribute) to 4 (very high level of offered performance). For instance, according to the attribute "ease of requesting a quote" (included in both case studies) level 4 has been assigned to companies that provide a catalogue with prices; level 3 concerned companies with a specific box on the website to request a quote; level 2 has been used when a specific e-mail address is provided; level 1 has been assigned if only generic contacts can be identified in companies web sites; level 0 has been never user, however it should be related to the impossibility to request a quote.

Figures 4.5 and 4.6 show the strategy canvas drawn respectively for spiders and components for glass staircases. In both fields an average curve for premium firms does not have sense because, the level of offered performance significantly vary for some attributes.

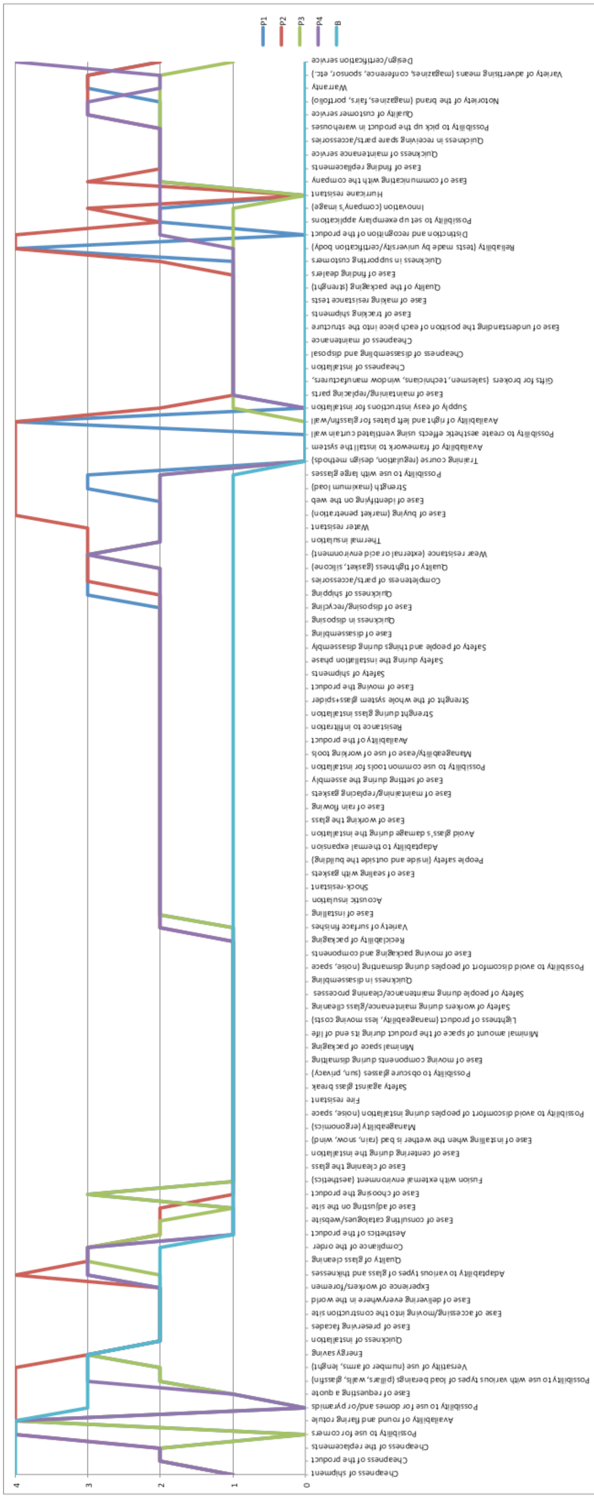

Figure 4.5 Strategy canvas of spider case study. Curves P1-P4 depict the offer of the four premium companies in this industrial field. Curve B shows the average offer of budget firms

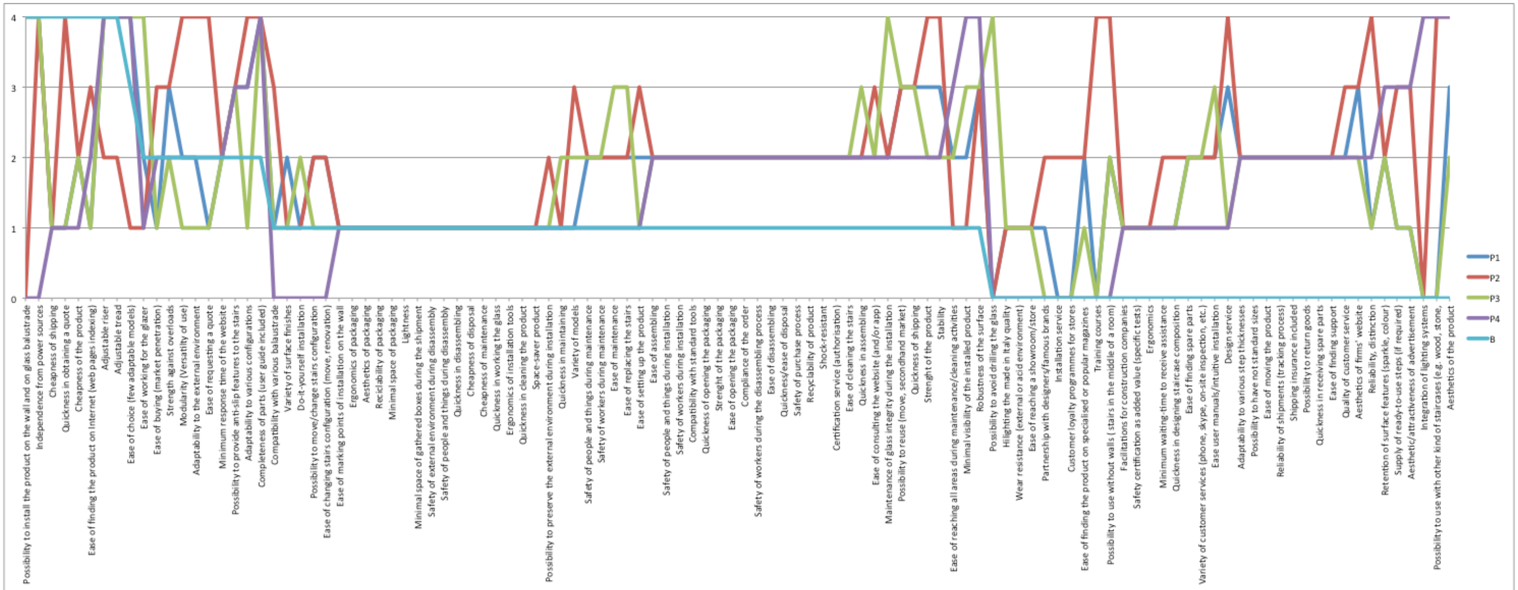

Figure 4.6 Strategy canvas of components for glass staircases. Curves P1-P4 depict the offer of the four premium companies in this industrial field. Curve B shows the average offer of budget firms

4.2.2 Step 2: Idea generation

The idea generation activity has been carried out employing the entire set of tool introduced in Section 3:

- Six Paths Framework (Kim and Mauborgne 2005);
- CRs Check List (Rotini et al. 2012);
- LCSO (Rotini et al. 2012);
- APS Check List (original tool);
- iDea (original tool).

In this Subsection the use of new tools, i.e. APS Check List and iDea have been accurately described, while only an excerpt of identified ideas obtained using the other three existing tools has been shown.

Table 4.2 shows a subgroup of new ideas/attributes identified using Six Paths Framework (the full set is included in Appendix B). The first row shows the paths and second and third rows include ideas generated thinking to each path for both case studies.

Six Paths Framework	Spider	Components for glass staircases
Look across alternative industries	energy saving; green ethics	possibility to use for disabled persons; ease of moving heavy objects; etc.
Look across strategic groups within industry	-	use of precious materials (e.g. high quality finishes); preassembled stairs
Redefine the industry buyer group	promotion of architect and construction companies; incentive (e.g. gifts) for buyers and/or influencers; etc.	promotion of architect and construction companies; incentive (e.g. gifts) for buyers and/or influencers; etc.
Look across to complementary product and service offerings	integration of lighting systems; possibility to use as antenna (e.g. TV, radio, Wi-Fi); etc.	design service; maintenance service; etc.
Rethink the functional-emotional orientation of an industry	customizability; use of precious materials	-
Participate in shaping external trends over time	possibility to project augmented reality on glasses; energy recovery; etc.	earthquake proof; domotic applications; etc.

Table 4.2 excerpt of new ideas/attributes identified using Six Paths Framework

Table 4.3 collects an excerpt of new ideas/attributes identified using CRs Check List (complete list can be found in Appendix B). The first row shows the list of CRs and second and third rows include ideas generated thinking to each CR for the two case studies.

CRs Check List	Spider	Components for glass staircases
The advantages arising from the exploitation of the product, which can be referred to the quality and the quantity of the desired output	acoustic resistance	possibility to bear very high weights
The amount of users for whom such benefits are met, thus the flexibility of the product according to different customer demands	customizability for companies (e.g. shapes, logos); customizability reserved to rich persons (e.g. gold, gemstones)	children safety (possibility to warn if children try to go upstairs/downstairs); compatibility with disabled/old persons
The capability of the product to meet the customer needs within the requested time	-	-
The adaptability of the product when working in diverging conditions with respect to the designed preferred ones	strength against acts of vandalism	possibility to use the product in external environments; possibility to melt the snow; possibility to automatically clean the stairs
The stability of the product performances when subjected to external perturbations	-	shock resistant
The chance to effectively control the system in order to obtain the expected outcomes	ease of centring the glass on load-bearing structure during installation; ease of regulating the system during installation	possibility to change parameters (riser, tread) after the installation
The possibility to expand or upgrade the range of product functioning	possibility to integrate antennas (e.g. TV, radio, Wi-Fi); possibility to integrate various kind of sensors (temperature, brightness, fire, gas, rain, wind, etc.); possibility to automatically clean glasses	possibility to purchase accessories for customizing the product
The opportunity provided to advantageously employ the product for not standard users or disabled people	-	compatibility with various stair lifts; support systems for blind persons
The possibility to customize the product or certain properties according to the user tastes and tendencies	possibility of having “invisible” spiders	possibility to choose customized finishes; possibility to have “invisible” supports
…	…	…

Table 4.3 excerpt of new ideas/attributes identified using CRs Check List

Figures 4.7 and 4.8 show new ideas/attributes identified using LCSO respectively for spider and components for glass staircases. Each box includes ideas generated focusing on the combination of line (system) and row (life cycle phase).

	Purchasing, choice and access activities	Before use operations	Utilization time	Elapsed time before further exploitations	End of the functioning
Environment in which the product/service is situated	Possibility to support design activities Aesthetics of the stores Possibility to promote the works of technicians Green ethics Humanitarian ethics (purchase helps poor people) Adaptability to different configuration Possibility to win prizes purchasing the product Management of bureaucracy Possibility to create a network among technicians, construction companies and glass makers Supply of digital documents (e.g. manuals, technical drawings, etc.) Supply of design software/tools Possibility to change glass orientation	Distinction of the construction site Possibility to track shipments Supply of boilersuits and PPE to workers Use of eco-friendly means of transport Consultancy on building site	Possibility to control external environment Possibility to project on the street logos/advertisements/coloured lights Possibility to integrate bicycle stand Possibility to integrate seats Possibility to integrate wifi antenna Possibility to integrare projecting roof Safety against glass break Possibility to provide information about the	Safety against thieves Safety against vandals Possibility to create lighting effects (e.g. showrooms, hotels, etc.) Possibility to detect dangerous circumstances (e.g. suspect airplanes)	Eco-friendly equipment for dismantling Possibility of reuse/move the building in poor countries
Product or service level	Customizability (finishes, shapes, materials, etc.) Ease of choosing the product (ease tool that guides to the best solution) Sound-proof Energy saving Sense of cheapness (discounts, promotions, gifts) All inclusive service (design and installation)	Ease of installing the product with bad weather Ease of identifying the position of each component in the building Possibility to verify the correct installation (e.g. through sensors)	Possibility to include windows in the facade Possibility to integrate domotic applications (e.g. speaker system, lighting systems, safety systems) Integrated heating/cooling system Possibility to use the spider to hang/place objects "invisible" spiders (aesthetichs) Strenght against extraordinary events (e.g. earthquake) Possibility to control glass obscuring Integration of projector	Anti-fog Possibility to warn about malfunctioning Possibility to warn about extraordinary events	Ease of selling the building Possibility to verify the integrity of the spiders in their end of life Discount on new purchase Possibility to reuse the product changing the configuration Possibility to reuse the product (e.g. roof, inner walls, etc.)
Parts, components and accessories	Availability of accessories (electronic devices, lighting systems, etc.) Supply of a scale model of the building Ease of finding replacements Customizability of the accessories	Recyclability of the packaging Water resistant packaging	Integration of emergency systems (e.g. water mist, emergency lights) Integrated air circulation system Possibility to attach ventilated facade	Possibility to control the structural integrity of the building	Ease of recycling parts and accessories

Figure 4.7 new ideas/attributes about spiders identified using LCSO

	Purchasing, choice and access activities	Before use operations	Utilization time	Elapsed time before further exploitations	End of the functioning
Environment in which the product/service is situated	Accessibility to the store/showroom for disabled persons Possibility to see real installation in show rooms Incentive (e.g. gifts) for buyers and/or influencers Possibility to buy online and pick up the product in the store Professional design software (e.g. Revit) license for free Possibility to have a personal showcase on company's web site (for professionals) Possibility to reserve a visit with an expert by a store/showroom Online tutorials Green ethics of the company Possibility to support humanitarian organisations Maintenance service for free Cleaning service for free Design quickness Possibility to see a rendering of the stair in its Possibility to purchase through the smartphone/tablet Compatibility with steps made by various materials (besides glass)	Free shipping Possibility to choose delivery day/hour Use of eco-friendly means of transport Possibility to avoid drilling the wall Compatibility with various kind of walls (plasterboard, stone, surfaces with irregular shapes etc.)	Possibility to use of commercial cleaning robot Safety against glass breakage Ease of moving things upstairs/downstairs Fire-resistant Anti-seismic	Ease of reaching all the surface for cleaning the product Alert about wear/collapsa	Disposal service Support in reconfiguring in new places (new house, home renovation) Possibility to reuse in poor countries
Product or service level	Customizability of the product Ease of choosing the product (es: few basic Possibility to use the stairs to make sport (communication with electronic devices) Compatibility with varios kinds of disabilities Safety for children and animals Possibility to use the product to hang/contain objects Strength in not standard circumstances (e.g. external environment, extraordinay events like earthquake) Possibility to move/reuse the product for different configurations/places Possibility to have "invisible" supports	Strenght of product surface	Possibility to use stairs as a seat Possibility to hang shelves Possibility to obtain a slide for children and/or things Integration of an elevator Possibility to change parameters (riser, tread) after the installation Possibility to use as an energy storage device (kinetic energy) Possibility to integrate heating/cooling systems Possibility to obscure the glass (avoid dizziness) Safety against fall Safety with atmospheric agents (external environment) Possibility to use in the dark Integration of lighting systems	Filth detection Reminder system for maintenance Minimal amount of space when the staircase is not used (space-saving) Possibility to install a stairlift Possibility to prevent the use of guests, children, thieves Ease of cleaning the product Possibility to move the staircase	Possibility to give back the product obtaining discount for new purchase Ease of selling second hand products
Parts, components and accessories	Cheapness of the accessories Supply of spare parts for free Adaptability of accessories to various components for glass staircases Customizability of the accessories Home interior design magazine for free Possibility to have preassembled staircases Possibility to reuse the packaging Supply of tools for installation Home accessories for free Management of bureaucratic practices	Supply of knee pads/mats for installers Strenght of the packaging against atmospheric agents Supply of an unique tool to assemble the staircase Possibility to insert/remove photos, postcards, drawings, etc. into the steps	Cleaning robot for free Possibility to detect users Integrated emergency systems (fire, gas, etc.) Integrated speaker system Integrated perfume diffuser	Ease of changing accessories Ease of fixing accessories Quickness in changing accessories Quickness in cleaning accessories Supply of cleaning products Possibility to add/change aesthetic accessories	Possibility to reuse accessories for new staircase Possibility to reuse accessories for different purposes

Figure 4.8 new ideas/attributes about components for glass staircases identified using LCSO

APS Check List is one of the two original tools developed to support the idea generation phase. As seen in the previous Chapter it collects the main categories of products and services and provides some examples. These hints have been used to identify complementary product and service offerings and/or new product features.

For instance the item "*products for preserving and maintaining"* (and related list of examples) stimulated for spider two ideas about complementary product, i.e. *supply of cleaning products for free* and *supply of products to insulate (gasket) for free*, and an idea about a new product feature, i.e. *possibility to automatically clean the glasses*.

Table 4.4 shows an excerpt of new ideas/attributes identified systematically analysing each item of APS Check List for both case studies (the full list of identified ideas is included in Appendix B).

APS Check List		Spider	Components for glass staircases
PRODUCTS	***Kits:*** *travel kit, hobby kit, vehicle kit, product care kit, body care kit, first aid kit, repair kit, tool kit, survival kit, educational kit, needle kit, etc.*	-	supply of product care kits
	Gadgets: *key chains, pens, t-shirts, hats, watches, office accessories, stickers, etc.*	-	-
	Product for colouring or changing colour: *paints, varnishes, lacquers, adhesive films, covers, cases, boxes, interchangeable parts, etc.*	supply of products for changing colour (e.g. paints, varnishes, interchangeable parts)	supply of product for changing colour/shape (adhesive films, covers, interchangeable parts)
	…	…	…
SERVICES	***Management services:*** *business management, business administration, financial affairs, real estate affairs, personal issue management, advertising, website, catering, etc.*	supply of real estate services; supply of advertising services	supply of real estate services; supply of advertising services
	Research and development services: *customized solutions, identification of best solutions, prototype development services, information search services, surveys and data analysis services, etc.*	included design service	possibility to customize the product during the design phase; identification of the best solution
	Installation/building services: *assembly services, test services, etc.*	installation service	-
	…	…	…

Table 4.4 new ideas/attributes identified using APS Check List

Eventually, the other original tool named iDea has been used selecting one of the three modules (standard module) described in the previous Chapter. This procedure, as seen above, combines default GDs with SHs, LCs and SYSs providing a list of hints that support the identification on new product ideas/attributes. For instance, the combination of "Ease" (Element of GDs) and "elapsed time before further exploitations" (Element of SHs) has led to the generation of new ideas about spiders and components for glass staircases, i.e. the possibility to automatically clean glasses and the possibility to make emergency calls respectively.

The first step of the tool concerns the selection of elements, for each Dimensions, that user want to analyse. Partner company decided to include all the items, deselecting only the GD "fulfilled needs" (Figure 4.9).

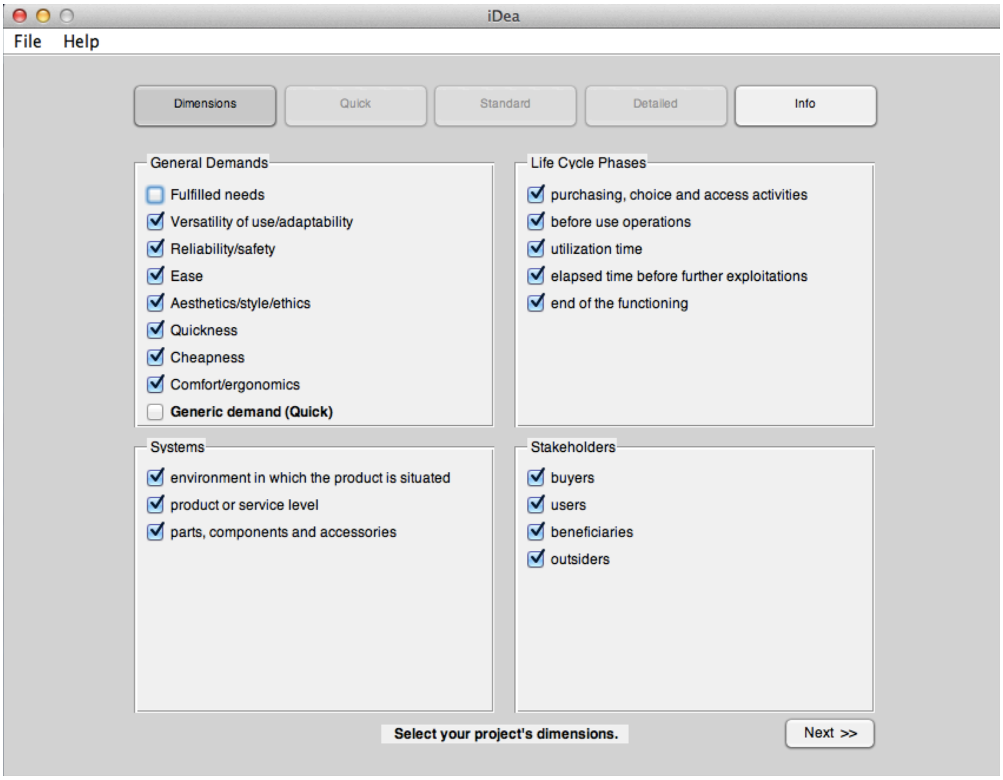

Figure 4.9 first screen of iDea tool. The GD "fulfilled needs" have been deselected

The decisions to use only standard tool and omit an Element of GDs have been made looking for a balance between time that expert could commit to this activity and possibility to explore the design space. Indeed, he supposed that already fulfilled needs would provide scarce innovative ideas and standard module would be a fair compromise to support a satisfactory idea generation activity generating 84 hints: $7GDs \times (5LCs + 3SYSs + 4SHs)$.

Figure 4.10 shows the standard module of iDea used to identify attributes and ideas. An excerpt of these ideas is provided in Table 4.5 while the full list is included in Appendix B. The first column of Table 4.5 collects hints generated by the tool while second and third columns shows identified ideas in the field of spider and components for glass staircases, respectively.

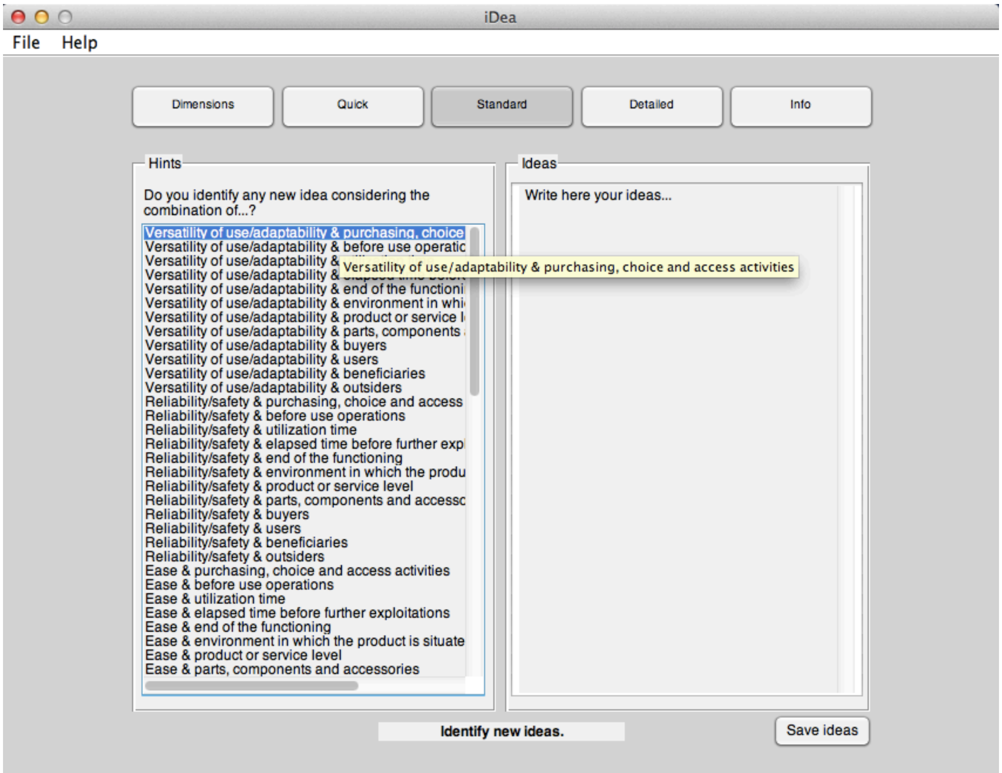

Figure 4.10 standard module of iDea tool. On the left there is the list of hints and on the right new ideas can be written down

Standard module of iDea	**Spider**	**Components for glass staircases**
Versatility of use/adaptability *related to* ***environment in which the product is situated***	possibility to change the shape of the building (dynamic)	possibility to use the product in external environments
Versatility of use/adaptability *related to* ***product or service level***	integration of lighting systems (for internal or external lighting); domotic applications; integrated apparatus for heating/cooling; integrated apparatus for ventilating	adaptability to surfaces that can change their shape
Versatility of use/adaptability *related to* ***parts, components and accessories***	supply of an unique basic component and lots of accessories to fit various configurations	possibility to combine parts in order to obtain different shapes
…	…	…

Table 4.5 new ideas/attributes identified using the standard module of iDea

All the ideas/attributes generated through the use of idea stimulation tools have been collected and doubles have been eliminated. Appendix B shows the final list of ideas/attributes, for both case studies, sorted in alphabetical order.

Among generated ideas partner company selected the most promising ones. Firm decided to make a brainstorming session, involving employees, managers and agents. Three criteria have been defined in order to make a choice:

1. potential success of the product (according to their experience);
2. technical feasibility (according to their current skills);
3. accordance with company's core business.

In the first part of the session all the ideas have been shared and three of them have been selected. These ideas included one or more attributes and a representative name have been assigned. In the second part of the meeting we asked participants to compare selected ideas and define a rank:

- spider:
  1) *projecting roof*: possibility to hang projecting roof (and tie rods) directly on spiders; ease of fastening/unfastening projecting roof; quickness in fastening/ unfastening projecting roof;
  2) *window*: possibility to include windows in the facade; quickness in opening/closing windows; possibility to air the inner environment; ease of opening/closing windows;
  3) *quick click*: independence from the use of tools during the installation/dismantling.
- components for glass staircases:
  1) *irregular*: compatibility with various kind of walls (plasterboard, stone, surfaces with irregular shapes, etc.); adaptability to surfaces that can change their shape;
  2) *design*: use of precious metals, jewellery, precious stones; variety of colours; variety of shapes; in line with home interior design;
  3) *quick click*: possibility to install with one hand.

These ranks allowed making a comparison with the outputs obtained later through the idea selection phase.

In order to plan the differentiation strategy the value curve of the main premium company has been taken as reference industrial standard. Then, new selected ideas have been expressed in terms of product profiles and compared with the standard.

Besides new attributes, existing ones have been included. Only attributes that maintain the same level of performance offered by the industrial standard have been neglected. Indeed they did not affect differentiation strategy. However they were put aside for the following design phase in which designer would find the way to offer that performance level.

Figures from 4.11 up to 4.16 shows the profiles of new selected product ideas compared with industrial standard curves.

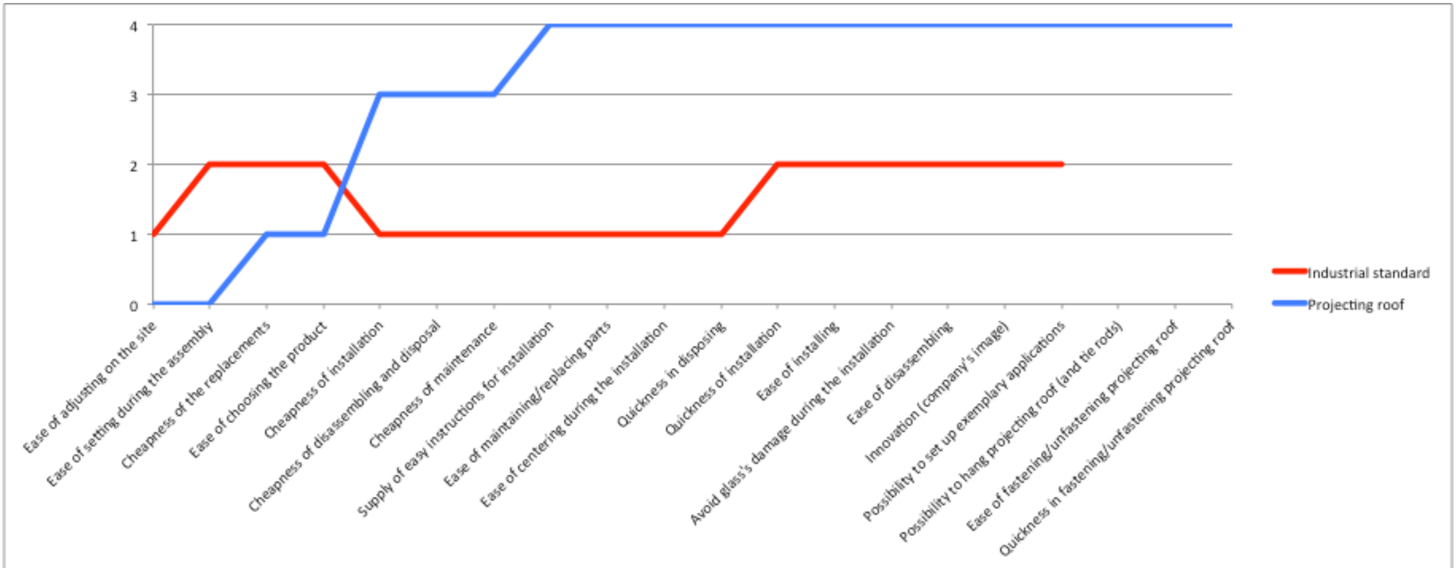

Figure 4.11 Strategy canvas that compares the industrial standard in the field of spider with the product profile defined "projecting roof"

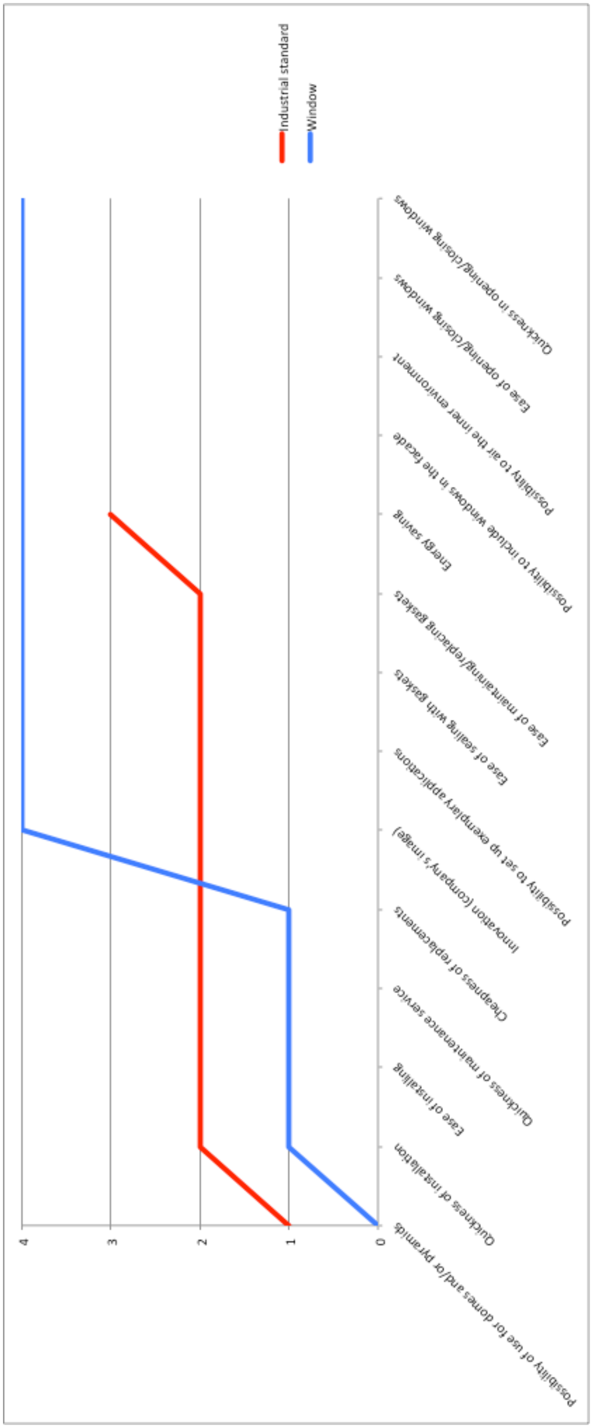

Figure 4.12 Strategy canvas that compares the industrial standard in the field of spider with the product profile defined “window”

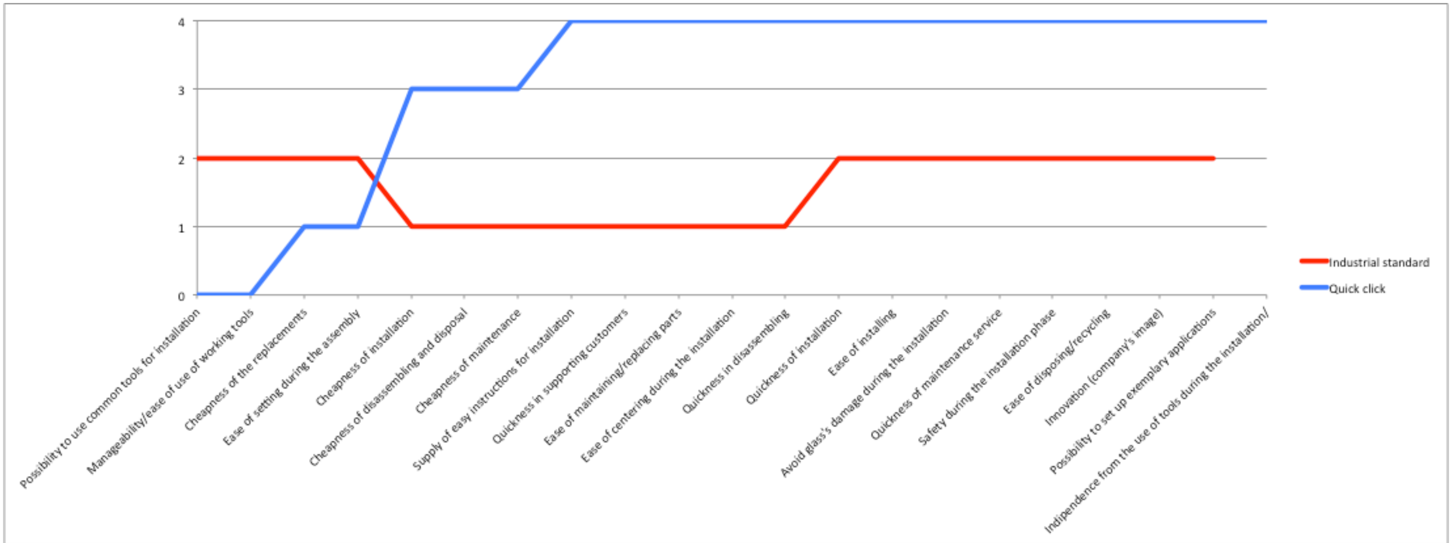

Figure 4.13 Strategy canvas that compares the industrial standard in the field of spider with the product profile defined "quick click"

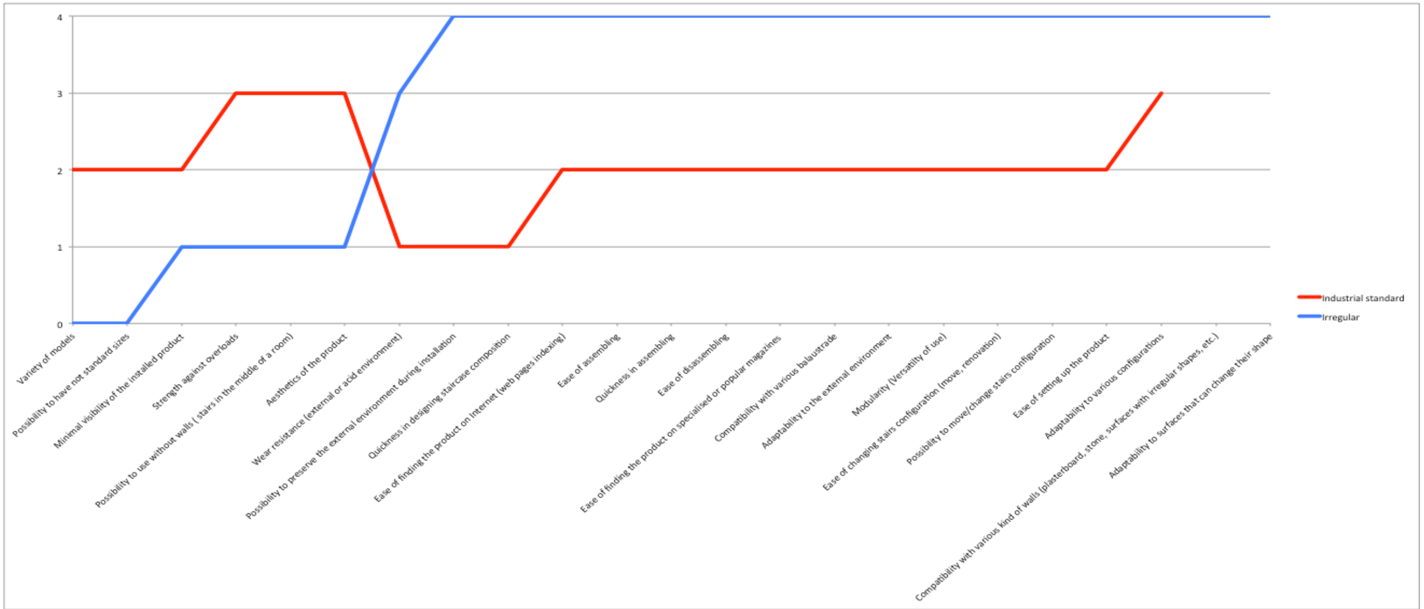

Figure 4.14 Strategy canvas that compares the industrial standard in the field of components for glass staircases with the product profile defined "irregular"

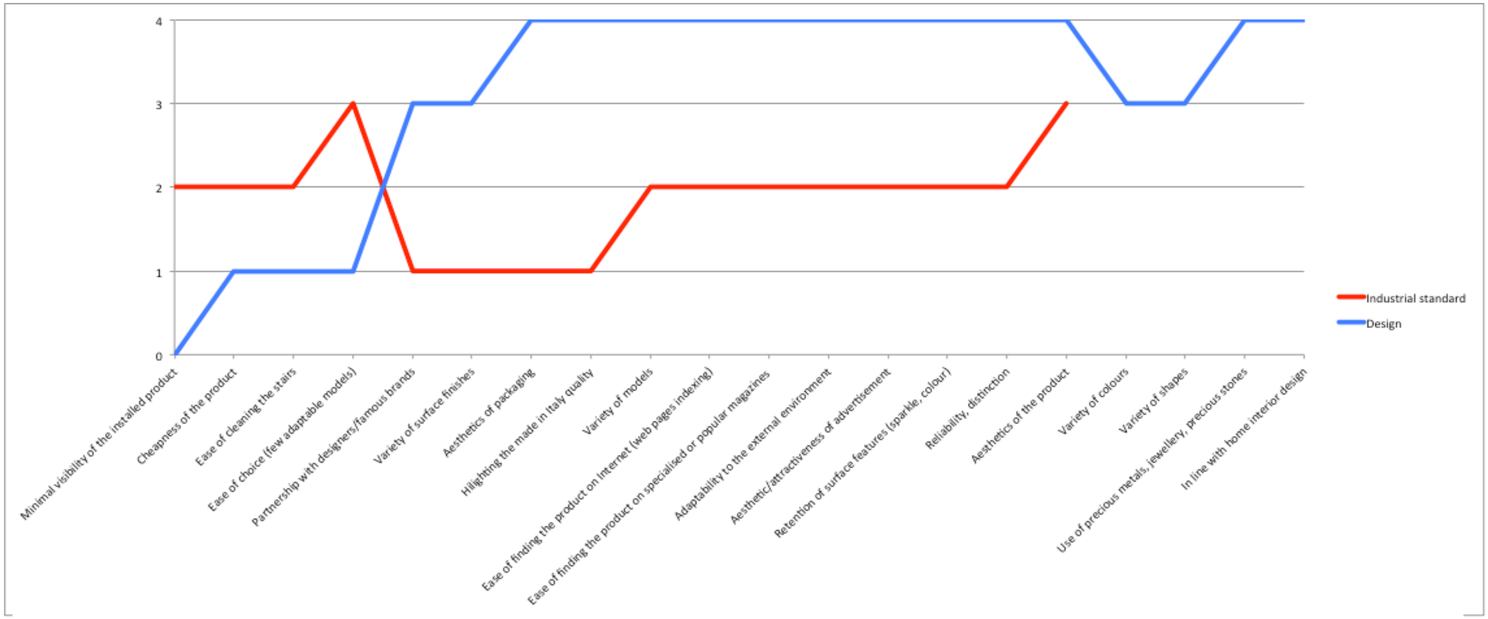

Figure 4.15 Strategy canvas that compares the industrial standard in the field of components for glass staircases with the product profile defined "design"

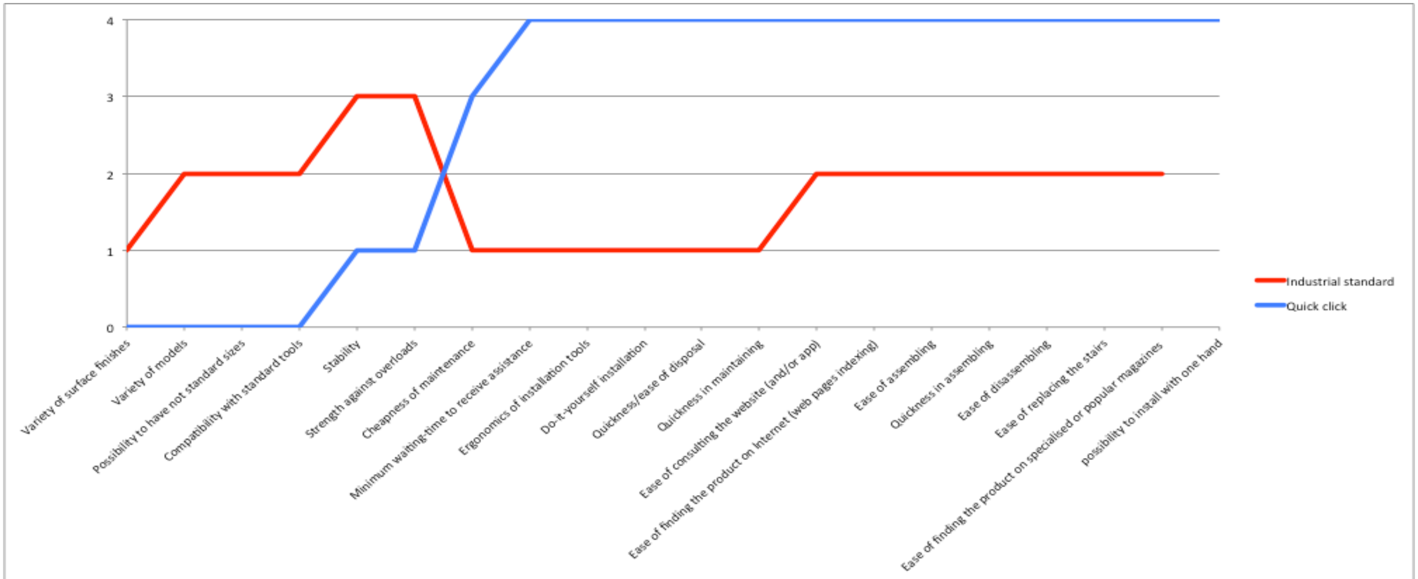

Figure 4.16 Strategy canvas that compares the industrial standard in the field of components for glass staircases with the product profile defined "quick click"

New Value Proposition Guidelines (Borgianni et al. 2013), introduced in the previous Chapter, have been used to make a quick check of risks and opportunities of new product ideas. For instance, Table 4.6 shows the list of attributes of new product profile called "projecting roof" in the field of spiders. The other Tables have been collected in Appendix B.

Attributes are classified in terms of strategic moves and functional features. Green boxes show favourable differentiation actions, while red boxes show actions that should be avoided, according to New Value Proposition Guidelines. Most of planned differentiation moves for all the ideas are favourable, according to the guidelines. However, few not recommended actions have been found too.

Besides, this first check the last idea selection step will show if and how much these profiles would succeed on the market.

Attributes	Actions	Functional Features
Ease of adjusting on the site	ELIMINATE	RES
Ease of setting during the assembly	ELIMINATE	RES
Cheapness of the replacements	REDUCE	RES
Ease of choosing the product	REDUCE	RES
Cheapness of installation	RAISE	RES
Cheapness of disassembling and disposal	RAISE	RES
Cheapness of maintenance	RAISE	RES
Supply of easy instructions for installation	RAISE	RES
Ease of maintaining/replacing parts	RAISE	RES
Ease of centring during the installation	RAISE	RES
Quickness in disposing	RAISE	RES
Quickness of installation	RAISE	RES
Ease of installing	RAISE	RES
Avoid glass's damage during the installation	RAISE	HF
Ease of disassembling	RAISE	RES
Innovation (company's image)	RAISE	UF
Possibility to set up exemplary applications	RAISE	UF
Possibility to hang projecting roof (and tie rods) directly on spiders	CREATE	UF
Ease of fastening/unfastening projecting roof	CREATE	RES
Quickness in fastening/unfastening projecting roof	CREATE	RES

Table 4.6 list of attributes of the new product profile "projecting roof" (spider). Attributes are classified in terms of strategic moves and functional features. Green boxes show favourable differentiation actions, red boxes show actions that should be avoided, according to New Value Proposition Guidelines

4.2.3 Step 3: Idea selection

In the last phase of the Product Planning process, ideas have been compared through benefits' and costs' analysis. The first one provided the potential success of the product, while the second one highlighted its feasibility. According to these data partner company made a new rank of product ideas.

1. Benefits' analysis

In order to assess potential success of new product ideas, the tool developed according to VAM formula (Borgianni et al. 2013) has been used. All the attributes classified according to their strategic moves (compared with industrial standard) and category (functional features) in the previous Section have been clustered as shown in Tables 4.7 and 4.8.

Actions/ Functional Features	Projecting roof	Window	Quick click
CREATE/UF	1	2	0
CREATE/HF	0	0	0
CREATE/RES	2	2	1
RAISE/UF	2	2	2
RAISE/HF	1	0	2
RAISE/RES	10	3	12
REDUCE/UF	0	0	0
REDUCE/HF	0	0	0
REDUCE/RES	2	4	2
ELIMINATE/UF	0	1	0
ELIMINATE/HF	0	0	1
ELIMINATE/RES	2	0	1

Table 4.7 number of attributes of the three new ideas of spider classified according to strategic moves and functional features

Actions/ Functional Features	Irregular	Design	Quick click
CREATE/UF	2	4	0
CREATE/HF	0	0	0
CREATE/RES	0	0	1
RAISE/UF	6	9	1
RAISE/HF	2	1	1
RAISE/RES	7	2	11
REDUCE/UF	2	0	0
REDUCE/HF	2	0	2
REDUCE/RES	0	3	0
ELIMINATE/UF	2	0	3
ELIMINATE/HF	0	1	0
ELIMINATE/RES	0	0	1

Table 4.8 number of attributes of the three new ideas of components for glass staircases classified according to strategic moves and functional features

Collected data have been used as input for the VAM tool. For instance, Figure 4.17 shows the VAM mask used to assess the potential success of "quick click" in the industrial field of spider.

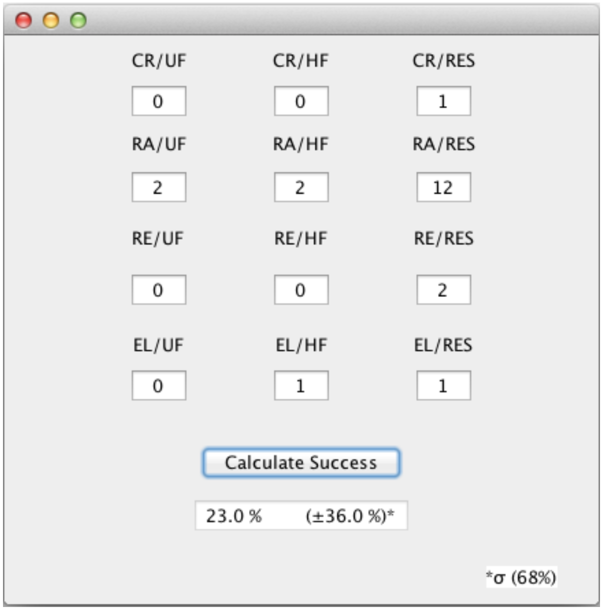

Figure 4.17 screenshot of VAM tool used to assess the potential success of the "quick click" product profile in the industrial field of spider

The boxes of the tool have been filled with the number of classified attributes and the tool gave as output a potential success of 23% (potential business failure) with an uncertainty of 36%. In other words "quick click" spider would have a success range from 0 up to 59%, i.e. there is little chance to succeed on the market.

Table 4.9 and 4.10 show VAM values obtained analysing new collected ideas in the field of spider and components for glass staircases, respectively.

New product profiles - Spider	VAM
Projecting roof	88% (± 27)
Window	84% (± 29)
Quick click	23% (± 36)

Table 4.9 VAM values (and uncertainties) of the three new product profiles in the field of spider

New product profiles - components for glass staircases	VAM
Irregular	98% (± 10)
Design	85% (± 31)
Quick click	72% (± 38)

Table 4.10 VAM values (and uncertainties) of the three new product profiles in the field of components for glass staircases

Besides the above mentioned "quick click" spider that could be a commercial flop, another original idea concerning components for glass staircases ("quick click") showed high uncertainties about its potential success (VAM=72% ± 38).

2. *Costs' analysis*

Feasibility of new product ideas has been assessed through the use of Profile Cost Matrix (PCM) described in the previous chapter. Companies identified the following list of needs/risks:

1. economic investment;
2. requested time;
3. requested skills;
4. reputation risks;
5. scarce novelty;
6. possible customers dissatisfaction.

For each item of this list a weight has been assigned using a scale from 0 up to 5. For instance, "possible customers dissatisfaction" obtained maximum importance (5), while "requested skills" was considered the less important one (1).

Correlation between attributes and companies' priorities has been assigned using null (0), low (1), medium (2) and high (3) values. For instance, the improved "supply of easy instructions for installation" requires limited economic investments and the assigned level of correlation was "L" (low). In other words it barely entails a reduction of feasibility of product idea.

All the attributes of three identified new product profiles have been collected in a unique table for each case study. Figure 4.18 shows an excerpt of the tool used to assess costs of new spider ideas. The full versions of both PCMs are presented in Appendix B.

		Company's Needs/Risks						
		1.	**2.**	**3.**	**4.**	**5.**	**6.**	
	Weight	4	3	1	4	2	5	***Attribute's Cost***
Product Attributes - Differentiation moves	Supply of easy instructions for installation - RAISE	L	L	N	N	N	N	7
	Quickness in supporting customers - RAISE	M	L	N	N	N	N	15
	Ease of maintaining/replacing parts - RAISE	L	M	N	N	N	N	13
	…	…	…	…	…	…	…	…

Figure 4.18 excerpt of Profile Cost Matrix of new spider profiles. N stands for null (0), L stands for low (1), M stands for medium (3) and H stands for high (9)

The cost of each attribute has been calculated using the formula (3) introduced in the previous Chapter. For example, raise of “supply of easy instructions for installation” (spider) entail a cost of 7:

$$Cost\ A_1 = 1{\times}4 + 1{\times}3 = 7 \quad (7)$$

The sum of costs of attributes belonging to new product profiles provided profiles' costs. These values have been resumed in Tables 4.11 and 4.12.

In order to compare these data, values have been scaled using the approach described in the previous Chapter. For instance, in the field of spider “window” profile entailed maximum costs (100), “projecting roof” showed minimum costs (0) and “quick click” have been set using formula (6):

$$Cost\ of\ \text{"quick click"} = \frac{479 - 467}{503 - 467} {\times} 100 = 33 \quad (8)$$

New product profiles - Spider	Cost	Scaled cost
Projecting roof	467	0 (MIN)
Window	503	100 (MAX)
Quick click	479	33

Table 4.11 costs the three new product profiles in the field of spider

New product profiles - components for glass staircases	Cost	Scaled cost
Irregular	867	100 (MAX)
Design	581	0 (MIN)
Quick click	842	91

Table 4.12 costs the three new product profiles in the field of components for glass staircases

3. Product profile's choice

In the last step of the process benefits (VAM values) and feasibility costs of new product profiles have been collected and compared through success-costs chart (Figures 4.19 and 4.20).

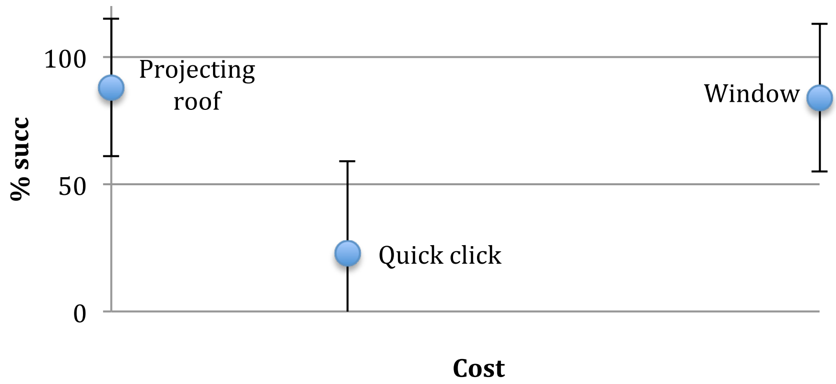

Figure 4.19 success-costs chart of new spider profiles. For each VAM value the uncertainties range is showed

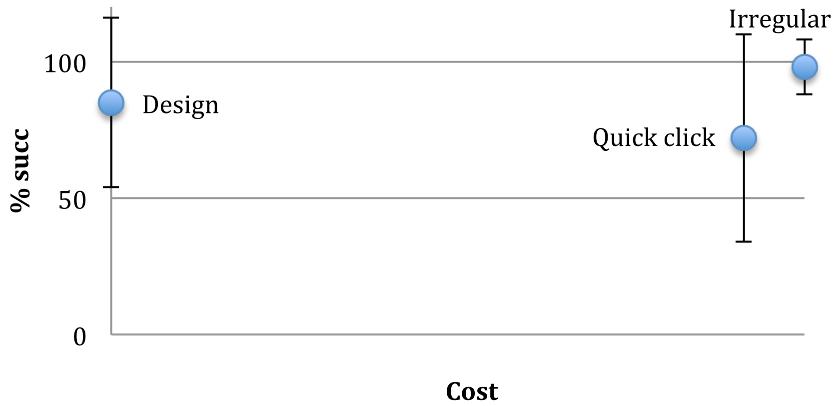

Figure 4.20 success-costs chart of new components for glass staircases profiles. For each VAM value the uncertainties range is showed

Observing these charts partner company made a new rank of profiles. Priorities have been confirmed in the field of spiders, while some changes have been made in the field of components for glass staircases (Tables 4.13 and 4.14).

New product profiles - Spider	Rank based on PCM	Rank before the use of PCM
Projecting roof	1	1
Window	2	2
Quick click	3	3

Table 4.13 comparison between ranks made before and after the use of idea selection tools in the field of spider. No changes appear

New product profiles - components for glass staircases	Rank based on PCM	Rank before the use of PCM
Irregular	1	2
Design	2	1
Quick click	3	3

Table 4.14 comparison between ranks made before and after the use of idea selection tools in the field of components for glass staircases. The first and second positions have been inverted

Decisions have been taken giving priority to most feasible ideas with potential success greater than 50% (considering uncertainty too). For this reason in the field of components for glass staircases "design" profile has been selected as the most promising one, followed by "irregular" idea that showed highest success, but also cost. "Quick click" maintained the third position because of high cost and uncertainties on potential success that could fall below the threshold of 50%. In the field of spider the rank remain the same, indeed "projecting roof" profile has high VAM and lowest cost, "window" profile has the highest value of VAM with highest cost and "quick click" has only few possibilities to succeed ($0<VAM<59\%$).

4.3 Discussion

Besides the main goal of this Chapter is the possibility of illustrating how developed method works, real case studies allowed assessing its main strengths and limits too.

According to company feedbacks the whole approach effectively support the Product Planning process and it was preferred to intuitive activities previously performed. Indeed, the method satisfies several companies' demands, highlighted in Chapter 2, integrating:

- computer applications that accelerate the second and third steps of the process;
- tools and hints to guide competitors' analysis;
- decision support system that allows to assess both benefits (potential success) and costs (feasibility) of new product ideas;
- a tool that allows to formally schematizing identified ideas (Strategy canvas).

In addition, these case studies provided promising outcomes concerning other ideal features:

- quickness and easiness of the method have been observed especially in the second and third steps of the process;
- idea stimulation tools allowed to identify a large quantity of new ideas that potentially allow to satisfy latent needs;
- independence from inputs subjectivity has been observed during idea selection activity. Indeed, involved experts even change their priorities before and after the use of the developed idea selection tools in one of the two tests. In addition, they confirmed that the new approach satisfy this need.

The use of developed approach by the firm did not highlight the need of considering customer preferences dynamics, involving customers and entrusting multidisciplinary teams.

Indeed, involved expert identified a large quantity of new ideas on his own and did not perceived risks using developed idea selection tools.

Eventually, the reliability of the method could not be demonstrated by these case studies because selected ideas have been not implemented and commercialized yet. However, the repeatability of positive outcomes within the two case studies can be considered a promising result.

Table 4.15 shows pros and cons highlighted by partner company. The latter can be used to optimise developed method. Above all time required to carry out the first step of Product Planning (information gathering) should be reduced and future research will focus on the development and/or integration of tools that allow accelerating it. According to the other two steps of the process, involved expert affirmed to be optimist about the possibility of individually subsuming the approach through a learning-by-doing process, gaining more and more confidence with proposed tools and reducing time spent to carry out these activities.

	Pros	Cons
Step 1: Information gathering	• exhaustiveness; • quick view of competitors' offers; • possibility to identify competitors in other industrial fields.	• it takes long time to carry out an exhaustive information gathering activity.
Step 2: Idea generation	• generation of lots of ideas; • identification of latent needs; • exploration of not intuitive product attributes that contribute to customer satisfaction.	• difficulty in choosing among collected idea stimulation tools (if time is limited).
Step 3: Idea selection	• possibility to examine in depth the feasibility of new projects; • possibility to forecast the potential success of new ideas; • quick comparison among new identified ideas.	• difficulty in classifying attributes for the first time.

Table 4.15 pros and cons of each step of the developed method provided by partner company

Some useful hints can be already provided in order to overcome highlighted limits:

1. during information gathering activity the search can be limited to main competitors and main competing factors in order to accelerate this task;
2. user can choose the preferred idea stimulation tool/s in order to accelerate the idea generation activity. When in doubt, iDea integrates in its logic most of the

items included in the other tools. Therefore, it could provide several hints included in the other approaches;

3. practice allows to simplify and accelerate the process of attributes' classification;
4. developed approach does not represent a straight path and each user can customize each activity in order to fit his/her needs. The practical application of this method could even require an iterative procedure in which information can be added and modified during the process.

5 Experiments about the iDea tool

In this Chapter four experiments to test the original iDea tool, developed to support idea stimulation, are described. Section 5.1 briefly illustrates these tests and Section 5.2-5.5 deeply described experiments, highlighting main obtained results. Eventually, Section 5.6 resumes main outputs, showing the capability of the developed method and prototype software to satisfy companies shared needs (Chapter 2) during idea generation activity.

5.1 Types of experiments

As seen in Chapter 1, idea generation is an essential activity within the Product Planning phase. Among ideal features of Product Planning methods, described in Chapter 2, those relevant for idea stimulation tools are:

1. use of computer applications;
2. possibility of actively involving customers;
3. possibility of entrusting multidisciplinary teams;
4. quickness and easiness of the method/tool;
5. effective support in the individuation of latent needs;
6. reliability of the approach.

Besides the first demand that has been satisfied developing iDea, four tests have been carried out in order to assess the last three features of the list.

The first test involved 24 Master Science (MS) students in Mechanical Engineering. The objectives of experiment concern the analysis of tool effectiveness, comparing its performances with those of an acknowledged Product Planning method (Six Paths Framework, described in Chapter 2). Three widely acknowledged metrics in the literature have been used to assess the ability of iDea to support the individuation of latent needs and reliability of developed tool: quantity, variety and novelty. In addition, a comparison of time spent by each student using iDea and Six Paths Framework has been planned in order to assess quickness of the method. More details about this first test and obtained results are described in Section 5.2.

The methodology was thus tested through three additional industrial experiments in which the developed prototype software was exploited. In all cases, the author participated to the test, by providing any explanation requested by the user in terms of procedures to follow and the meaning of the concepts underlying Dimensions, Specifications and Elements (described in Chapter 3). However, the creative process of the users have been not influenced at all, since support substantially aimed at saving the time of experimenters, who should otherwise consult the guide.

The purpose of the tests consisted in verifying the applicability of the proposed instrument and its effective capability to stimulate new product ideas for industrial players too. At the same time, the experiments revealed problems related to the utilization of the tool and not predicted benefits descending from its application, further considered as side results.

More in detail, the first case study was carried out by a scholar with a vast knowledge about design methods and a great experience in the field of household electrical appliances, matured in manifold projects involving branches of big corporations and SMEs working as specialized suppliers in such an industrial domain. The second experiment involved the project coordinator of a start-up firm, named B10nix (see more at www.b10nix.com). The enterprise designs and produces innovative artefacts exploiting the latest advances in Human-Computer Interaction (HCI) field, with a particular focus on wearable technologies. The involved subject currently coordinates B10nix's research team, besides being legal representative and co-founder of the firm after many years of experience in the field of HCI. Third industrial experiment involved an expert of the glass accessories firm in which the whole Product Planning approach have been tested (see Chapter 4). This investigation focused on the identification of new ideas in the field of sliding glass door handle. In spite of the limited use of the tool, described in the previous Section, this experiment showed the results obtained employing all the modules of iDea.

The first industrial test was mainly thought to evaluate the usability of the tool and assessing its capability to support the individuation of latent needs. In addition, time spent to carry out the test has been compared with time required to identify the same number of ideas in similar projects. The second and third experiments have been planned with the aim of estimating the utility of developed tool in industrial contexts, by drafting a comparison between the method and seeded practices in terms of quickness and easiness of use and ability to support the individuation of latent needs.

These tests will be widely illustrated in the following Sections 5.2-5.5, while further considerations will be drawn in Section 5.6.

The possibility of actively involving customers and multidisciplinary teams has been not tested because the author decided to firstly assess the potential effectiveness of the tool when it is used by a single user. However, future experiments will be carried out in order to understand how it works involving groups.

5.2 Test one: Six paths framework vs. iDea

The first experiment have been planned in order to assess ability of iDea to support the individuation of latent needs and reliability of the developed tool, through the analysis of quantity, novelty and variety of generated ideas. By exploiting these metrics, the scope stood in comparing the performances of the presented proposal and those of a widely acknowledged approach, i.e. Six paths framework (Kim and Mauborgne 2005), that supports the idea generation activity, providing some hints to guide an individual "Brainstorming" process (see Chapter 2 for more details).

The choice of this instrument leant upon the need of picking up a successful technique, besides diffused in industry, which however satisfies only part of the ideal properties resumed in Section 5.1. Indeed, this tool suffers from the lack of patterns allowing a useful computer implementation and it offers only mere qualitative indications that are not sufficiently systematic to assure the reliability of the approach. In addition, it has been never tested with multidisciplinary teams and/or customers, even if there should be no contraindications.

The thesis has already clarified how most of idea generation processes in industry are essentially entrusted to intuition and random stimuli (e.g. recently consulted information sources, new products of the competitors). Analogies come out accidentally, based on teamwork members' inspiration, personal creativity and talent. Hence, the free and unsupported search for new ideas represents the most proper benchmark for the sake of comparison.

The conducted experiment has involved 24 volunteer MS Students in Mechanical Engineering, University of Florence (Italy), which were attending the Course in Product Design and Development. The experiment consisted in two individual idea generation sessions, lasting three-hours, during which each participant working individually tried to identify original product attributes.

Before the first session, the students were trained about the fundaments of Product Planning and the role of information gathering in this design phase. Besides, prior to the first session, the Course had illustrated the cited Blue Ocean Strategy and Brainstorming, thus providing references about individual and group ideation techniques. In addition, the author's research team illustrated to the students the opportunity of exploiting Brainstorming strategy by individuals instead of teams, like in the mentioned nominal group technique.

At the beginning of the first session, the students were randomly subdivided in two groups (A and B). At the end of the idea generation task, each participant was asked to pick up one or more benefits descending from the generated original attributes and briefly describes the main traits of a new product consistent with the individuated advantages. The experiment foresaw different reference products to work with; group A dealt with cameras, while group B analysed domestic coffee makers. The two categories of product represent everyday devices, about which students were supposed to have already sufficient information about recent developments, thus avoiding time-consuming information gathering.

Between the two sessions, the basic notions of the proposed methodology and iDea software application were illustrated. The second session was performed with the same format of the first one, with two differences only:

- each participant was asked to use iDea to stimulate new product attributes, by exploiting one or more combination tools (quick, standard, detailed), according to their preferences;
- the products to deal with were reversed between groups A and B, so as to avoid conditioning from the first session, potentially leading to replicate the results.

The first task of the tests, i.e. the generation of new product attributes, aimed at assessing quantity. Indeed, this variable has been correlated to the number of new product attributes that students have identified and listed.

The evaluation of novelty represents the objective of the second task of the test, i.e. describing a more elaborated idea treasuring (some of) the identified original product attributes (see Appendix B). It is worth noting that novelty metrics cannot be applied to any of the identified ideas, by not including the ontological components foreseen in the SAPPhIRE model. Then, according to the criteria described by Sarkar and Chakrabarti (2011), the following degrees of novelty were associated to new product ideas:

- None, when there is no difference with respect to already existing products; e.g. a camera with interchangeable covers (see e.g. Canon Powershot D10);

- Low, when components or subassemblies are substituted to achieve the same functions through a known behaviour or when parts from other devices are originally integrated to perform the functions they are commonly intended to; e.g. a coffee machine with an integrated radio;
- Medium, when besides changing the disposition or the presence of components, the working principle is modified; e.g. a coffee machine whereas brews are delivered upwards and stored into thermally insulated bins, so to avoid temperature losses as it normally happens to coffee drops falling into mugs by gravity;
- High, when, besides structural and behavioural changes, the delivered function requires different inputs and/or implies consequences or transformations which were not displayed by existing products; e.g. a camera which distinguishes pictured colours and automatically retrieves objects with the same hue on the Web, so to find clothes or other items to be suitably combined with available stuff;
- Very high, when unprecedented functions are displayed; e.g. a coffee machine brewing transparent drinks that do not blemish clothes, paper sheets or other objects in general.

Eventually, the variety assesses the third task of the test. This metric allows assessing the ability of exploring the design space, identifying ideas that are very different from one to another. In order to assess the variety, the reference approach developed by Shah et al. (2003) has been followed. Although this method has been originally developed to assess technical solutions, it can be easily adapted to Product Planning. The author required to introduce ad hoc categories to shape a "genealogy tree", which is suitable to characterize the design space of Product Planning instead of Conceptual Design. The four Value Dimensions (Chapter 3) have been used to differentiate ideas at the highest hierarchy. Further detail levels refer to Elements and Specifications (see Appendix A) that characterize the value provided by new product features with a decreasing degree of abstraction.

For instance, the set of ideas generated in the first session by the student identified as "id14" working with coffee machines (Table 5.1), has been structured through the "genealogy tree" of Figure 5.1.

Student	Group	Test	List of ideas
id14	B	1	• Rollaway device, integrated into kitchen furniture; • Direct link to the water supply network; • Possibility of washing the cups directly into the device; • Easy management of the device through Wi-Fi connection; • Integration into the device of an alarm clock that wakes up in the morning and automatically prepares coffee.

Table 5.1 list of ideas generated in the first session of the test by the students "id14", belonging to the group B. The reference topic was the ideation of new domestic coffee makers

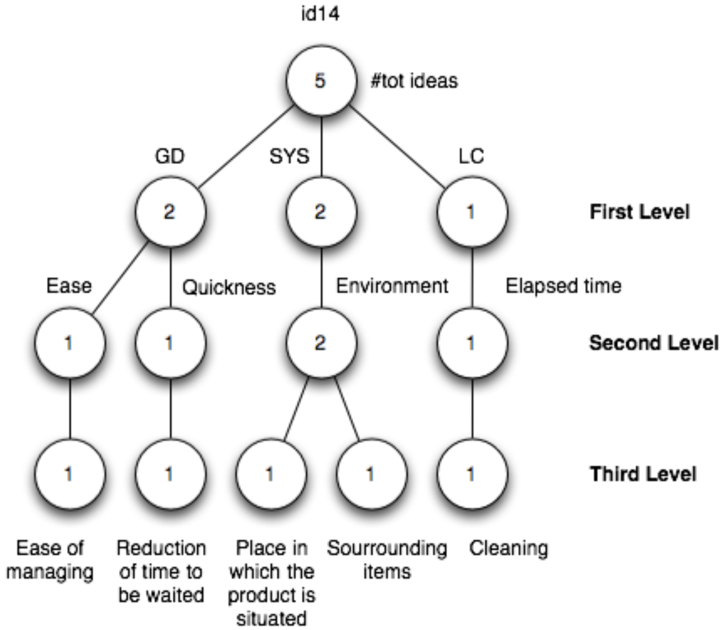

Figure 5.1 tree diagram used to divide the ideas generated in the first session of the test by the student "id14". The reference topic was the ideation of new domestic coffee makers. GD, LC, SYS and SH stand for General Demands, Life Cycle phases, Systems and Stakeholders, respectively

The reference formula proposed by Shah et al. (2003) to assess variety is:

$$V_i = \sum_{j=1}^{3} S_j \times B_j / V_{max} \quad (9)$$

whereas Vi is the variety assessed for the ideas generated by the i-th tester; Sj is the score assigned for the level j (suggested scores are 9, 3, 1 for General Demands, elements and specifications, respectively); Bj is the number of branches at level j; Vmax is the greatest possible variety score. This value is a constant, according to the proposed classification of ideas. Indeed, it can be calculated using the numerator of formula (9) and considering the number of Dimensions (four), elements (twenty) and standard specifications (one hundred-fourteen) included in the model (Vmax=210). For instance, the following extent of variety, expressed in terms of the fraction of the maximum achievable value, is calculated for the above sample of ideas (Table 5.1):

$$V_{14} = \frac{9\times3 + 3\times4 + 1\times5}{210} = 0{,}2 = 20\% \quad (10)$$

The author gathered the results of the tests and, for each participant, observed the number of identified new product features, as well as determined the degree of novelty (considering just those product attributes clearly not included in commercial products) and variety for the final ideas.

Appendix A reports all the results of the two-session experiment and Table 5.2 reports an excerpt of those outputs. The Table indicates, besides the quantity of features, the novelty and the variety of ideas, if each single test (marked by an ID) has treated cameras (if No, the topic is coffee machines) and has benefitted from the use of iDea (if No, it refers to the intuitive session).

Test ID	Camera as a topic	Use of iDea	Quantity of new product features	Novelty of final ideas	Variety of new product features	Time dedicated to ideation
1	Yes	No	3	Medium	7%	120’
2	Yes	No	2	None	12%	90’
3	Yes	No	6	Low	23%	95’
…	…	…	…	…	…	…

Table 5.2 outcomes of the experiment in terms of quantity and variety of new generated product features and novelty of described final ideas. Last column shows time dedicated to ideation

The obtained results have been analysed considering each case study independently. A normal distribution of quantity and variety data has been hypothesized, calculating mean and standard deviation of the samples (Table 5.3).

		Quantity		Variety	
Case studies	**Tools**	**μ**	**σ**	**μ**	**σ**
Camera	Six Paths Framework	4	2,2	15%	6%
	iDea	20,7	9,4	40%	7%
Domestic Coffee Maker	Six Paths Framework	5	2,1	16%	5%
	iDea	19,8	9,4	39%	10%

Table 5.3 mean and standard deviation of the quantity and the variety of ideas generated in the test. The two case studies, i.e. cameras and domestic coffee makers, have been analysed separately

According to novelty main results are collected in Table 5.4 and graphically shown in Figure 5.2 and 5.3, respectively concerning cameras and domestic coffee makers case study.

		Degree of novelty				
Case studies	**Tools**	**None**	**Low**	**Medium**	**High**	**Very high**
Camera	Six Paths Framework	33,33%	50%	8,34%	8,33%	0
	iDea	16,67%	50%	0	33,33%	0
Domestic Coffee Maker	Six Paths Framework	50%	50%	0	0	0
	iDea	16,67%	33,33%	8,34%	33,33%	8,33%

Table 5.4 degree of novelty of ideas generated in the test. The two case studies, i.e. cameras and domestic coffee makers, have been analysed separately

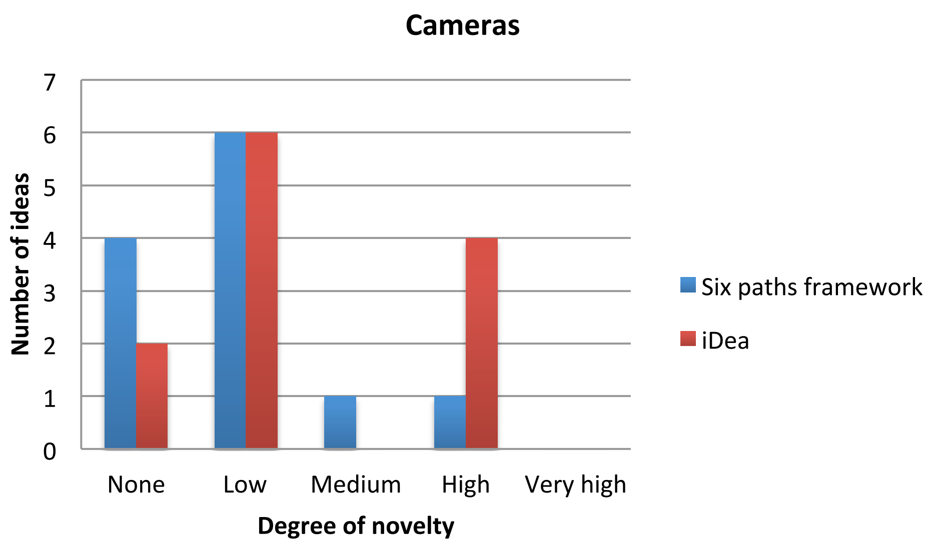

Figure 5.2 distribution of degree of novelty of cameras' ideas identified using Six paths framework and iDea

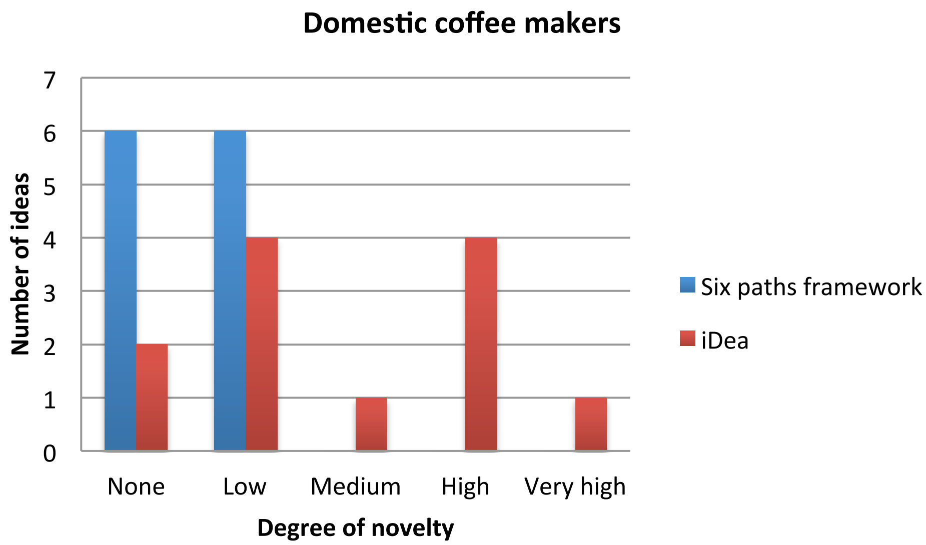

Figure 5.3 distribution of degree of novelty of domestic coffee makers' ideas identified using Six paths framework and iDea

The results show a considerable growth of quantity and variety of ideas for both industrial domains by using iDea. It is worth noticing that a quick overlook of the data is sufficient to individuate very similar variations for both the examples. The increase of quantity and variety is so conspicuous that no statistical test has been conducted to reveal the significance of administering the developed software in order to perform idea generation. The observed increment of standard deviations in sessions using iDea suggests that this tool could highlight differences among the personal skills of users. Indeed, some students largely benefited from the tool identifying lots of new ideas, while the number of new opportunities barely raised in other cases. However, this preliminary result should be further investigated with future specific tests.

iDea supported the identification of more ideas with a high degree of novelty and fewer none and low novelty concepts than Six paths framework. In addition, developed tool allowed identifying an idea with a very high degree of novelty.

Eventually, the test highlighted the appropriateness of the presented instrument in terms of increasing designers' workload. Indeed, the author has observed a growth of the time dedicated to ideation from 106 minutes (on average) for the Six paths framework session to 148 minutes for iDea session (students were left free to conclude the tests if they thought to produce new ideas no longer). Moreover, a reduction by about one-third of the average time elapsed to identify new ideas has been observed, as shown in Table 5.5.

Case studies	**Tools**	**Average time elapsed to identify new ideas**
Camera	Six Paths Framework	26' 30"
	iDea	7' 9"
Domestic Coffee Maker	Six Paths Framework	21' 12"
	iDea	7' 28"

Table 5.5 average time elapsed to identify new ideas. The two case studies, i.e. cameras and domestic coffee makers, have been analysed separately

Despite the underlined role played by iDea in the experiment, the assessment of its utility in the industry cannot be automatically inferred from the presented results. The first testing session has simulated the ideation process of a designer in an industrial context, in which, as observed in many companies, formal Product Planning methodologies have been not introduced and the generation of novel attributes is entrusted to intuition. In each case, this simulation can result inaccurate by considering the differences between the volunteer students and members of R&D departments, e.g. in terms of experience, domain knowledge, motivation. Besides, certain firms can benefit from different idea stimulation techniques or design-by-analogy methods.

Sections 5.3-5.5 document the application of iDea performed by a scholar with a great experience on NPD techniques and some specific industrial sector, the chief of a start-up enterprise and an expert of a glass accessories firm. The results provide a first overview of the capabilities of the proposed methodology in the industrial environment, thus partially filling the gaps of the above-described experiment.

5.3 Test two: household ovens

The second test of iDea involved a scholar with a great experience on NPD techniques and involved in several research activities devoted to innovate white goods for a multinational corporation. The tester decided to analyse the field of household ovens, since he was involved in a project concerning the innovation of this kind of product. The experimenter already possessed an up-to-date knowledge about the current competing factors of household ovens and the topics of many long-term NPD projects in this industrial domain.

The employment of iDea regarded all the three combination procedures, whereas no item concerning Dimensions, Specifications and Elements was deselected. This choice was performed for a twofold motivation: on the one hand, all the items were considered pertinent in the given industrial field; on the other hand, this could help the developers assessing the reference time for a full exploration of the associated concepts, as proposed by the methodology. The tester decided to take note of all the emerging product attributes, regardless they were seeded in the industry or original. At the end of the whole idea stimulation task, all the emerged competing factors were classified in known properties, benefits that have been already conceived through previous NPD activities (but not implemented yet), totally original characteristics. Table 5.6 provides an overview of the results, including the quantity of attributes generated through and the time dedicated to the three modules of iDea.

	Already known and implemented competing factors	Conceived competing factors, not implemented yet	Newly emerged competing factors	Spent time (about)
Quick module	29	15	2	40min
Standard module	93	30	15	40min
Detailed module	143	77	39	3h
TOTAL	**265**	**122**	**56**	**4h 20min**

Table 5.6 overview of the outcomes of the first experiment involving the developed methodology and iDea prototype software in terms of distinct product attributes generated or clearly identified through the three modules

The outcomes reported in Table 5.6 demonstrate the capability of the instrument to perform an accurate examination of the possible sources of value characterizing an artefact and the quickness of use of the tool. Indeed, user identified in 4 hours and 20 minutes the same number of ideas collected in similar projects in months (using intuitive approaches). Unfortunately, such results cannot be compared with any reference list of attributes and, hence, no statement can be formulated about the capability of the instrument to perform all-encompassing explorations. In any case, the usability of the method through iDea computer application has been verified, since the tester has autonomously produced an articulated bundle of competing factors, including original ideas. The new attributes include both benefits that can be easily fulfilled through existing technologies and more bizarre or futuristic ideas. None of them will be revealed, since the tester will employ them as a driver for proposing the new R&D objectives to partner firms.

5.4 Test three: wearable systems to capture and analyse the movement of people

The third test of iDea involved the CEO and project coordinator of B10nix, a firm that offers software and hardware systems for HCI. These systems although being relatively new in the marketplace, follow a continuous innovation process in order to improve their performance and enlarge the context of use. In this sense, the artefacts that are presented in the homepage of the firm well suit the application of instruments intended to individuate new sources of value. In this perspective, the tester decided to exploit iDea to approach the identification of new business opportunities concerning the use of wearable HCI systems in the context of rehabilitation through physiotherapy. More in detail, the analysed artefacts currently stand in arrays of sensors and electrodes hosted in worn garments or tailored bands, capable to assist injured people in performing physiotherapy exercises and evaluating the extent of improvements. Dedicated software gathers relevant data and supports physiotherapists in the post-processing phase.

The experimenter employed the three combination modules, but some items were excluded, because of being deemed not pertinent to the analysed product (at least in its current stage of development), while some group of Elements was customized by introducing specific terms. Although during the discussion many implemented product attributes were clearly revealed, just new product ideas were recorded. New product attributes, likely to be implemented in subsequent versions of the treated HCI system, emerged by using the combination options as follows:

- 4 new ideas with the Quick module (about 25 minutes spent);
- 9 new ideas with the Standard module (about 2 hours spent);
- 4 new ideas with the Detailed module (about 3 hours spent, whereas the duration of the procedure for customizing the items lasted 25 minutes).

It is worth highlighting that some ideas were stimulated through different modules and combinations. The above numbers refer to product characteristics that had not previously emerged during the test.

The content of the ideas will not be revealed, since the tester considered them relevant for future developments of the wearable system to monitor people's movement. They regard both new attributes to improve the functioning of the product and additional services likely to enhance the experience of using the analysed artefact with respect to a variety of stakeholders.

A final interview was conducted to evaluate the applicability of the proposed instrument in industrial contexts and its supposed efficacy if compared with commonly employed Product Planning practices. The design team is currently performing Brainstorming sessions to generate ideas and planning to follow a more customer-oriented approach, by asking potential users for feedback with respect to new products the firm intends to develop. The outcomes of conjoint Brainstorming meetings are variable in terms of both quality and quantity of produced ideas; the main limitation of this approach stands, according to the experimenter, in the generation of very fuzzy concepts that do not undergo sufficient elaboration because of continuous shifts towards different areas of the design space. In these terms, the employment of the methodology and the developed software allows generating a larger number of ideas if the time spent and the human resources are taken into account. Therefore both quickness and easiness of use and ability to support the individuation of latent needs have been confirmed with this experiment.

The tester greatly appreciated the possibility to write down and subsequently better define the new benefits to be offered too. Indeed, it often happened during the test that new ideas were refined by considering different combinations of dimensions at any detail level. Other strengths of the approach were individuated in the capability to perform a very wide exploration of the possible benefits a product should fulfil, by pointing out the full spectrum of main characteristics taken into account during the initial development of the wearable HCI system, lasting four years. Furthermore, the same experimenter revealed the intention to replicate the task both alone and together with other members of the research team and/or perspective customers. In addition, he affirmed to be optimist about the possibility of individually subsuming the approach of the methodology through a learning-by-doing process, gaining more and more confidence with respect to introduced terms and combinations.

5.5 Test four: sliding glass door handle

The last experiment involved an expert of the firm in which the whole approach presented in this thesis has been tested. The company had to identify new opportunities in the field of handle for glass sliding doors, because in the last decades competitiveness in this market becomes high and products have never been innovated.

In this test expert decided to use all the modules of iDea and no item concerning Dimensions, Specifications and Elements was deselected because they were considered pertinent in the given industrial field.

The tool supported the identification of 51 completely new ideas. Even in this case, the content of the ideas cannot be revealed since the tester decided to implement some of them in future products.

Expert was asked to assess identified ideas according to feasibility and will to implement them in future NPD projects. Four metrics have been used to classify identified ideas:

- feasible and promising;
- feasible but not promising;
- not feasible (according to company's available resources) but promising;
- not feasible (according to company's available resources) and not promising.

Table 5.7 shows an excerpt of obtained outputs and Figure 5.4 illustrates the results of this analysis.

Ideas	Feasible and promising	Feasible but not promising	Not feasible (according to company's available resources) but promising	Not feasible (according to company's available resources) and not promising
Idea 1	•			
Idea 2			•	
Idea 3		•		
…				

Table 5.7 excerpt of the analysis carried out to understand feasibility and will to implement new identified ideas

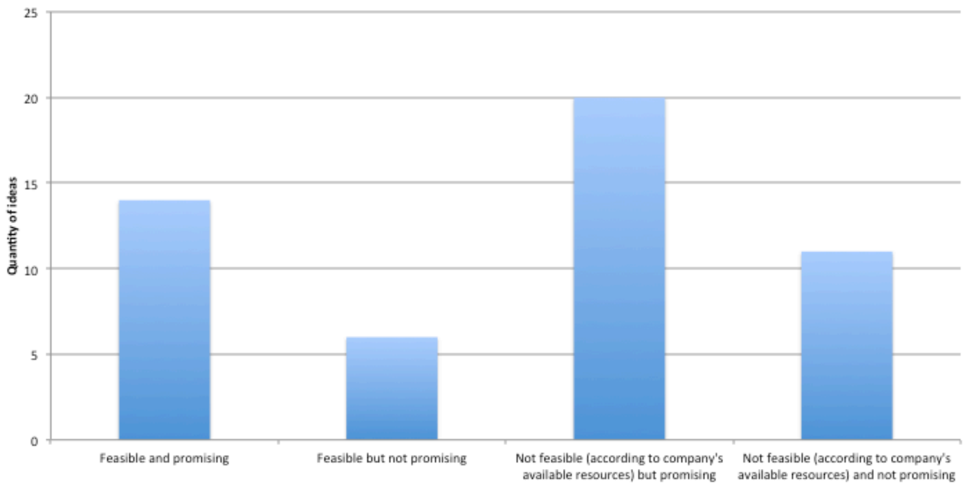

Figure 5.4 results of analysis aimed at assessing the feasibility and will to implement new identified ideas in the field of handle for glass sliding doors

As shown in this Figure 5.4 most of identified ideas has been considered promising but only a part of them could be developed according to company's currently available resources.

In addition, iDea supported the identification of more not currently feasible products than feasible ones in the short time. Therefore, the tool can be also used to develop a database of promising ideas and wait the right moment to implement them.

Eventually, expert confirmed that the number of ideas identified using the original tool was larger than opportunities stimulated by commonly employed intuitive practices (considering the same time spent).

5.6 Discussion

The tests demonstrated the capability of the discussed tool to help identifying new product attributes, features and ideas also for people with a great orientation towards the industrial world. The articulated testing campaign has revealed the capability of the tool to:

- foster the generation of new product attributes, by drastically augmenting their number if compared to intuitive strategies (*effective support in the individuation of latent needs*, *reliability of the approach*);
- increase the degree of novelty of new product ideas (*effective support in the individuation of latent needs*, *reliability of the approach*);
- increase the variety of generated ideas, highlight how users have been able to widely explore the design space (*effective support in the individuation of latent needs*, *reliability of the approach*);
- be usable in multiple industrial domains (*reliability of the approach*);
- provide a support for industrial players both for mature systems (such as household ovens and door handle) and innovative products (such wearable HCI artefacts) developed through long-lasting and accurate design processes (*reliability of the approach*);

- be quicker than commonly used approaches, considering the same number of generated ideas (*quickness and easiness of the method/tool*)
- generate a detailed framework of existing competing factors, besides supporting the generation of new ideas. This side result could be exploited when requiring to perform benchmark activities or to carry out innovation initiatives swivelled on the enhancement of current product attributes;
- represent a support in the field of designing Product-Service Systems (see Test 3).

The first three points of the above bulleted list represent fundamental criteria to evaluate the effectiveness of idea generation techniques. However, additional metrics could be used in future tests to assess the tool through judgements provided by a representative sample of experts (Kaufman et al. 2007):

- quality of ideas: it is related to the technical feasibility of proposed ideas (Shah et al. 2003) and allows understanding how many ideas could be actually implemented in new products;
- creativity of ideas: it is related to the ability of generating novel and valuable ideas. It can be assessed analysing together novelty and usefulness of generated ideas (Sarkar and Chakrabarti 2011).

The application of the developed methodology in real industrial cases shows how the proposed approach has qualitatively overcome the performances of common Product Planning practices. If compared with the time and human resources dedicated to idea generation, the employment of the methodology results a brief task, also thanks to the presence of iDea software prototype. Whereas industrial practitioners would not be inclined to modify their established approach to Product Planning, the exploitation of the developed tool would not however result in a significant loss of time (if the common duration of NPD cycles is considered). In another perspective, the described instrument can be seen as a support for Brainstorming sessions, whose idea stimulation is fostered by the systematic way of exploring potential benefits for users and stakeholders.

With respect to the number of generated ideas, the quantities of new attributes emerging from Test 2 and the other two industrial experiments clearly differ. Very diverging outcomes concern also the pace of generating new ideas by using the three modules, as highlighted in Table 5.8 that compares the second and third tests (time in Test 4 has not been recorded). Whereas standard and detailed modules show the best generation frequency in the second experiment, the quick combination strategy results the most prolific within the third test. These varying results do not allow individuating a most suitable matching mode and, hence, additional tests are required to fine-tune the combination procedures.

	Experiment 2	**Experiment 3**
Quick module	20 minutes	6 minutes
Standard module	3 minutes	20 minutes
Detailed module	5 minutes	39 minutes
Overall	5 minutes	20 minutes

Table 5.8 approximate average time elapsed to stimulate new ideas with the proposed matching modes

The main weakness of the developed tool, as revealed by testers, stands in the possibility of provoking a sense of boredom by submitting the user to a very large number of stimuli. According to their comments, this bad feeling is tolerated whereas the motivation in employing the instrument is high, but drops of attention can likely occur also in these cases. This aspect partially conflicts with the effort paid to increase individuals' workload. In this sense, some hypothesized measures include the improvement of the interface of the software by benefitting of studies in the field of HCI.

Eventually, despite the manifold outcomes provided by the tests a complete validation activity is still required. It would consist in the exploitation of the emerged value drivers, their industrial implementation and the verification of the success of the so designed innovative products. Hence, such a validation should require long times before observing market results, clearly incompatible with the divulgation of the findings.

Besides above mentioned future development of the tool and possible tests to assess its effectiveness, open issues that could be analysed in future researches concern:

- usability of the instrument by research teams and/or customers instead of individuals;
- the dependence of the results from individual skills;
- the capability to support more or less creative people.

6 Overall discussion

In this Chapter a brief discussion about the results achieved during the research activities is presented.

Section 6.1 summarizes the results of the testing activities focusing on the evaluated performances of the method in terms of effectiveness, robustness and repeatability.

Eventually, Section 6.2 shows the level of achievement of the methodological objectives and suggests future research paths starting from obtained results and still open issues.

6.1 Effectiveness, robustness and repeatability of the method

Developed approach has been applied in the industry with the aim of supporting the identification of new product profiles in the field of components for point-fixed curtain wall and glass staircases. In addition, one of the original tools developed to support the idea generation phase have been further tested with very different goods (i.e. cameras, domestic coffee makers, household ovens, rehabilitation devices and sliding glass door handles). These experiments allowed assessing effectiveness, robustness and repeatability of the proposed method and tools.

The tests of the whole approach in spider and glass accessories industries highlighted its effectiveness in supporting all the activities of Product Planning, from information gathering to idea selection. Involved experts preferred this method to previously performed intuitive approaches, because it provides a roadmap and a toolkit to effectively guide designers and/or decision makers in the early fuzzy tasks of design process.

Subjective assessments have been minimized, giving way to repeatable patterns that limit time waste and uncertainties. Indeed, users carried out all the activities of Product Planning in a short time and with few doubts about loss of information and taken decisions.

According to the idea generation activity, tests of the original developed tool, iDea, allowed to identify several opportunities in various industrial fields from mature systems up to innovative products. The tests showed an increase of the quantity, variety and novelty of generated ideas compared to diffused intuitive approaches. The testers appreciated the possibility to record identified ideas and the capability to perform a wide exploration of new product opportunities, that usually are identified in a long time (months or years) and necessarily collaborating with other experts. In addition, the tool provided as side result the capability to support the generation of a complete list of existing competing factors.

Therefore it can support the first information gathering activity too. A not minor advantage has emerged in terms of supporting the identification of both new product and related service ideas. Eventually, it allowed to better structure already identified breakthrough ideas.

The proposed abstraction process, from features to needs, limited psychological inertia and allowed to identify several new ideas, even if some of them result not feasible in the short time or not promising. Promising ideas not selected by the companies have been saved in a database that can be used for future projects. Therefore, the time spent by users in Product Planning not only allowed to identify an innovative idea that would be developed in the following phases of the design process but it could also ease and accelerate future NPD activities.

On the other hand, the capability of the approach to explore the design space and support the selection of a successful product profile could not be demonstrated until emerged value drivers will be implemented and the success of so designed innovative products will be verified. Hence, such a validation should require long time before observing market results. In addition, the whole approach has been tested in a unique industrial sector (even if two completely different products have been analysed). Therefore, future tests of the method should be carried out in different fields (as made for the iDea tool).

The main weakness emerged testing iDea concerns the possibility of provoking a sense of boredom by submitting the user to a very large number of stimuli. This problem is connected to the basic HCI prototype and how users employed the tool (using all three combination modules in succession). Indeed, in Test 1 students could exploit one or more combination modules according to their preferences and boredom has not observed. Hence, future researches should focus on the improvement of HCI and on the testing of single modules.

In conclusion the numerous applications of the developed method and tools in different contexts have demonstrated its effectiveness in identifying several new product opportunities and provided promising results in supporting all the other activities of Product Planning.

Moreover, the performed experimentation activity has verified a good repeatability of the results as well as a good robustness, even if it cannot be considered a full validation of the proposed approach. Eventually, the application of the developed tools to support idea generation and selection has revealed a good potential effectiveness even if they should be further fully validated.

Besides these promising results concerning effectiveness, robustness and repeatability of developed method, next Section illustrates the level of achievement of methodological objectives described in Chapter 1. In addition it highlights which ideal features, required by companies (Chapter 2), have been implemented in the developed method and suggests future research opportunities.

6.2 Achievement of the methodological objectives and further research opportunities

Here in the following a discussion about the level of attainment of the research (Chapter 1) and methodological (Chapter 2) objectives is performed. According to each objective, what has been done is briefly summarized together with further research initiatives that could be performed starting from the results achieved during these years.

General research objectives concerned:

- *investigation of current problems encountered by industrial subjects in the Product Planning phase*: this task has been carried out interviewing and observing activities performed by six companies operating in different fields (from traditional mechanics to electronic products) and characterized by different sizes (from small enterprises up to branches of multinational corporations) that sell their products worldwide. The survey disclosed a first set of not negligible needs concerning Product Planning practices that are deemed to be shared with many other companies;
- *comparison of perceived needs of companies with respect to Product Planning activities and the benefits offered by techniques described in the literature*: a state of art analysis of approaches that support one or more activities of Product Planning has been carried out. Currently offered features have been compared with those required by companies, highlighting current lacks and already fulfilled needs;
- *definition of requirements of an ideal approach to support Product Planning*: companies demands have been collected highlighting not already supported features;
- *development of an original method to effectively support firms during the whole Product Planning process*: an original approach have been developed focusing on companies needs perceived during the Product Planning phase. Existing tool and original ones have been integrated in the developed method that support all Product Planning activities.

After the experiments made to test the developed approach, ideal identified features can be compared to offered ones:

1. *Quickness and easiness of the method/tool*: this feature results one of the less supported companies' demand by existing approaches. According to performed experiments, the developed method satisfies this requirement. Indeed, it allowed reducing companies' committed resources both providing roadmaps and tools that reduce time and required skills to carry out the Product Planning phase. In addition, the possibility to individually use the approach allows to accelerate the process and reduce costs (less involved human resources);
2. *Development of computer applications*: some of existing methods have been implemented into computer applications in order to accelerate and make easier one or more Product Planning activities. Developed approach includes a computer-aided tool to support idea generation (and partially information gathering) phase, namely iDea, and a tool to support the idea selection phase calculating the potential success of a product (based on VAM);
3. *Effective support in the individuation of latent needs*: most of literature approaches support the exploration of latent needs and developed method completely satisfy this requirement too. Indeed, all the tests highlight its ability to support the identification of several breakthrough ideas able to satisfy latent needs;
4. *Integrated competitors' analysis*: this feature is barely supported by existing methods. Developed approach integrates an analysis of competitors' offers and allows identifying industrial standard(s). In case studies several competing factors have been collected and these data allowed to define the starting point for a differentiation strategy;

5. *Consideration of customer preferences dynamics*: the developed method is based on an abstraction process from product features to customer needs that breaks away from preferences dynamics. New identified product attributes are classified according to general categories and product profiles are assessed according to these classifications. However, this need will have to be faced in the following phases of the design process, in which the set of attributes will be converted into product features;
6. *Reliability of the approach*: proposed approach and one of the two original tools developed to support the idea generation activity have been tested with products belonging to different industrial fields obtaining promising results. However, as seen above, the capability of the approach to explore the design space and support the selection of a successful product profile could not be demonstrated until emerged value drivers are implemented and the success of so designed innovative products is verified;
7. *Support in selecting the most beneficial product idea*: the developed method, like other existing approaches, supports the last decision-making phase of Product Planning. Experiments provided promising results because involved experts even changed their preferences after the use of proposed set of tools and claimed that the analysis of potential success and costs effectively supports idea selection activity;
8. *Independence from inputs subjectivity*: the proposed approach limits the employment of personal judgments and guides users through repeatable patterns. Tests showed the ability of the method to make objective decisions. The potential success of new product profiles is assessed through a formula and feasibility depends on objective parameters related to company's objectives and available resources. As seen above, the approach allowed experts to change preferences after the use of developed decision support tools;
9. *Possibility of involving customers in the Product Planning activities*: this need is strictly related to the possibility of minimizing the risks of failure concerning new identified ideas. Developed approach limits this risk including a tool to assess the potential success of new product profiles, providing the range of uncertainties on this data too. Therefore, the proposed proactive strategy supports the identification of breakthrough products overcoming the main limit of this category of methods, i.e. the uncertainty due to the absence of customer feedback;
10. *Possibility of entrusting the Product Planning phase to multidisciplinary teams*: even if multidisciplinary teams can potentially use developed approach no tests have been already carried out. However, the use of the method by a single user allowed understanding its potential effectiveness. Indeed, users identify lots of new opportunities and a comparison of iDea, tested by single person, and Brainstorming, carried out by multidisciplinary teams, highlighted the preference claimed by experts of the original tool;
11. *Possibility of formally schematizing the identified ideas*: this demand is barely satisfied by existing approaches. Developed method includes the graphical tool proposed by Kim and Mauborgne (2005) that allows to represent new offers and compare them with competitors ones, in order to check planned differentiation strategies and accelerate the following phases of the design process.

Therefore, general research objectives have been achieved and an original method to support Product Planning has been developed. Carried out experiments highlighted the ability of the original approach and tools to meet diffused needs of companies. Above all, required features not already included in most of literature approaches have been provided and future experiments will try to confirm preliminary obtained results.

A complete validation activity would consist in the development and sale of innovative designed products in order to verify their commercial success. Such a validation should require long times, however companies involved in the tests will be monitored in order to obtain feedback about new commercialized products.

As seen above, future researches will include experiments to test the usability of the developed approach by research teams instead of individuals. In addition, future research paths could include the dependence of the results from individual skills and knowledge of a specific industrial sector, the capability to support more or less creative people, the potential benefits of introducing stimuli through forms of pictorial communication (e.g. sketches, photos and/or videos). Future experiments could also analyse how confidence with respect to the proposed method and tools raises at various step of learning-by-doing process, improving both quickness of use and achievable results.

In order to accelerate the information gathering activity text mining tools can be integrated. This kind of techniques is already used in other phases of the design process. For instance, as seen in Chapter 3, these tools can be employed to make automatic searches into patents with the aim of analysing existing and emerging technologies. In the Product Planning phase this kind of tools could support the identification of competing factors and customer needs, accelerating the analysis of as-is scenario.

Moreover, developed approach has to be better linked with the subsequent NPD phases. According to this objective, it can be integrated into PDM/PLM commercial software that collects, stores and simplifies the management of data in the whole product development process (Rosa et al. 2015). Currently the method allows to record and store generated ideas in the form of a semantic description and future researches will try to help users in translating ideas into sketches and models from which to start the subsequent design phase, using 3D CAD tools.

Future tests could also be planned with the aim of assessing if the introduction of details, typical of the Back End of design process, in Front End could accelerate these phases, support the definition of feasible product concepts and improve the link between the two macrophases (as suggested in Rosa et al. 2015), at the cost of limiting the range of new identifiable opportunities.

Identified companies' needs could result biased by the limited quantity of investigated firms and search criteria to carry out the state-of-art-analysis of Product Planning methods could be extended, in order to include further contributions. Therefore, other scholars can expand the sample of investigated companies in order to strengthen the obtained outputs and additional methods and tools can be analysed through the lenses of the properties listed in Chapter 2, or even using further ones.

Besides the improvement of the approach, different strategies (according to different type of firm) have to be acted in order to introduce new methods in the companies:

- Company type A (companies 3 and 5 of the survey): it is characterized by seeded routines and the lack of specific competencies that hinder the introduction of more structured Product Planning tools; unwillingness to risk and change; strict adherence to customer opinions. These firms should be primarily persuaded of the opportunities provided by more systematic approaches and proactive strategies. In each case, they would require strengthening their technical and research structure in light of introducing new tools for Product Planning;

- Company type B (companies 2 and 4 of the survey): it is characterized by a strong propensity to risk and change, favoured by a quite flexible organization suitable to implement and test new approaches. In case these methods should properly work in companies' reference field, they could be easily implemented;
- Company type C (companies 1 and 6 of the survey): it is characterized by the availability of significant know-how and experience. These firms meet all the requirements to profitably test new Product Planning approaches. However, the introduction of new methods would radically alter the complex companies' structure. Hence, these enterprises probably need flexible methods that offer various intermediate steps of implementation, in order to make (at least) the idea generation activity more formal.

Furthermore, according to companies' survey, the unsuccessful transfer to the industry of idea generation and selection methods (like other techniques developed within the engineering design) proposed by academia is due to the following factors:

- scholars' "dogmatic" approach;
- communication problems;
- insufficient promotion of research results (several firms do not know scholars' works);
- cultural problems;
- distance from the business world and its needs;
- supposed unsuitability of the methods in certain industrial fields.

Therefore, scholars should start advertising their works and reinforcing the links with industry. In this way, they could have a major understanding of firms' needs and develop more suitable methods and tools.

Eventually, it has to be considered that, although Product Planning strongly affects the success of innovation projects, any failure in the subsequent design phases can likewise prevent new artefacts from thriving in the marketplace. As a consequence, another not negligible research issue is represented by the pressing need of fine-tuning reliable approaches to validate the methods dedicated to Product Planning, requiring to separate the effects of not efficient design phases.

7 Conclusions

In this Thesis an original methodology and a set of tools aimed at supporting the first critical phase of design process, i.e. Product Planning, has been presented. Developed approach supports the user during each activity of Product Planning from information gathering up to the selection of a new product idea that will be developed in the following design phases.

In order to identify requirements of an ideal Product Planning method an extensive survey of literature approaches and an analysis of companies' demands have been carried out.

The first original contribution of the research concerns the identification of a category of Product Planning approaches, not already classified, that has been named "hybrid" because it merge, as a matter of fact, peculiarities of recognized clusters, i.e. proactive and responsive approaches. Hybrid methods try to discover and fulfil customers' latent needs by actively (collaborating to the generation of new ideas) or passively (assessing new ideas identified by the firm) involving the end users of the product in the idea generation process.

Proposed approach has been developed with the aim of supporting in a proactive way the user during the Product Planning phase. Indeed, this kind of approaches (as seen in Chapter 2) supports the development of breakthrough products without requiring a great amount of time and resources. In order to minimize the uncertainty due to the absence of customer feedback that characterises responsive methods, developed approach includes:

- responsive techniques to collect customer data in the first information gathering step (see Subsection 4.2.1 for more details);
- a tool (VAM) to assess the commercial success of new identified ideas, without the need of collecting customer feedback (see Subsection 4.2.3 for more details).

During experiments of developed approach, involved experts suggested using proposed idea stimulation tools involving groups composed of both designers and potential customers. This new way of employing developed techniques has not been already tested, however it could allow using the approach as a hybrid method too.

The analysis of companies' demands has been performed by interviewing and directly observing design activities of six companies. Although the surveyed companies cannot be considered a representative sample of enterprises, due to their limited number, the author believes that the highlighted needs can be shared by several other organizations.

Eleven features of an ideal Product Planning approach have been identified:

1. Quickness and easiness of the method/tool;
2. Use of computer applications;
3. Effective support in the individuation of latent needs;
4. Integrated competitors' analysis;
5. Consideration of customer preferences dynamics;
6. Reliability of the approach;
7. Support in selecting the most beneficial product idea;
8. Independence from inputs subjectivity;
9. Possibility of actively involving customers in the Product Planning activities;
10. Possibility of entrusting the Product Planning phase to multidisciplinary teams;
11. Possibility of formally schematizing the identified ideas.

None of the identified literature approaches supports all the activities of Product Planning and only partially satisfy above listed features. Above all, features 1-4-8-11 are not included in most of literature techniques.

The original method has been developed with the aim of guiding the user in the early phase of NPD projects, always focusing on companies' demands. The proposed roadmap has been integrated with several original tools that have been developed with the aim of effectively supporting each activity of Product Planning:

- *information gathering*: besides guidelines to support the search of information an original algorithm to identify the industrial standard/s in the reference market have been developed;
- *idea generation*: two original tools to support the stimulation of new ideas (APS Check List and iDea) and an approach to check planned differentiation strategies (Graphic analysis of Strategy Canvas) have been developed. The first idea stimulation tool supports the exploration of new opportunities through a checklist that includes the main categories of product and services. They can suggest original product accessories or new related services, besides new product attributes. The second tool generates hints combining four dimensions that generate value for the customer (according to the literature). The original algorithm has been implemented in a software prototype and tested with several industrial case studies obtaining promising results. Eventually the third approach has been developed combining two existing tools (Strategy Canvas and New Value Proposition guidelines). It allows to focus on currently offered performances and check if planned differentiation strategies could provide promising results;
- *idea selection*: in order to assess the potential success of a new product idea the VAM formula (Borgianni et al. 2013) has been chosen. An algorithm to assess the uncertainties on the output of VAM has been proposed and a software tool has been developed. On the other hand assessment of the costs (feasibility) has been supported by an original developed tool, namely Profile Cost Matrix, that allows focusing on company's available resources and policy. Eventually, the final choice has been supported proposing the success-cost chart that provides a quick view of potential success and feasibility of compared new product profiles.

The whole approach with collected and developed tools has been tested in two industrial case studies, i.e. components for point-fixed curtain wall and glass staircases. Involved experts provided promising feedbacks about method's effectives. Indeed, the approach allowed to depict current market scenario and deeply analyse competitors' offers, identify lots of new opportunities and select the most promising product idea according to its potential market success and feasibility, reducing risks connected to uncertainties. On the other hand, these tests provided useful hints to improve the usability of the method too.

One of the original tool developed to support the idea generation activity, i.e. iDea, have been tested in various industrial contexts in order to assess its usability and effectiveness.

The first experiments involved 24 MS students of Mechanical Engineering (University of Florence) and compared the developed tool with a well-known approach, i.e. Six Paths Framework. This test obtained promising outcomes in terms of quantity, variety and novelty of generated ideas. In addition, experiment provided interesting results, deemed worth of future research, like the possible independence of the obtained outputs from the type of the product to be innovated (in the test cameras and domestic coffee makers have been analysed) and the fact that iDea can deeply highlight the differences among the personal skills of users.

The second experiment involved a scholar with a great experience on NPD techniques that collaborates with a multinational corporation of white goods. The tester autonomously used the tool to identify new opportunities in the field of household ovens. The outcomes demonstrate the capability of the instrument to perform a wide exploration of possible sources of value. In addition, the tool supported the analysis of competing factors too.

The third experiment involved the CEO of B10nix, a firm that offers software and hardware systems for HCI. The test analyse a wearable systems to capture and analyse the movement of people in the context of rehabilitation through physiotherapy. Expert identified several new ideas to improve both functioning of the product and related offered services. A final interview focus on the comparison between iDea and previously employed approach, i.e. Brainstorming. The limits claimed by the expert about their Brainstorming sessions concern the generation of very fuzzy concepts that do not undergo sufficient elaboration and variability in terms of both quality and quantity of produced ideas. In these terms, the employment of iDea allowed generating a larger number of ideas in less time.

The last experiment of iDea involved an expert of the firm in which the whole developed approach has been tested. The user employed the tool in order to identify new opportunities in the field of handle for glass sliding doors. Identified ideas have been assessed according to their potential feasibility and company's will to implement them in future NPD projects. Most of identified ideas have been considered promising but only a part of them could be developed according to company's currently available resources. Promising ideas have been stored in a database, waiting the right moment to implement them.

Despite the evidences arisen from the experiments, further researches are required to fully validate the major inspiring capabilities of the developed approach and tools. In addition, scholars can try to address open research issues, described in the previous Chapter, in order to assess how the original approach works in different contexts, with multidisciplinary teams, and using further metrics to assess its potentialities.

Eventually, future efforts will have to be focused on the integration of developed method and tools that support the Product Planning phase with the subsequent NPD phases.

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Bibliography

Achiche S, Appio FP, McAloone TC, Di Minin A (2013) Fuzzy decision support for tools selection in the core front-end activities of new product development. Res Eng Des 24(1):1-18. doi: 10.1007/s00163-012-0130-4

Adams ME, Day GS, Dougherty D (1998) Enhancing new product development performance: an organizational learning perspective. J Prod Innovat Manag 15(5):403-422. doi: 10.1111/1540-5885.1550403

Agouridas V, McKay A, Winand H, de Pennington A (2008) Advanced product planning: a comprehensive process for systemic definition of new product requirements. Requir Eng 13(1):19-48. doi: 10.1007/s00766-007-0055-z

Altshuller GS (1984) Creavity as an exact science. The Theory of Solution of Inventive Problems. Gordon & Breach Science Publishers, New York

Aiken M, Krosp J, Shirani A, Martin J (1994) Electronic brainstorming in small and large groups. Inform Manage 27(3):141-149. doi: 10.1016/0378-7206(94)90042-6

Akao Y (2004) Quality function deployment: integrating customer requirements into product design. Productivity Press, New York

Alam I (2006) Removing the fuzziness from the fuzzy front-end of service innovations through customer interactions. Ind Market Manag 35(4):468-480. doi: 10.1016/j.indmarman.2005.04.004

Al-Hakim L, Kusiak A, Mathew J (2000) A graph-theoretic approach to conceptual design with functional perspectives. Comput Aided Design 32(14):867-875. doi: 10.1016/S0010-4485(00)00075-0

Anderson JC, Jain DC, Chintagunta PK (1992) Customer value assessment in business markets: a state-of-practice study. J Bus-Bus Mark 1(1):3-29. doi:10.1300/J033v01n01_02

Arai T, Shimomura Y (2004) Proposal of service CAD system-a tool for service engineering. CIRP Ann-Manuf Techn 53(1):397-400. doi: 10.1016/S0007-8506(07)60725-2

Aspara J, Hietanen J, Parvinen P, Tikkanen H (2008) An exploratory empirical verification of Blue Ocean Strategies: findings from Sales Strategy. 8th International Business Research Conference, IBR 2008, Dubai, United Arab Emirates, 27-28 March

Atuahene‐Gima K, Slater SF, Olson EM (2005) The contingent value of responsive and proactive market orientations for new product program performance. J Prod Innovat Manag 22(6):464-482. doi: 10.1111/j.1540-5885.2005.00144.x

Aurich JC, Mannweiler C, Schweitzer E (2010) How to design and offer services successfully. CIRP J Manuf Sci Technol 2(3):136-143. doi:10.1016/j.cirpj.2010.03.002

Ayers D, Dahlstrom R, Skinner SJ (1997) An exploratory investigation of organizational antecedents to new product success. J Marketing Res 34(1):107-116. doi: 10.2307/3152068

Balachandra R, Friar JH (1997) Factors for success in R&D projects and new product innovation: a contextual framework. IEEE Trans Eng Manag 44(3):276-287. doi: 10.1109/17.618169

Baldussu A, Cascini G (2015) About integration opportunities between TRIZ and Biomimetics for inventive design. Procedia Eng 131:3-13. doi:10.1016/j.proeng.2015.12.342

Barczak G, Griffin A, Kahn KB (2009) Perspective: trends and drivers of success in NPD practices: results of the 2003 PDMA best practices study. J Prod Innovat Manag 26(1):3-23. doi: 10.1111/j.1540-5885.2009.00331.x

Barnes C, Childs T, Lillford S (2010) Kansei/Affective Engineering for the european fast-moving consumer goods industry. In: Nagamachi M (ed) Kansei/Affective Engineering. CRC Press, Boca Raton, pp 253-274

Basberg BL (1987) Patents and the measurement of technological change: a survey of the literature. Res policy, 16(2):131-141. doi: 10.1016/0048-7333(87)90027-8

Bell S. (2008) International Brand Management of Chinese Companies: Case Studies on the Chinese Household Appliances and Consumer Electronics Industry Entering US and Western European Markets. Springer, Heidelberg

Berthon P, Hulbert J, Pitt L (1999) To serve or to create? Strategic orientations towards customers and innovation. Calif Manage Rev 42(1):37-58.

Bhide A (1994) How entrepreneurs craft strategies that work. Harvard Bus Rev 72(2):150-161.

Bonner JM (2005) The influence of formal controls on customer interactivity in new product development. Ind Market Manag 34(1):63-69. ISSN-0017-8012

Borgianni Y, Cascini G, Pucillo F, Rotini F (2013) Supporting product design by anticipating the success chances of new value profiles. Comput Ind 64(4):421-435. doi: 10.1016/j.compind.2013.02.004

Borgianni Y, Cascini G, Rotini F (2012) Investigating the patterns of value-oriented innovations in blue ocean strategy. Int J Innov Sci 4(3):123-142. doi: 10.1260/1757-2223.4.3.123

Borgianni Y, Rotini F (2013) Towards the fine-tuning of a predictive Kano model for supporting product and service design. Total Qual Manag Bus (ahead-of-print) 1-21. doi:10.1080/14783363.2013.791119

Boztepe S (2007) Toward a framework of product development for global markets: a user-value-based approach. Des Stud 28(5):513-533. doi: 10.1016/j.destud.2007.02.010

Brem A, Voigt KI (2009) Integration of market pull and technology push in the corporate front end and innovation management-Insights from the German software industry. Technovation 29(5):351-367. doi: 10.1016/j.technovation.2008.06.003

Bruce M, Cooper R (2000) Creative product design. Wiley and Sons, New York

Burt RS (2004) Structural holes and good ideas. Am J Sociol 110(2):349-399. doi: 10.1086/421787

Büyüközkan G, Feyzioğlu O (2004) A new approach based on soft computing to accelerate the selection of new product ideas. Comput Ind 54(2):151-167. doi: 10.1016/j.compind.2003.09.007

Buzan T, Buzan B (1996) The mind map book how to use radiant thinking to maximise your brain's untapped potential. Plume, New York

Cagan J, Vogel CM (2001) Creating Breakthrough Products: Innovation from Product Planning to Program Approval. Prentice Hall, Upper Saddle River

Campbell RS (1983) Patent trends as a technological forecasting tool. World Pat Inf 5(3):137-143. doi: 10.1016/0172-2190(83)90134-5

Cantamessa M, Montagna F, Messina M (2013) Multistakeholder Analysis of Requirements to Design Real Innovations. 19th International Conference On Engineering Design, ICED13, Seoul, Korea, August 19-22, pp 19-22

Cascini G (2012) TRIZ-based anticipatory design of future products and processes. J Integr Des Process Sci 16(3):29-63. doi: 10.3233/jid-2012-0005

Cascini G, Rotini F, Russo D (2011) Networks of trends: systematic definition of evolutionary scenarios. Procedia Eng 9:355-367. doi:10.1016/j.proeng.2011.03.125

Cascini G, Russo D (2007) Computer-aided analysis of patents and search for TRIZ contradictions. Int J Prod Dev 4(1-2):52-67. doi: 10.1504/IJPD.2007.011533

Chan SL, Ip WH (2011) A dynamic decision support system to predict the value of customer for new product development. Decis Support Syst 52(1):178-188. doi: 10.1016/j.dss.2011.07.002

Chen CH, Yan W (2008) An in-process customer utility prediction system for product conceptualisation. Expert Syst Appl 34(4):2555-2567. doi: 10.1016/j.eswa.2007.04.019

Chidamber SR, Kon HB (1994) A research retrospective of innovation inception and success: the technology-push, demand-pull question. Int J Technol Manag 9(1):94-112.

Chong YT, Chen CH (2010) Customer needs as moving targets of product development: a review. Int J Adv Manuf Tech 48(1-4):395-406. doi: 10.1007/s00170-009-2282-6

Christensen CM, Bower JL (1996) Customer power, strategic investment, and the failure of leading firms. Strateg Manag J 17(3):197-218. doi: 10.1002/(SICI)1097-0266(199603)17:3<197::AID-SMJ804>3.0.CO;2-U

Coates NF, Cook I, Robinson H (1997) Idea generation techniques in an industrial market. J Marketing Practice Appl Marketing Sci 3(2):107-118. doi: 10.1108/EUM0000000004336

Cooper RG (1990) Stage-gate systems: a new tool for managing new products. Bus Horizons 33(3):44-54. doi:10.1016/0007-6813(90)90040-i

Cooper RG (1999) The invisible success factors in product innovation. J Prod Innovat Manag 16(2):115-133. doi: 10.1111/1540-5885.1620115

Cooper RG (2011) Winning at new products, 4th edition. Basic Books, New York

Cooper WH, Gallupe BR (1993) Brainstorming electronically. Sloan Manag Rev 35(1):27-37.

Cousineau M, Lauer TW, Peacock E (2004) Supplier source integration in a large manufacturing company. Supply Chain Manag 9(1):110-117. doi: 10.1108/13598540410517629

Dahan E, Hauser JR (2002) The virtual customer. J Prod Innovat Manag 19(5):332-353. doi: 10.1111/1540-5885.1950332

Dahl DW, Moreau P (2002) The influence and value of analogical thinking during new product ideation. J Marketing Res 39(1):47-60. doi: 10.1509/jmkr.39.1.47.18930

Dalkey N, Helmer O (1963) An experimental application of the Delphi method to the use of experts. Manag Sci 9(3):458-467. doi: 10.1287/mnsc.9.3.458

De Bono E (1968) New think: the use of lateral thinking in the generation of new ideas. Basic Books, New York

De Bono E (2009) Six Thinking Hats, 2nd edition. Penguin, London

De Bono E (2010) Lateral thinking: Creativity step by step. HarperCollins, New York

Diehl M, Stroebe W (1991) Productivity loss in idea-generating groups: tracking down the blocking effect. J Pers Soc Psychol 61(3):392-403. doi: 10.1037/0022-3514.61.3.392

Di Stefano G, Gambardella A, Verona G (2012) Technology push and demand pull perspectives in innovation studies: current findings and future research directions. Res Policy 41(8):1283-1295. doi: 10.1016/j.respol.2012.03.021

Drumwright ME (1996) Company advertising with a social dimension: the role of noneconomic criteria. J Marketing 60(4):71-87. doi: 10.2307/1251902

Eckert C, Bertoluci G, Yannou B (2014) Handling subjective product properties in engineering, food and fashion. 13th International Design Conference, DESIGN 2014, Dubrovnik, Croatia, 19-22 May, pp 791-800

Ernst H (2002) Success factors of new product development: a review of the empirical literature. Int J Manag Rev 4(1):1-40. doi: 10.1111/1468-2370.00075

Feldman LP, Page AL (1984) Principles vs. practice in new product planning. J Prod Innovat Manag 1(1):43-55. doi: 10.1016/S0737-6782(84)80042-9

Figueira J, Greco S, Ehrgott M (2005). Multiple criteria decision analysis: state of the art surveys. Springer, Berlin. ISBN 978-0-387-23081-8

Flint DJ (2002) Compressing new product success-to-success cycle time: deep customer value understanding and idea generation. Ind Market Manag 31(4):305-315. doi: 10.1016/S0019-8501(01)00165-1

Flint DJ, Mentzer JT (2000) Logisticians as marketers: their role when customers' desired value changes. J Bus Logist 21(2):19-46. ISSN: 0197-6729

Fombrun CJ (1996) Reputation: Realizing value from the corporate image. Harvard Business Press, Boston

Furnham A (2000) The brainstorming myth. Bus Strateg Rev 11(4):21-28. doi: 10.1111/1467-8616.00154

Füller J, Matzler K (2007) Virtual product experience and customer participation-A chance for customer-centred, really new products. Technovation 27(6):378-387. doi: 10.1016/j.technovation.2006.09.005

García N, Sanzo MJ, Trespalacios JA (2008) New product internal performance and market performance: evidence from Spanish firms regarding the role of trust, interfunctional integration, and innovation type. Technovation 28(11):713-725. doi: 10.1016/j.technovation.2008.01.001

Gausemeier J, Brink V, Ihmels S, Kokoschka M, Reymann F (2009) Strategic product- and technology-planning with the innovation-database: a field-proven approach from the marketoriented product idea up to an operational development roadmap. IEEE International Conference on Industrial Technology, ICIT 2009, Gippsland, Australia, 10-13 February, pp 1-6

Geschka H (1996) Creativity techniques in Germany. Creat Innov Manag 5(2):87-92. doi: 10.1111/j.1467-8691.1996.tb00125.x

Godkin L, Allcorn, S (2008). Overcoming organizational inertia: A tripartite model for achieving strategic organizational change. J Appl Bus Econ, 8(1):82-94.

Gordon WJ (1961) Synectics: The development of creative capacity. Harper, Oxford

Grewal D, Krishnan R, Levy M, Munger J (2010) Retail success and key drivers. In: Krafft M, Mantrala, MK (eds) Retailing in the 21st Century. Springer Berlin Heidelberg, Berlin, pp 15-30

Guo W (2012) A research on fuzzy front end of npd in Chinese equipment manufacturing firms: A theoretical model. IEEE Control and Decision Conference, CCDC 2012, Taiyuan, China, 23-25 May, pp 493-497

Gupta AK, Raj SP, Wilemon D (1986) A model for studying R&D. Marketing interface in the product innovation process. J Marketing 50(2):7-17.

Haig M (2011) Brand Failures. Kogan Page, London

Hartono M, Chuan TK, Peacock JB (2012) Cultural differences in applying Kansei Engineering to services. IEEE Southeast Asian Network of Ergonomics Societies Conference, SEANES 2012, Langkawi, Malaysia, 9-12 July, pp 1-5

Hamel G, Prahalad CK (1994) Competing for the Future. HBS Press, Boston

Henard DH, Szymanski DM (2001) Why some new products are more successful than others. J Marketing Res 38(3):362-375. doi: 10.1509/jmkr.38.3.362.18861

Hüsig S, Kohn S (2009) Computer aided innovation-State of the art from a new product development perspective. Comput Ind 60(8):551-562. doi: 10.1016/j.compind.2009.05.011

Jetter AJ, Sperry RC (2013) Fuzzy cognitive maps for product planning: using stakeholder knowledge to achieve corporate responsibility. IEEE Hawaii International Conference on System Sciences, HICSS 2013, Wailea, Hawaii, 7-10 January, pp 925-934

Johne FA, Snelson PA (1988) Success factors in product innovation: a selective review of the literature. J Prod Innovat Manag 5(2):114-128. doi: 10.1111/1540-5885.520114

Kahn KB (2011) Product Planning Essentials. M.E. Sharpe, New York

Kano N, Seraku N, Takahashi F, Tsuji S (1984) Attractive quality and must-be quality. J Jpn Soc Qual Control 14(2):39-48.

Kano N (1995) Upsizing the organization by attractive quality creation. In: Kanji GK (ed) Total Quality Management. Springer Netherlands, Dordrecht, pp 60-72

Kano N (2001) Life cycle and creation of attractive quality. 4th International Conference on Quality Management and Organisational Development, QMOD 2001, Linköping, Sweden, 12-14 September, pp 18-36

Kaufman JC, Lee J, Baer J, Lee S (2007) Captions, consistency, creativity, and the consensual assessment technique: New evidence of reliability. Think Skills Creat 2(2):96-106. http://dx.doi.org/10.1016/j.tsc.2007.04.002

Kärkkäinen H, Piippo P, Puumalainen K, Tuominen M (2001) Assessment of hidden and future customer needs in Finnish business-to-business companies. R&D Manage 31(4):391-407. doi: 10.1111/1467-9310.00227

Kärkkäinen H, Elfvengren K (2002) Role of careful customer need assessment in product innovation management-empirical analysis. Int J Prod Econ 80(1):85-103. doi: 10.1016/S0925-5273(02)00245-1

Kim WC, Mauborgne R (2005) Blue Ocean Strategy. Harvard Business School Press, Cambridge

Kim J, Wilemon D (2002) Focusing the fuzzy front–end in new product development. R&D Manage 32(4):269-279. doi: 10.1111/1467-9310.00259

Kimita K, Shimomura Y, Arai T (2009) A customer value model for sustainable service design. CIRP J Manuf Sci Technol 1(4):254-261. doi: 10.1016/j.cirpj.2009.06.003

Klein A, Spiegel G (2013) Social media in the product development process of the automotive industry: a new approach. In: Kurosu M. (ed) Human-Computer Interaction: Users and Contexts of Use. Springer Berlin Heidelberg, Berlin, pp 396-401

Koen PA, Ajamian G, Boyce S, Clamen A, Fisher E, Fountoulakis S, Johnson A, Puri P, Seibert R (2002) Fuzzy Front End: Effective Methods, Tools and Techniques. Wiley and Sons, New York

Koen P, Ajamian G, Burkart R, Clamen A, Davidson J, D'Amore R, Elkins C, Herald K, Incorvia M, Johnson A, Karol R, Seibert R, Slavejkov A, Wagner K (2001) Providing clarity and a common language to the" fuzzy front end". Res Technol Manage 44(2):46-55.

Kotler P (2007) Marketing Management, 12th edition. Prentice Hall, Englewood Cliffs

Krishnan V, Ulrich KT (2001) Product development decisions: a review of the literature. Manage Sci 47(1):1-21. doi: 10.1287/mnsc.47.1.1.10668

Lee AH, Kang HY, Yang CY, Lin CY (2010) An evaluation framework for product planning using FANP, QFD and multi-choice goal programming. Int J Prod Res 48(13):3977-3997. doi:10.1080/00207540902950845

Lee C, Cho Y, Seol H, Park Y (2012) A stochastic patent citation analysis approach to assessing future technological impacts. Technol Forecast Soc 79(1):16-29. doi: 10.1016/j.techfore.2011.06.009

Lee CW, Suh Y, Kim IK, Park JH, Yun MH (2010) A systematic framework for evaluating design concepts of a new product. Hum Factors Ergon Manuf 20(5):424-442. doi: 10.1002/hfm.20193

Leenders MA, Wierenga B (2002) The effectiveness of different mechanisms for integrating marketing and R&D. J Prod Innovat Manag 19(4):305-317. doi: 10.1111/1540-5885.1940305

Leinsdorff T (1995) Buying behavior and product planning. Int J Prod Econ 41(1):237-239. doi: 10.1016/0925-5273(95)00068-2

Levinthal DA, March JG (1993) The myopia of learning. Strateg Manage J 14(2):95-112. doi: 10.1002/smj.4250141009

Li YL, Tang JF, Chin KS, Luo XG, Pu Y, Jiang YS (2012) On integrating multiple type preferences into competitive analyses of customer requirements in product planning. Int J Prod Econ 139(1):168-179. doi: 10.1016/j.ijpe.2012.03.031

Li Y, Wang J, Li X, Zhao W (2007) Design creativity in product innovation. Int J Adv Manuf Tech 33(3-4):213-222. doi: 10.1007/s00170-006-0457-y

Liao SH, Hsieh CL, Huang SP (2008) Mining product maps for new product development. Expert Syst Appl 34(1):50-62. doi: 10.1016/j.eswa.2006.08.027

Liberatore MJ, Stylianou AC (1995) Toward a framework for developing knowledge-based decision support systems for customer satisfaction assessment: An application in new product development. Expert Syst Appl 8(1):213-228. doi: 10.1016/0957-4174(94)E0011-I

Lindič J, Bavdaž M, Kovačič H (2012) Higher growth through the Blue Ocean Strategy: implications for economic policy. Res Policy 41(5):928-938. DOI: 10.1016/j.respol.2012.02.010

Lindstrom M (2008) Buyology: truth and lies about why we buy. Broadway Books, New York

Linstone HA, Turoff M (1975) The delphi method. Addison-Wesley, Reading

Löfgren M, Witell L, Gustafsson A (2011) Theory of attractive quality and life cycles of quality attributes. TQM J 23(2):235-246. doi: 10.1108/17542731111110267

Luor T, Lu HP, Chien KM, Wu TC (2012) Contribution to quality research: a literature review of Kano's model from 1998 to 2012. Total Qual Manag Bus (ahead-of-print) 1-14. doi:10.1080/14783363.2012.733264

March JG (1991) Exploration and exploitation in organizational learning. Organ Sci 2(1):71-87. doi: 10.1287/orsc.2.1.71

Martin B, Hanington B (2012) Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions. Rockport Publishers, Beverly

Matsatsinis NF, Siskos Y (1999) MARKEX: An intelligent decision support system for product development decisions. Eur J Oper Res 113(2):336-354. doi: 10.1016/S0377-2217(98)00220-3

Matzler K, Hinterhuber HH (1998) How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function deployment. Technovation 18(1):25-38. doi: 10.1016/S0166-4972(97)00072-2

McAdam R, McClelland J (2002) Individual and team-based idea generation within innovation management: organisational and research agendas. Eur J Innovat Manag 5(2):86-97. doi: 10.1108/14601060210428186

McAdams DA, Stone RB, Wood KL (1999) Functional interdependence and product similarity based on customer needs. Res Eng Des 11(1):1-19. doi:10.1007/s001630050001.

Michaud C, Llerena D (2006) An economic perspective on remanufactured products: industrial and consumption challenges for life cycle engineering. 13th CIRP International Conference on Life Cycle Engineering, LCE 2006, Leuven, Belgiumm 31 May - 2 June, pp 543-548.

Miles DL (1949) How to cut costs with Value Analysis. McGraw Hill Publishing, New York

Mishra S, Kim D, Lee DH (1996) Factors affecting new product success: cross ‐ country comparisons. J Prod Innovat Manag 13(6):530-550. doi: 10.1111/1540-5885.1360530

Montagna F (2011) Decision-aiding tools in innovative product development contexts. Res Eng Des 22(2):63-86. doi: 10.1007/s00163-011-0103-z

Monteiro C, Arcoverde DF, da Silva FQ, Ferreira HS (2010) Software support for the fuzzy front end stage of the innovation process: a systematic literature review. IEEE International Conference on Management of Innovation and Technology, ICMIT 2010, Singapore, 2-5 June, pp 426-431

Montoya ‐ Weiss MM, O'Driscoll TM (2000) From experience: applying performance support technology in the fuzzy front end. J Prod Innovat Manag 17(2):143-161. doi: 10.1111/1540-5885.1720143

Nagamachi M (1995) Kansei engineering: a new ergonomic consumer-oriented technology for product development. Int J Ind Ergonom 15(1):3-11. doi: 10.1016/0169-8141(94)00052-5

Nagle TT, Holden RK (1995) The strategy and tactics of pricing. Prentice Hall, Englewood Cliffs

Narver JC, Slater SF, MacLachlan DL (2004) Responsive and Proactive Market Orientation and New ‐ Product Success. J Prod Innovat Manag 21(5):334-347. doi: 10.1111/j.0737-6782.2004.00086.x

Nilsson-Witell L, Fundin A (2005) Dynamics of service attributes: a test of Kano's theory of attractive quality. Int J Serv Ind Manag 16(2):152-168. doi: 10.1108/09564230510592289

Nunamaker JF, Dennis AR, Valacich JS, Vogel DR (1991) Information technology for negotiating groups: generating options for mutual gain. Manage Sci 37(10):1325-1346. doi: 10.1287/mnsc.37.10.1325

O'Connor GC (1998) Market learning and radical innovation: a cross case comparison of eight radical innovation projects. J Prod Innovat Manag 15(2):151-166. doi: 10.1111/1540-5885.1520151

Osborne AF (1953) Applied Imagination. Scribner: Oxford

Osterwalder A, Pigneur Y (2010) Business model generation: a handbook for visionaries, game changers, and challengers. John Wiley & Sons: Hoboken

Oulasvirta A, Kurvinen E, Kankainen T (2003) Understanding contexts by being there: case studies in bodystorming. Pers Ubiquit Comput 7(2):125-134. doi: 10.1007/s00779-003-0238-7

Oztekin A, Iseri A, Zaim S, Nikov A (2013) A Taguchi-based Kansei engineering study of mobile phones at product design stage. Prod Plan Control 24(6):465-474. doi:10.1080/09537287.2011.633575

Pahl G, Beitz W, Feldhusen J, Grote KH (2007) Engineering design: a systematic approach. Springer, London

Park CW, Jaworski BJ, Maclnnis DJ (1986) Strategic brand concept-image management. J Marketing 50(4):135-145.

Ramesh B, Tiwana A (1999) Supporting collaborative process knowledge management in new product development teams. Decis Support Syst 27(1):213-235. doi: 10.1016/S0167-9236(99)00045-7

Rangaswamy A, Lilien GL (1997) Software tools for new product development. J Marketing Res 34(1):177-184.

Reid SE, De Brentani U (2004) The fuzzy front end of new product development for discontinuous innovations: a theoretical model. J Prod Innovat Manag 21(3):170-184. doi: 10.1111/j.0737-6782.2004.00068.x

Reinertsen DG (1999) Taking the fuzziness out of the fuzzy front-end. Res Technol Manage 42(6):25-31.

Reynolds TJ, Gutman J (1988) Laddering theory, method, analysis, and interpretation. J Advertising Res 28(1):11-31.

Riel A, Neumann M, Tichkiewitch S (2013) Structuring the early fuzzy front-end to manage ideation for new product development. CIRP Ann-Manuf Techn 62(1):107-110. doi: 10.1016/j.cirp.2013.03.128

Rietzschel EF, Nijstad BA, Stroebe W (2006) Productivity is not enough: a comparison of interactive and nominal brainstorming groups on idea generation and selection. J Exp Soc Psychol 42(2):244-251. doi: 10.1016/j.jesp.2005.04.005

Rochford L (1991) Generating and screening new products ideas. Ind Market Manag 20(4):287-296. doi: 10.1016/0019-8501(91)90003-X

Rohrbeck R, Steinhoff F, Perder F (2008) Virtual customer integration in the innovation process: evaluation of the web platforms of multinational enterprises (MNE). IEEE Portland International Conference on Management of Engineering & Technology, PICMET 2008, Cape Town, South Africa, 27-31 July, pp 469-478

Rosa F, Rovida E, Viganò R, Razzetti E (2011) Proposal of a technical function grammar oriented to biomimetic. J Eng Design 22(11-12):789-810. doi: 10.1080/09544828.2011.603296

Rosa F, Rovida E, Viganó R (2015) Embodiment for requirements. Int J Interact Des Manuf 1-14. doi: 10.1007/s12008-015-0269-0

Rotini F, Borgianni Y, Cascini G (2012) Re-engineering of Products and Processes. Springer, London

Rubenstein AH (1994) At the front end of the R&D/Innovation process: idea development and entrepreneurship. Int J Technol Manage 9(5-6):652-677. doi: 10.1504/IJTM.1994.025595

Sakao T (2009) Quality engineering for early stage of environmentally conscious design. TQM J 21(2):182-193. doi: 10.1108/17542730910938164

Sarkar P, Chakrabarti A (2011) Assessing design creativity. Des Stud, 32(4):348-383. doi:10.1016/j.destud.2011.01.002.

Schilling M (2008) Strategic Management of Technological Innovation. McGraw-Hill, New York

Schütte ST, Eklund J, Axelsson JR, Nagamachi M (2004) Concepts, methods and tools in Kansei Engineering. Theor Issues Ergon Sci 5(3):214-231. doi:10.1080/1463922021000049980

Shah JJ, Smith SM., Vargas-Hernandez N (2003) Metrics for measuring ideation effectiveness. Des Stud 24(2):111-134. doi:10.1016/S0142-694X(02)00034-0.

Sheu DD, Lee HK (2011) A proposed process for systematic innovation. Int J Prod Res, 49(3):847-868. doi:10.1080/00207540903280549

Shinno H, Hashizume H (2002) Structured method for identifying success factors in new product development of machine tools. CIRP Ann-Manuf Techn 51(1):281-284. doi: 10.1016/S0007-8506(07)61517-0

Shinno H, Yoshioka H, Marpaung S (2006) A structured method for analysing product specification in product planning for machine tools. J Eng Design 17(4):347-356. doi:10.1080/09544820600647734

Simonton DK (2003) Scientific creativity as constrained stochastic behavior: the integration of product, person, and process perspectives. Psychol Bull 129(4):475-494. doi: 10.1037/0033-2909.129.4.475

Schön DA (1967) Technology and change: the new Heraclitus. Delacorte Press, New York

Smith PG, Reinertsen DG (1991) Developing products in half the time. Van Nostrand Reinhold, New York

Song XM, Parry ME (1996) What separates Japanese new product winners from losers. J Prod Innovat Manag 13(5):422-439. doi: 10.1111/1540-5885.1350422

Song XM, Thieme RJ, Xie J (1998) The impact of cross‐functional joint involvement across product development stages: an exploratory study. J Prod Innovat Manag 15(4):289-303. doi: 10.1111/1540-5885.1540289

Soukhoroukova A, Spann M, Skiera B (2012) Sourcing, filtering, and evaluating new product ideas: an empirical exploration of the performance of idea markets. J Prod Innovat Manag 29(1):100-112. doi: 10.1111/j.1540-5885.2011.00881.x

Sowrey T (1990) Idea generation: identifying the most useful techniques. Eur J Marketing 24(5):20-29. doi: 10.1108/03090569010140228

Stasch SF, Lonsdale RT, La Venka NN (1992) Developing a framework for sources of new product ideas. J Consum Mark 9(2):5-15. doi: 10.1108/07363769210036980

Tan KC, Shen XX (2000) Integrating Kano's model in the planning matrix of quality function deployment. Total Qual Manage 11(8):1141-1151. doi: 10.1080/095441200440395

Tay FE, Gu J (2002) Product modeling for conceptual design support. Comput Ind 48(2):143-155. doi:10.1016/S0166-3615(02)00014-3

Tomiyama T, Gu P, Jin Y, Lutters D, Kind C, Kimura F (2009) Design methodologies: industrial and educational applications. CIRP Ann-Manuf Techn 58(2):543-565. doi: 10.1016/j.cirp.2009.09.003

Tripsas M (2008) Customer preference discontinuities: a trigger for radical technological change. Manage Decis Econ 29(2‐3):79-97. doi: 10.1002/mde.1389

Toubia O (2006) Idea generation, creativity, and incentives. Market Sci 25(5):411-425. doi: 10.1287/mksc.1050.0166

Tsai KH, Chou C, Kuo JH (2008) The curvilinear relationships between responsive and proactive market orientations and new product performance: a contingent link. Ind Market Manag 37(8):884-894. doi: 10.1016/j.indmarman.2007.03.005

Tseng MM, Jiao J (1998) Computer-aided requirement management for product definition: a methodology and implementation. Concurrent Eng Res A 6(2):145-160. doi:10.1177/1063293X9800600205

Ulrich KT, Eppinger SD (2011) Product design and development. McGraw Hill, New York

Ulwick AW (2002) Turn customer input into innovation. Harvard Bus Rev 80(1):91-97.

Urban GL, Hauser JR (1993) Design and marketing of new products, 2nd edition. Prentice Hall, Englewood Cliffs

Valacich JS, Dennis AR, Connolly T (1994) Idea generation in computer-based groups: A new ending to an old story. Organ Behav Hum Dec 57(3):448-467. doi: 10.1006/obhd.1994.1024

Van Dijk C, Van Den Ende J (2002) Suggestion systems: transferring employee creativity into practicable ideas. R&D Manag, 32(5):387-395. doi: 10.1111/1467-9310.00270

VanGundy AB (1984) Brain writing for new product ideas: an alternative to brainstorming. J Consum Mark 1(2):67-74. doi: 10.1108/eb008097

Van Kleef E, van Trijp H, Luning P (2005) Consumer research in the early stages of new product development: a critical review of methods and techniques. Food Qual Prefer 16(3):181-201. doi: 10.1016/j.foodqual.2004.05.012

Verma D, Fabrycky WJ (1997) Systematically identifying system engineering practices and methods. IEEE Trans Aerosp Electron Syst 33(2):587-595. doi: 10.1109/7.588377

Von Hippel E (1986) Lead users: a source of novel product concepts. Manag Sci 32(7):791-805. doi: 10.1287/mnsc.32.7.791

Von Hippel E (2005) Democratizion innovation. The MIT Press, Cambridge

Wall M, Gausemeier J, Peitz C (2013) Technology push–based product planning-future markets for emerging technologies. Int J Tech Market 8(1):61-81. doi: 10.1504/IJTMKT.2013.051965

Wang KC (2011) A hybrid Kansei engineering design expert system based on grey system theory and support vector regression. Expert Syst Appl 38(7):8738-8750. doi: 10.1016/j.eswa.2011.01.083

Ward J, Shefelbine S, Clarkson PJ (2003) Requirements capture for medical device design. 14th International Conference on Engineering Design, ICED 03, Stockholm, Sweden, August 19-21, pp 65-66.

Weissman A, Petrov M, Gupta SK (2011) A computational framework for authoring and searching product design specifications. Adv Eng Inform 25(3):516-534. doi:10.1016/j.aei.2011.02.001

Whyte JK, Davies A, Salter AJ, Gann DM (2003) Designing to compete: lessons from Millennium Product winners. Des Stud 24(5):395-409. doi: 10.1016/S0142-694X(02)00050-9

Woodruff RB (1997) Customer value: the next source for competitive advantage. J Acad Market Sci 25(2):139-153. doi: 10.1007/BF02894350

Woodruff RB, Gardial S (1996) Know your customer: new approaches to customer value and satisfaction. Blackwell Business, Cambridge

Yang CC (2011) Constructing a hybrid Kansei engineering system based on multiple affective responses: Application to product form design. Comput Ind Eng 60(4):760-768. doi: 10.1016/j.cie.2011.01.011

Yoon B, Park Y (2004) A text-mining-based patent network: Analytical tool for high-technology trend. J High Technol Manag Res 15(1):37-50. doi:10.1016/j.hitech.2003.09.003

Zhai LY, Khoo LP, Zhong ZW (2009) A dominance-based rough set approach to Kansei Engineering in product development. Expert Syst Appl 36(1):393-402. doi: 10.1016/j.eswa.2007.09.041

Zhang Q, Doll WJ (2001) The fuzzy front end and success of new product development: a causal model. Eur J Innovat Manag 4(2):95-112. doi: 10.1108/14601060110390602

Zhao M, Dholakia RR (2009) A multi-attribute model of web site interactivity and customer satisfaction: an application of the Kano model. Manag Serv Qual 19(3):286-307. doi: 10.1108/09604520910955311

Appendix A

A.1 APS Check List

APS Check List
PRODUCTS • **Kits:** travel kit, hobby kit, vehicle kit, product care kit, body care kit, first aid kit, repair kit, tool kit, survival kit, educational kit, needle kit, etc. • **Gadgets:** key chains, pens, t-shirts, hats, watches, office accessories, stickers, etc. • **Product for colouring or changing colour:** paints, varnishes, lacquers, adhesive films, covers, cases, boxes, interchangeable parts, etc. • **Products for preserving and maintaining:** preservatives, substances for preserving food and beverages, laundry and cleaning products, house, vehicles and general products maintenance accessories, cleaning, polishing, scouring and abrasive preparations and accessories, lubricants, absorbing and wetting products, dust removal systems, sponges, brushes, steelwool, products for expelling/destroying vermin, fungicides, herbicides, packing, stopping and insulating materials, etc. • **Product for hygienic and beauty care of human beings or animals:** soaps, shampoo, balm, shower gel, perfumery, essential oils, hair lotions, cosmetics, dentifrices and toothbrushes, hairbrush and combs, air dryers, products for beard and hair, hair removal products, etc. • **Fuels:** liquid fuels, solid fuels, gaseous fuels. • **Products for human and animal health:** pharmaceutical, parapharmaceutical, orthopaedic, veterinary products, etc. • **Working apparatus and instruments:** scientific, nautical, optical, measuring, signalling, checking (supervision), life-saving apparatus and instruments, apparatus for recording, calculating machines, data processing equipment, computers, computer software, do-it-yourself tools, ropes, string, nets, containers, apparatus and instruments for conducting, switching, transforming, accumulating, regulating or controlling electricity, digital recording media, etc. • **Products for basic human needs:** apparatus for lighting, heating, steam generating, cooking, refrigerating, drying, ventilating, water supply, communication systems, etc. • **Vehicles and products for moving**: cars, motorcycle, moped, quad, tractor, bike, tricycle, skateboard, scooter, lorry, fork lift, caravan, private jet, motorboat, water motor, yacht, tickets/season tickets for public vehicle (train, ship, plane, bus, tram, taxi), lift, walking frame, escalator, etc.

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- **Weapons and human safety products:** firearms, ammunition and projectiles, explosives, cold weapon, self-defence tools, warning device, etc.
- **Jewelry and watches:** precious metals, jewellery, precious stones, horological and chronometric instruments, etc.
- **Musical instruments:** stringed instruments, percussion instruments, wind instruments, electronic instruments, instruments accessories, instruments replacements, etc.
- **Stationery and office products:** pens, pen holders, organizers, highlighters, post-it, scratch pads, calendars, calculator, paper clips, sticker, photos, magazine rack, etc.
- **Free time and travelling products**: trunks and travelling bags, umbrellas and parasols, beauty case, gymnastic and sporting articles, animals and accessories for animals, gardening accessories (garden tools, seeds, natural plants and flowers), smokers' articles, photographic instruments, audio apparatus, video instruments, books and magazines, blogs, social networks, do-it-yourself accessories, etc.
- **Pieces of forniture:** furniture, mirrors, picture frames, paintings, carpets, ornaments, replicas and scale models, decorations (permanent, for festivity, for anniversaries), etc.
- **Textiles and needlework products:** fabrics, bed covers, table covers, towels, trousseau, awnings, padding and stuffing materials, yarns and threads, laces, embroidery, ribbons and lace, buttons, hooks and eyes, pins and needles, various appliques, tarpaulins, sails, etc.
- **Apparel and footwear:** clothes, shoes, hats, belts, bags, scarfs, gloves, underwear, tailor made apparel and footwear, baby/children apparel, pets apparel and accessories, dolls apparel and accessories, etc.
- **Games and toys:** board games, stuffed animals, videogames, building blocks/bricks, playing cards, wooden toys, magic kits and toys, dolls, etc.
- **Food and beverage:** meat, fish, fruits and vegetables, frozen foods, dried foods, canned foods, jellies, jams, compotes, eggs, milk and milk products, edible oils and fats, coffee, tea, cocoa, mineral and aerated waters and other non-alcoholic beverages, fruit beverages and fruit juices, syrups and other preparations for making beverages, alcoholic beverages, rice, flour and preparations made from cereals, bread, pastry and confectionery, gluten free and dietetic food, ices, sugar, honey, yeast, salt, mustard, vinegar, sauces (condiments), spices, ice, foodstuffs for animals, etc.
- **Wrapping and carrying products**: bags, boxes, sacks, shock absorbent products, baskets, trunks, cans, bottles, glasses, dispensers, handles, etc.

SERVICES

- **Management services:** business management, business administration, financial affairs, real estate affairs, personal issue management, advertising, website, catering, etc.
- **Research and development services:** customized solutions, identification of best solutions, prototype development services, information search services, surveys and data analysis services, etc.
- **Installation/building services:** assembly services, test services, etc.
- **Communication services:** web communication services, telecommunications services, postal service, person-to-person, etc.

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- **Transport, packaging and storage of goods services:** packaging, delivery, product demonstrations, product storage services, moving/relocation services, transport services, etc.
- **Maintaining and disposal services:** repair services, cleaning services, agriculture, horticulture and forestry services, disinfestation services, snow removal services, clear out services, garbage disposal services, product take-back services (end-of-life), etc.
- **Training services:** in loco, online, via telephone/VoIP, courses, consulting, handbooks, etc.
- **Free time and travelling services:** travel-planning services, fun, sports and cultural activities, services for providing food and drink, cinema, theatre, library, temporary accommodation, baby sitting, pet sitting, weather forecast, translation services, etc.
- **Services for human and animal health:** medical services, veterinary services, pharmaceutical services, rehabilitation services, health visiting services, etc.
- **Services for hygienic and beauty care of human beings or animals:** barber, hairstylist, beautician, masseur, spa, pets grooming, etc.
- **Security services for the protection of property and individuals:** legal services, insurance, bodyguards, banks, night watch, etc.
- **Rental services:** vehicles, sports equipment, apparel/costumes, working tools and machines, beach umbrellas, beach chair, beach loungers, gazebo, houses, offices, plots, shops, plants, etc.
- **Certification services:** energetic certification, quality certification, health and safety certification, acoustics certification, qualifying certification (sport, language, skills), vehicle test, etc.
- **Supply services:** goods, human resources, gas, water, energy, etc.
- **Information services:** newscast, newspaper, radio, Internet, mobile, etc.
- **Social services:** disabled people assistance, elderly care, poor and needy people assistance, children assistance, pets assistance, etc.

A.2 List of Elements and Specification of the iDea tool

General Demands	
Elements	**Specifications**
Fulfilled needs	• Quality of the expected outcomes; • Quantity or extent of the expected outcomes; • Duration of the expected outcomes; • Fun and adventure.
Versatility of use/ adaptability	• Suitability of the product according to different demands; • Adaptability of the product in diverging conditions with respect to the designed preferred ones; • Expand or upgrade the range of product functionalities.

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Reliability/ safety	• Controllability of the system in order to obtain the expected outcomes; • Integrity of the product itself, its resistance to planned or accidental stress or collisions, the strength against wear or corrosion; • The limitation of damages towards the external environment; • The limitation of damages provoked by the external environment; • The safety and innocuousness for human health and people's psychological and social conditions; • The duration, the expected life of the product.
Ease	• The reduction of the information and skills to be gathered during the product life cycle; • The ease of acquiring the product, due to market penetration and distribution policies; • The ease of managing, maintaining, assembling, disassembling, upgrading, substituting components or accessories; • The independence from the use of other materials, instruments, technical systems; • The reduction of auxiliary functions to be delivered; • The additional services provided in order to attenuate the consumption of individual resources, the customer care.
Aesthetics/ style/ethics	• Customize the product or certain properties; • The possibility of benefitting of the product (or its parts) for different employment after the end of its life; • The aesthetical requirements and the emotional dimension of the product, the style, the fashion content; • What the product evokes, the lifestyle that the object implies, the prestige it generates for the owner as a feeling of distinction and recognition; • The environmental sustainability; • The ethics as a distinguishing factor.
Quickness	• The reduction of time to be waited before the functioning of the product delivers the expected outcomes; • The limitation of the time required to perform operations.
Cheapness	• The reduction of the consumption of parts, components or consumables; • The limitation of the required energy (or human power) needed for the product during its lifecycle; • Product/service cheapness; • Accessories cheapness; • Cheapness of various activities during product life cycle.
Comfort/ ergonomics	• The absence of bother for the people; • The comfort of use, the ergonomics, the manageability; • The limitation of occupied space; • The lightness and the portability.

Stakeholders	
Elements	**Specifications**
Buyers	• Manager, decision maker • Parents or tutor • Reseller • Professional • Agent
Users	• Teacher/trainer • Worker, employee • Disabled person • Not-standard user
Beneficiaries	• Community, citizenry • Children • Patients • Animals
Outsiders	• Maintenance technicians or helpers • Third party developers • Assistants • Neighbours • Relatives • Consultants, advisors • Unknown people coming into casual contact with the product

Lifecycle phases	
Elements	**Specifications**
Purchasing, choice and access activities	• Identifying the product on the web • Identifying the product on leaflets, brochures • Identifying the product in the shop • Identifying the product on various kind of advertising • Comparing with similar products • Communicating with the firm • Reaching the shop • Waiting to be assisted • Managing the payment (cash, credit card, etc.) • Using coupons and discounts • Receiving prizes or free accessories/services
Before use operations	• Shipping • Carrying • Unpacking • Training • Assembling • Managing administration issues, bureaucracies • Communicating with the firm

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Utilization time	• Switching on/off • Handling • Feeding • Performing other operations in the mean time • Using the product • Using accessories
Elapsed time before further exploitations	• Exploiting the outcomes of the product utilization • Maintaining • Cleaning • Repairing • Storing • Mounting accessories or changing parts • Protecting the product • Carrying • Waiting for the system being ready • Receiving assistance
End of the functioning	• Reselling the product and its accessories • Recycling or disposing of the product • Donating the product to needy people • Using the product as a collection item • Using the product for alternative employments

System hierarchies	
Elements	**Specifications**
Environment in which the product is situated	• Weather conditions • External environment • Place in which the product is situated (room or virtual space) • Tools or matched machinery • Matched or surrounding items • Other similar or identical systems placed nearby
Product or service level	• Product in general • Service in general
Parts, components and accessories	• Case • Engine and transmission • Connecting or fastening means • Handle • Opening/closing means • Movement means • Expansions • Aesthetic accessories • Bags, packaging • Fuel or consumables • Battery and chargers

A.3 Combinations of the Specifications belonging to the General Demands with those forming the Elements of other Dimensions in the detailed module of iDea

Specifications of the General Demands	Specifications combined in the detailed mode: reference Elements they belong to
Quality of the expected outcomes	-
Quantity or extent of the expected outcomes	-
Duration of the expected outcomes	-
Fun and adventure	LC: Utilization time
Suitability of the product according to different demands	SH: all
Adaptability of the product in diverging conditions with respect to the designed preferred ones	LC: all
Expand or upgrade the range of product functionalities	-
Controllability of the system in order to obtain the expected outcomes	SYS: Product or service level; Parts, components and accessories
Integrity of the product itself, its resistance to planned or accidental stress or collisions, the strength against wear or corrosion	SYS: Parts, components and accessories
The limitation of damages towards the external environment	SYS: Environment in which the product is situated
The limitation of damages provoked by the external environment	SYS: Environment in which the product is situated
The safety and innocuousness for human health and people's psychological and social conditions	SH: all
The duration, the expected life of the product	SYS: Product or service level; Parts, components and accessories
The reduction of the information and skills to be gathered during the product life cycle	LC: all
The ease of acquiring the product, due to market penetration and distribution policies	LC: Purchasing, choice and access activities
The ease of managing, maintaining, assembling, disassembling, upgrading, substituting components or accessories	SYS: Parts, components and accessories
The independence from the use of other materials, instruments, technical systems	SYS: Environment in which the product is situated
The reduction of auxiliary functions to be delivered	LC: all
The additional services provided in order to attenuate the consumption of individual resources, the customer care	-

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Customize the product or certain properties	SYS: Product or service level; Parts, components and accessories
The possibility of benefitting of the product (or its parts) for different employment after the end of its life	LC: End of the functioning
The aesthetical requirements and the emotional dimension of the product, the style, the fashion content	SYS: Parts, components and accessories
What the product evokes, the lifestyle that the object implies, the prestige it generates for the owner as a feeling of distinction and recognition	SH: Buyers; Users
The environmental sustainability	LC: all
The ethics as a distinguishing factor	-
The reduction of time to be waited before the functioning of the product delivers the expected outcomes	LC: Before use operations
The limitation of the time required to perform operations	LC: all
The reduction of the consumption of parts, components or consumables	SYS: Parts, components and accessories
The limitation of the required energy (or human power) needed for the product during its lifecycle	LC: all
Product/service cheapness	-
Accessories cheapness	SYS: Parts, components and accessories
Cheapness of various activities during product life cycle	LC: all
The absence of bother for the people	SH: all
The comfort of use, the ergonomics, the manageability	LC: Before use operations; Utilization time; Elapsed time before further exploitations; End of the functioning
The limitation of occupied space	LC: Before use operations; Utilization time; Elapsed time before further exploitations; End of the functioning
The lightness and the portability	SYS: Product or service level; Parts, components and accessories

Appendix B

B.1 Ideas identified in case studies using Six Paths Framework

Six Paths Framework	Spider	Components for glass staircases
Look across alternative industries	energy saving; green ethics	possibility to use for disabled persons; ease of moving heavy objects; anti-fall protection system; possibility to quickly change position; space-saver
Look across strategic groups within industry	-	use of precious materials (e.g. high quality finishes); preassembled stairs
Redefine the industry buyer group	promotion of architect and construction companies; incentive (e.g. gifts) for buyers and/or influencers; management of bureaucratic practices; possibility to obscure glasses	Promotion of architect and construction companies; incentive (e.g. gifts) for buyers and/or influencers; all inclusive service; incentives for public buildings; customizability with company's logo; possibility of obtaining a slide for children
Look across to complementary product and service offerings	integration of lighting systems; possibility to use as antenna (e.g. TV, radio, Wi-Fi); ability to move air; possibility to control temperature and humidity	design service; maintenance service; cleaning service
Rethink the functional-emotional orientation of an industry	customizability; use of precious materials	-
Participate in shaping external trends over time	possibility to project augmented reality on glasses; energy recovery; domotic applications; possibility to use for modern buildings with irregular shape	earthquake proof; domotic applications; integration of lighting systems; kinetic charge system; people recognition

B.2 Ideas identified in case studies using CRs Check List

CRs Check List	Spider	Components for glass staircases
The advantages arising from the exploitation of the product, which can be referred to the quality and the quantity of the desired output	acoustic resistance	possibility to bear very high weights
The amount of users for whom such benefits are met, thus the flexibility of the product according to different customer demands	customizability for companies (e.g. shapes, logos); customizability reserved to rich persons (e.g. gold, gemstones)	children safety (possibility to warn if children try to go upstairs/downstairs); compatibility with disabled/old persons
The capability of the product to meet the customer needs within the requested time	-	-
The adaptability of the product when working in diverging conditions with respect to the designed preferred ones	strength against acts of vandalism	possibility to use the product in external environments; possibility to melt the snow; possibility to automatically clean the stairs
The stability of the product performances when subjected to external perturbations	-	shock resistant
The chance to effectively control the system in order to obtain the expected outcomes	ease of centring the glass on load-bearing structure during installation; ease of regulating the system during installation	possibility to change parameters (riser, tread) after the installation
The possibility to expand or upgrade the range of product functioning	possibility to integrate antennas (e.g. TV, radio, Wi-Fi); possibility to integrate various kind of sensors (temperature, brightness, fire, gas, rain, wind, etc.); possibility to automatically clean glasses	possibility to purchase accessories for customizing the product
The opportunity provided to advantageously employ the product for not standard users or disabled people	-	compatibility with various stair lifts; support systems for blind persons
The possibility to customize the product or certain properties according to the user tastes and tendencies	possibility of having "invisible" spiders	possibility to choose customized finishes; possibility to have "invisible" supports
The possibility to use the system for different employments after the termination of main product functioning	-	possibility to use the product to hang/contain objects

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The aesthetical requirements and the emotional dimension of the product, the style, the fashion content, what it evokes in the user, the lifestyle that the object implies, the prestige it generates for the owner as a feeling of distinction and recognition	use of precious materials/high quality finishes	use of precious materials/high quality finishes; customizability; use of unconventional materials (e.g. wrought iron, wood)
The fun and adventure resulting from the use of the system	integration of lighting systems; integrated speaker system; integration of projector	possibility to obtain a slide for children and/or things; possibility to use stairs to make sport (communication with electronic devices)
The integrity of the product itself, its resistance to planned or accidental stress or collisions, the strength against wear or corrosion	strength against corrosion; strength against birds' collisions	-
The limitation of damages towards treated objects or neighbouring systems	-	anti-seismic; fire-resistant
The environmental sustainability, the recyclability, the possibility to reuse the system or its parts reducing the amount of waste	green ethics; recyclability; possibility of reusing the product in the end of its life (e.g. inner walls, roofs, staircases, etc.)	recyclability; possibility to give back the product obtaining discount for new purchase
The ethics of the product as a distinguishing factor	possibility to support poor people constructing building for them	possibility to support humanitarian organisations buying the product
The safety and innocuousness for human health and people's psychological and social conditions	-	possibility to obscure the glass (avoid dizziness)
The absence of bother for the user employing the product or for surrounding people, the comfort of use, the ergonomics, the manageability	-	-
The reliability, the limited frequency of system failures	-	-
The duration, the expected life of the product	-	-

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The limitation of occupied space, the lessening of the encumbrance, the accessibility, meant as a shrunk quantity of space required to allow the users to employ, store, transport, maintain and dismantle the product	-	possibility to move/close the staircase when it is not used
The working speed, the reduction of time to be waited before the functioning of the product delivers the expected outcomes, including the duration of the period to be waited before physically benefiting of the bought item or service after the purchase	-	possibility to have preassembled/ partially preassembled staircase
The limitation of the time required to maintain or fix the product, to change accessories, to dismantle the system, to learn how to use it, to administer or to accomplish the involved bureaucracies	-	-
The reduction of the information and skills to be gathered in order to correctly use and control the product, the ease of employment, the user friendliness, the limitation of required training	availability of tutorial; supply of design/regulations manuals	possibility to use stairs like a scale (integrated weight sensor); possibility to use stairs like a light switch (integrated switch); possibility to heat/cool external environment
The ease of acquiring the product, due to market penetration and distribution policies	-	ease of buying the product on-line
The ease of managing, maintaining, assembling, disassembling, upgrading, substituting components or accessories	possibility to add functionalities	ease of creating new configurations; supply of tools for maintenance (e.g. restoration/replacement)
The ease of choosing and individuating the product in the marketplace, according to recognizable features, due to technical, aesthetical or communication issues	-	-
The independence from the use of different materials, instruments, technical systems	-	-
The absence or limitation of the consumption of consumable items or materials	integration of energy recovery systems (sun/wind)	-

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The reduction of auxiliary functions to be delivered in order to use, install, dismount or dispose the system	supply of tools for installation/maintenance	-
The limitation of the required energy needed for the product working, maintaining, installing, disposing, recycling; its efficiency	-	-
The decrease of the human power needed to use or transport the product, including its lightness and portability	use of innovative materials like carbon fibre	manageability
The additional services provided in order to attenuate the consumption of individual resources, as those listed in the previous bullets, the customer care	consultancy on building site	-
The cheapness of product, accessories, access activities, maintenance and every other cost element for the stakeholders	sense of cheapness (prizes, free services); cheapness of accessories; free assistance	cheapness of move

B.3 Ideas identified in case studies using APS Check List

APS Check List		Spider	Components for glass staircases
PRODUCTS	***Kits:*** *travel kit, hobby kit, vehicle kit, product care kit, body care kit, first aid kit, repair kit, tool kit, survival kit, educational kit, needle kit, etc.*	-	supply of product care kits
	Gadgets: *key chains, pens, t-shirts, hats, watches, office accessories, stickers, etc.*	-	-
	Product for colouring or changing colour: *paints, varnishes, lacquers, adhesive films, covers, cases, boxes, interchangeable parts, etc.*	supply of products for changing colour (e.g. paints, varnishes, interchangeable parts)	supply of product for changing colour/shape (adhesive films, covers, interchangeable parts)

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PRODUCTS	***Products for preserving and maintaining:*** *preservatives, substances for preserving food and beverages, laundry and cleaning products, house, vehicles and general products maintenance accessories, cleaning, polishing, scouring and abrasive preparations and accessories, lubricants, absorbing and wetting products, dust removal systems, sponges, brushes, steelwool, products for expelling/destroying vermin, fungicides, herbicides, packing, stopping and insulating materials, etc.*	possibility to automatically clean the glasses; supply of cleaning products; supply of products to insulate (gasket) for free	possibility to use standard cleaning robots; possibility to automatically remove dust; possibility to automatically clean steps; supply of cleaning products for free; possibility to remove liquids (e.g. rain)
	Product for hygienic and beauty care of human beings or animals: *soaps, shampoo, balm, shower gel, perfumery, essential oils, hair lotions, cosmetics, dentifrices and toothbrushes, hairbrush and combs, air dryers, products for beard and hair, hair removal products, etc.*	-	integrated fragrance diffuser
	Fuels: *liquid fuels, solid fuels, gaseous fuels.*	-	-
	Products for human and animal health: *pharmaceutical, parapharmaceutical, orthopaedic, veterinary products, etc.*	-	-
	Working apparatus and instruments: *scientific, nautical, optical, measuring, signalling, checking (supervision), life-saving apparatus and instruments, apparatus for recording, calculating machines, data processing equipment, computers, computer software, do-it-yourself tools, ropes, string, nets, containers, apparatus and instruments for conducting, switching, transforming, accumulating, regulating or controlling electricity, digital recording media, etc.*	possibility to warn in the event of damages, wear, dangerous natural events; integration of fire sprinklers	possibility to warn if children/animals/thieves try to go upstairs/downstairs; possibility to warn when staircase have to be cleaned; integration of life-saving apparatus (e.g. emergency call, first-aid kit)
	Products for basic human needs: *apparatus for lighting, heating, steam generating, cooking, refrigerating, drying, ventilating, water supply, communication systems, etc.*	integrated apparatus for lighting; integrated apparatus for heating/cooling; integrated apparatus for ventilating	integrated apparatus for lighting; integrated apparatus for heating/cooling

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PRODUCTS	***Vehicles and products for moving****: cars, motorcycle, moped, quad, tractor, bike, tricycle, skateboard, scooter, lorry, fork lift, caravan, private jet, motorboat, water motor, yacht, tickets/season tickets for public vehicle (train, ship, plane, bus, tram, taxi), lift, walking frame, escalator, etc.*	possibility to integrate bicycle stands	possibility to hang bikes under the stair
	Weapons and human safety products: *firearms, ammunition and projectiles, explosives, cold weapon, self-defence tools, warning device, etc.*	integration of warning device	integration of warning device
	Jewelry and watches: *precious metals, jewellery, precious stones, horological and chronometric instruments, etc.*	use of precious metals, jewellery, precious stones	use of precious metals, jewellery, precious stones
	Musical instruments: *stringed instruments, percussion instruments, wind instruments, electronic instruments, instruments accessories, instruments replacements, etc.*	integrated speaker system	integrated speaker system
	Stationery and office products: *pens, pen holders, organizers, highlighters, post-it, scratch pads, calendars, calculator, paper clips, sticker, photos, magazine rack, etc.*	-	-
	Free time and travelling products*: trunks and travelling bags, umbrellas and parasols, beauty case, gymnastic and sporting articles, animals and accessories for animals, gardening accessories (garden tools, seeds, natural plants and flowers), smokers' articles, photographic instruments, audio apparatus, video instruments, books and magazines, blogs, social networks, do-it-yourself accessories, etc.*	-	free book or subscription to magazines purchasing the product; supply of accessories for DIY
	Pieces of forniture: *furniture, mirrors, picture frames, paintings, carpets, ornaments, replicas and scale models, decorations (permanent, for festivity, for anniversaries), etc.*	supply of scale model of the building	-
	Textiles and needlework products: *fabrics, bed covers, table covers, towels, trousseau, awnings, padding and stuffing materials, yarns and threads, laces, embroidery, ribbons and lace, buttons, hooks and eyes, pins and needles, various appliques, tarpaulins, sails, etc.*	-	-

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PRODUCTS	***Apparel and footwear:*** *clothes, shoes, hats, belts, bags, scarfs, gloves, underwear, tailor made apparel and footwear, baby/children apparel, pets apparel and accessories, dolls apparel and accessories, etc.*	-	-
	Games and toys: *board games, stuffed animals, videogames, building blocks/bricks, playing cards, wooden toys, magic kits and toys, dolls, etc.*	-	-
	Food and beverage: *meat, fish, fruits and vegetables, frozen foods, dried foods, canned foods, jellies, jams, compotes, eggs, milk and milk products, edible oils and fats, coffee, tea, cocoa, mineral and aerated waters and other non-alcoholic beverages, fruit beverages and fruit juices, syrups and other preparations for making beverages, alcoholic beverages, rice, flour and preparations made from cereals, bread, pastry and confectionery, gluten free and dietetic food, ices, sugar, honey, yeast, salt, mustard, vinegar, sauces (condiments), spices, ice, foodstuffs for animals, etc.*	-	-
	Wrapping and carrying products*: bags, boxes, sacks, shock absorbent products, baskets, trunks, cans, bottles, glasses, dispensers, handles, etc.*	-	-
SERVICES	***Management services:*** *business management, business administration, financial affairs, real estate affairs, personal issue management, advertising, website, catering, etc.*	supply of real estate services; supply of advertising services	supply of real estate services; supply of advertising services
	Research and development services: *customized solutions, identification of best solutions, prototype development services, information search services, surveys and data analysis services, etc.*	included design service	possibility to customize the product during the design phase; identification of the best solution
	Installation/building services: *assembly services, test services, etc.*	installation service	-
	Communication services: *web communication services, telecommunications services, postal service, person-to-person, etc.*	customer support system based on real-time web communication tools (e.g. chat)	-
	Transport, packaging and storage of goods services: *packaging, delivery, product demonstrations, product storage services, moving/relocation services, transport services, etc.*	possibility to carry potential customer to existing building	supply of moving/relocation services

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SERVICES	***Maintaining and disposal services:*** *repair services, cleaning services, agriculture, horticulture and forestry services, disinfestation services, snow removal services, clear out services, garbage disposal services, product take-back services (end-of-life), etc.*	supply of repair service for free**;** supply of cleaning service**;** supply of disposal service	supply of repair service for free**;** supply of cleaning service**;** automatic snow removal; supply of clearing out service, supply of disposal service
	Training services: *in loco, online, via telephone/VoIP, courses, consulting, handbooks, etc.*	supply of tutorials, manuals, software for technicians	supply of tutorials, manuals, software for technicians
	Free time and travelling services: *travel-planning services, fun, sports and cultural activities, services for providing food and drink, cinema, theatre, library, temporary accommodation, baby sitting, pet sitting, weather forecast, translation services, etc.*	possibility to win/receive holiday package purchasing the product; supply of temporary houses/offices during installation/renovation	possibility to win/receive holiday package purchasing the product
	Services for human and animal health: *medical services, veterinary services, pharmaceutical services, rehabilitation services, health visiting services, etc.*	-	-
	Services for hygienic and beauty care of human beings or animals: *barber, hairstylist, beautician, masseur, spa, pets grooming, etc.*	possibility to receive entrance tickets for health spa purchasing the product (buyer and/or technicians)	possibility to receive entrance tickets for health spa purchasing the product
	Security services for the protection of property and individuals: *legal services, insurance, bodyguards, banks, night watch, etc.*	supply of free insurance; supply of night watch service	supply of free insurance
	Rental services: *vehicles, sports equipment, apparel/costumes, working tools and machines, beach umbrellas, beach chair, beach loungers, gazebo, houses, offices, plots, shops, plants, etc.*	rental services for working tools and machines	-
	Certification services: *energetic certification, quality certification, health and safety certification, acoustics certification, qualifying certification (sport, language, skills), vehicle test, etc.*	supply of energetic certification; supply of acoustics certification	management of bureaucratic practices (e.g. planning permission)
	Supply services: *goods, human resources, gas, water, energy, etc.*	-	-
	Information services: *newscast, newspaper, radio, Internet, mobile, etc.*	-	-
	Social services: *disabled people assistance, elderly care, poor and needy people assistance, children assistance, pets assistance, etc.*	-	possibility to support humanitarian organisations buying the product

B.4 Ideas identified in case studies using the standard module of iDea

Standard module of iDea	Spider	Components for glass staircases
Versatility of use/adaptability *related to* ***environment in which the product is situated***	possibility to change the shape of the building (dynamic)	possibility to use the product in external environments
Versatility of use/adaptability *related to* ***product or service level***	integration of lighting systems (for internal or external lighting); domotic applications; integrated apparatus for heating/cooling; integrated apparatus for ventilating	adaptability to surfaces that can change their shape
Versatility of use/adaptability *related to* ***parts, components and accessories***	supply of an unique basic component and lots of accessories to fit various configurations	possibility to combine parts in order to obtain different shapes
Versatility of use/adaptability *related to* ***buyers***	customizability/adaptability to innovative projects	integration of an interior design section into the website
Versatility of use/adaptability *related to* ***users***	possibility to obscure glasses	support systems for blind persons
Versatility of use/adaptability *related to* ***beneficiaries***	entrance deigned focusing on disabled persons	possibility to limit the access (children, animals, thieves, guests)
Versatility of use/adaptability *related to* ***outsiders***	possibility to integrate bicycle stands; possibility to hang projecting roof	possibility to use the product to hang/contain objects; integration of lighting systems (under-stair lighting); possibility to be combined with other piece of furniture (e.g. table, bed, sofa, etc.)
Versatility of use/adaptability *related to* ***purchasing, choice and access activities***	-	variety of shapes
Versatility of use/adaptability *related to* ***before use operations***	possibility to install in any kind of environment (see, desert, glacier, etc.)	possibility to reuse the packaging; possibility to reuse the installation tools
Versatility of use/adaptability *related to* ***utilization time***	possibility to orient glasses in the event of high wind	possibility to use stairs to make sport (communication with electronic devices); integrated apparatus for heating/cooling; integrated apparatus for ventilating; integrated fragrance diffuser; integrated speaker system

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Versatility of use/adaptability *related to* ***elapsed time before further exploitations***	possibility to use the building as media building	possibility to integrate emergency light into the product; possibility to integrate a router (Wi-Fi)
Versatility of use/adaptability *related to* ***end of the functioning***	possibility to reuse damaged parts for different employments	ease of creating new configurations (sale, move, restoration)
Reliability/safety *related to* ***environment in which the product is situated***	safety of people against glass breakage	earthquake proof; possibility to melt the snow (external environment); possibility to kill frost (external environment); possibility to dry the rain (external environment)
Reliability/safety *related to* ***product or service level***	earthquake proof	possibility to bear very high weights
Reliability/safety *related to* ***parts, components and accessories***	possibility to monitor the heat exchange of the building	surface strength during installation (protective film)
Reliability/safety *related to* ***buyers***	warranty with no expiration date	safety in on-line purchase
Reliability/safety *related to* ***users***	strength against acts of vandalism	safety systems for disabled persons; anti-fall protection system (children)
Reliability/safety *related to* ***beneficiaries***	integration of fire sprinklers	possibility to obscure the glass (avoid dizziness)
Reliability/safety *related to* ***outsiders***	possibility to hang projecting roof (and tie rods) directly on spiders	anti-fall protection system (things); shock resistant
Reliability/safety *related to* ***purchasing, choice and access activities***	-	-
Reliability/safety *related to* ***before use operations***	-	ease DIY tutorials
Reliability/safety *related to* ***utilization time***	possibility to integrate emergency light into the spiders	-
Reliability/safety *related to* ***elapsed time before further exploitations***	possibility to warn in the event of dangerous circumstances; possibility to monitor the structural integrity of the building	possibility to detect users; possibility to automatically clean steps
Reliability/safety *related to* ***end of the functioning***	-	reliability/safety during move (staircase relocation)
Ease *related to* ***environment in which the product is situated***	distinction and recognition of buildings	possibility to make virtual tour in on-line showrooms
Ease *related to* ***product or service level***	possibility to use the product to hang/contain objects	ease of using new features (e.g. domotic control systems)
Ease *related to* ***parts, components and accessories***	ease of customizing the product; ease of opening/closing window; ease of fastening/unfastening projecting roof	possibility to automatically fix damages; supply of cleaning service

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Ease *related to* ***buyers***	-	-
Ease *related to* ***users***	possibility to support office/shop activities	possibility to limit the access (children, animals, thieves, guests)
Ease *related to* ***beneficiaries***	possibility to project augmented reality on glasses	ease and safe to use for children
Ease *related to* ***outsiders***	possibility to receive useful information (time, weather forecast, news, etc.)	ease of identifying the brand (unique shape, original colour, logo in plain sight)
Ease *related to* ***purchasing, choice and access activities***	possibility to design the facade/building directly on company website	-
Ease *related to* ***before use operations***	independence from the use of tools during the installation/dismantling	ease of taking home using cars
Ease *related to* ***utilization time***	integration of a virtual assistant	-
Ease *related to* ***elapsed time before further exploitations***	possibility to automatically clean glasses	possibility to make emergency calls
Ease *related to* ***end of the functioning***	-	-
Aesthetics/style/ethics *related to* ***environment in which the product is situated***	possibility to use the building as media building	possibility to have "invisible" supports; in line with home interior design
Aesthetics/style/ethics *related to* ***product or service level***	possibility of having "invisible" spiders	possibility to create light scenarios; variety of colours
Aesthetics/style/ethics *related to* ***parts, components and accessories***	variety of colours; use of precious materials	-
Aesthetics/style/ethics *related to* ***buyers***	possibility to make DIY customization	aesthetics of the website; aesthetics of the stores and/or showrooms
Aesthetics/style/ethics *related to* ***users***	possibility to create light scenarios	possibility to change aesthetical features (shape, colour, material)
Aesthetics/style/ethics *related to* ***beneficiaries***	possibility to dynamically change aesthetics of the building (e.g. material that change colour with light/humidity)	possibility to use for disabled persons; supply of glass stair lift (aesthetics)
Aesthetics/style/ethics *related to* ***outsiders***	-	-
Aesthetics/style/ethics *related to* ***purchasing, choice and access activities***	aesthetics of the stores and/or showrooms	supply of an interior design magazines made by the company
Aesthetics/style/ethics *related to* ***before use operations***	aesthetics of building site; aesthetics of company's lorries; supply of boilersuits and PPE to workers	aesthetics of company's lorries
Aesthetics/style/ethics *related to* ***utilization time***	integration of chromotherapy systems	possibility to change aesthetical features (shape and colour)

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Aesthetics/style/ethics *related to* ***elapsed time before further exploitations***	possibility to change aesthetical features (shape and colour)	possibility to close staircase (space-saver) obtaining aesthetical effects (e.g. paints)
Aesthetics/style/ethics *related to* ***end of the functioning***	possibility to reuse components, before disposal, to build modern artworks	possibility to reuse products after disposal for different employments (e.g. shelves)
Quickness *related to* ***environment in which the product is situated***	-	quickness in opening/closing staircase (space-saver model)
Quickness *related to* ***product or service level***	ease of centring the glass on load-bearing structure during installation	-
Quickness *related to* ***parts, components and accessories***	quickness in cleaning glasses; quickness in changing/fixing damaged parts	possibility to have preassembled/ partially preassembled staircase
Quickness *related to* ***buyers***	supply of an unique basic component and lots of accessories to fit various configurations (quick choice)	-
Quickness *related to* ***users***	quickness in opening/closing windows	quickness in customizing the product (adhesive films, covers, interchangeable parts, etc.)
Quickness *related to* ***beneficiaries***	-	-
Quickness *related to* ***outsiders***	possibility to obtain information about the building through the product (e.g. integrated audio guide)	quickness in identifying dangerous circumstances (e.g. damages, wear, natural events)
Quickness *related to* ***purchasing, choice and access activities***	-	customer support system based on real-time web communication tools (e.g. chat)
Quickness *related to* ***before use operations***	quickness in fastening/ unfastening projecting roof	possibility to install with one hand
Quickness *related to* ***utilization time***	-	-
Quickness *related to* ***elapsed time before further exploitations***	quickness in using new features (e.g. domotic control systems)	quickness in using new features (e.g. domotic control systems)
Quickness *related to* ***end of the functioning***	-	-
Cheapness *related to* ***environment in which the product is situated***	supply of a planning supervisor	domotic applications
Cheapness *related to* ***product or service level***	-	-
Cheapness *related to* ***parts, components and accessories***	design service for free	cheapness of accessories for customizing the product

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Cheapness** related to **buyers	possibility to refund the purchase (e.g. within 30 days)	possibility to refund the purchase (e.g. within 30 days); possibility to refund gas if customer use his/her own car to take home the product
Cheapness** related to **users	possibility to use for internal calls; integrated data storage server	cheapness of accessories for disabled persons
Cheapness** related to **beneficiaries	possibility to use as antenna (e.g. TV, radio, Wi-Fi)	supply of household products for free
Cheapness** related to **outsiders	free Wi-Fi service	free Wi-Fi service
Cheapness** related to **purchasing, choice and access activities	cheapness of customization service	-
Cheapness** related to **before use operations	-	-
Cheapness** related to **utilization time	-	possibility to store energy from renewable sources
Cheapness** related to **elapsed time before further exploitations	-	supply of cleaning products for free
Cheapness** related to **end of the functioning	ease of selling the building (e.g. supply of a real estate service)	possibility to give back the product obtaining discount for new purchase; ease of selling second hand products
Comfort/ergonomics** related to **environment in which the product is situated	-	-
Comfort/ergonomics** related to **product or service level	integrated dehumidifier; integrated speaker system; integrated fragrance diffuser	possibility to change parameters (riser, tread) after the installation
Comfort/ergonomics** related to **parts, components and accessories	possibility to change colour in order to save energy (i.e. black in winter and white in summer)	-
Comfort/ergonomics** related to **buyers	possibility to receive free samples and brochures at home/office	possibility to receive free samples (e.g. for professionals)
Comfort/ergonomics** related to **users	supply of temporary houses/offices during installation/renovation; integration of suction port for smokers	possibility to use the staircase like a comfortable seat
Comfort/ergonomics** related to **beneficiaries	acoustic resistance; possibility to air the inner environment	compatibility with various stair lifts
Comfort/ergonomics** related to **outsiders	possibility to install benches	-

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Comfort/ergonomics** related to **purchasing, choice and access activities	possibility to purchase the product through an app; possibility to purchase the product using professional design software (e.g. business deal with CAD companies)	comfort in the store/showroom
Comfort/ergonomics** related to **before use operations	ergonomics of installation tools	supply of knee pads/mats for installers
Comfort/ergonomics** related to **utilization time	-	massage steps
Comfort/ergonomics** related to **elapsed time before further exploitations	maintenance of an ideal microclimate	possibility to receive useful information (time, weather forecast, news, etc.)
Comfort/ergonomics** related to **end of the functioning	-	-

B.5 List of ideas identified in case studies using all the idea stimulation tools

Spider	Components for glass staircases
adaptability to different configuration	accessibility to the store/showroom for disabled persons
aesthetics of company's lorries	adaptability of accessories to various components for glass staircases
aesthetics of building site	adaptability to surfaces that can change their shape
aesthetics of the stores and/or showrooms	aesthetics of company's lorries
all inclusive service (design and installation)	aesthetics of the stores and/or showrooms
anti-fog	aesthetics of the website
availability of accessories (electronic devices, lighting systems, etc.)	alert about wear/collapse
cheapness of accessories	all inclusive service (design, installation, maintenance, disposal)
cheapness of customization service	anti-fall protection system (children)
consultancy on building site	anti-fall protection system (things)
customer support system based on real-time web communication tools (e.g. chat)	anti-seismic
customizability (finishes, shapes, materials, etc.)	cheapness of accessories for disabled persons
customizability of the accessories	cheapness of accessories for customizing the product
customizability reserved to rich persons (e.g. gold, gemstones)	cheapness of move
customizability/adaptability to innovative projects	cheapness of the accessories
discount on new purchase	cleaning robot for free
distinction and recognition of buildings	comfort in the store/showroom

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distinction of the construction site	compatibility with disabled/old persons
earthquake proof	compatibility with steps made by various materials (besides glass)
ease of centring the glass on load-bearing structure during installation	compatibility with various kinds of disabilities
ease of choosing the product (ease tool that guides to the best solution)	compatibility with various kinds of walls (plasterboard, stone, surfaces with irregular shapes, etc.)
ease of customizing the product	compatibility with various stair lifts
ease of fastening/unfastening projecting roof	customer support system based on real-time web communication tools (e.g. chat)
ease of finding replacements	customizability of the accessories
ease of identifying the position of each component in the building	customizability of the product
ease of installing the product with bad weather	customizability with company's logo
ease of opening/closing window	design quickness
ease of recycling parts and accessories	domotic applications
ease of regulating the system during installation	ease DIY tutorials
ease of selling the building (e.g. supply of a real estate service)	ease of buying the product on-line
eco-friendly equipment for dismantling	ease of changing accessories
energy saving	ease of choosing the product (e.g. few basic models)
entrance deigned focusing on disabled persons	ease of cleaning the product
ergonomics of installation tools	ease of creating new configurations (sale, move, restoration)
free assistance	ease of fixing accessories
free Wi-Fi service	ease of identifying the brand (unique shape, original colour, logo in plain sight)
green ethics	ease of moving heavy objects
humanitarian ethics (purchase helps poor people)	ease of moving things upstairs/downstairs
incentive (e.g. gifts) for buyers and/or influencers	ease of reaching all the surface for cleaning the product
included design service	ease of selling second hand products
independence from the use of tools during the installation/dismantling	ease of taking home using cars
installation service	ease of using for children
integrated air circulation system	ease of using new features (e.g. domotic control systems)
integrated apparatus for ventilating	filth detection
integrated data storage server	fire-resistant
integrated dehumidifier	free book or subscription to magazines purchasing the product
integrated fragrance diffuser	free shipping
integrated heating/cooling system	free Wi-Fi service
integrated speaker system	green ethics of the company
integration of fire sprinklers	home accessories for free

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integration of a virtual assistant	home interior design magazine for free
integration of chromotherapy systems	identification of the best solution
integration of emergency systems (e.g. water mist, emergency lights)	incentive (e.g. gifts) for buyers and/or influencers
integration of energy recovery systems (sun/wind)	incentives for public buildings
integration of lighting systems (for internal or external lighting)	integrated apparatus for heating/cooling
integration of projector (video, movies, video conferences)	integrated apparatus for ventilating
integration of suction port for smokers	integrated emergency systems (fire, gas, etc.)
maintenance of an ideal microclimate	integrated fragrance diffuser
management of bureaucratic practices	integrated speaker system
possibility of reuse/move the building in poor countries	integration of an elevator
possibility to air the inner environment	integration of an interior design section into the website
possibility to add functionalities	integration of life-saving apparatus (e.g. emergency call, first-aid kit)
possibility to attach ventilated facade	integration of lighting systems
possibility to automatically clean glasses	integration of warning devices
possibility to carry potential customer to existing building	kinetic charge system
possibility to change aesthetical features (shape and colour)	manageability
possibility to change colour in order to save energy (i.e. black in winter and white in summer)	management of bureaucratic practices (e.g. planning permission)
possibility to change the shape of the building (dynamic)	massage steps
possibility to control external environment (webcam)	minimal amount of space when the staircase is not used (space-saving)
possibility to control temperature and humidity	online tutorials
possibility to control the structural integrity of the building	people recognition
possibility to create a network among technicians, construction companies and glass makers	possibility to add/change aesthetic accessories
possibility to create light scenarios	possibility to automatically clean the stairs
possibility to design the facade/building directly on company website	possibility to automatically fix damages
possibility to detect dangerous circumstances (e.g. suspect airplanes)	possibility to automatically remove dust
possibility to dynamically change aesthetics of the building (e.g. material that change colour with light/humidity)	possibility to avoid drilling the wall
possibility to hang projecting roof (and tie rods) directly on spiders	possibility to be combined with other piece of furniture (e.g. table, bed, sofa, etc.)
possibility to have “invisible” spiders	possibility to bear very high weights
possibility to include windows in the facade	possibility to buy online and pick up the product in the store

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possibility to install benches	possibility to change aesthetical features (shape, colour, material)
possibility to install in any kind of environment (see, desert, glacier, etc.)	possibility to change parameters (riser, tread) after the installation
possibility to integrate bicycle stands	possibility to choose delivery day/hour
possibility to integrate domotic applications (e.g. speaker system, lighting systems, safety systems)	possibility to close staircase (space-saver) obtaining aesthetical effects (e.g. paints)
possibility to integrate emergency light into the spiders	possibility to combine parts in order to obtain different shapes
possibility to integrate seats	possibility to create light scenarios
possibility to integrate various kinds of sensors (temperature, brightness, fire, gas, rain, wind, etc.)	possibility to customize the product during the design phase
possibility to make DIY customization	possibility to detect users
possibility to monitor the heat exchange of the building	possibility to dry the rain (external environment)
possibility to monitor the structural integrity of the building	possibility to give back the product obtaining discount for new purchase
possibility to obscure glasses	possibility to hang bikes under the stair
possibility to obtain information about the building through the product (e.g. integrated audio guide)	possibility to hang shelves
possibility to orient glasses in the event of high wind	possibility to have “invisible” supports
possibility to project augmented reality on glasses	possibility to have a personal showcase on company’s web site (for professionals)
possibility to project on the street logos/advertisements/coloured lights	possibility to have preassembled/ partially preassembled staircase
possibility to promote the works of technicians	possibility to insert/remove photos, postcards, drawings, etc. into the steps
possibility to provide information about the building or external environment (e.g. augmented reality, audio tour)	possibility to install a stair lift
possibility to purchase the product through an app	possibility to install with one hand
possibility to purchase the product using professional design software (e.g. business deal with cad companies)	possibility to integrate a router (Wi-Fi)
possibility to receive entrance tickets for health spa purchasing the product (buyer and/or technicians)	possibility to integrate emergency light into the product
possibility to receive free samples and brochures at home/office	possibility to kill frost (external environment)
possibility to receive useful information (time, weather forecast, news, etc.)	possibility to limit the access (children, animals, thieves, guests)
possibility to refund the purchase (e.g. within 30 days)	possibility to make emergency calls
possibility to reuse components, before disposal, to build modern artworks	possibility to make virtual tour in on-line showrooms
possibility to reuse damaged parts for different employments	possibility to melt the snow (external environment)
possibility to reuse the product (e.g. roof, inner walls, etc.)	possibility to move/close the staircase when it is not used

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possibility to reuse the product changing the configuration	possibility to move/reuse the product for different configurations/places
possibility to reuse the product in the end of its life (e.g. inner walls, roofs, staircases, etc.)	possibility to obscure the glass (avoid dizziness)
possibility to support design activities	possibility to obtain a slide for children and/or things
possibility to support office/shop activities	possibility to purchase accessories for customizing the product
possibility to support poor people constructing building for them	possibility to purchase through the smartphone/tablet
possibility to track shipments	possibility to quickly change position
possibility to use as antenna (e.g. TV, radio, Wi-Fi)	possibility to receive entrance tickets for health spa purchasing the product
possibility to use for internal calls	possibility to receive free samples (e.g. for professionals)
possibility to use for modern buildings with irregular shape	possibility to receive useful information (time, weather forecast, news, etc.)
possibility to use the building as media building	possibility to refund gas if customer use his/her own car to take home the product
possibility to use the product to hang/contain objects	possibility to refund the purchase (e.g. within 30 days)
possibility to verify the correct installation (e.g. through sensors)	possibility to remove liquids (e.g. rain)
possibility to verify the integrity of the spiders in their end of life	possibility to reserve a visit with an expert by a store/showroom
possibility to warn in the event of damages, wear, dangerous natural events	possibility to reuse accessories for new staircase
possibility to win/receive holiday package purchasing the product	possibility to reuse in poor countries
promotion of architect and construction companies	possibility to reuse products after disposal for different employments (e.g. shelves)
quickness in changing/fixing damaged parts	possibility to reuse the installation tools
quickness in cleaning glasses	possibility to reuse the packaging
quickness in fastening/ unfastening projecting roof	possibility to see a rendering of the stair in its environment
quickness in opening/closing windows	possibility to see real installation in show rooms
quickness in using new features (e.g. domotic control systems)	possibility to store energy from renewable sources
recyclability	possibility to support humanitarian organisations buying the product
recyclability of the packaging	possibility to use as an energy storage device (kinetic energy)
rental services for working tools and machines	possibility to use commercial cleaning robot
safety against thieves	possibility to use for disabled persons
safety of people against glass breakage	possibility to use in the dark
sense of cheapness (prizes, free services)	possibility to use stairs like a light switch (integrated switch)

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sound-proof	possibility to use stairs like a scale (integrated weight sensor)
strength against extraordinary events (e.g. earthquake)	possibility to use stairs to make sport (communication with electronic devices)
strength against acts of vandalism	possibility to use the product in external environments
strength against birds' collisions	possibility to use the product to hang/contain objects
strength against corrosion	possibility to use the staircase like a comfortable seat
supply of cleaning products	possibility to warn if children/animals/thieves try to go upstairs/downstairs
supply of cleaning service	possibility to warn when staircase have to be cleaned
supply of a planning supervisor	possibility to win/receive holiday package purchasing the product
supply of a scale model of the building	professional design software (e.g. Revit) license for free
supply of acoustics certification	promotion of architect and construction companies
supply of advertising services	quickness in changing accessories
supply of an unique basic component and lots of accessories to fit various configurations (quick choice)	quickness in cleaning accessories
supply of boilersuits and PPE to workers	quickness in customizing the product (adhesive films, covers, interchangeable parts, etc.)
supply of design software/tools	quickness in identifying dangerous circumstances (e.g. damages, wear, natural events)
supply of design/regulations manuals	quickness in opening/closing staircase (space-saver model)
supply of digital documents (e.g. manuals, technical drawings, etc.)	quickness in using new features (e.g. domotic control systems)
supply of disposal service	recyclability
supply of energetic certification	reliability/safety during move (staircase relocation)
supply of free insurance	reminder system for maintenance
supply of night watch service	safety against glass breakage
supply of products for changing colour (e.g. paints, varnishes, interchangeable parts)	safety for children and animals
supply of products to insulate (gasket) for free	safety in on-line purchase
supply of real estate services	safety systems for disabled persons
supply of repair service for free	safety with atmospheric agents (external environment)
supply of scale model of the building	shock resistant
supply of temporary houses/offices during installation/renovation	space-saver
supply of tools for installation/maintenance	strength of product surface
supply of tutorials, manuals, software for technicians	strength of the packaging against atmospheric agents

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use of eco-friendly means of transport	strength in not standard circumstances (e.g. external environment, extraordinary events like earthquake)
use of innovative materials like carbon fibre	supply of accessories for DIY
use of precious materials/high quality finishes	supply of advertising services
variety of colours	supply of an interior design magazines made by the company
warranty with no expiration date	supply of an unique tool to assemble the staircase
water resistant packaging	supply of cleaning products
	supply of cleaning service
	supply of clearing out service
	supply of design service
	supply of disposal service
	supply of free insurance
	supply of glass stair lift (aesthetics)
	supply of household products for free
	supply of knee pads/mats for installers
	supply of maintenance service
	supply of moving/relocation services
	supply of product care kits
	supply of product for changing colour/shape (adhesive films, covers, interchangeable parts)
	supply of real estate services
	supply of repair service for free
	supply of spare parts for free
	supply of tools for installation
	supply of tools for maintenance (e.g. restoration/replacement)
	supply of tutorials, manuals, software for technicians
	support in reconfiguring in new places (new house, home renovation)
	support systems for blind persons
	surface strength during installation (protective film)
	use of eco-friendly means of transport
	use of precious metals, jewellery, precious stones
	use of unconventional materials (e.g. wrought iron, wood)
	variety of colours
	variety of shapes

B.6 List of attributes of new identified product profiles, classified in terms of strategic moves and functional features

In the Tables green boxes show favourable differentiation actions, red boxes show actions that should be avoided, according to New Value Proposition Guidelines.

New product profile "window" (spider)		
Attributes	**Actions**	**Functional Features**
Possibility of use for domes and/or pyramids	ELIMINATE	UF
Quickness of installation	REDUCE	RES
Ease of installing	REDUCE	RES
Quickness of maintenance service	REDUCE	RES
Cheapness of replacements	REDUCE	RES
Innovation (company's image)	RAISE	UF
Possibility to set up exemplary applications	RAISE	UF
Ease of sealing with gaskets	RAISE	RES
Ease of maintaining/replacing gaskets	RAISE	RES
Energy saving	RAISE	RES
Possibility to include windows in the facade	CREATE	UF
Possibility to air the inner environment	CREATE	UF
Ease of opening/closing windows	CREATE	RES
Quickness in opening/closing windows	CREATE	RES

New product profile "quick click" (spider)		
Attributes	**Actions**	**Functional Features**
Possibility to use common tools for installation	ELIMINATE	RES
Manageability/ease of use of working tools	ELIMINATE	HF
Cheapness of the replacements	REDUCE	RES
Ease of setting during the assembly	REDUCE	RES
Cheapness of installation	RAISE	RES
Cheapness of disassembling and disposal	RAISE	RES
Cheapness of maintenance	RAISE	RES
Supply of easy instructions for installation	RAISE	RES
Quickness in supporting customers	RAISE	RES
Ease of maintaining/replacing parts	RAISE	RES
Ease of centring during the installation	RAISE	RES
Quickness in disassembling	RAISE	RES
Quickness of installation	RAISE	RES
Ease of installing	RAISE	RES
Avoid glass's damage during the installation	RAISE	HF
Quickness of maintenance service	RAISE	RES
Safety during the installation phase	RAISE	HF

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Ease of disposing/recycling	RAISE	RES
Innovation (company's image)	RAISE	UF
Possibility to set up exemplary applications	RAISE	UF
Independence from the use of tools during the installation/dismantling	CREATE	RES

New product profile "irregular" (components for glass staircases)		
Attributes	**Actions**	**Functional Features**
Variety of models	ELIMINATE	UF
Possibility to have not standard sizes	ELIMINATE	UF
Minimal visibility of the installed product	REDUCE	HF
Strength against overloads	REDUCE	HF
Possibility to use without walls (stairs in the middle of a room)	REDUCE	UF
Aesthetics of the product	REDUCE	UF
Wear resistance (external or acid environment)	RAISE	HF
Possibility to preserve the external environment during installation	RAISE	HF
Quickness in designing staircase composition	RAISE	RES
Ease of finding the product on Internet (web pages indexing)	RAISE	RES
Ease of assembling	RAISE	RES
Quickness in assembling	RAISE	RES
Ease of disassembling	RAISE	RES
Ease of finding the product on specialised or popular magazines	RAISE	RES
Compatibility with various balustrade	RAISE	UF
Adaptability to the external environment	RAISE	UF
Modularity (Versatility of use)	RAISE	UF
Ease of changing stairs configuration (move, renovation)	RAISE	UF
Possibility to move/change stairs configuration	RAISE	UF
Ease of setting up the product	RAISE	RES
Adaptability to various configurations	RAISE	UF
Compatibility with various kinds of walls (plasterboard, stone, surfaces with irregular shapes, etc.)	CREATE	UF
Adaptability to surfaces that can change their shape	CREATE	UF

New product profile "design" (components for glass staircases)		
Attributes	**Actions**	**Functional Features**
Minimal visibility of the installed product	ELIMINATE	HF
Cheapness of the product	REDUCE	RES
Ease of cleaning the stairs	REDUCE	RES
Ease of choice (few adaptable models)	REDUCE	RES

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Partnership with designers/famous brands	RAISE	UF
Variety of surface finishes	RAISE	UF
Aesthetics of packaging	RAISE	UF
Highlighting the made in Italy quality	RAISE	UF
Variety of models	RAISE	UF
Ease of finding the product on Internet (web pages indexing)	RAISE	RES
Ease of finding the product on specialised or popular magazines	RAISE	RES
Adaptability to the external environment	RAISE	UF
Aesthetic/attractiveness of advertisement	RAISE	UF
Retention of surface features (sparkle, colour)	RAISE	HF
Reliability, distinction	RAISE	UF
Aesthetics of the product	RAISE	UF
Variety of colours	CREATE	UF
Variety of shapes	CREATE	UF
Use of precious metals, jewellery, precious stones	CREATE	UF
In line with home interior design	CREATE	UF

New product profile "quick click" (components for glass staircases)		
Attributes	**Actions**	**Functional Features**
Variety of surface finishes	ELIMINATE	UF
Variety of models	ELIMINATE	UF
Possibility to have not standard sizes	ELIMINATE	UF
Compatibility with standard tools	ELIMINATE	RES
Stability	REDUCE	HF
Strength against overloads	REDUCE	HF
Cheapness of maintenance	RAISE	RES
Minimum waiting-time to receive assistance	RAISE	RES
Ergonomics of installation tools	RAISE	HF
Do-it-yourself installation	RAISE	UF
Quickness/ease of disposal	RAISE	RES
Quickness in maintaining	RAISE	RES
Ease of consulting the website (and/or app)	RAISE	RES
Ease of finding the product on Internet (web pages indexing)	RAISE	RES
Ease of assembling	RAISE	RES
Quickness in assembling	RAISE	RES
Ease of disassembling	RAISE	RES
Ease of replacing the stairs	RAISE	RES
Ease of finding the product on specialised or popular magazines	RAISE	RES
Possibility to install with one hand	CREATE	RES

B.7 PCM used to assess costs of new product profiles identified in case studies

- Profile Cost Matrix of new spider profiles. N stands for null (0), L stands for low (1), M stands for medium (3) and H stands for high (9)

		Company's Needs/Risks						
		1.	2.	3.	4.	5.	6.	
	Weight	4	3	1	4	2	5	***Attribute's Cost***
Product Attributes - Differentiation moves	Supply of easy instructions for installation - RAISE	L	L	N	N	N	N	7
	Quickness in supporting customers - RAISE	M	L	N	N	N	N	15
	Ease of maintaining/replacing parts - RAISE	L	M	N	N	N	N	13
	Cheapness of installation - RAISE	L	M	N	N	N	N	13
	Cheapness of disassembling and disposal - RAISE	M	L	N	N	N	N	15
	Cheapness of maintenance - RAISE	L	L	N	L	N	N	11
	Ease of centring during the installation - RAISE	L	M	L	N	N	N	14
	Quickness in disassembling - RAISE	M	L	N	N	N	N	15
	Quickness in disposing - RAISE	L	L	N	N	N	N	7
	Quickness of installation - RAISE	M	M	N	N	N	N	21

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Product Attributes - Differentiation moves	Quickness of installation - REDUCE	N	N	N	M	L	H	59
	Ease of installing - RAISE	M	M	N	N	N	N	21
	Ease of installing - REDUCE	N	N	N	M	M	M	33
	Avoid glass's damage during the installation - RAISE	L	M	M	N	N	N	16
	Quickness of maintenance service - RAISE	L	M	L	N	N	N	14
	Quickness of maintenance service - REDUCE	N	N	N	L	L	M	21
	Cheapness of the replacements - REDUCE	N	N	N	M	M	L	23
	Ease of setting during the assembly - REDUCE	N	N	N	L	L	M	21
	Ease of adjusting on the site - ELIMINATE	N	N	L	M	M	H	64
	Possibility to use common tools for installation - ELIMINATE	N	N	N	L	M	M	25
	Manageability/ ease of use of working tools - ELIMINATE	N	N	N	M	H	H	75

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Product Attributes - Differentiation moves	Safety during the installation phase - RAISE	L	L	M	N	N	N	10
	Ease of disassembling - RAISE	L	L	L	N	N	N	8
	Ease of disposing/recycling - RAISE	L	L	L	N	N	N	8
	Innovation (company's image) - RAISE	H	H	H	N	N	N	72
	Possibility to set up exemplary applications - RAISE	M	M	L	N	N	N	22
	Possibility of use for domes and/or pyramids - ELIMINATE	N	N	N	L	H	M	37
	Ease of sealing with gaskets - RAISE	L	L	M	N	N	N	10
	Ease of maintaining/replacing gaskets - RAISE	L	M	M	N	N	N	16
	Ease of choosing the product - REDUCE	N	L	L	L	L	L	15
	Energy saving - RAISE	H	M	M	N	N	N	48
	Ease of setting during the assembly - ELIMINATE	N	N	N	M	L	M	29
	Independence from the use of tools during the installation/ dismantling - CREATE	M	H	N	N	N	N	39

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Product Attributes - Differentiation moves	Possibility to include windows in the facade - CREATE	H	H	H	N	N	N	72
	Possibility to air the inner environment - CREATE	M	H	M	N	N	N	42
	Ease of opening/closin g windows - CREATE	M	M	M	N	N	N	24
	Quickness in opening/closin g windows - CREATE	M	M	M	N	N	N	24
	Possibility to hang projecting roof (and tie rods) directly on spiders - CREATE	M	H	H	N	N	N	48
	Ease of fastening/unfas tening projecting roof - CREATE	M	M	M	N	N	N	24
	Quickness in fastening/unfas tening projecting roof - CREATE	M	M	M	N	N	N	24

- Profile Cost Matrix of components for glass staircases. N stands for null (0), L stands for low (1), M stands for medium (3) and H stands for high (9)

		Company's Needs/Risks						
		1.	2.	3.	4.	5.	6.	
	Weight	4	3	1	4	2	5	***Attribute's Cost***
Product Attributes - Differentiation moves	Minimum waiting-time to receive assistance - RAISE	L	L	N	N	N	N	7
	Ergonomics of installation tools - RAISE	M	M	N	N	L	N	23
	Do-it-yourself installation - RAISE	H	H	N	N	N	L	68
	Quickness/ease of disposal - RAISE	H	H	N	N	N	L	68
	Cheapness of maintenance - RAISE	M	L	N	N	L	N	9
	Quickness in maintaining - RAISE	M	M	N	N	L	N	23
	Variety of surface finishes - ELIMINATE	N	N	N	H	H	L	59
	Variety of surface finishes - RAISE	M	M	L	N	N	N	22
	Variety of models - ELIMINATE	N	L	N	M	M	M	36
	Variety of models - RAISE	H	H	M	N	N	N	66
	Ease of finding the product on Internet (web pages indexing)- RAISE	M	L	H	N	N	N	24
	Ease of consulting the website (and/or app) - RAISE	M	L	H	N	N	N	24
	Ease of assembling - RAISE	M	H	N	L	N	N	43
	Quickness in assembling - RAISE	H	H	M	M	N	N	78
	Cheapness of the product - REDUCE	N	L	N	N	M	H	54

Continue on next page

Product Attributes - Differentiation moves	Possibility to have not standard sizes - ELIMINATE	N	N	N	L	L	L	11
	Ease of assembling - RAISE	H	M	L	N	L	N	48
	Compatibility with standard tools - ELIMINATE	N	N	N	M	M	L	23
	Ease of disassembling - RAISE	M	M	N	L	L	L	32
	Ease of replacing the stairs - RAISE	M	M	L	M	N	N	34
	Ease of finding the product on specialised or popular magazines - RAISE	M	M	H	N	N	N	30
	Stability - REDUCE	N	N	N	H	H	H	99
	Strength against overloads - REDUCE	N	N	N	H	H	H	99
	Ease of choice (few adaptable models) - REDUCE	N	N	N	L	L	M	21
	Possibility to preserve the external environment during installation - RAISE	M	M	M	N	N	N	24
	Wear resistance (external or acid environment) - RAISE	M	L	M	N	N	N	18
	Quickness in designing staircase composition - RAISE	M	M	H	M	N	N	42
	Compatibility with various balustrade - RAISE	M	L	N	N	N	N	15
	Minimal visibility of the installed product - REDUCE	N	N	N	L	L	M	21

Continue on next page

Product Attributes - Differentiation moves	Minimal visibility of the installed product - ELIMINATE	N	N	N	M	M	H	63
	Adaptability to the external environment - RAISE	H	M	N	N	N	N	45
	Modularity (Versatility of use) - RAISE	H	M	M	L	N	N	52
	Possibility to move/change stairs configuration - RAISE	M	L	N	L	N	N	19
	Ease of changing stairs configuration (move, renovation) - RAISE	H	M	N	N	N	N	45
	Ease of setting up the product - RAISE	H	M	L	L	N	N	50
	Possibility to use without walls (stairs in the middle of a room) - REDUCE	N	N	N	L	M	M	25
	Aesthetics of the product - REDUCE	N	N	N	M	H	H	75
	Aesthetics of the product - RAISE	M	L	M	N	N	N	18
	Adaptability to various configurations - RAISE	M	M	N	L	N	N	25
	Aesthetics of packaging - RAISE	L	N	L	N	N	N	5
	Partnership with designers/famous brands - RAISE	H	L	H	N	N	N	48
	Highlighting the made in Italy quality - RAISE	L	N	L	N	N	N	5
	Aesthetic/attractive ness of advertisement - RAISE	M	M	M	N	M	N	30

Continue on next page

Product Attributes - Differentiation moves	Ease of cleaning the stairs - REDUCE	N	N	N	L	L	L	11
	Retention of surface features (sparkle, colour) - RAISE	M	L	M	N	N	N	18
	Reliability, distinction - RAISE	L	M	M	N	N	N	16
	Possibility to install with one hand - CREATE	M	H	L	M	N	N	52
	Compatibility with various kind of walls (plasterboard, stone, surfaces with irregular shapes, etc.) - CREATE	L	H	M	N	N	N	34
	Adaptability to surfaces that can change their shape - CREATE	M	M	M	N	N	N	24
	Variety of colours - CREATE	L	N	N	N	N	N	4
	Variety of shapes - CREATE	H	H	L	N	N	N	64
	Use of precious metals, jewellery, precious stones - CREATE	M	L	N	N	N	N	15
	In line with home interior design - CREATE	M	M	L	N	N	N	22

B.8 Favourite ideas/set of attributes generated by students using Six paths framework and iDea during the test

- **Tests with Six Paths Framework**

	Camera		**Domestic coffee maker**
ID	**Selected idea/set of features**	**ID**	**Selected idea/set of features**
1	Camera for colour-blind persons; possibility to customize the device according to specific health problems; supply of a dedicated software for visually impaired people	13	Adaptability to various environments (shapes and colours); possibility to use both powder and coffee pods; integrated water purifier that eliminate limescale

Continue on next page

2	Modular camera (ease and quick change of parts); variety of accessories/modules; possibility to have a light and ease basic configuration; possibility to customize aesthetics of the camera	14	Rollaway device, integrated into kitchen furniture (aesthetics and minimal amount of space); direct link to the water supply network; easy management of the device through Wi-Fi connection
3	Diving watch with camera; possibility to share photos on social networks; possibility to connect watch to smartphone in order to edit photos; customizable clock face; integration of Google maps service; variety of colours and watchbands; absence of memory storage (directly connected to other devices)	15	Integration into the device of an alarm clock that wakes up in the morning and automatically prepares coffee; ease to clean
4	Camera connected to the cloud (unlimited storage); supply of frequent updates with new functionalities; possibility to recognise objects	16	Customizable domestic coffee maker; possibility to change aesthetics (colours, shapes); possibility to add features (hi-fi, radio, clock, timer); self-cleaning; possibility to customize cups
5	Camera for athletes; light and robust device; availability of several accessories for various kind of sports; possibility to charge camera without cables; availability of more memory storages (e.g. two slots for memory cards); self-cleaning lens; possibility to reuse accessories on other products	17	Domestic coffee machine that can make in the same time different coffee according to people tastes; possibility to control the device from smartphone; possibility to set a timer and save different settings
6	Cover for smartphone with an integrated zoom to make professional photos; water-proof; dust resistant; shock-proof; scratch-resistant; possibility to hook the camera on helmets or belts	18	Possibility to entertain the user while he/she wait the coffee; small size and weight; ease to move the product
7	Camera that recognise places, objects, monuments, objects, works of art and automatically provides vocal and/or visual information	19	Domestic coffee maker controlled by smart devices; possibility to automatically order consumer products (powder and coffee pods)
8	Vintage camera that allows to print photos (like old Polaroid); ease to share photos on social networks	20	Travel coffee machine; adaptability to various environments (shapes and colours); possibility to make various hot drinks; shock-proof; scratch-resistant; light and ergonomic; noiseless; possibility to connect to smartphone; possibility to read messages (sms, mail, etc.)
9	Camera-drone-submarine that can fly and move into the water taking pictures; connection with smartphones (control and share photos); long battery life; possibility to take photos and make video in the dark (e.g. infrared)	21	Possibility to control the coffee maker from the smartphone; integrated sugar dispenser; possibility to mix coffee with milk, chocolate and/or other things; high quality of made coffee

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10	Camera with manual zoom (long life battery); quick customer service; availability of several accessories and various colours; absence of physical buttons (only touch screen); possibility to make 3D photos and videos; possibility to create an account on a social network purposely developed to share photos among users of the new camera	22	Possibility to customize the aesthetics of the product (colour and/or decoration); travel coffee machine; possibility to use both powder and coffee pods; possibility to make additional hot drinks; possibility to automatically add sugar (selecting a level)
11	Camera with voice-controlled system; ease to use for children and old people; ease to make selfie; supply of a set of recorded jokes to make smile	23	Moka pot that allows to check water and coffee levels; possibility to dose powdered coffee (clean environment); possibility to avoid tighten the bolts
12	Camera connected to the cloud (unlimited storage); possibility to connect to the cloud using devices like ATMs and print photos	24	Travel coffee machine; possibility to use the product without a connection to electricity grid

- **Tests with iDea**

	Domestic coffee maker		Camera
ID	**Selected idea/set of features**	**ID**	**Selected idea/set of features**
25	Domestic coffee maker integrated into kitchen furniture; possibility to wash and dry cups; integrated loudspeaker and coffee aroma diffusor	37	Cameras for medical applications: mole mapping, X-rays; ease to sharing information between doctor and patient; possibility to capture and print 3D photos for blind people; camera for colour-blind persons
26	Domestic coffee maker with an integrated small oven to heat breakfast; possibility to make cigarettes inserting tobacco, paper and filters	38	Possibility to recognise colours and search products on the web characterized by those tints
27	Domestic coffee maker with an integrated thermos; possibility to keep warm the coffee; possibility to use thermos' cap as a cup; possibility to take note on the body of the machine like on a board; integrated flowerpot; supply of a backpack as packaging (possibility of reusing it)	39	Camera connected to cloud or other devices like smartphones (unlimited storage); possibility to check the battery life (or further information) on other devices like smartphones
28	Travel coffee machine; possibility to select the level of coffee; integrated cup; integrated sugar dispenser that allows to select quantity of sugar	40	Camera for nature lovers; possibility to customize the camera according to the visited environment (e.g. bird watching, snorkeling); possibility to reproduce sounds of nature; possibility to download guidebooks; possibility to wear camera accessories
29	Domestic coffee machine with fingerprint reader that recognise pre-set information (type of coffee, quantity of sugar, etc.); supply of a thermos	41	Camera that can be connect with other devices or to Internet in order to share photos; possibility to send original postcards

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30	Possibility to make various hot and cold drinks; direct link to the water supply network; integrated water purifier; possibility to make an home distribution network (e.g. bedroom, living room and kitchen); possibility to automatically dispose waste; possibility to read news on a screen; supply of people recognition system that automatically makes favourite type of coffee; possibility to control the device from smartphone	42	Camera with long life battery; possibility to use the device like a digital photo frame and/or a projector when it is not used; possibility to change the colours (e.g. covers)
31	Domestic coffee maker that provides generic (weather, traffic, news) and personal (date, events) information; possibility to customize the aesthetic of the device; possibility to make sketch on the coffee or milk foam; possibility to customize cups used with the device	43	Wearable camera for visually impaired people (glasses); supply of voice-controlled system; possibility to reproduce sound, smells, tastes and tactile feel; possibility to detect architectural boundaries and danger; supply of cloud service to store photos, automatic tag function that recognise peoples; possibility to charge the device with solar power
32	Domestic coffee maker similar to drinks dispensers; possibility to make various drinks; possibility to use handy cartridge that can be ordered and received at home (without shipping costs)	44	Camera with an original minimalist shape; shock-proof; scratch-resistant; pleasing to the touch; possibility to stick the camera to every surface and absorb energy; water-proof; dust resistant; possibility to connect the camera to moving devices (e.g. drones); supply of audio instruction manuals; possibility to program the device (e.g. Programmable Logic Controller); possibility to take 3D and 360° photos; possibility to edit photos on the device; possibility to record and reproduce sounds, smells and tastes; possibility to connect the camera to a 3D printer; possibility to make holograms; supply of entertainment services; integrated projector; possibility to add vocal descriptions to photos; chameleon-like surface
33	Domestic coffee maker connected to Internet that can be used to listen music, read news, see videos; integrated clock, alarm and timer	45	Modular camera that can be assembled changing aesthetics and functions; possibility to continuously update parts and operative system (avoid disposing the product and buying new cameras)
34	Possibility to control the quantity of coffee and required water; possibility to buy components and assemble the coffee maker	46	Customizable camera; ease to use and robust; possibility to float if it is lost into the water

Continue on next page

35	Domestic coffee maker with people recognition system that automatically makes favourite type of coffee (espresso, Americano, etc.) or it provides advices according to people tastes; possibility to make drinks for children; aesthetics of graphical interface; generation of nice sounds	47	Independence of the camera from other devices (e.g. possibility to modify photos directly on the camera); long life battery; ease to use and charge
36	Possibility to make coloured or transparent coffee (that do not blemish clothes, paper sheets or other objects in general)	48	Possibility to surf the Internet (Wi-Fi); possibility to downloads apps (e.g. filters, games); possibility to upload photos on social networks and/or on the cloud; possibility to customize the product before the purchase (e.g. web configurator)

B.9 Main outcomes of the test of iDea carried out with MS students

Test ID	Camera as a topic	Use of iDea	Quantity of new product features	Novelty of final ideas	Variety of new product features	Time dedicated to ideation
1	Yes	No	3	Medium	7%	120’
2	Yes	No	2	None	12%	90’
3	Yes	No	6	Low	23%	95’
4	Yes	No	3	None	9%	90’
5	Yes	No	5	Low	17%	120’
6	Yes	No	3	Low	19%	75’
7	Yes	No	7	Low	14%	120’
8	Yes	No	2	Low	12%	75’
9	Yes	No	3	Low	14%	90’
10	Yes	No	1	None	6%	75’
11	Yes	No	5	High	22%	95’
12	Yes	No	8	None	25%	135’
13	No	No	3	Low	19%	125’
14	No	No	5	Low	21%	135’
15	No	No	3	None	9%	90’
16	No	No	4	Low	10%	120’
17	No	No	5	Low	17%	125’
18	No	No	5	None	22%	130’
19	No	No	3	Low	10%	125’
20	No	No	7	None	19%	100’
21	No	No	10	None	25%	115’
22	No	No	7	None	16%	75’
23	No	No	5	Low	10%	100’
24	No	No	3	None	13%	115’
25	No	Yes	20	High	40%	165’

Continue on next page

26	No	Yes	21	Low	37%	145’
27	No	Yes	31	Medium	50%	145’
28	No	Yes	12	Low	30%	135’
29	No	Yes	14	High	37%	130’
30	No	Yes	20	None	41%	145’
31	No	Yes	28	High	49%	145’
32	No	Yes	8	None	24%	150’
33	No	Yes	16	Low	32%	120’
34	No	Yes	7	Low	30%	75’
35	No	Yes	21	High	43%	165’
36	No	Yes	39	Very high	57%	165’
37	Yes	Yes	28	High	46%	170’
38	Yes	Yes	17	High	38%	165’
39	Yes	Yes	15	Low	36%	165’
40	Yes	Yes	13	Low	35%	160’
41	Yes	Yes	19	High	39%	155’
42	Yes	Yes	13	None	30%	155’
43	Yes	Yes	27	High	47%	150’
44	Yes	Yes	34	None	52%	150’
45	Yes	Yes	20	Low	39%	140’
46	Yes	Yes	18	Low	40%	145’
47	Yes	Yes	14	Low	30%	150’
48	Yes	Yes	30	Low	46%	170’

Appendix C

C.1 Java code of VAM tool

```
import java.util.Random;
import javax.swing.JOptionPane;

/**
 *
 * @author danielebacciotti
 */
public class Succ extends javax.swing.JFrame {

    /**
     * Creates new form Succ
     */
    public Succ() {
        initComponents();
    }

    @SuppressWarnings("unchecked")
    // <editor-fold defaultstate="collapsed" desc="Generated Code">
    private void initComponents() {

        jTextField1 = new javax.swing.JTextField();
        jTextField2 = new javax.swing.JTextField();
        jTextField3 = new javax.swing.JTextField();
        jTextField4 = new javax.swing.JTextField();
        jTextField5 = new javax.swing.JTextField();
        jTextField6 = new javax.swing.JTextField();
        jTextField7 = new javax.swing.JTextField();
        jTextField8 = new javax.swing.JTextField();
        jTextField9 = new javax.swing.JTextField();
        jLabel1 = new javax.swing.JLabel();
        jLabel2 = new javax.swing.JLabel();
        jLabel3 = new javax.swing.JLabel();
        jLabel4 = new javax.swing.JLabel();
```

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```
jLabel5 = new javax.swing.JLabel();
jLabel6 = new javax.swing.JLabel();
jLabel7 = new javax.swing.JLabel();
jLabel8 = new javax.swing.JLabel();
jLabel9 = new javax.swing.JLabel();
jTextField10 = new javax.swing.JTextField();
jButton1 = new javax.swing.JButton();
jLabel10 = new javax.swing.JLabel();
jLabel11 = new javax.swing.JLabel();
jLabel12 = new javax.swing.JLabel();
jTextField11 = new javax.swing.JTextField();
jTextField12 = new javax.swing.JTextField();
jTextField13 = new javax.swing.JTextField();
jLabel13 = new javax.swing.JLabel();
textField1 = new java.awt.TextField();
jTextField14 = new javax.swing.JTextField();

setDefaultCloseOperation(javax.swing.WindowConstants.EXIT_ON_CLOSE);
setBackground(new java.awt.Color(255, 255, 255));

jTextField1.setHorizontalAlignment(javax.swing.JTextField.CENTER);
jTextField1.setText("0");
jTextField1.addActionListener(new java.awt.event.ActionListener() {
   public void actionPerformed(java.awt.event.ActionEvent evt) {
      jTextField1ActionPerformed(evt);
   }
});

jTextField2.setHorizontalAlignment(javax.swing.JTextField.CENTER);
jTextField2.setText("0");

jTextField3.setHorizontalAlignment(javax.swing.JTextField.CENTER);
jTextField3.setText("0");

jTextField4.setHorizontalAlignment(javax.swing.JTextField.CENTER);
jTextField4.setText("0");

jTextField5.setHorizontalAlignment(javax.swing.JTextField.CENTER);
jTextField5.setText("0");

jTextField6.setHorizontalAlignment(javax.swing.JTextField.CENTER);
jTextField6.setText("0");

jTextField7.setHorizontalAlignment(javax.swing.JTextField.CENTER);
jTextField7.setText("0");

jTextField8.setHorizontalAlignment(javax.swing.JTextField.CENTER);
jTextField8.setText("0");
```

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```
jTextField9.setHorizontalAlignment(javax.swing.JTextField.CENTER);
jTextField9.setText("0");

jLabel1.setText("CR/UF");

jLabel2.setText("CR/HF");

jLabel3.setText("CR/RES");

jLabel4.setText("RA/UF");

jLabel5.setText("RA/HF");

jLabel6.setText("RA/RES");

jLabel7.setText("RE/UF");

jLabel8.setText("RE/HF");

jLabel9.setText("RE/RES");

jTextField10.setEditable(false);
jTextField10.setHorizontalAlignment(javax.swing.JTextField.CENTER);

jButton1.setText("Calculate Success");
jButton1.addActionListener(new java.awt.event.ActionListener() {
   public void actionPerformed(java.awt.event.ActionEvent evt) {
      jButton1ActionPerformed(evt);
   }
});

jLabel10.setText("EL/UF");

jLabel11.setText("EL/HF");

jLabel12.setText("EL/RES");

jTextField11.setHorizontalAlignment(javax.swing.JTextField.CENTER);
jTextField11.setText("0");

jTextField12.setHorizontalAlignment(javax.swing.JTextField.CENTER);
jTextField12.setText("0");

jTextField13.setHorizontalAlignment(javax.swing.JTextField.CENTER);
jTextField13.setText("0");

textField1.setEditable(false);
```

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```
            textField1.setEnabled(false);
            textField1.setForeground(new java.awt.Color(255, 255, 255));
            textField1.setVisible(false);
            textField1.addActionListener(new java.awt.event.ActionListener() {
                public void actionPerformed(java.awt.event.ActionEvent evt) {
                    textField1ActionPerformed(evt);
                }
            });

            jTextField14.setEditable(false);
            jTextField14.setBorder(null);
            jTextField14.addActionListener(new java.awt.event.ActionListener() {
                public void actionPerformed(java.awt.event.ActionEvent evt) {
                    jTextField14ActionPerformed(evt);
                }
            });

            org.jdesktop.layout.GroupLayout layout = new
org.jdesktop.layout.GroupLayout(getContentPane());
            getContentPane().setLayout(layout);
            layout.setHorizontalGroup(
                layout.createParallelGroup(org.jdesktop.layout.GroupLayout.LEADING)
                .add(org.jdesktop.layout.GroupLayout.TRAILING,
layout.createSequentialGroup()

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.TRAILING)
                        .add(layout.createSequentialGroup()
                            .addContainerGap(90, Short.MAX_VALUE)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.LEADING)
                                .add(org.jdesktop.layout.GroupLayout.TRAILING,
layout.createParallelGroup(org.jdesktop.layout.GroupLayout.CENTER)
                                    .add(jTextField11,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 44,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                                    .add(jLabel10)
                                    .add(jLabel7)
                                    .add(jTextField4,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 44,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                                    .add(jLabel4)
                                    .add(jTextField1,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 44,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                                    .add(jLabel1))
                                .add(org.jdesktop.layout.GroupLayout.TRAILING, jTextField7,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 44,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE))
```

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```
                         .add(0, 0, 0)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.CENTER)
                            .add(jButton1)
                            .add(jLabel8)
                            .add(jLabel5)
                            .add(jLabel2)
                            .add(jLabel11)
                            .add(jTextField2,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 46,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                            .add(jTextField5,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 46,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                            .add(jTextField8,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 46,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                            .add(jTextField12,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                            .add(jTextField10,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 162,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE))

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.CENTER)
                            .add(jLabel3)
                            .add(jTextField3,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 36,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                            .add(jLabel6)
                            .add(jTextField6,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 36,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                            .add(jLabel9)
                            .add(jTextField9,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 36,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                            .add(jLabel12)
                            .add(jTextField13,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE))
                         .addPreferredGap(org.jdesktop.layout.LayoutStyle.RELATED, 90,
Short.MAX_VALUE))
                       .add(layout.createSequentialGroup()
```

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```
.addContainerGap(org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
Short.MAX_VALUE)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.LEADING)
                    .add(org.jdesktop.layout.GroupLayout.TRAILING, textField1,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                    .add(org.jdesktop.layout.GroupLayout.TRAILING,
layout.createSequentialGroup()
                      .add(jTextField14,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 52,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                      .add(30, 30, 30)))
                  .add(jLabel13)))
              .add(0, 0, 0))
          );

          layout.linkSize(new java.awt.Component[] {jLabel1, jLabel4, jLabel7},
org.jdesktop.layout.GroupLayout.HORIZONTAL);

          layout.linkSize(new java.awt.Component[] {jTextField1, jTextField11,
jTextField12, jTextField13, jTextField2, jTextField3, jTextField4, jTextField5, jTextField6,
jTextField7, jTextField8, jTextField9}, org.jdesktop.layout.GroupLayout.HORIZONTAL);

          layout.setVerticalGroup(
            layout.createParallelGroup(org.jdesktop.layout.GroupLayout.LEADING)
            .add(layout.createSequentialGroup()
              .add(10, 10, 10)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.CENTER)
                .add(jLabel3)
                .add(jLabel1)
                .add(jLabel2, org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE, Short.MAX_VALUE))
              .addPreferredGap(org.jdesktop.layout.LayoutStyle.RELATED)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.CENTER)
                .add(jTextField1, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                .add(jTextField2, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                .add(jTextField3, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE))
```

Continue on next page

```
                    .addPreferredGap(org.jdesktop.layout.LayoutStyle.RELATED)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.CENTER)
                        .add(jLabel4, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 19,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                        .add(jLabel5)
                        .add(jLabel6))
                    .addPreferredGap(org.jdesktop.layout.LayoutStyle.RELATED)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.CENTER)
                        .add(jTextField4, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                        .add(jTextField5, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                        .add(jTextField6, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE))
                    .addPreferredGap(org.jdesktop.layout.LayoutStyle.RELATED)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.CENTER)
                        .add(jLabel7, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 31,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                        .add(jLabel8, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE, 16,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                        .add(jLabel9))
                    .addPreferredGap(org.jdesktop.layout.LayoutStyle.RELATED)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.LEADING)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.CENTER)
                            .add(jTextField8,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                            .add(jTextField9,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE))
                        .add(jTextField7, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE))
                    .add(18, 18, 18)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.CENTER)
                        .add(jLabel10)
                        .add(jLabel11)
```

Continue on next page

```
                        .add(jLabel12))
                    .addPreferredGap(org.jdesktop.layout.LayoutStyle.RELATED)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.CENTER)
                        .add(jTextField11,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                        .add(jTextField12,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                        .add(jTextField13,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE))
                    .add(29, 29, 29)
                    .add(jButton1)
                    .addPreferredGap(org.jdesktop.layout.LayoutStyle.RELATED)
                    .add(jTextField10, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                    .add(12, 12, 12)

.add(layout.createParallelGroup(org.jdesktop.layout.GroupLayout.LEADING)
                        .add(jLabel13, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
27, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                        .add(textField1, org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE)
                        .add(org.jdesktop.layout.GroupLayout.TRAILING, jTextField14,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE,
org.jdesktop.layout.GroupLayout.DEFAULT_SIZE,
org.jdesktop.layout.GroupLayout.PREFERRED_SIZE))
                    .add(12, 12, 12))
        );

        layout.linkSize(new java.awt.Component[] {jTextField2, jTextField3,
jTextField5, jTextField6, jTextField8, jTextField9},
org.jdesktop.layout.GroupLayout.VERTICAL);

        pack();
    }// </editor-fold>

    private void jButton1ActionPerformed(java.awt.event.ActionEvent evt) {
        int num1, num2, num3, num4, num5, num6, num7, num8, num9, num10,
num11, num12;
        try {
```

Continue on next page

```
                num1 = Integer.parseInt(this.jTextField1.getText());

            } catch (Exception exc) {
                JOptionPane.showMessageDialog(this, "Bad 1st number", "Error",
JOptionPane.ERROR_MESSAGE);
                return;
            }
                // if (num1<0) {
            //  JOptionPane.showMessageDialog(this, "Bad 1st number", "Error",
JOptionPane.ERROR_MESSAGE);
            // } else {
            //    }
            try {
                num2 = Integer.parseInt(this.jTextField2.getText());
            } catch (Exception e) {
                JOptionPane.showMessageDialog(this, "Bad 2nd number", "Error",
JOptionPane.ERROR_MESSAGE);
                return;
            }
            try {
                num3 = Integer.parseInt(this.jTextField3.getText());
            } catch (Exception e) {
                JOptionPane.showMessageDialog(this, "Bad 3rd number", "Error",
JOptionPane.ERROR_MESSAGE);
                return;
            }
            try {
                num4 = Integer.parseInt(this.jTextField4.getText());
            } catch (Exception e) {
                JOptionPane.showMessageDialog(this, "Bad 4th number", "Error",
JOptionPane.ERROR_MESSAGE);
                return;
            }
            try {
                num5 = Integer.parseInt(this.jTextField5.getText());
            } catch (Exception e) {
                JOptionPane.showMessageDialog(this, "Bad 5th number", "Error",
JOptionPane.ERROR_MESSAGE);
                return;
            }
            try {
                num6 = Integer.parseInt(this.jTextField6.getText());
            } catch (Exception e) {
                JOptionPane.showMessageDialog(this, "Bad 6th number", "Error",
JOptionPane.ERROR_MESSAGE);
                return;
            }
            try {
```

Continue on next page

```
                num7 = Integer.parseInt(this.jTextField7.getText());
            } catch (Exception e) {
                JOptionPane.showMessageDialog(this, "Bad 7th number", "Error",
JOptionPane.ERROR_MESSAGE);
                return;
            }
            try {
                num8 = Integer.parseInt(this.jTextField8.getText());
            } catch (Exception e) {
                JOptionPane.showMessageDialog(this, "Bad 8th number", "Error",
JOptionPane.ERROR_MESSAGE);
                return;
            }
            try {
                num9 = Integer.parseInt(this.jTextField9.getText());
            } catch (Exception e) {
                JOptionPane.showMessageDialog(this, "Bad 9th number", "Error",
JOptionPane.ERROR_MESSAGE);
                return;
            }
            try {
                num10 = Integer.parseInt(this.jTextField11.getText());
            } catch (Exception e) {
                JOptionPane.showMessageDialog(this, "Bad 10th number", "Error",
JOptionPane.ERROR_MESSAGE);
                return;
            }
            try {
                num11 = Integer.parseInt(this.jTextField12.getText());
            } catch (Exception e) {
                JOptionPane.showMessageDialog(this, "Bad 11th number", "Error",
JOptionPane.ERROR_MESSAGE);
                return;
            }
            try {
                num12 = Integer.parseInt(this.jTextField13.getText());
            } catch (Exception e) {
                JOptionPane.showMessageDialog(this, "Bad 12th number", "Error",
JOptionPane.ERROR_MESSAGE);
                return;
            }

                double[] c0 = new double[5000];
                double mean0 = -3.19, std0 = 1.43;
                Random rng0 = new Random();
               for(int i = 0;i<c0.length;i++) {
                c0[i] = mean0 + std0 * rng0.nextGaussian();
               }
```

Continue on next page

```
 double[] c1 = new double[5000];
 double mean1 = 3.44, std1 = 0.78;
 Random rng1 = new Random();
for(int i = 0;i<c1.length;i++) {
 c1[i] = mean1 + std1 * rng1.nextGaussian();
}
 double[] c2 = new double[5000];
 double mean2 = 1.32, std2 = 0.83;
 Random rng2 = new Random();
for(int i = 0;i<c2.length;i++) {
 c2[i] = mean2 + std2 * rng2.nextGaussian();
}
 double[] c3 = new double[5000];
 double mean3 = 2.87, std3 = 1.38;
 Random rng3 = new Random();
for(int i = 0;i<c3.length;i++) {
 c3[i] = mean3 + std3 * rng3.nextGaussian();
}
 double[] c4 = new double[5000];
 double mean4 = 0.97, std4 = 0.54;
 Random rng4 = new Random();
for(int i = 0;i<c4.length;i++) {
 c4[i] = mean4 + std4 * rng4.nextGaussian();
}
 double[] c5 = new double[5000];
 double mean5 = 1.75, std5 = 0.83;
 Random rng5 = new Random();
for(int i = 0;i<c5.length;i++) {
 c5[i] = mean5 + std5 * rng5.nextGaussian();
}
 double[] c6 = new double[5000];
 double mean6 = 0.41, std6 = 0.38;
 Random rng6 = new Random();
for(int i = 0;i<c6.length;i++) {
 c6[i] = mean6 + std6 * rng6.nextGaussian();
}
 double[] c7 = new double[5000];
 double mean7 = -0.84, std7 = 0.6;
 Random rng7 = new Random();
for(int i = 0;i<c7.length;i++) {
 c7[i] = mean7 + std7 * rng7.nextGaussian();
}
 double[] c8 = new double[5000];
 double mean8 = -0.27, std8 = 1.17;
 Random rng8 = new Random();
for(int i = 0;i<c8.length;i++) {
 c8[i] = mean8 + std8 * rng8.nextGaussian();
}
```

Continue on next page

```
                double[] c9 = new double[5000];
                double mean9 = -1.78, std9 = 0.62;
                Random rng9 = new Random();
                for(int i = 0;i<c9.length;i++) {
                c9[i] = mean9 + std9 * rng9.nextGaussian();
                }
                double[] c10 = new double[5000];
                double mean10 = -0.46, std10 = 0.68;
                Random rng10 = new Random();
                for(int i = 0;i<c10.length;i++) {
                c10[i] = mean10 + std10 * rng10.nextGaussian();
                }
                double[] c11 = new double[5000];
                double mean11 = -9.49, std11 = 2.65;
                Random rng11 = new Random();
                for(int i = 0;i<c11.length;i++) {
                c11[i] = mean11 + std11 * rng11.nextGaussian();
                }
                double[] c12 = new double[5000];
                double mean12 = -1.65, std12 = 0.82;
                Random rng12 = new Random();
                for(int i = 0;i<c12.length;i++) {
                c12[i] = mean12 + std12 * rng12.nextGaussian();
                }
                double[] answer = new double[5000];
                double somma = 0;
                double somma1 = 0;
                for(int i = 0;i<answer.length;i++) {
                answer[i] = 100*(1/(1+Math.exp(-(c0[i] + c1[i]*num1 + c2[i]*num2 +
c3[i]*num3 + c4[i]*num4 + c5[i]*num5 + c6[i]*num6+ c7[i]*num7 + c8[i]*num8 +
c9[i]*num9 + c10[i]*num10 + c11[i]*num11 + c12[i]*num12))));
                somma=somma+answer[i];
                somma1=somma1+answer[i]*answer[i];
                }
                double media=Math.round(somma/answer.length);
                double stdev=Math.round(Math.sqrt((somma1-
somma*somma/answer.length)/(answer.length-1)));
                this.jTextField10.setText(media + " %"+ "        "+"(±"+stdev+" %)*");
                this.jTextField14.setText("*σ (68%)");
        }

        private void jTextField1ActionPerformed(java.awt.event.ActionEvent evt) {

        }

        private void textField1ActionPerformed(java.awt.event.ActionEvent evt) {

        }
```

Continue on next page

```
        private void jTextField14ActionPerformed(java.awt.event.ActionEvent evt) {

        }
      //z = -3,19 + 3,44*UF/cr + 1,32*HF/cr + 2,87*RES/cr + 0,97*UF/ra + 1,75*HF/ra +
0,41*RES/ra- 0,84*UF/re - 0,27*HF/re - 1,78*RES/re - 0,46*UF/el-9,49*HF/el-
1,65*RES/el
       // z_tesi= -0.94 + 0.96*cr/uf + 0.34*cr/hf + 1.03*cr/res + 0.79*ra/hf + 0.38*ra/res -
0.44*re/uf - 0.82*re/res - 1.66*el/hf - 0.23*el/res
        /**
         * @param args the command line arguments
         */
        public static void main(String args[]) {
            /*
             * Set the Nimbus look and feel
             */
            //<editor-fold defaultstate="collapsed" desc=" Look and feel setting code
(optional) ">
            /*
             * If Nimbus (introduced in Java SE 6) is not available, stay with the
             * default look and feel. For details see
             * http://download.oracle.com/javase/tutorial/uiswing/lookandfeel/plaf.html
             */
            try {
                for (javax.swing.UIManager.LookAndFeelInfo info :
javax.swing.UIManager.getInstalledLookAndFeels()) {
                    if ("Nimbus".equals(info.getName())) {
                        javax.swing.UIManager.setLookAndFeel(info.getClassName());
                        break;
                    }
                }
            } catch (ClassNotFoundException ex) {

java.util.logging.Logger.getLogger(Succ.class.getName()).log(java.util.logging.Level.SEVE
RE, null, ex);
            } catch (InstantiationException ex) {

java.util.logging.Logger.getLogger(Succ.class.getName()).log(java.util.logging.Level.SEVE
RE, null, ex);
            } catch (IllegalAccessException ex) {

java.util.logging.Logger.getLogger(Succ.class.getName()).log(java.util.logging.Level.SEVE
RE, null, ex);
            } catch (javax.swing.UnsupportedLookAndFeelException ex) {

java.util.logging.Logger.getLogger(Succ.class.getName()).log(java.util.logging.Level.SEVE
RE, null, ex);
            }
```

Continue on next page

```
        //</editor-fold>

        /*
         * Create and display the form
         */
        java.awt.EventQueue.invokeLater(new Runnable() {

            @Override
            public void run() {
                new Succ().setVisible(true);
            }
        });
    }
    // Variables declaration
    private javax.swing.JButton jButton1;
    private javax.swing.JLabel jLabel1;
    private javax.swing.JLabel jLabel10;
    private javax.swing.JLabel jLabel11;
    private javax.swing.JLabel jLabel12;
    private javax.swing.JLabel jLabel13;
    private javax.swing.JLabel jLabel2;
    private javax.swing.JLabel jLabel3;
    private javax.swing.JLabel jLabel4;
    private javax.swing.JLabel jLabel5;
    private javax.swing.JLabel jLabel6;
    private javax.swing.JLabel jLabel7;
    private javax.swing.JLabel jLabel8;
    private javax.swing.JLabel jLabel9;
    private javax.swing.JTextField jTextField1;
    private javax.swing.JTextField jTextField10;
    private javax.swing.JTextField jTextField11;
    private javax.swing.JTextField jTextField12;
    private javax.swing.JTextField jTextField13;
    private javax.swing.JTextField jTextField14;
    private javax.swing.JTextField jTextField2;
    private javax.swing.JTextField jTextField3;
    private javax.swing.JTextField jTextField4;
    private javax.swing.JTextField jTextField5;
    private javax.swing.JTextField jTextField6;
    private javax.swing.JTextField jTextField7;
    private javax.swing.JTextField jTextField8;
    private javax.swing.JTextField jTextField9;
    private java.awt.TextField textField1;
    // End of variables declaration
}
```

C.2 Matlab code of iDea

```
function [] = iDea()

SCR = get(0,'Screensize');  % Get screensize.
S.fh = figure('numbertitle','off',...
              'menubar','none',...
              'units','pixels',...
              'position',[(SCR(3)-850)/2 ,(SCR(4)-612)/2
, 850, 612],...
              'name','iDea',...
              'resize','off');
%Menu %%%%%%%%%%%%%%%%%%%
S.fm(1) = uimenu(S.fh,'label','File');

S.fm(2) = uimenu(S.fm(1),'Label','New
Project...','Accelerator','N');
S.fm(3) = uimenu(S.fm(1),'Label','Open
Project...','Accelerator','O');
S.fm(4) =
uimenu(S.fm(1),'Label','Save','Separator','on',...
               'Accelerator','S','enable','off');
S.fm(5) = uimenu(S.fm(1),'Label','Save
As...','enable','off');
S.fm(6) =
uimenu(S.fm(1),'Label','Quit','Callback','exit',...
               'Separator','on','Accelerator','Q');

S.fm(7) = uimenu(S.fh,'label','Help');

S.fm(8) =
uimenu(S.fm(7),'Label','Tutorial','Accelerator','T',...
              'Callback',{@fmT_call});
S.fm(9) = uimenu(S.fm(7),'Label','Comments and
suggestions...',...
              'Separator','on','Callback',{@fmC_call});
S.fm(10) = uimenu(S.fm(7),'Label','About',
'Separator','on',...
              'Callback',{@fmA_call});

% Pushbuttons
S.pbO = uicontrol('style','pushbutton',...
                 'units','pixels',...
                 'position',[255 100 175 30],...
                 'string','Open a Project...',...
                 'fontsize',14);
S.pbN = uicontrol('style','pushbutton',...
                 'units','pixels',...
```

Continue on next page

```
                        'position',[440 100 175 30],...
                        'string','Start a New Project!',...
                        'fontsize',14);
S.pb1 = uicontrol('style','pushbutton',...
                        'units','pixels',...
                        'position',[663 23 80 30],...
                        'visible','off',...
                        'string','Next  >>',...
                        'fontsize',12);
S.pb2 = uicontrol('style','pushbutton',...
                        'units','pixels',...
                        'position',[663 23 80 30],...
                        'visible','off',...
                        'string','<<  Back',...
                        'fontsize',12);
S.pb3 = uicontrol('style','pushbutton',...
                        'units','pixels',...
                        'position',[658 23 85 30],...
                        'visible','off',...
                        'string','Save ideas',...
                        'fontsize',12);
S.pb3bis = uicontrol('style','pushbutton',...
                        'units','pixels',...
                        'position',[658 23 85 30],...
                        'visible','off',...
                        'string','Save ideas',...
                        'fontsize',12);
S.pb4 = uicontrol('style','pushbutton',...
                        'units','pixels',...
                        'position',[663 23 80 30],...
                        'visible','off',...
                        'string','Next  >>',...
                        'fontsize',12);
S.pb5 = uicontrol('style','pushbutton',...
                        'units','pixels',...
                        'position',[110 23 80 30],...
                        'visible','off',...
                        'string','<<  Back',...
                        'fontsize',12);
S.pb6 = uicontrol('style','pushbutton',... %to SYS
                        'units','pixels',...
                        'position',[663 23 80 30],...
                        'visible','off',...
                        'string','Next  >>',...
                        'fontsize',12);
S.pb7 = uicontrol('style','pushbutton',... %to SH
                        'units','pixels',...
                        'position',[663 23 80 30],...
                        'visible','off',...
                        'string','Next  >>',...
```

Continue on next page

```
                        'fontsize',12);
     S.pb8 = uicontrol('style','pushbutton',... %comb detailed
                        'units','pixels',...
                        'position',[663 23 80 30],...
                        'visible','off',...
                        'string','Next  >>',...
                        'fontsize',12);

     S.pb_add(1) = uicontrol('style','pushbutton',... %add GD
                        'units','pixels',...
                        'position',[655 316 80 30],...
                        'visible','off',...
                        'string','Add',...
                        'fontsize',12);
     S.pb_add(2) = uicontrol('style','pushbutton',... %add LC
                        'units','pixels',...
                        'position',[655 316 80 30],...
                        'visible','off',...
                        'string','Add',...
                        'fontsize',12);
     S.pb_add(3) = uicontrol('style','pushbutton',... %add SYS
                        'units','pixels',...
                        'position',[655 316 80 30],...
                        'visible','off',...
                        'string','Add',...
                        'fontsize',12);
     S.pb_add(4) = uicontrol('style','pushbutton',... %add SH
                        'units','pixels',...
                        'position',[655 316 80 30],...
                        'visible','off',...
                        'string','Add',...
                        'fontsize',12);

     S.pb_del(1) = uicontrol('style','pushbutton',... %delete
GD
                        'units','pixels',...
                        'position',[655 286 80 30],...
                        'visible','off',...
                        'string','Delete',...
                        'fontsize',12);
     S.pb_del(2) = uicontrol('style','pushbutton',... %delete
LC
                        'units','pixels',...
                        'position',[655 286 80 30],...
                        'visible','off',...
                        'string','Delete',...
                        'fontsize',12);
     S.pb_del(3) = uicontrol('style','pushbutton',... %delete
SYS
                        'units','pixels',...
```

Continue on next page

```
                            'position',[655 286 80 30],...
                            'visible','off',...
                            'string','Delete',...
                            'fontsize',12);
     S.pb_del(4) = uicontrol('style','pushbutton',... %delete
SH
                            'units','pixels',...
                            'position',[655 286 80 30],...
                            'visible','off',...
                            'string','Delete',...
                            'fontsize',12);

     % Edit Text
     S.ed = uicontrol('style','edit',...
                           'unit','pix',...
                           'position',[436 316 215 30],...
                           'visible','off',...
                           'fontsize',12,...
                           'string',[],...
                           'HorizontalAlignment','left');

     S.ed_void = uicontrol('style','edit',...%save pathfile
project
                           'unit','pix',...
                           'visible','off');

     S.ed_void2 = uicontrol('style','edit',...%save pathfile
ideas text
                           'unit','pix',...
                           'visible','off');
     % Panels
     S.pn(1) = uipanel('Title','General Demands',...
                          'FontSize',12,...
                          'visible','off',...
                          'Position',[.13 .485 .36 .38]);
     S.pn(2) = uipanel('Title','Life Cycle Phases',...
                          'FontSize',12,...
                          'visible','off',...
                          'Position',[.51 .485 .36 .38]);
     S.pn(3) = uipanel('Title','Systems',...
                          'FontSize',12,...
                          'visible','off',...
                          'Position',[.13 .09 .36 .38]);
     S.pn(4) = uipanel('Title','Stakeholders',...
                          'FontSize',12,...
                          'visible','off',...
                          'Position',[.51 .09 .36 .38]);
     S.pn5 = uipanel('Title','Hints',...
                          'FontSize',12,...
                          'visible','off',...
```

Continue on next page

```
                        'Position',[.13 .088 .365 .777]);
      S.pn6 = uipanel('Title','Ideas',...
                        'FontSize',12,...
                        'visible','off',...
                        'Position',[.505 .088 .365 .777]);
      S.pna(1) = uipanel('Title','General Demands',...
                        'FontSize',12,...
                        'visible','off',...
                        'Position',[.13 .450 .740 .415]);
      S.pna(2) = uipanel('Title','Life Cycle Phases',...
                        'FontSize',12,...
                        'visible','off',...
                        'Position',[.13 .450 .740 .415]);
      S.pna(3) = uipanel('Title','Systems',...
                        'FontSize',12,...
                        'visible','off',...
                        'Position',[.13 .450 .740 .415]);
      S.pna(4) = uipanel('Title','Stakeholders',...
                        'FontSize',12,...
                        'visible','off',...
                        'Position',[.13 .450 .740 .415]);
      % Checkboxes
      S.ch(1) = uicontrol('style','check',...
                         'unit','pix',...
                         'position',[120 478 190 35],...
                         'visible','off',...
                         'value',1,...
                         'string','Fulfilled needs',...
                         'fontsize',12);
      S.ch(2) = uicontrol('style','check',...
                         'unit','pix',...
                         'position',[120 455 180 35],...
                         'visible','off',...
                         'value',1,...
                         'string','Versatility of
use/adaptability',...
                         'fontsize',12);
      S.ch(3) = uicontrol('style','check',...
                         'unit','pix',...
                         'position',[120 432 180 35],...
                         'visible','off',...
                         'value',1,...
                         'string','Reliability/safety',...
                         'fontsize',12);
      S.ch(4) = uicontrol('style','check',...
                         'unit','pix',...
                         'position',[120 409 180 35],...
                         'visible','off',...
                         'value',1,...
                         'string','Ease',...
```

Continue on next page

```
                    'fontsize',12);
    S.ch(5) = uicontrol('style','check',...
                    'unit','pix',...
                    'position',[120 386 180 35],...
                    'visible','off',...
                    'value',1,...
                    'string','Aesthetics/style/ethics',...
                    'fontsize',12);
    S.ch(6) = uicontrol('style','check',...
                    'unit','pix',...
                    'position',[120 363 300 35],...
                    'visible','off',...
                    'value',1,...
                    'string','Quickness',...
                    'fontsize',12);
    S.ch(7) = uicontrol('style','check',...
                    'unit','pix',...
                    'position',[120 340 180 35],...
                    'visible','off',...
                    'value',1,...
                    'string','Cheapness',...
                    'fontsize',12);
    S.ch(8) = uicontrol('style','check',...
                    'unit','pix',...
                    'position',[120 317 180 35],...
                    'visible','off',...
                    'value',1,...
                    'string','Comfort/ergonomics',...
                    'fontsize',12);

    S.ch(9) = uicontrol('style','check',...
                    'unit','pix',...
                    'position',[443 478 245 35],...
                    'visible','off',...
                    'value',1,...
                    'string','purchasing, choice and access
activities',...
                    'fontsize',12);
    S.ch(10) = uicontrol('style','check',...
                    'unit','pix',...
                    'position',[443 455 180 35],...
                    'visible','off',...
                    'value',1,...
                    'string','before use operations',...
                    'fontsize',12);
    S.ch(11) = uicontrol('style','check',...
                    'unit','pix',...
                    'position',[443 432 180 35],...
                    'visible','off',...
                    'value',1,...
```

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```
                      'string','utilization time',...
                      'fontsize',12);
     S.ch(12) = uicontrol('style','check',...
                      'unit','pix',...
                      'position',[443 409 245 35],...
                      'visible','off',...
                      'value',1,...
                      'string','elapsed time before further
exploitations',...
                      'fontsize',12);
     S.ch(13) = uicontrol('style','check',...
                      'unit','pix',...
                      'position',[443 386 180 35],...
                      'visible','off',...
                      'value',1,...
                      'string','end of the functioning',...
                      'fontsize',12);

     S.ch(14) = uicontrol('style','check',...
                      'unit','pix',...
                      'position',[120 238 265 35],...
                      'visible','off',...
                      'value',1,...
                      'string','environment in which the
product is situated',...
                      'fontsize',12);
     S.ch(15) = uicontrol('style','check',...
                      'unit','pix',...
                      'position',[120 215 180 35],...
                      'visible','off',...
                      'value',1,...
                      'string','product or service level',...
                      'fontsize',12);
     S.ch(16) = uicontrol('style','check',...
                      'unit','pix',...
                      'position',[120 192 220 35],...
                      'visible','off',...
                      'value',1,...
                      'string','parts, components and
accessories',...
                      'fontsize',12);

     S.ch(17) = uicontrol('style','check',...
                      'unit','pix',...
                      'position',[443 238 180 35],...
                      'visible','off',...
                      'value',1,...
                      'string','buyers',...
                      'fontsize',12);
     S.ch(18) = uicontrol('style','check',...
```

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```
                 'unit','pix',...
                 'position',[443 215 180 35],...
                 'visible','off',...
                 'value',1,...
                 'string','users',...
                 'fontsize',12);
S.ch(19) = uicontrol('style','check',...
                 'unit','pix',...
                 'position',[443 192 180 35],...
                 'visible','off',...
                 'value',1,...
                 'string','beneficiaries',...
                 'fontsize',12);
S.ch(20) = uicontrol('style','check',...
                 'unit','pix',...
                 'position',[443 169 180 35],...
                 'visible','off',...
                 'value',1,...
                 'string','outsiders',...
                 'fontsize',12);

S.ch(21) = uicontrol('style','check',...
                 'unit','pix',...
                 'position',[120 294 180 35],...
                 'visible','off',...
                 'string','Generic demand (Quick)',...
                 'fontsize',12,'fontweight','bold');

% Toggles will act as the tabs.
S.tg(1) = uicontrol('style','toggle',...
                    'units','pixels',...
                    'position',[110 550 125 40],...
                    'visible','off',...
                    'string','Dimensions',...
                    'val',1);
S.tg(2) = uicontrol('style','toggle',...
                    'units','pixels',...
                    'position',[237.5 550 125 40],...
                    'visible','off',...
                    'string','Quick',...
                    'value',0,...
                    'enable','off');
S.tg(3) = uicontrol('style','toggle',...
                    'units','pixels',...
                    'position',[365 550 125 40],...
                    'visible','off',...
                    'string','Standard',...
                    'value',0,...
                    'enable','off');
S.tg(4) = uicontrol('style','toggle',...
```

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```
                            'units','pixels',...
                            'position',[492.5 550 125 40],...
                            'visible','off',...
                            'string','Detailed',...
                            'value',0,...
                            'enable','off');
S.tg(5) = uicontrol('style','toggle',...
                            'units','pixels',...
                            'position',[620 550 125 40],...
                            'visible','off',...
                            'string','Info',...
                            'value',0,...
                            'enable','on');
%Toggle detailed
S.tga(1) = uicontrol('style','toggle',...
                            'units','pixels',...
                            'position',[230 23 125 30],...
                            'fontsize',12,...
                            'string','Life Cycle',...
                            'visible','off',...
                            'val',1);
S.tga(2) = uicontrol('style','toggle',...
                            'units','pixels',...
                            'position',[365 23 125 30],...
                            'fontsize',12,...
                            'string','Systems',...
                            'visible','off',...
                            'value',0);
S.tga(3) = uicontrol('style','toggle',...
                            'units','pixels',...
                            'position',[500 23 125 30],...
                            'fontsize',12,...
                            'string','Stakeholders',...
                            'visible','off',...
                            'value',0);
%Text
S.txi = uicontrol('style','text',...
                         'units','pixels',...
                         'position',[110 490 634 37],...
                         'visible','on',...
                         'string',{'Welcome to iDea!'},...
                         'BackgroundColor',[0.8 0.8 0.8],...
                         'fontsize',43);
S.txi2 = uicontrol('style','text',...
                         'units','pixels',...
                         'position',[110 150 634 25],...
                         'visible','on',...
                         'string',{'What do you want to do?'},...
                         'BackgroundColor',[0.8 0.8 0.8],...
                         'fontsize',21);
```

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```
    S.tx1 = uicontrol('style','text',...
                      'units','pixels',...
                      'position',[110 33 637 510],...
                      'visible','off',...
                      'string',{' ',' ',' ',' ',' ',' ','
',...
                      ' ','iDea is a tool that supports','the
idea generation.',...
                      'Hope you enjoy.',' ','
','Copyright:',...
                      'Daniele Bacciotti 2014'},...
                      'fontsize',18,'fontweight','bold');
    S.tx2 = uicontrol('style','text',...
                      'unit','pix',...
                      'position',[322 30 210 16],...
                      'visible','off',...
                      'visible','off',...
                      'string',{'Select your project''s
dimensions.'},...
                      'fontsize',12,'fontweight','bold');
    S.tx3 = uicontrol('style','text',...
                      'unit','pix',...
                      'position',[337 30 180 16],...
                      'visible','off',...
                      'string',{'Select a tool or go
back.'},...
                      'fontsize',12,'fontweight','bold');
    S.tx4 = uicontrol('style','text',...
                      'unit','pix',...
                      'position',[322 30 210 16],...
                      'visible','off',...
                      'string',{'Identify new ideas.'},...
                      'fontsize',12,'fontweight','bold');
    S.tx5(1) = uicontrol('style','text',...
                      'unit','pix',...
                      'position',[121 487 245 16],...
                      'visible','off',...
                      'string','Do you identify any new idea
considering...?',...

'fontsize',12,'HorizontalAlignment','left');
    S.tx5(2) = uicontrol('style','text',...
                      'unit','pix',...
                      'position',[121 460 100 16],...
                      'visible','off',...
                      'string','Life cycle phase/s:',...

'fontsize',12,'HorizontalAlignment','left');
    S.tx5(3) = uicontrol('style','text',...
                      'unit','pix',...
```

Continue on next page

```
                      'position',[121 319 100 16],...
                      'visible','off',...
                      'string','System/s:',...

'fontsize',12,'HorizontalAlignment','left');
     S.tx5(4) = uicontrol('style','text',...
                      'unit','pix',...
                      'position',[121 180 245 16],...
                      'visible','off',...
                      'string','Stakeholder/s:',...

'fontsize',12,'HorizontalAlignment','left');
     S.tx6 = uicontrol('style','text',...
                      'unit','pix',...
                      'position',[121 463 245 40],...
                      'visible','off',...
                      'string','Do you identify any new idea
considering the combination of...?',...

'fontsize',12,'HorizontalAlignment','left');
     S.tx7 = uicontrol('style','text',...
                      'unit','pix',...
                      'position',[302 528 250 16],...
                      'visible','off',...
                      'string',{'Select the GDs and explore
the dimension.'},...
                      'fontsize',12,'fontweight','bold');
     S.tx8 = uicontrol('style','text',...
                      'unit','pix',...
                      'position',[285 528 280 16],...
                      'visible','off',...
                      'string',{'Select the LC phases and
explore the dimension.'},...
                      'fontsize',12,'fontweight','bold');
     S.tx9 = uicontrol('style','text',...
                      'unit','pix',...
                      'position',[302 528 250 16],...
                      'visible','off',...
                      'string',{'Select the SYSs and explore
the dimension.'},...
                      'fontsize',12,'fontweight','bold');
     S.tx10 = uicontrol('style','text',...
                      'unit','pix',...
                      'position',[302 528 250 16],...
                      'visible','off',...
                      'string',{'Select the SHs and explore
the dimension.'},...
                      'fontsize',12,'fontweight','bold');
     S.tx11 = uicontrol('style','text',...
                      'unit','pix',...
```

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```
                  'position',[420 415 11 16],...
                  'visible','off',...
                  'string',{'>'},...
                  'fontsize',12,'fontweight','bold');

% Lists
S.ls(1) = uicontrol('style','list',...
                  'unit','pix',...
                  'position',[125 317 279 180],...
                  'value', [],...
                  'visible','off',...
                  'min',0,'max',2,...
                  'fontsize',12,...
                  'string',{});
S.ls(2) = uicontrol('style','list',...
                  'unit','pix',...
                  'position',[448 317 279 180],...
                  'value', [],...
                  'visible','off',...
                  'min',0,'max',2,...
                  'fontsize',12,...
                  'string',{});
S.ls(3) = uicontrol('style','list',...
                  'unit','pix',...
                  'position',[125 78 279 180],...
                  'value', [],...
                  'visible','off',...
                  'min',0,'max',2,...
                  'fontsize',12,...
                  'string',{});
S.ls(4) = uicontrol('style','list',...
                  'unit','pix',...
                  'position',[448 78 279 180],...
                  'value', [],...
                  'visible','off',...
                  'min',0,'max',2,...
                  'fontsize',12,...
                  'string',{});
S.ls5(1) = uicontrol('style','list',...
                  'unit','pix',...
                  'position',[120 347 293 110],...
                  'value', [],...
                  'visible','off',...
                  'min',0,'max',2,...
                  'fontsize',12,...
                  'string',{});
S.ls5(2) = uicontrol('style','list',...
                  'unit','pix',...
                  'position',[120 206 293 110],...
                  'value', [],...
```

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```
                 'visible','off',...
                 'min',0,'max',2,...
                 'fontsize',12,...
                 'string',{});
S.ls5(3) = uicontrol('style','list',...
                 'unit','pix',...
                 'position',[120 67 293 110],...
                 'value', [],...
                 'visible','off',...
                 'min',0,'max',2,...
                 'fontsize',12,...
                 'string',{});
S.ed1 = uicontrol('style','edit',...
                 'unit','pix',...
                 'position',[435 68 300 438],...
                 'max', 2,...
                 'visible','off',...
                 'fontsize',12,...
                 'string','Write here your ideas...',...
                 'HorizontalAlignment','left');
S.ls6 = uicontrol('style','list',...
                 'unit','pix',...
                 'position',[120 68 293 403],...
                 'visible','off',...
                 'min',0,'max',2,...
                 'fontsize',12,...
                 'string',{});
S.ls7 = uicontrol('style','list',...
                 'unit','pix',...
                 'position',[120 68 293 415],...
                 'visible','off',...
                 'min',0,'max',2,...
                 'fontsize',12,...
                 'string',{});
S.lsa(1) = uicontrol('style','list',...
                 'unit','pix',...
                 'position',[120 290 293 215],...
                 'visible','off',...
                 'value', [],...
                 'min',0,'max',2,...
                 'fontsize',12,...
                 'string',{});
S.lsa(2) = uicontrol('style','list',...
                 'unit','pix',...
                 'position',[120 290 293 215],...
                 'visible','off',...
                 'value', [],...
                 'min',0,'max',2,...
                 'fontsize',12,...
                 'string',{});
```

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```
    S.lsa(3) = uicontrol('style','list',...
                     'unit','pix',...
                     'position',[120 290 293 215],...
                     'visible','off',...
                     'value', [],...
                     'min',0,'max',2,...
                     'fontsize',12,...
                     'string',{});
    S.lsa(4) = uicontrol('style','list',...
                     'unit','pix',...
                     'position',[120 290 293 215],...
                     'visible','off',...
                     'value', [],...
                     'min',0,'max',2,...
                     'fontsize',12,...
                     'string',{});
    S.lsa2(1) = uicontrol('style','list',...
                     'unit','pix',...
                     'position',[439 350 293 155],...
                     'value', [],...
                     'visible','off',...
                     'min',0,'max',2,...
                     'fontsize',12,...
                     'string',{'Quality of the expected
outcomes',...
                     'Quantity or extent of the expected
outcomes',...
                     'Duration of the expected outcomes',...
                     'Fun and adventure'});
    S.lsa2(2) = uicontrol('style','list',...
                     'unit','pix',...
                     'position',[439 350 293 155],...
                     'value', [],...
                     'visible','off',...
                     'min',0,'max',2,...
                     'fontsize',12,...
                     'string',{'Suitability of the product
according to different demands',...
                     'Adaptability of the product in
diverging conditions with respect to the designed preferred
ones',...
                     'Expand or upgrade the range of product
functionalities'});
    S.lsa2(3) = uicontrol('style','list',...
                     'unit','pix',...
                     'position',[439 350 293 155],...
                     'value', [],...
                     'visible','off',...
                     'min',0,'max',2,...
                     'fontsize',12,...
```

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```
                      'string',{'Controllability of the system
in order to obtain the expected outcomes',...
                      'Integrity of the product itself, its
resistance to planned or accidental stress or collision, the
strength against wear or corrosion',...
                      'The limitation of damages towards the
external environment',...
                      'The limitation of damages provoked by
the external environment',...
                      'The safety and innocuousness for human
health and people''s psychological and social conditions',...
                      'The duration, the expected life of the
product'});
     S.lsa2(4) = uicontrol('style','list',...
                      'unit','pix',...
                      'position',[439 350 293 155],...
                      'value', [],...
                      'visible','off',...
                      'min',0,'max',2,...
                      'fontsize',12,...
                      'string',{'The reduction of the
information and skills to be gathered during the product life
cycle',...
                      'The ease of acquiring the product, due
to market penetration and distribution policies',...
                      'The ease of managing, maintaining,
assembling, disassembling, upgrading, substituting components
or accessories',...
                      'The independence from the use of other
materials, instruments, technical systems',...
                      'The reduction of auxiliary functions to
be delivered',...
                      'The additional services provided in
order to attenuate the consumption of individual resources,
the customer care'});
     S.lsa2(5) = uicontrol('style','list',...
                      'unit','pix',...
                      'position',[439 350 293 155],...
                      'value', [],...
                      'visible','off',...
                      'min',0,'max',2,...
                      'fontsize',12,...
                      'string',{'Customize the product or
certain properties',...
                      'The possibility of benefitting of the
product (or its parts) for different employment after the end
of its life',...
                      'The aesthetical requirements and the
emotional dimension of the product, the style, the fashion
content',...
```

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```
                        'What the product evokes, the lifestyle
that the object implies, the prestige it generates for the
owner as a feeling of distinction and recognition',...
                        'The environmental sustainability',...
                        'The ethics as a distinguishing
factor'});
     S.lsa2(6) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'The reduction of time to be
waited before the functioning of the product delivers the
expected outcomes',...
                        'The limitation of the time required to
perform operations'});
     S.lsa2(7) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'The reduction of the
consumption of parts, components or consumables',...
                        'The limitation of the required energy
(or human power) needed for the product during its
lifecycle',...
                        'Product/service cheapness',...
                        'Accessories cheapness',...
                        'Cheapness of various activities during
product life cycle'});
     S.lsa2(8) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'The absence of bother for the
people',...
                        'The comfort of use, the ergonomics, the
manageability',...
                        'The limitation of occupied space',...
                        'The lightness and the portability'});

     S.lsa2(9) = uicontrol('style','list',...
                        'unit','pix',...
```

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```
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'identifying the product on
the web',...
                        'identifying the product on leaflets,
brochures',...
                        'identifying the product in the
shop',...
                        'identifying the product on various kind
of advertising',...
                        'comparing with similar products',...
                        'communicating with the firm',...
                        'reaching the shop',...
                        'waiting to be assisted',...
                        'managing the payment (cash, credit
card, etc.)',...
                        'using coupons and discounts',...
                        'receiving prizes or free
accessories/services'});
     S.lsa2(10) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'shipping',...
                        'carrying',...
                        'unpacking',...
                        'training',...
                        'assembling',...
                        'managing administration issues,
bureaucracies',...
                        'communicating with the firm'});
     S.lsa2(11) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'switching on/off',...
                        'handling',...
                        'feeding',...
                        'performing other operations in the mean
time',...
                        'using the product',...
```

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```
                        'using accessories'});
     S.lsa2(12) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'exploiting the outcomes of
the product utilization',...
                        'maintaining',...
                        'cleaning',...
                        'repairing',...
                        'storing',...
                        'mounting accessories or changing
parts',...
                        'protecting the product',...
                        'carrying',...
                        'waiting for the system being ready',...
                        'receiving assistance'});
     S.lsa2(13) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'reselling the product and its
accessories',...
                        'recycling or disposing of the
product',...
                        'donating the product to needy
people',...
                        'using the product as a collection
item',...
                        'using the product for alternative
employments'});

     S.lsa2(14) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'weather conditions',...
                        'external environment',...
                        'place in which the product is situated
(room or virtual space)',...
                        'tools or matched machinery',...
```

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```
                        'matched or surrounding items',...
                        'other similar or identical systems
placed nearby'});
     S.lsa2(15) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'product in general',...
                        'service in general'});
     S.lsa2(16) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'case',...
                        'engine and transmission',...
                        'connecting or fastening means',...
                        'handle',...
                        'opening/closing means',...
                        'movement means',...
                        'expansions',...
                        'aesthetic accessories',...
                        'bags, packaging',...
                        'fuel or consumables',...
                        'battery and chargers'});

     S.lsa2(17) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'manager, decision maker',...
                        'parents or tutor',...
                        'reseller',...
                        'professional',...
                        'agent'});
     S.lsa2(18) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
```

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```
                        'string',{'teacher/trainer',...
                        'worker, employee',...
                        'disabled person',...
                        'not-standard user'});
    S.lsa2(19) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'community, citizenry',...
                        'children',...
                        'patients',...
                        'animals'});
    S.lsa2(20) = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{'maintenance technicians or
helpers',...
                        'third party developers',...
                        'assistants',...
                        'neighbors',...
                        'relatives',...
                        'consultants, advisors',...
                        'unknown people coming into casual
contact with the product'});
    S.lsa2_null = uicontrol('style','list',...
                        'unit','pix',...
                        'position',[439 350 293 155],...
                        'value', [],...
                        'visible','off',...
                        'min',0,'max',2,...
                        'fontsize',12,...
                        'string',{});
    %Images
    S.ax(1) = axes('units','pixels',...
                'visible','off',...
                'position',[145 20 570 250]);
    S.im(1)=imshow('GD.png');
    set(S.im(1),'visible','off');
    S.ax(2) = axes('units','pixels',...
                'visible','off',...
                'position',[150 72 540 200]);
    S.im(2)=imshow('LC.png');
    set(S.im(2),'visible','off');
```

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```
S.ax(3) = axes('units','pixels',...
            'visible','off',...
            'position',[153 66 545 205]);
S.im(3)=imshow('SYS.png');
set(S.im(3),'visible','off');
S.ax(4) = axes('units','pixels',...
            'visible','off',...
            'position',[140 62 550 210]);
S.im(4)=imshow('SH.png');
set(S.im(4),'visible','off');

S.ax(5) = axes('units','pixels',...
            'visible','off',...
            'position',[135 200 580 260]);
S.im(5)=imshow('iDea.png');
set(S.im(5),'visible','on');

% Set remaining properties.
set(S.pbO,'callback',{@pbO_call,S})  % Set the callbacks.
set(S.pbN,'callback',{@pbN_call,S})
set(S.pb1,'callback',{@pb1_call,S})
set(S.pb2,'callback',{@pb2_call,S})
set(S.pb3,'callback',{@pb3_call,S})
set(S.pb3bis,'callback',{@pb3bis_call,S})
set(S.pb4,'callback',{@pb4_call,S})
set(S.pb5,'callback',{@pb5_call,S})
set(S.pb6,'callback',{@pb6_call,S})
set(S.pb7,'callback',{@pb7_call,S})
set(S.pb8,'callback',{@pb8_call,S})
set(S.pb_add(1),'callback',{@pbadd1_call,S})
set(S.pb_add(2),'callback',{@pbadd2_call,S})
set(S.pb_add(3),'callback',{@pbadd3_call,S})
set(S.pb_add(4),'callback',{@pbadd4_call,S})
set(S.pb_del(1),'callback',{@pbdel1_call,S})
set(S.pb_del(2),'callback',{@pbdel2_call,S})
set(S.pb_del(3),'callback',{@pbdel3_call,S})
set(S.pb_del(4),'callback',{@pbdel4_call,S})
set(S.tg(:),{'callback'},{{@tg_call,S}})
set(S.tga(:),{'callback'},{{@tga_call,S}})
set(S.ch(21),{'callback'},{{@ch21_call,S}})
set(S.lsa(1),{'callback'},{{@lsa1_call,S}})
set(S.lsa(2),{'callback'},{{@lsa2_call,S}})
set(S.lsa(3),{'callback'},{{@lsa3_call,S}})
set(S.lsa(4),{'callback'},{{@lsa4_call,S}})

set(S.fm(2),{'callback'},{{@fm2_call,S}})
set(S.fm(3),{'callback'},{{@fm3_call,S}})
set(S.fm(4),{'callback'},{{@fm4_call,S}})
set(S.fm(5),{'callback'},{{@fm5_call,S}})
```

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```
set(S.ls6,{'callback'},{{@ls6_call,S}})
set(S.ls7,{'callback'},{{@ls7_call,S}})
set(S.lsa2(1),{'callback'},{{@lsa21_call,S}})
set(S.lsa2(2),{'callback'},{{@lsa22_call,S}})
set(S.lsa2(3),{'callback'},{{@lsa23_call,S}})
set(S.lsa2(4),{'callback'},{{@lsa24_call,S}})
set(S.lsa2(5),{'callback'},{{@lsa25_call,S}})
set(S.lsa2(6),{'callback'},{{@lsa26_call,S}})
set(S.lsa2(7),{'callback'},{{@lsa27_call,S}})
set(S.lsa2(8),{'callback'},{{@lsa28_call,S}})
set(S.lsa2(9),{'callback'},{{@lsa29_call,S}})
set(S.lsa2(10),{'callback'},{{@lsa210_call,S}})
set(S.lsa2(11),{'callback'},{{@lsa211_call,S}})
set(S.lsa2(12),{'callback'},{{@lsa212_call,S}})
set(S.lsa2(13),{'callback'},{{@lsa213_call,S}})
set(S.lsa2(14),{'callback'},{{@lsa214_call,S}})
set(S.lsa2(15),{'callback'},{{@lsa215_call,S}})
set(S.lsa2(16),{'callback'},{{@lsa216_call,S}})
set(S.lsa2(17),{'callback'},{{@lsa217_call,S}})
set(S.lsa2(18),{'callback'},{{@lsa218_call,S}})
set(S.lsa2(19),{'callback'},{{@lsa219_call,S}})
set(S.lsa2(20),{'callback'},{{@lsa220_call,S}})

%New project Menu
function [] = fm2_call(varargin)
S = varargin{3};
[file, path] = uiputfile(...
 {'*.mat'},'Save as');
if file==0
    return
end
pathfile=joinseq(path,file);
set(S.ed_void,'String',[]);
set(S.ed_void,'String',pathfile);

set(S.ch(1),'value',1);
set(S.ch(2),'value',1);
set(S.ch(3),'value',1);
set(S.ch(4),'value',1);
set(S.ch(5),'value',1);
set(S.ch(6),'value',1);
set(S.ch(7),'value',1);
set(S.ch(8),'value',1);
set(S.ch(9),'value',1);
set(S.ch(10),'value',1);
set(S.ch(11),'value',1);
set(S.ch(12),'value',1);
set(S.ch(13),'value',1);
set(S.ch(14),'value',1);
set(S.ch(15),'value',1);
```

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```
     set(S.ch(16),'value',1);
     set(S.ch(17),'value',1);
     set(S.ch(18),'value',1);
     set(S.ch(19),'value',1);
     set(S.ch(20),'value',1);
     set(S.ch(21),'value',0);
     set(S.ed1 ,'string','Write here your ideas...',...
               'Enable', 'inactive',...
               'Callback', @print_string,...
               'ButtonDownFcn', @clear);
     set(S.lsa2(1) ,'string', {'Quality of the expected
outcomes',...
                   'Quantity or extent of the expected
outcomes',...
                   'Duration of the expected outcomes',...
                   'Fun and adventure'});
     set(S.lsa2(2) ,'string',{'Suitability of the product
according to different demands',...
                   'Adaptability of the product in diverging
conditions with respect to the designed preferred ones',...
                   'Expand or upgrade the range of product
functionalities'});
     set(S.lsa2(3) ,'string',{'Controllability of the system
in order to obtain the expected outcomes',...
                   'Integrity of the product itself, its
resistance to planned or accidental stress or collision, the
strength against wear or corrosion',...
                   'The limitation of damages towards the
external environment',...
                   'The limitation of damages provoked by the
external environment',...
                   'The safety and innocuousness for human
health and people''s psychological and social conditions',...
                   'The duration, the expected life of the
product'});
     set(S.lsa2(4) ,'string',{'The reduction of the
information and skills to be gathered during the product life
cycle',...
                   'The ease of acquiring the product, due to
market penetration and distribution policies',...
                   'The ease of managing, maintaining,
assembling, disassembling, upgrading, substituting components
or accessories',...
                   'The independence from the use of other
materials, instruments, technical systems',...
                   'The reduction of auxiliary functions to
be delivered',...
                   'The additional services provided in order
to attenuate the consumption of individual resources, the
customer care'});
```

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```
     set(S.lsa2(5) ,'string',{'Customize the product or
certain properties',...
                     'The possibility of benefitting of the
product (or its parts) for different employment after the end
of its life',...
                     'The aesthetical requirements and the
emotional dimension of the product, the style, the fashion
content',...
                     'What the product evokes, the lifestyle
that the object implies, the prestige it generates for the
owner as a feeling of distinction and recognition',...
                     'The environmental sustainability',...
                     'The ethics as a distinguishing factor'});
     set(S.lsa2(6) ,'string',{'The reduction of time to be
waited before the functioning of the product delivers the
expected outcomes',...
                     'The limitation of the time required to
perform operations'});
     set(S.lsa2(7) ,'string',{'The reduction of the
consumption of parts, components or consumables',...
                     'The limitation of the required energy (or
human power) needed for the product during its lifecycle',...
                     'Product/service cheapness',...
                     'Accessories cheapness',...
                     'Cheapness of various activities during
product life cycle'});
     set(S.lsa2(8) ,'string',{'The absence of bother for the
people',...
                     'The comfort of use, the ergonomics, the
manageability',...
                     'The limitation of occupied space',...
                     'The lightness and the portability'});
     set(S.lsa2(9) ,'string',{'identifying the product on the
web',...
                     'identifying the product on leaflets,
brochures',...
                     'identifying the product in the shop',...
                     'identifying the product on various kind
of advertising',...
                     'comparing with similar products',...
                     'communicating with the firm',...
                     'reaching the shop',...
                     'waiting to be assisted',...
                     'managing the payment (cash, credit card,
etc.)',...
                     'using coupons and discounts',...
                     'receiving prizes or free
accessories/services'});
     set(S.lsa2(10) ,'string',{'shipping',...
                     'carrying',...
```

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```
                    'unpacking',...
                    'training',...
                    'assembling',...
                    'managing administration issues,
bureaucracies',...
                    'communicating with the firm'});
     set(S.lsa2(11) ,'string',{'switching on/off',...
                    'handling',...
                    'feeding',...
                    'performing other operations in the mean
time',...
                    'using the product',...
                    'using accessories'});
     set(S.lsa2(12) ,'string',{'exploiting the outcomes of the
product utilization',...
                    'maintaining',...
                    'cleaning',...
                    'repairing',...
                    'storing',...
                    'mounting accessories or changing
parts',...
                    'protecting the product',...
                    'carrying',...
                    'waiting for the system being ready',...
                    'receiving assistance'});
     set(S.lsa2(13) ,'string',{'reselling the product and its
accessories',...
                    'recycling or disposing of the
product',...
                    'donating the product to needy people',...
                    'using the product as a collection
item',...
                    'using the product for alternative
employments'});
     set(S.lsa2(14) ,'string',{'weather conditions',...
                    'external environment',...
                    'place in which the product is situated
(room or virtual space)',...
                    'tools or matched machinery',...
                    'matched or surrounding items',...
                    'other similar or identical systems placed
nearby'});
     set(S.lsa2(15) ,'string',{'product in general',...
                    'service in general'});
     set(S.lsa2(16) ,'string',{'case',...
                    'engine and transmission',...
                    'connecting or fastening means',...
                    'handle',...
                    'opening/closing means',...
                    'movement means',...
```

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```
                     'expansions',...
                     'aesthetic accessories',...
                     'bags, packaging',...
                     'fuel or consumables',...
                     'battery and chargers'});
     set(S.lsa2(17) ,'string',{'manager, decision maker',...
                     'parents or tutor',...
                     'reseller',...
                     'professional',...
                     'agent'});
     set(S.lsa2(18) ,'string',{'teacher/trainer',...
                     'worker, employee',...
                     'disabled person',...
                     'not-standard user'});
     set(S.lsa2(19) ,'string',{'community, citizenry',...
                     'children',...
                     'patients',...
                     'animals'});
     set(S.lsa2(20) ,'string',{'maintenance technicians or
helpers',...
                     'third party developers',...
                     'assistants',...
                     'neighbors',...
                     'relatives',...
                     'consultants, advisors',...
                     'unknown people coming into casual contact
with the product'});

     state.ch1 = get(S.ch(1),'value');
     state.ch2 = get(S.ch(2),'value');
     state.ch3 = get(S.ch(3),'value');
     state.ch4 = get(S.ch(4),'value');
     state.ch5 = get(S.ch(5),'value');
     state.ch6 = get(S.ch(6),'value');
     state.ch7 = get(S.ch(7),'value');
     state.ch8 = get(S.ch(8),'value');
     state.ch9 = get(S.ch(9),'value');
     state.ch10 = get(S.ch(10),'value');
     state.ch11 = get(S.ch(11),'value');
     state.ch12 = get(S.ch(12),'value');
     state.ch13 = get(S.ch(13),'value');
     state.ch14 = get(S.ch(14),'value');
     state.ch15 = get(S.ch(15),'value');
     state.ch16 = get(S.ch(16),'value');
     state.ch17 = get(S.ch(17),'value');
     state.ch18 = get(S.ch(18),'value');
     state.ch19 = get(S.ch(19),'value');
     state.ch20 = get(S.ch(20),'value');
     state.ch21 = get(S.ch(21),'value');
     state.ed1 = get(S.ed1 ,'string');
```

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```
     state.lsa21 = get(S.lsa2(1) ,'string');
     state.lsa22 = get(S.lsa2(2) ,'string');
     state.lsa23 = get(S.lsa2(3) ,'string');
     state.lsa24 = get(S.lsa2(4) ,'string');
     state.lsa25 = get(S.lsa2(5) ,'string');
     state.lsa26 = get(S.lsa2(6) ,'string');
     state.lsa27 = get(S.lsa2(7) ,'string');
     state.lsa28 = get(S.lsa2(8) ,'string');
     state.lsa29 = get(S.lsa2(9) ,'string');
     state.lsa210 = get(S.lsa2(10) ,'string');
     state.lsa211 = get(S.lsa2(11) ,'string');
     state.lsa212 = get(S.lsa2(12) ,'string');
     state.lsa213 = get(S.lsa2(13) ,'string');
     state.lsa214 = get(S.lsa2(14) ,'string');
     state.lsa215 = get(S.lsa2(15) ,'string');
     state.lsa216 = get(S.lsa2(16) ,'string');
     state.lsa217 = get(S.lsa2(17) ,'string');
     state.lsa218 = get(S.lsa2(18) ,'string');
     state.lsa219 = get(S.lsa2(19) ,'string');
     state.lsa220 = get(S.lsa2(20) ,'string');

     save(pathfile,'state')

     set([S.fm(4);S.fm(5)],'enable','on');
     set([S.tx2;S.ch(:);S.pn(:);S.tg(:);S.pb1],'visible','on')
;
     set([S.txi;S.txi2;S.im(5);S.im(1);S.im(2);S.im(3);S.im(4)
;S.pbO;S.pbN;...
         S.pb2;S.pb3;S.pb3bis;S.pb4;S.pb5;...

S.pb6;S.pb7;S.pb8;S.pb_add(1);S.pb_add(2);S.pb_add(3);S.pb_add
(4);...

S.pb_del(1);S.pb_del(2);S.pb_del(3);S.pb_del(4);S.ed;S.pn5;S.p
n6;...

S.pna(1);S.pna(2);S.pna(3);S.pna(4);S.tga(1);S.tga(2);S.tga(3)
;...

S.tx1;S.tx3;S.tx4;S.tx5(1);S.tx5(2);S.tx5(3);S.tx5(4);S.tx6;S.
tx7;...

S.tx8;S.tx9;S.tx10;S.tx11;S.ls(1);S.ls(2);S.ls(3);S.ls(4);S.ls
5(1);...

S.ls5(2);S.ls5(3);S.ed1;S.ls6;S.ls7;S.lsa(1);S.lsa(2);S.lsa(3)
;...

S.lsa(4);S.lsa2(1);S.lsa2(2);S.lsa2(3);S.lsa2(4);S.lsa2(5);S.l
sa2(6);...
```

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```
S.lsa2(7);S.lsa2(8);S.lsa2(9);S.lsa2(10);S.lsa2(11);S.lsa2(12)
;...

S.lsa2(13);S.lsa2(14);S.lsa2(15);S.lsa2(16);S.lsa2(17);S.lsa2(
18);...
         S.lsa2(19);S.lsa2(20);S.lsa2_null],'visible','off');
     set(S.tg([2,3,4,5]),'val',0);
     set(S.tg([2,3,4]),'enable','off');

     %New project Button
     function [] = pbN_call(varargin)
     S = varargin{3};
     [file, path] = uiputfile(...
      {'*.mat'},'Save as');
     if file==0
         return
     end
     pathfile=joinseq(path,file);
     set(S.ed_void,'String',[]);
     set(S.ed_void,'String',pathfile);

     state.ch1 = get(S.ch(1),'value');
     state.ch2 = get(S.ch(2),'value');
     state.ch3 = get(S.ch(3),'value');
     state.ch4 = get(S.ch(4),'value');
     state.ch5 = get(S.ch(5),'value');
     state.ch6 = get(S.ch(6),'value');
     state.ch7 = get(S.ch(7),'value');
     state.ch8 = get(S.ch(8),'value');
     state.ch9 = get(S.ch(9),'value');
     state.ch10 = get(S.ch(10),'value');
     state.ch11 = get(S.ch(11),'value');
     state.ch12 = get(S.ch(12),'value');
     state.ch13 = get(S.ch(13),'value');
     state.ch14 = get(S.ch(14),'value');
     state.ch15 = get(S.ch(15),'value');
     state.ch16 = get(S.ch(16),'value');
     state.ch17 = get(S.ch(17),'value');
     state.ch18 = get(S.ch(18),'value');
     state.ch19 = get(S.ch(19),'value');
     state.ch20 = get(S.ch(20),'value');
     state.ch21 = get(S.ch(21),'value');
     state.ed1 = get(S.ed1 ,'string');
     state.lsa21 = get(S.lsa2(1) ,'string');
     state.lsa22 = get(S.lsa2(2) ,'string');
     state.lsa23 = get(S.lsa2(3) ,'string');
     state.lsa24 = get(S.lsa2(4) ,'string');
     state.lsa25 = get(S.lsa2(5) ,'string');
     state.lsa26 = get(S.lsa2(6) ,'string');
```

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```
state.lsa27 = get(S.lsa2(7) ,'string');
state.lsa28 = get(S.lsa2(8) ,'string');
state.lsa29 = get(S.lsa2(9) ,'string');
state.lsa210 = get(S.lsa2(10) ,'string');
state.lsa211 = get(S.lsa2(11) ,'string');
state.lsa212 = get(S.lsa2(12) ,'string');
state.lsa213 = get(S.lsa2(13) ,'string');
state.lsa214 = get(S.lsa2(14) ,'string');
state.lsa215 = get(S.lsa2(15) ,'string');
state.lsa216 = get(S.lsa2(16) ,'string');
state.lsa217 = get(S.lsa2(17) ,'string');
state.lsa218 = get(S.lsa2(18) ,'string');
state.lsa219 = get(S.lsa2(19) ,'string');
state.lsa220 = get(S.lsa2(20) ,'string');

save(pathfile,'state')

set([S.fm(4);S.fm(5)],'enable','on');
set([S.tx2;S.ch(:);S.pn(:);S.tg(:);S.pb1],'visible','on')
;
set([S.txi;S.txi2;S.im(5);S.pbO;S.pbN],'visible','off');
set(S.ed1, 'Enable', 'inactive',...
           'Callback', @print_string,...
           'ButtonDownFcn', @clear);

%Open Project Menu
function [] = fm3_call(varargin)
S = varargin{3};
[file, path] = uigetfile({'*.mat'},'Select file');
if file==0
    return
end
pathfile=joinseq(path,file);
load (pathfile)
 set(S.ch(1),'value',state.ch1);
 set(S.ch(2),'value',state.ch2);
 set(S.ch(3),'value',state.ch3);
 set(S.ch(4),'value',state.ch4);
 set(S.ch(5),'value',state.ch5);
 set(S.ch(6),'value',state.ch6);
 set(S.ch(7),'value',state.ch7);
 set(S.ch(8),'value',state.ch8);
 set(S.ch(9),'value',state.ch9);
 set(S.ch(10),'value',state.ch10);
 set(S.ch(11),'value',state.ch11);
 set(S.ch(12),'value',state.ch12);
 set(S.ch(13),'value',state.ch13);
 set(S.ch(14),'value',state.ch14);
 set(S.ch(15),'value',state.ch15);
 set(S.ch(16),'value',state.ch16);
```

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```
      set(S.ch(17),'value',state.ch17);
      set(S.ch(18),'value',state.ch18);
      set(S.ch(19),'value',state.ch19);
      set(S.ch(20),'value',state.ch20);
      set(S.ch(21),'value',state.ch21);
      set(S.ed1,'string',state.ed1);
      set(S.lsa2(1),'string',state.lsa21);
      set(S.lsa2(2),'string',state.lsa22);
      set(S.lsa2(3),'string',state.lsa23);
      set(S.lsa2(4),'string',state.lsa24);
      set(S.lsa2(5),'string',state.lsa25);
      set(S.lsa2(6),'string',state.lsa26);
      set(S.lsa2(7),'string',state.lsa27);
      set(S.lsa2(8),'string',state.lsa28);
      set(S.lsa2(9),'string',state.lsa29);
      set(S.lsa2(10),'string',state.lsa210);
      set(S.lsa2(11),'string',state.lsa211);
      set(S.lsa2(12),'string',state.lsa212);
      set(S.lsa2(13),'string',state.lsa213);
      set(S.lsa2(14),'string',state.lsa214);
      set(S.lsa2(15),'string',state.lsa215);
      set(S.lsa2(16),'string',state.lsa216);
      set(S.lsa2(17),'string',state.lsa217);
      set(S.lsa2(18),'string',state.lsa218);
      set(S.lsa2(19),'string',state.lsa219);
      set(S.lsa2(20),'string',state.lsa220);

      set(S.ed_void,'String',[]);
      set(S.ed_void,'String',pathfile);
      set([S.fm(4);S.fm(5)],'enable','on');

set([S.tx2;S.ch(:);S.pn(:);S.tg(:);S.pb1],'visible','on');

set([S.txi;S.txi2;S.im(5);S.im(1);S.im(2);S.im(3);S.im(4);S.pb
O;S.pbN;...
        S.pb2;S.pb3;S.pb3bis;S.pb4;S.pb5;...

S.pb6;S.pb7;S.pb8;S.pb_add(1);S.pb_add(2);S.pb_add(3);S.pb_add
(4);...

S.pb_del(1);S.pb_del(2);S.pb_del(3);S.pb_del(4);S.ed;S.pn5;S.p
n6;...

S.pna(1);S.pna(2);S.pna(3);S.pna(4);S.tga(1);S.tga(2);S.tga(3)
;...

S.tx1;S.tx3;S.tx4;S.tx5(1);S.tx5(2);S.tx5(3);S.tx5(4);S.tx6;S.
tx7;...

S.tx8;S.tx9;S.tx10;S.tx11;S.ls(1);S.ls(2);S.ls(3);S.ls(4);S.ls
```

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```
5(1);...

S.ls5(2);S.ls5(3);S.ed1;S.ls6;S.ls7;S.lsa(1);S.lsa(2);S.lsa(3)
;...

S.lsa(4);S.lsa2(1);S.lsa2(2);S.lsa2(3);S.lsa2(4);S.lsa2(5);S.l
sa2(6);...

S.lsa2(7);S.lsa2(8);S.lsa2(9);S.lsa2(10);S.lsa2(11);S.lsa2(12)
;...

S.lsa2(13);S.lsa2(14);S.lsa2(15);S.lsa2(16);S.lsa2(17);S.lsa2(
18);...
        S.lsa2(19);S.lsa2(20);S.lsa2_null],'visible','off');
    set(S.tg([2,3,4,5]),'val',0);
    set(S.tg([2,3,4]),'enable','off');

    %Open Project Button
    function [] = pbO_call(varargin)
    S = varargin{3};
    [file, path] = uigetfile({'*.mat'},'Select file');
    if file==0
        return
    end
    pathfile=joinseq(path,file);
    load (pathfile)
     set(S.ch(1),'value',state.ch1);
     set(S.ch(2),'value',state.ch2);
     set(S.ch(3),'value',state.ch3);
     set(S.ch(4),'value',state.ch4);
     set(S.ch(5),'value',state.ch5);
     set(S.ch(6),'value',state.ch6);
     set(S.ch(7),'value',state.ch7);
     set(S.ch(8),'value',state.ch8);
     set(S.ch(9),'value',state.ch9);
     set(S.ch(10),'value',state.ch10);
     set(S.ch(11),'value',state.ch11);
     set(S.ch(12),'value',state.ch12);
     set(S.ch(13),'value',state.ch13);
     set(S.ch(14),'value',state.ch14);
     set(S.ch(15),'value',state.ch15);
     set(S.ch(16),'value',state.ch16);
     set(S.ch(17),'value',state.ch17);
     set(S.ch(18),'value',state.ch18);
     set(S.ch(19),'value',state.ch19);
     set(S.ch(20),'value',state.ch20);
     set(S.ch(21),'value',state.ch21);
     set(S.ed1,'string',state.ed1);
     set(S.lsa2(1),'string',state.lsa21);
     set(S.lsa2(2),'string',state.lsa22);
```

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```
      set(S.lsa2(3),'string',state.lsa23);
      set(S.lsa2(4),'string',state.lsa24);
      set(S.lsa2(5),'string',state.lsa25);
      set(S.lsa2(6),'string',state.lsa26);
      set(S.lsa2(7),'string',state.lsa27);
      set(S.lsa2(8),'string',state.lsa28);
      set(S.lsa2(9),'string',state.lsa29);
      set(S.lsa2(10),'string',state.lsa210);
      set(S.lsa2(11),'string',state.lsa211);
      set(S.lsa2(12),'string',state.lsa212);
      set(S.lsa2(13),'string',state.lsa213);
      set(S.lsa2(14),'string',state.lsa214);
      set(S.lsa2(15),'string',state.lsa215);
      set(S.lsa2(16),'string',state.lsa216);
      set(S.lsa2(17),'string',state.lsa217);
      set(S.lsa2(18),'string',state.lsa218);
      set(S.lsa2(19),'string',state.lsa219);
      set(S.lsa2(20),'string',state.lsa220);

      set(S.ed_void,'String',[]);
      set(S.ed_void,'String',pathfile);
      set([S.fm(4);S.fm(5)],'enable','on');

set([S.tx2;S.ch(:);S.pn(:);S.tg(:);S.pb1],'visible','on');
      set([S.txi;S.txi2;S.im(5);S.pbO;S.pbN],'visible','off');

     %Save
     function [] = fm4_call(varargin)
     S = varargin{3};
     state.ch1 = get(S.ch(1),'value');
     state.ch2 = get(S.ch(2),'value');
     state.ch3 = get(S.ch(3),'value');
     state.ch4 = get(S.ch(4),'value');
     state.ch5 = get(S.ch(5),'value');
     state.ch6 = get(S.ch(6),'value');
     state.ch7 = get(S.ch(7),'value');
     state.ch8 = get(S.ch(8),'value');
     state.ch9 = get(S.ch(9),'value');
     state.ch10 = get(S.ch(10),'value');
     state.ch11 = get(S.ch(11),'value');
     state.ch12 = get(S.ch(12),'value');
     state.ch13 = get(S.ch(13),'value');
     state.ch14 = get(S.ch(14),'value');
     state.ch15 = get(S.ch(15),'value');
     state.ch16 = get(S.ch(16),'value');
     state.ch17 = get(S.ch(17),'value');
     state.ch18 = get(S.ch(18),'value');
     state.ch19 = get(S.ch(19),'value');
     state.ch20 = get(S.ch(20),'value');
     state.ch21 = get(S.ch(21),'value');
```

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```
state.ed1 = get(S.ed1 ,'string');
state.lsa21 = get(S.lsa2(1) ,'string');
state.lsa22 = get(S.lsa2(2) ,'string');
state.lsa23 = get(S.lsa2(3) ,'string');
state.lsa24 = get(S.lsa2(4) ,'string');
state.lsa25 = get(S.lsa2(5) ,'string');
state.lsa26 = get(S.lsa2(6) ,'string');
state.lsa27 = get(S.lsa2(7) ,'string');
state.lsa28 = get(S.lsa2(8) ,'string');
state.lsa29 = get(S.lsa2(9) ,'string');
state.lsa210 = get(S.lsa2(10) ,'string');
state.lsa211 = get(S.lsa2(11) ,'string');
state.lsa212 = get(S.lsa2(12) ,'string');
state.lsa213 = get(S.lsa2(13) ,'string');
state.lsa214 = get(S.lsa2(14) ,'string');
state.lsa215 = get(S.lsa2(15) ,'string');
state.lsa216 = get(S.lsa2(16) ,'string');
state.lsa217 = get(S.lsa2(17) ,'string');
state.lsa218 = get(S.lsa2(18) ,'string');
state.lsa219 = get(S.lsa2(19) ,'string');
state.lsa220 = get(S.lsa2(20) ,'string');

a=get(S.ed_void,'String');
if a~=0
save(a,'state') %%%%pathfile
end

%Save as
function [] = fm5_call(varargin)
S = varargin{3};
[file, path] = uiputfile(...
 {'*.mat'},'Save as');
if file==0
    return
end
pathfile=joinseq(path,file);
set(S.ed_void,'String',[]);
set(S.ed_void,'String',pathfile);

state.ch1 = get(S.ch(1),'value');
state.ch2 = get(S.ch(2),'value');
state.ch3 = get(S.ch(3),'value');
state.ch4 = get(S.ch(4),'value');
state.ch5 = get(S.ch(5),'value');
state.ch6 = get(S.ch(6),'value');
state.ch7 = get(S.ch(7),'value');
state.ch8 = get(S.ch(8),'value');
state.ch9 = get(S.ch(9),'value');
state.ch10 = get(S.ch(10),'value');
state.ch11 = get(S.ch(11),'value');
```

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```
    state.ch12 = get(S.ch(12),'value');
    state.ch13 = get(S.ch(13),'value');
    state.ch14 = get(S.ch(14),'value');
    state.ch15 = get(S.ch(15),'value');
    state.ch16 = get(S.ch(16),'value');
    state.ch17 = get(S.ch(17),'value');
    state.ch18 = get(S.ch(18),'value');
    state.ch19 = get(S.ch(19),'value');
    state.ch20 = get(S.ch(20),'value');
    state.ch21 = get(S.ch(21),'value');
    state.ed1 = get(S.ed1 ,'string');
    state.lsa21 = get(S.lsa2(1) ,'string');
    state.lsa22 = get(S.lsa2(2) ,'string');
    state.lsa23 = get(S.lsa2(3) ,'string');
    state.lsa24 = get(S.lsa2(4) ,'string');
    state.lsa25 = get(S.lsa2(5) ,'string');
    state.lsa26 = get(S.lsa2(6) ,'string');
    state.lsa27 = get(S.lsa2(7) ,'string');
    state.lsa28 = get(S.lsa2(8) ,'string');
    state.lsa29 = get(S.lsa2(9) ,'string');
    state.lsa210 = get(S.lsa2(10) ,'string');
    state.lsa211 = get(S.lsa2(11) ,'string');
    state.lsa212 = get(S.lsa2(12) ,'string');
    state.lsa213 = get(S.lsa2(13) ,'string');
    state.lsa214 = get(S.lsa2(14) ,'string');
    state.lsa215 = get(S.lsa2(15) ,'string');
    state.lsa216 = get(S.lsa2(16) ,'string');
    state.lsa217 = get(S.lsa2(17) ,'string');
    state.lsa218 = get(S.lsa2(18) ,'string');
    state.lsa219 = get(S.lsa2(19) ,'string');
    state.lsa220 = get(S.lsa2(20) ,'string');

    save(pathfile,'state')

    %Help
    function [] = fmT_call(varargin)
    system(['open Tutorial.ppsm']);
    helpdlg('Open the Tutorial file','Tutorial');
    function [] = fmC_call(varargin)
    helpdlg('Mail to daniele.bacciotti@unfi.it','Support us')
    function [] = fmA_call(varargin)
    helpdlg('iDea is a tool that supports the idea generation
developed by Daniele Bacciotti @LMTI University of Florence.
©2014','About')

    %Clear Idea textbox
    function clear(hObj, event)

      set(hObj, 'String', '', 'Enable', 'on');
      uicontrol(hObj); % This activates the edit box and
```

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```
                        % places the cursor in the box,
                        % ready for user input.

function print_string(hObj, event)

  get(hObj, 'String');

function [] = ch21_call(varargin)
% Callback for ch21.
S = varargin{3};
 if (get(S.ch(21),'value') == get(S.ch(21),'max'))
     set(S.ch(1:8),'value',0);
 else
     set(S.ch(1:8),'value',1);
 end

function [] = pb1_call(varargin)
% Callback for pushbutton1.
S = varargin{3};
set(S.tg(:),'enable','on');  % Turn on 'Fit' tab.
set([S.pb2;S.ls(:);S.tx3],'visible','on');
set([S.ch(:);S.pb1;S.tx2],'visible','off');
set(S.tg([1,5]),'val',0);
set(S.ls(:),'string',{});

%Select General Demands
for i=1:8
 a=get(S.ch(i),'string');
 c=get(S.ls(1),'string');
 if (get(S.ch(i),'value') == get(S.ch(i),'max'))
     set(S.ls(1),'str',{c{:},a});
 end
end

b=get(S.ch(21),'string'); %Generic Demand
if (get(S.ch(21),'value') == get(S.ch(21),'max'))
    warndlg('Generic demand can be only used with quick
tool.','Warning!')
    set(S.ls(1),'str',b);
    set(S.tg([3,4]),'enable','off');
end
%Select Life Cycle Phases
for i=9:13
 a=get(S.ch(i),'string');
 c=get(S.ls(2),'string');
 if (get(S.ch(i),'value') == get(S.ch(i),'max'))
     set(S.ls(2),'str',{c{:},a});
 end
end
%Select Systems
```

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```
    for i=14:16
     a=get(S.ch(i),'string');
     c=get(S.ls(3),'string');
     if (get(S.ch(i),'value') == get(S.ch(i),'max'))
         set(S.ls(3),'str',{c{:},a});
     end
    end
    %Select Stakeholders
    for i=17:20
     a=get(S.ch(i),'string');
     c=get(S.ls(4),'string');
     if (get(S.ch(i),'value') == get(S.ch(i),'max'))
         set(S.ls(4),'str',{c{:},a});
     end
    end
    % Warning GD
    if (get(S.ch(1),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(2),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(3),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(4),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(5),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(6),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(7),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(8),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(21),'value') == get(S.ch(i),'min')) &&...
    warndlg('Select at least the "generic
demand".','Warning!')
    set([S.pb2;S.tx3;S.ls(:)],'visible','off');
    set([S.ch(:);S.pb1;S.tx2],'visible','on');
    set(S.tg([2,3,4]),'enable','off');
    set(varargin{3}.ls(:),'string',{});%reset list
    end
    % Warning LC
    if (get(S.ch(9),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(10),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(11),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(12),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(13),'value') == get(S.ch(i),'min'))
    warndlg('Select at least one life cycle
phase.','Warning!')
    set([S.pb2;S.tx3;S.ls(:)],'visible','off');
    set([S.ch(:);S.pb1;S.tx2],'visible','on');
    set(S.tg([2,3,4]),'enable','off');
    set(varargin{3}.ls(:),'string',{});%reset list
    end
    % Warning SYS
    if (get(S.ch(14),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(15),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(16),'value') == get(S.ch(i),'min'))
    warndlg('Select at least one system.','Warning!')
```

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```
    set([S.pb2;S.tx3;S.ls(:)],'visible','off');
    set([S.ch(:);S.pb1;S.tx2],'visible','on');
    set(S.tg([2,3,4]),'enable','off');
    set(varargin{3}.ls(:),'string',{});%reset list
    end
    % Warning SH
    if (get(S.ch(17),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(18),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(19),'value') == get(S.ch(i),'min')) &&...
       (get(S.ch(20),'value') == get(S.ch(i),'min'))
    warndlg('Select at least one stakeholder.','Warning!')
    set([S.pb2;S.tx3;S.ls(:)],'visible','off');
    set([S.ch(:);S.pb1;S.tx2],'visible','on');
    set(S.tg([2,3,4]),'enable','off');
    set(varargin{3}.ls(:),'string',{});%reset list
    end

    function [] = pb2_call(varargin)
    % Callback for pushbutton2.
    S = varargin{3};
    set(S.tg([2,3,4]),'enable','off');
    set([S.pb2;S.tx3;S.ls(:)],'visible','off');
    set([S.ch(:);S.pb1;S.tx2],'visible','on');
    set(S.ls(:),'string',{});%reset list

    function [] = pb3_call(varargin) %Save as ideas
    % Callback for the pb3.
    S = varargin{3};
    s=get(S.ed1,'string');

    [file, path] =
uiputfile({'*.txt';'*.doc';'*.docx';'*.*'},'Save');
    if file==0
        return
    end
    pathfile=joinseq(path,file);
    set(S.ed_void2,'String',[]);
    set(S.ed_void2,'String',pathfile);
        dlmwrite(pathfile, s, '');

    set(S.pb3,'visible','off');
    set(S.pb3bis,'visible','on');

    function [] = pb3bis_call(varargin) %Save ideas
    % Callback for the pb3bis.
    S = varargin{3};
    s=get(S.ed1,'string');
    a=get(S.ed_void2,'String');
    if a~=0
    dlmwrite(a, s, '');
```

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```
end

function [] = lsa1_call(varargin) %GD detailed
S = varargin{3};
set(S.lsa2_null,'visible','off');
contents1 = get(S.lsa(1),'String');
selectedText1 = contents1{get(S.lsa(1),'Value')};
GD(1) = {'Fulfilled needs'};
GD(2) = {'Versatility of use/adaptability'};
GD(3) = {'Reliability/safety'};
GD(4) = {'Ease'};
GD(5) = {'Aesthetics/style/ethics'};
GD(6) = {'Quickness'};
GD(7) = {'Cheapness'};
GD(8) = {'Comfort/ergonomics'};

for i=1:8
 match(i) = strcmp(GD(i), selectedText1);
 if (match(i) == 1)
   set(S.lsa2(i),{'visible'},{'on'});
 else
   set(S.lsa2(i),{'visible'},{'off'});
 end
end

function [] = lsa2_call(varargin)
S = varargin{3};
set(S.lsa2_null,'visible','off');
contents2 = get(S.lsa(2),'String');
selectedText2 = contents2{get(S.lsa(2),'Value')};
LC(9) = {'purchasing, choice and access activities'};
LC(10) = {'before use operations'};
LC(11) = {'utilization time'};
LC(12) = {'elapsed time before further exploitations'};
LC(13) = {'end of the functioning'};

for i=9:13
 match(i) = strcmp(LC(i), selectedText2);
 if (match(i) == 1)
   set(S.lsa2(i),{'visible'},{'on'});
 else
   set(S.lsa2(i),{'visible'},{'off'});
 end
end

function [] = lsa3_call(varargin)
S = varargin{3};
set(S.lsa2_null,'visible','off');
contents3 = get(S.lsa(3),'String');
selectedText3 = contents3{get(S.lsa(3),'Value')};
```

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```
     SYS(14) = {'environment in which the product is
situated'};
     SYS(15) = {'product or service level'};
     SYS(16) = {'parts, components and accessories'};

     for i=14:16
      match(i) = strcmp(SYS(i), selectedText3);
      if (match(i) == 1)
        set(S.lsa2(i),{'visible'},{'on'});
      else
        set(S.lsa2(i),{'visible'},{'off'});
      end
     end

     function [] = lsa4_call(varargin)
     S = varargin{3};
     set(S.lsa2_null,'visible','off');
     contents4 = get(S.lsa(4),'String');
     selectedText4 = contents4{get(S.lsa(4),'Value')};
     SH(17) = {'buyers'};
     SH(18) = {'users'};
     SH(19) = {'beneficiaries'};
     SH(20) = {'outsiders'};

     for i=17:20
      match(i) = strcmp(SH(i), selectedText4);
      if (match(i) == 1)
        set(S.lsa2(i),{'visible'},{'on'});
      else
        set(S.lsa2(i),{'visible'},{'off'});
      end
     end

     function [] = pb4_call(varargin) %GD next detailed
     S = varargin{3};
     set(S.lsa2(:),'value', []);
     set(S.ed,'string',[]);
     set([S.tga(:);S.pb5;S.pb6;S.pb_add(2);S.pb_del(2);S.pna(2
);...

S.tx8;S.pna(2);S.lsa(2);S.lsa2_null;S.im(2)],'visible','on');
     set([S.pna(1);S.lsa(1);S.tx7;S.pb4;S.lsa2(1);S.lsa2(2);S.
lsa2(3);...

S.lsa2(4);S.lsa2(5);S.lsa2(6);S.lsa2(7);S.lsa2(8);S.lsa2(9);S.
pb_add(1);...
         S.pb_del(1);S.im(1)],'visible','off');
     set(S.tga(1),'val',1);
     set(S.tga([2,3]),'val',0);
     set(S.tga([2,3]),'enable','off');
```

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```
set(S.lsa([2,3,4]),'string',{});

%Select Life Cycle Phases
for i=9:13
 a1=get(S.ch(i),'string');
 c1=get(S.lsa(2),'string');
 if (get(S.ch(i),'value') == get(S.ch(i),'max'))
     set(S.lsa(2),'str',{c1{:},a1});
 end
end
%Select Systems
for i=14:16
 a1=get(S.ch(i),'string');
 c1=get(S.lsa(3),'string');
 if (get(S.ch(i),'value') == get(S.ch(i),'max'))
     set(S.lsa(3),'str',{c1{:},a1});
 end
end
%Select Stakeholders
for i=17:20
 a1=get(S.ch(i),'string');
 c1=get(S.lsa(4),'string');
 if (get(S.ch(i),'value') == get(S.ch(i),'max'))
     set(S.lsa(4),'str',{c1{:},a1});
 end
end

function [] = pb5_call(varargin) %GD back detailed
S = varargin{3};
set(S.lsa2(:),'value', []);
set(S.ed,'string',[]);
set([S.pna(1);S.lsa(1);S.tx7;S.pb4;S.lsa2_null;S.pb_add(1
);S.pb_del(1);S.im(1)],...
        'visible','on');
set([S.tga(:);S.pb5;S.pb6;S.pb7;S.pb8;S.pb_add(2);S.pb_ad
d(3);S.pb_add(4);...

S.pb_del(2);S.pb_del(3);S.pb_del(4);S.pna(2);S.pna(3);S.pna(4)
;S.lsa2(1);...

S.lsa(2);S.lsa(3);S.lsa(4);S.lsa2(9);S.lsa2(10);S.lsa2(11);S.l
sa2(12);...

S.lsa2(13);S.lsa2(14);S.lsa2(15);S.lsa2(16);S.lsa2(17);S.lsa2(
18);...

S.lsa2(19);S.lsa2(20);S.tx8;S.tx9;S.tx10;S.im(2);S.im(3);S.im(
4)]...
        ,'visible','off');
```

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```
     function [] = pb6_call(varargin) %to SYS
     S = varargin{3};
     set(S.tga([1,3]),'val',0)
     set(S.tga(2),'val',1)
     set(S.tga(2),'enable','on');
     set(S.lsa2(:),'value', []);
     set(S.ed,'string',[]);
     set([S.pb7;S.lsa(3);S.lsa2_null;S.pna(3);S.tx9;S.pb_add(3
);S.pb_del(3);S.im(3)],...
        {'visible'},{'on'})
     set([S.pb6;S.lsa(2);S.lsa2(9);S.lsa2(10);S.lsa2(11);S.lsa
2(12);S.lsa2(13);...

S.pna(2);S.tx8;S.pb_add(2);S.pb_del(2);S.im(2)],{'visible'},{'
off'})

     function [] = pb7_call(varargin) %to SH
     S = varargin{3};
     set(S.tga([1,2]),'val',0)
     set(S.tga(3),'val',1)
     set(S.tga(3),'enable','on');
     set(S.lsa2(:),'value', []);
     set(S.ed,'string',[]);
     set([S.pb8;S.lsa(4);S.lsa2_null;S.pna(4);S.tx10;S.pb_add(
4);S.pb_del(4);S.im(4)],...
        {'visible'},{'on'})
     set([S.pb7;S.lsa(3);S.lsa2(14);S.lsa2(15);S.lsa2(16);...

S.pna(3);S.tx9;S.pb_add(3);S.pb_del(3);S.im(3)],{'visible'},{'
off'})

     function [] = pb8_call(varargin) %Detailed combinations
     S = varargin{3};
     set(S.ls7,'string',{});
     set([S.tx4;S.tx5(1);S.pn5;S.pn6;S.ls7;S.ed1],'visible','o
n');

     a=get(S.ed_void2,'string');
     if a~=0
      set(S.pb3bis,'visible','on');
     else
      set(S.pb3,'visible','on');
     end

     set([S.tga(:);S.pb5;S.pb8;S.pb_add(:);S.pb_del(:);S.pna(:
);S.lsa(:);...

S.lsa2(:);S.lsa2_null;S.tx8;S.tx9;S.tx10;S.tx11;S.ed;S.im(:)],
'visible','off');
```

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```
    %Not combined
    gda(1) = {'Quality of the expected outcomes'};
    gda(2) = {'Quantity or extent of the expected outcomes'};
    gda(3) = {'Duration of the expected outcomes'};
    gda(4) = {'Expand or upgrade the range of product
functionalities'};
    gda(5) = {'The additional services provided in order to
attenuate the consumption of individual resources, the
customer care'};
    gda(6) = {'The ethics as a distinguishing factor'};
    gda(7) = {'Product/service cheapness'};
    %Combined with LC
    gda(8) = {'Adaptability of the product in diverging
conditions with respect to the designed preferred ones'};
    gda(9) = {'The reduction of the information and skills to
be gathered during the product life cycle'};
    gda(10) = {'The reduction of auxiliary functions to be
delivered'};
    gda(11) = {'The environmental sustainability'};
    gda(12) = {'The limitation of the time required to
perform operations'};
    gda(13) = {'The limitation of the required energy (or
human power) needed for the product during its lifecycle'};
    gda(14) = {'Cheapness of various activities during
product life cycle'};
    %Combined with LC2,LC3,LC4,LC5
    gda(15) = {'The comfort of use, the ergonomics, the
manageability'};
    gda(16) = {'The limitation of occupied space'};
    %Combined with LC1
    gda(17) = {'The ease of acquiring the product, due to
market penetration and distribution policies'};
    %Combined with LC2
    gda(18) = {'The reduction of time to be waited before the
functioning of the product delivers the expected outcomes'};
    %Combined with LC3
    gda(19) = {'Fun and adventure'};
    %Combined with LC5
    gda(20) = {'The possibility of benefitting of the product
(or its parts) for different employment after the end of its
life'};
    %Comnined with SYS,SUB
    gda(21) = {'Controllability of the system in order to
obtain the expected outcomes'};
    gda(22) = {'The duration, the expected life of the
product'};
    gda(23) = {'Customize the product or certain
properties'};
    gda(24) = {'The lightness and the portability'};
    %Combined with SUP
```

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```
     gda(25) = {'The limitation of damages towards the
external environment'};
     gda(26) = {'The limitation of damages provoked by the
external environment'};
     gda(27) = {'The independence from the use of other
materials, instruments, technical systems'};
     %Combined with SUB
     gda(28) = {'Integrity of the product itself, its
resistance to planned or accidental stress or collision, the
strength against wear or corrosion'};
     gda(29) = {'The ease of managing, maintaining,
assembling, disassembling, upgrading, substituting components
or accessories'};
     gda(30) = {'The aesthetical requirements and the
emotional dimension of the product, the style, the fashion
content'};
     gda(31) = {'The reduction of the consumption of parts,
components or consumables'};
     gda(32) = {'Accessories cheapness'};
     %Combined with SH
     gda(33) = {'Suitability of the product according to
different demands'};
     gda(34) = {'The safety and innocuousness for human health
and people''s psychological and social conditions'};
     gda(35) = {'The absence of bother for the people'};
     %Combined with SH1,SH2
     gda(36) = {'What the product evokes, the lifestyle that
the object implies, the prestige it generates for the owner as
a feeling of distinction and recognition'};
     %Combined with LC,SYS,SH (New GDs)

     totgda=(gda(:));

     a=get(S.lsa2(1), 'String');
     b=get(S.lsa2(2), 'String');
     c=get(S.lsa2(3), 'String');
     d=get(S.lsa2(4), 'String');
     e=get(S.lsa2(5), 'String');
     f=get(S.lsa2(6), 'String');
     g=get(S.lsa2(7), 'String');
     h=get(S.lsa2(8), 'String');

     tot1 = vertcat(a,b,c,d,e,f,g,h);

     if (get(S.ch(1), 'Value') == 0)
     tot1 = setdiff(tot1,a);
     end
     if (get(S.ch(2), 'Value') == 0)
     tot1 = setdiff(tot1,b);
     end
```

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```
if (get(S.ch(3), 'Value') == 0)
tot1 = setdiff(tot1,c);
end
if (get(S.ch(4), 'Value') == 0)
tot1 = setdiff(tot1,d);
end
if (get(S.ch(5), 'Value') == 0)
tot1 = setdiff(tot1,e);
end
if (get(S.ch(6), 'Value') == 0)
tot1 = setdiff(tot1,f);
end
if (get(S.ch(7), 'Value') == 0)
tot1 = setdiff(tot1,g);
end
if (get(S.ch(8), 'Value') == 0)
tot1 = setdiff(tot1,h);
end

for i=1:7
oldstr=get(S.ls7,'String');
nameidx = getnameidx(tot1, gda(i));
 if (nameidx > 0)
  set(S.ls7,'String',{oldstr{:},gda{i}});
 end
end

for i=8:14
    for j=9:13
        o = get(S.ls7,'String');
        m = getnameidx(tot1, gda(i));
        n=get(S.lsa2(j),'string');
        w=get(S.ch(j),'value');
         if ((m > 0) && (w==1))
            aa=strcat(gda(i),{' & '},n);
            set(S.ls7,'str',{o{:},aa{:}});
         end
    end
end

for i=15:16
  for j=10:13
      o = get(S.ls7,'String');
      m = getnameidx(tot1, gda(i));
      n=get(S.lsa2(j),'string');
      w=get(S.ch(j),'value');
       if ((m > 0) && (w==1))
          aa=strcat(gda(i),{' & '},n);
          set(S.ls7,'str',{o{:},aa{:}});
       end
```

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```
  end
end

o = get(S.ls7,'String');
m = getnameidx(tot1, gda(17));
n=get(S.lsa2(9),'string');
w=get(S.ch(9),'value');
  if ((m > 0) && (w==1))
     aa=strcat(gda(17),{' & '},n);
     set(S.ls7,'str',{o{:},aa{:}});
  end

o = get(S.ls7,'String');
m = getnameidx(tot1, gda(18));
n=get(S.lsa2(10),'string');
w=get(S.ch(10),'value');
  if ((m > 0) && (w==1))
     aa=strcat(gda(18),{' & '},n);
     set(S.ls7,'str',{o{:},aa{:}});
  end

o = get(S.ls7,'String');
m = getnameidx(tot1, gda(19));
n=get(S.lsa2(11),'string');
w=get(S.ch(11),'value');
  if ((m > 0) && (w==1))
     aa=strcat(gda(19),{' & '},n);
     set(S.ls7,'str',{o{:},aa{:}});
  end

o = get(S.ls7,'String');
m = getnameidx(tot1, gda(20));
n=get(S.lsa2(13),'string');
w=get(S.ch(13),'value');
  if ((m > 0) && (w==1))
     aa=strcat(gda(20),{' & '},n);
     set(S.ls7,'str',{o{:},aa{:}});
  end

for i=21:24
  for j=15:16
      o = get(S.ls7,'String');
      m = getnameidx(tot1, gda(i));
      n=get(S.lsa2(j),'string');
      w=get(S.ch(j),'value');
       if ((m > 0) && (w==1))
          aa=strcat(gda(i),{' & '},n);
          set(S.ls7,'str',{o{:},aa{:}});
       end
  end
```

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```
    end

    for i=25:27
        o = get(S.ls7,'String');
        m = getnameidx(tot1, gda(i));
        n=get(S.lsa2(14),'string');
        w=get(S.ch(j),'value');
          if ((m > 0) && (w==1))
             aa=strcat(gda(i),{' & '},n);
             set(S.ls7,'str',{o{:},aa{:}});
          end
    end

    for i=28:32
        o = get(S.ls7,'String');
        m = getnameidx(tot1, gda(i));
        n=get(S.lsa2(16),'string');
        w=get(S.ch(16),'value');
          if ((m > 0) && (w==1))
             aa=strcat(gda(i),{' & '},n);
             set(S.ls7,'str',{o{:},aa{:}});
          end
    end

    for i=33:35
      for j=17:20
          o = get(S.ls7,'String');
          m = getnameidx(tot1, gda(i));
          n=get(S.lsa2(j),'string');
          w=get(S.ch(j),'value');
           if ((m > 0) && (w==1))
              aa=strcat(gda(i),{' & '},n);
              set(S.ls7,'str',{o{:},aa{:}});
           end
      end
    end

    for j=17:18
        o = get(S.ls7,'String');
        m = getnameidx(tot1, gda(36));
        n=get(S.lsa2(j),'string');
        w=get(S.ch(j),'value');
          if ((m > 0) && (w==1))
             aa=strcat(gda(36),{' & '},n);
             set(S.ls7,'str',{o{:},aa{:}});
          end
    end

    b=setdiff(tot1,totgda);
    d=size(b,1);
```

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```
for i=1:d
  for j=9:20
    o = get(S.ls7,'String');
    n=get(S.lsa2(j),'string');
    w=get(S.ch(j),'value');
      if (w==1)
          aa=strcat(b(i),{' & '},n);
          set(S.ls7,'str',{o{:},aa{:}});
      end
  end
end

function [] = pbadd1_call(varargin) %Add GD
S = varargin{3};
contents1 = get(S.lsa(1),'String');
selectedText1 = contents1{get(S.lsa(1),'Value')};
GD(1) = {'Fulfilled needs'};
GD(2) = {'Versatility of use/adaptability'};
GD(3) = {'Reliability/safety'};
GD(4) = {'Ease'};
GD(5) = {'Aesthetics/style/ethics'};
GD(6) = {'Quickness'};
GD(7) = {'Cheapness'};
GD(8) = {'Comfort/ergonomics'};

for i=1:8
 oldstr1 = get(S.lsa2(i),'string'); % The string as it is
now.
 addstr1 = {get(S.ed,'string')}; % The string to add to
the stack.
 void_S = {''};
 void_cmp = strcmp(addstr1, void_S);
 match1(i) = strcmp(GD(i), selectedText1);
 if (match1(i) == 1) && (void_cmp == 0)
   set(S.lsa2(i),'str',{oldstr1{:},addstr1{:}}); % Put
the new string on bottom.
 end
 set(S.lsa2(:),'value', []);
end
set(S.ed,'string',[]);

function [] = pbadd2_call(varargin) %Add LC
S = varargin{3};
contents2 = get(S.lsa(2),'String');
selectedText2 = contents2{get(S.lsa(2),'Value')};
LC(9) = {'purchasing, choice and access activities'};
LC(10) = {'before use operations'};
LC(11) = {'utilization time'};
LC(12) = {'elapsed time before further exploitations'};
LC(13) = {'end of the functioning'};
```

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```
for i=9:13
 oldstr2 = get(S.lsa2(i),'string'); % The string as it is
now.
 addstr2 = {get(S.ed,'string')}; % The string to add to
the stack.
 void_S = {''};
 void_cmp = strcmp(addstr2, void_S);
 match2(i) = strcmp(LC(i), selectedText2);
 if (match2(i) == 1) && (void_cmp == 0)
   set(S.lsa2(i),'str',{oldstr2{:},addstr2{:}});
 end
 set(S.lsa2(:),'value', []);
end
set(S.ed,'string',[]);

function [] = pbadd3_call(varargin) %Add SYS
S = varargin{3};
contents3 = get(S.lsa(3),'String');
selectedText3 = contents3{get(S.lsa(3),'Value')};
SYS(14) = {'environment in which the product is
situated'};
SYS(15) = {'product or service level'};
SYS(16) = {'parts, components and accessories'};

for i=14:16
 oldstr3 = get(S.lsa2(i),'string'); % The string as it is
now.
 addstr3 = {get(S.ed,'string')}; % The string to add to
the stack.
 void_S = {''};
 void_cmp = strcmp(addstr3, void_S);
 match3(i) = strcmp(SYS(i), selectedText3);
 if (match3(i) == 1) && (void_cmp == 0)
   set(S.lsa2(i),'str',{oldstr3{:},addstr3{:}});
 end
 set(S.lsa2(:),'value', []);
end
set(S.ed,'string',[]);

function [] = pbadd4_call(varargin) %Add SH
S = varargin{3};
contents4 = get(S.lsa(4),'String');
selectedText4 = contents4{get(S.lsa(4),'Value')};
SH(17) = {'buyers'};
SH(18) = {'users'};
SH(19) = {'beneficiaries'};
SH(20) = {'outsiders'};

for i=17:20
```

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```
      oldstr4 = get(S.lsa2(i),'string'); % The string as it is
now.
      addstr4 = {get(S.ed,'string')}; % The string to add to
the stack.
      void_S = {''};
      void_cmp = strcmp(addstr4, void_S);
      match4(i) = strcmp(SH(i), selectedText4);
      if (match4(i) == 1) && (void_cmp == 0)
        set(S.lsa2(i),'str',{oldstr4{:},addstr4{:}});
      end
      set(S.lsa2(:),'value', []);
     end
     set(S.ed,'string',[]);

     function [] = pbdel1_call(varargin) %Delete GD
     S = varargin{3};
     contents1 = get(S.lsa(1),'String');
     selectedText1 = contents1{get(S.lsa(1),'Value')};
     GD(1) = {'Fulfilled needs'};
     GD(2) = {'Versatility of use/adaptability'};
     GD(3) = {'Reliability/safety'};
     GD(4) = {'Ease'};
     GD(5) = {'Aesthetics/style/ethics'};
     GD(6) = {'Quickness'};
     GD(7) = {'Cheapness'};
     GD(8) = {'Comfort/ergonomics'};

     for i=1:8
      match1(i) = strcmp(GD(i), selectedText1);
      L = get(S.lsa2(i),{'string','value'});  % Get the users
choice.
      if ~isempty(L{1}) && (match1(i) == 1)
         L{1}(L{2}(:)) = [];  % Delete the selected strings.
         set(S.lsa2(i),'string',L{1},'val',1) % Set the new
string.
      end
      if isempty(L{1})
         set(S.lsa2(i),'string',GD(i));
      end
     set(S.lsa2(i),'value', []);
     end

     function [] = pbdel2_call(varargin) %Delete LC
     S = varargin{3};
     contents2 = get(S.lsa(2),'String');
     selectedText2 = contents2{get(S.lsa(2),'Value')};
     LC(9) = {'purchasing, choice and access activities'};
     LC(10) = {'before use operations'};
     LC(11) = {'utilization time'};
     LC(12) = {'elapsed time before further exploitations'};
```

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```
LC(13) = {'end of the functioning'};

for i=9:13
 match2(i) = strcmp(LC(i), selectedText2);
 M = get(S.lsa2(i),{'string','value'});  % Get the users
choice.
 if ~isempty(M{1}) && (match2(i) == 1)
    M{1}(M{2}(:)) = [];  % Delete the selected strings.
    set(S.lsa2(i),'string',M{1},'val',1) % Set the new
string.
 end
 if isempty(M{1})
    set(S.lsa2(i),'string',LC(i));
 end
set(S.lsa2(i),'value', []);
end

function [] = pbdel3_call(varargin) %Delete SYS
S = varargin{3};
contents3 = get(S.lsa(3),'String');
selectedText3 = contents3{get(S.lsa(3),'Value')};
SYS(14) = {'environment in which the product is
situated'};
SYS(15) = {'product or service level'};
SYS(16) = {'parts, components and accessories'};

for i=14:16
 match3(i) = strcmp(SYS(i), selectedText3);
 N = get(S.lsa2(i),{'string','value'});  % Get the users
choice.
 if ~isempty(N{1}) && (match3(i) == 1)
    N{1}(N{2}(:)) = [];  % Delete the selected strings.
    set(S.lsa2(i),'string',N{1},'val',1) % Set the new
string.
 end
 if isempty(N{1})
    set(S.lsa2(i),'string',SYS(i));
 end
set(S.lsa2(i),'value', []);
end

function [] = pbdel4_call(varargin) %Delete SH
S = varargin{3};
contents4 = get(S.lsa(4),'String');
selectedText4 = contents4{get(S.lsa(4),'Value')};
SH(17) = {'buyers'};
SH(18) = {'users'};
SH(19) = {'beneficiaries'};
SH(20) = {'outsiders'};
```

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```
     for i=17:20
      match4(i) = strcmp(SH(i), selectedText4);
      O = get(S.lsa2(i),{'string','value'});  % Get the users
choice.
      if ~isempty(O{1}) && (match4(i) == 1)
         O{1}(O{2}(:)) = [];  % Delete the selected strings.
         set(S.lsa2(i),'string',O{1},'val',1) % Set the new
string.
      end
      if isempty(O{1})
         set(S.lsa2(i),'string',SH(i));
      end
     set(S.lsa2(i),'value', []);
     end

     function [] = tga_call(varargin)
     % Callback for togglebuttons adavanced.
     [h,S] = varargin{[1,3]};  % Get calling handle ans
structure.

     if get(h,'val')==0  % Here the Toggle is already pressed.
         set(h,'val',1) % To keep the Tab-like functioning.
     end

     switch h
         case S.tga(1)
             set(S.tga([2,3]),'val',0)
             set(S.lsa2(:),'value', []);
             set(S.ed,'string',[]);

set([S.lsa(2);S.lsa2_null;S.pna(2);S.tx8;S.pb_add(2);S.pb_del(
2);S.im(2)],...
                 {'visible'},{'on'})

set([S.lsa(3);S.lsa(4);S.lsa2(9);S.lsa2(10);S.lsa2(11);S.lsa2(
12);S.lsa2(13);...

S.lsa2(14);S.lsa2(15);S.lsa2(16);S.lsa2(17);S.lsa2(18);S.lsa2(
19);...

S.lsa2(20);S.pna(3);S.pna(4);S.tx9;S.tx10;S.pb_add(3);S.pb_add
(4);...

S.pb_del(3);S.pb_del(4);S.im(3);S.im(4);],{'visible'},{'off'})


         case S.tga(2)
             set(S.tga([1,3]),'val',0)
             set(S.lsa2(:),'value', []);
             set(S.ed,'string',[]);
```

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```
set([S.lsa(3);S.lsa2_null;S.pna(3);S.tx9;S.pb_add(3);S.pb_del(
3);S.im(3)],...
                 {'visible'},{'on'})

set([S.lsa(2);S.lsa(4);S.lsa2(2);S.lsa2(9);S.lsa2(10);S.lsa2(1
1);...

S.lsa2(12);S.lsa2(13);S.lsa2(14);S.lsa2(15);S.lsa2(16);S.lsa2(
17);...

S.lsa2(18);S.lsa2(19);S.lsa2(20);S.pna(2);S.pna(4);S.tx8;...

S.tx10;S.pb_add(2);S.pb_add(4);S.pb_del(2);S.pb_del(4);S.im(2)
;S.im(4);],...
                 {'visible'},{'off'})

         otherwise
             set(S.tga([1,2]),'val',0)
             set(S.lsa2(:),'value', []);
             set(S.ed,'string',[]);

set([S.lsa(4);S.lsa2_null;S.pna(4);S.tx10;S.pb_add(4);S.pb_del
(4);S.im(4)],...
                 {'visible'},{'on'})

set([S.lsa(2);S.lsa(3);S.lsa2(9);S.lsa2(10);S.lsa2(11);S.lsa2(
12);...

S.lsa2(13);S.lsa2(14);S.lsa2(15);S.lsa2(16);S.lsa2(17);S.lsa2(
18);...

S.lsa2(19);S.lsa2(20);S.pna(2);S.pna(3);S.tx8;S.tx9;...

S.pb_add(2);S.pb_add(3);S.pb_del(2);S.pb_del(3);S.im(2);S.im(3
)],...
                 {'visible'},{'off'})

     end

     function [] = tg_call(varargin)
     % Callback for togglebuttons.
     [h,S] = varargin{[1,3]};  % Get calling handle ans
structure.

     if get(h,'val')==0  % Here the Toggle is already pressed.
         set(h,'val',1) % To keep the Tab-like functioning.
     end

     % Each case of the switch has one toggle associated with
```

Continue on next page

```
it.  When a toggle
     % is selected the uicontrols which belong to it are made
visible, and the
     % others are made invisible.
     switch h
         case S.tg(1)
             set(S.tg([2,3,4,5]),'val',0)
             set(S.tg([2,3,4]),'enable','off');

set([S.pb1;S.ch(:);S.pn(:);S.tx2],{'visible'},{'on'})

set([S.tx1;S.tx3;S.tx4;S.ls5(:);S.ed1;S.ed;S.ls6;S.ls(:);S.lsa
2(:);...

S.lsa2_null;S.pb2;S.pb3;S.pb3bis;S.pb4;S.pb5;S.pb6;S.pb7;S.pb8
;S.pb_add(:);S.pb_del(:);...

S.pn5;S.pn6;S.tx5(:);S.tx6;S.tx7;S.tx8;S.tx9;S.tx10;S.tx11;S.l
s7;...
                 S.lsa(:);S.tga(:);S.pna(:);S.im(:)],
{'visible'},{'off'})

         case S.tg(2)
             set(S.tg([1,3,4,5]),'val',0)
             set(S.ls5(:),'string',{});

set([S.ls5(:);S.ed1;S.pn5;S.pn6;S.tx4;S.tx5(:)],...
                 {'visible'},{'on'})

             a=get(S.ed_void2,'string');
             if a~=0
                set(S.pb3bis,'visible','on');
             else
                set(S.pb3,'visible','on');
             end


set([S.pb1;S.pb2;S.pb4;S.pb5;S.pb6;S.pb7;S.pb8;S.pb_add(:);S.p
b_del(:);...

S.tx1;S.tx2;S.tx3;S.tx6;S.tx7;S.tx8;S.tx9;S.tx10;S.tx11;...

S.ch(:);S.ls(:);S.pn(:);S.lsa2(:);S.lsa2_null;S.ls6;S.ls7;...

S.tga(:);S.lsa(:);S.pna(:);S.ed;S.im(:)],{'visible'},{'off'})

             d=get(S.ls(2),'string');
             set(S.ls5(1),'string',d(:));
             e=get(S.ls(3),'string');
             set(S.ls5(2),'string',e(:));
```

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```
            f=get(S.ls(4),'string');
            set(S.ls5(3),'string',f(:));

        case S.tg(3)
            set(S.tg([1,2,4,5]),'val',0)
            set(S.ls6,'string',{});

set([S.ls6;S.ed1;S.pn5;S.pn6;S.tx4;S.tx6],{'visible'},{'on'})

            a=get(S.ed_void2,'string');
            if a~=0
               set(S.pb3bis,'visible','on');
            else
               set(S.pb3,'visible','on');
            end


set([S.pb1;S.pb2;S.pb4;S.pb5;S.pb6;S.pb7;S.pb8;S.pb_add(:);S.p
b_del(:);...

S.tx1;S.tx2;S.tx3;S.tx5(:);S.tx7;S.tx8;S.tx9;S.tx10;S.tx11;...

S.ch(:);S.ls(:);S.ed;S.ls5(:);S.ls7;S.pn(:);S.pna(:);S.tga(:);
...

S.lsa(:);S.lsa2(:);S.lsa2_null;S.im(:)],{'visible'},{'off'})

            for j=1:8
                l=get(S.ch(j),'string');
                for k=9:13
                     m=get(S.ch(k),'string');
                     n=get(S.ls6,'string');
                    if (get(S.ch(j),'value') ==
get(S.ch(j),'max'))&&...
                       (get(S.ch(k),'value') ==
get(S.ch(k),'max'))
                        aa=strcat(l,{' & '},m);
                        set(S.ls6,'str',{n{:},aa{:}});%GD&LC
                    end
                end

                for p=14:16
                     q=get(S.ch(p),'string');
                     n=get(S.ls6,'string');
                    if (get(S.ch(j),'value') ==
get(S.ch(j),'max'))&&...
                       (get(S.ch(p),'value') ==
get(S.ch(p),'max'))
                        aa=strcat(l,{' & '},q);
                        set(S.ls6,'str',{n{:},aa{:}});
```

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```
%GD&SYS
                    end
                end

                for r=17:20
                     s=get(S.ch(r),'string');
                     n=get(S.ls6,'string');
                    if (get(S.ch(j),'value') ==
get(S.ch(j),'max'))&&...
                      (get(S.ch(r),'value') ==
get(S.ch(r),'max'))
                       aa=strcat(l,{' & '},s);
                       set(S.ls6,'str',{n{:},aa{:}}); %GD&SH
                    end
                end
            end

        case S.tg(4)
            set(S.tg([1,2,3,5]),'val',0)
            set(S.ls7,'string',{});
            set(S.lsa(1),'string',{});
            set(S.lsa2(:),'value', []);

set([S.pb4;S.pb_add(1);S.pb_del(1);S.lsa(1);S.pna(1);S.tx7;...

S.tx11;S.lsa2_null;S.ed;S.im(1)],{'visible'},{'on'})

set([S.pb1;S.pb2;S.pb3;S.pb3bis;S.pb5;S.pb6;S.pb7;S.pb8;S.pb_a
dd(2);S.pb_add(3);...

S.pb_add(4);S.pb_del(2);S.pb_del(3);S.pb_del(4);...

S.pn(:);S.pn5;S.pn6;S.ch(:);S.ls(:);S.ls5(:);S.ls6;S.ls7;...

S.tga(:);S.lsa(2);S.lsa(3);S.lsa(4);S.pna(2);S.pna(3);...

S.pna(4);S.tx1;S.tx2;S.tx3;S.tx4;S.tx5(:);S.tx6;S.tx8;...

S.tx9;S.tx10;S.ed1;S.im(2);S.im(3);S.im(4)],{'visible'},{'off'
})

            for i=1:8
                a1=get(S.ch(i),'string');
                c1=get(S.lsa(1),'string');
             if (get(S.ch(i),'value') == get(S.ch(i),'max'))
                 set(S.lsa(1),'str',{c1{:},a1});
             end
            end

            set(S.im(1),'visible','on');
```

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```
            set(S.im(4),'visible','off');

        otherwise
            set(S.tg([1,2,3,4]),'val',0)
            set(S.tx1,{'visible'},{'on'})

set([S.pb1;S.pb2;S.pb3;S.pb3bis;S.pb4;S.pb5;S.pb6;S.pb7;S.pb8;
S.pb_add(:);S.pb_del(:);...

S.tx2;S.tx3;S.tx4;S.tx5(:);S.tx6;S.tx7;S.tx8;S.tx9;S.tx10;...

S.tx11;S.ch(:);S.ls(:);S.ls5(:);S.ls6;S.ls7;S.ed1;S.ed;S.pn(:)
;...

S.pn5;S.pn6;S.pna(:);S.tga(:);S.lsa(:);S.lsa2(:);S.lsa2_null;S
.im(:)],...
                {'visible'},{'off'})

    end

    function [] = ls6_call(varargin)
    S = varargin{3};
    contents1 = get(S.ls6,'String');
    selectedText1 = contents1{get(S.ls6,'Value')};
    set(S.ls6,'Tooltip',selectedText1);

    function [] = ls7_call(varargin)
    S = varargin{3};
    contents1 = get(S.ls7,'String');
    selectedText1 = contents1{get(S.ls7,'Value')};
    set(S.ls7,'Tooltip',selectedText1);

    function [] = lsa21_call(varargin)
    S = varargin{3};
    contents1 = get(S.lsa2(1),'String');
    selectedText1 = contents1{get(S.lsa2(1),'Value')};
    set(S.lsa2(1),'Tooltip',selectedText1);

    function [] = lsa22_call(varargin)
    S = varargin{3};
    contents1 = get(S.lsa2(2),'String');
    selectedText1 = contents1{get(S.lsa2(2),'Value')};
    set(S.lsa2(2),'Tooltip',selectedText1);

    function [] = lsa23_call(varargin)
    S = varargin{3};
    contents1 = get(S.lsa2(3),'String');
    selectedText1 = contents1{get(S.lsa2(3),'Value')};
    set(S.lsa2(3),'Tooltip',selectedText1);
```

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```
function [] = lsa24_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(4),'String');
selectedText1 = contents1{get(S.lsa2(4),'Value')};
set(S.lsa2(4),'Tooltip',selectedText1);

function [] = lsa25_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(5),'String');
selectedText1 = contents1{get(S.lsa2(5),'Value')};
set(S.lsa2(5),'Tooltip',selectedText1);

function [] = lsa26_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(6),'String');
selectedText1 = contents1{get(S.lsa2(6),'Value')};
set(S.lsa2(6),'Tooltip',selectedText1);

function [] = lsa27_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(7),'String');
selectedText1 = contents1{get(S.lsa2(7),'Value')};
set(S.lsa2(7),'Tooltip',selectedText1);

function [] = lsa28_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(8),'String');
selectedText1 = contents1{get(S.lsa2(8),'Value')};
set(S.lsa2(8),'Tooltip',selectedText1);

function [] = lsa29_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(9),'String');
selectedText1 = contents1{get(S.lsa2(9),'Value')};
set(S.lsa2(9),'Tooltip',selectedText1);

function [] = lsa210_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(10),'String');
selectedText1 = contents1{get(S.lsa2(10),'Value')};
set(S.lsa2(10),'Tooltip',selectedText1);

function [] = lsa211_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(11),'String');
selectedText1 = contents1{get(S.lsa2(11),'Value')};
set(S.lsa2(11),'Tooltip',selectedText1);

function [] = lsa212_call(varargin)
S = varargin{3};
```

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```
contents1 = get(S.lsa2(12),'String');
selectedText1 = contents1{get(S.lsa2(12),'Value')};
set(S.lsa2(12),'Tooltip',selectedText1);

function [] = lsa213_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(13),'String');
selectedText1 = contents1{get(S.lsa2(13),'Value')};
set(S.lsa2(13),'Tooltip',selectedText1);

function [] = lsa214_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(14),'String');
selectedText1 = contents1{get(S.lsa2(14),'Value')};
set(S.lsa2(14),'Tooltip',selectedText1);

function [] = lsa215_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(15),'String');
selectedText1 = contents1{get(S.lsa2(15),'Value')};
set(S.lsa2(15),'Tooltip',selectedText1);

function [] = lsa216_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(16),'String');
selectedText1 = contents1{get(S.lsa2(16),'Value')};
set(S.lsa2(16),'Tooltip',selectedText1);

function [] = lsa217_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(17),'String');
selectedText1 = contents1{get(S.lsa2(17),'Value')};
set(S.lsa2(17),'Tooltip',selectedText1);

function [] = lsa218_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(18),'String');
selectedText1 = contents1{get(S.lsa2(18),'Value')};
set(S.lsa2(18),'Tooltip',selectedText1);

function [] = lsa219_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(19),'String');
selectedText1 = contents1{get(S.lsa2(19),'Value')};
set(S.lsa2(19),'Tooltip',selectedText1);

function [] = lsa220_call(varargin)
S = varargin{3};
contents1 = get(S.lsa2(20),'String');
selectedText1 = contents1{get(S.lsa2(20),'Value')};
set(S.lsa2(20),'Tooltip',selectedText1);
```

Appendix D

During PhD the author has published three conference and two journal papers. In addition, a work has been submitted for consideration to *Research in Engineering Design*. These papers are listed below:

1. D. Bacciotti, Y. Borgianni, F. Rotini (2013) *'Overview of methods supporting product planning: open research issues' 19th International Conference on Engineering Design (ICED13), Seoul, Korea, 19-22 August*;
2. D. Bacciotti, Y. Borgianni, F. Rotini (2014) *'Exploring the dimensions of value: the Four Dimensions framework' 13th International Design Conference (DESIGN 2014), Dubrovnik, Croatia, 19-22 May*;
3. D. Bacciotti, Y. Borgianni, F. Rotini (2015) 'A CAD tool to support idea generation in the Product Planning phase' 12th International CAD Conference (CAD'15), London, United Kingdom, 22-25 June;
4. D. Bacciotti, Y. Borgianni, F. Rotini (2016) *'A CAD tool to support idea generation in the Product Planning phase' Accepted in International Journal of Computer-Aided Design & Applications* (in press);
5. D. Bacciotti, Y. Borgianni, F. Rotini (2016) *'An original design tool for stimulating the ideation of new product features' Computers in Industry, 75*, 80-100
6. D. Bacciotti, Y. Borgianni, G. Cascini, F. Rotini (under review) *'Product Planning techniques: investigating the differences between research trajectories and industry expectations' Submitted for consideration to Research in Engineering Design*.

These works will be included in the following pages, except for the first and third papers. Indeed, contents of the first work are widely integrated in Chapter 1, 2 and in paper submitted for consideration to Research in Engineering Design, while paper accepted in International Journal of Computer-Aided Design & Applications is the extended version of the other omitted work.

D.1 Exploring the dimensions of value: the Four Dimensions framework

D. Bacciotti, Y. Borgianni and F. Rotini

Abstract

Companies have to develop innovative and valuable products in order to achieve competitive advantage. To this aim, the idea generation task should be effectively supported within the Product Planning phase, whose goal is defining the main product features. According to this objective, the paper proposes a tool, namely Four Dimensions framework, that urges designers looking for new customer requirements through the mapping of General Demands, Stakeholders, Life Cycle and Systems. The tool has been simulated through an application to the first Apple iMac (1998), obtaining promising results.

1. Introduction

In today's highly competitive marketplace, companies have to innovate their commercial offer in order to survive. It is widely acknowledged in literature that innovating means designing something that will not only work from a technical point of view, but will also make business sense (e.g. Schilling 2008; Cantamessa et al. 2013). According to this belief, firms should carefully analyse and continuously improve their design activities, in order to develop products and services that generate new value for customers.

Several scholars agree with the observation that initial design stages and markedly Product Planning result particularly crucial to determine the successful achievement of innovation initiatives (e.g. Pahl and Beitz 2007; Ulrich and Eppinger 2008). In the recalled phase, one of the main activities is the idea generation task that allows identifying distinguishing features or original ideas regarding a new product (Alam 2006; Riel et al. 2013). Although a well-managed idea generation can be considered as a primary source of commercial success and several methods to support this activity exist, many companies do not allocate sufficient resources to perform this stage accurately (Alam 2006). Such a discrepancy can be put into relationship with the perception of idea generation as a random process, where ideas may be detected only by intuition, observations, discussions or accidents, without using structured approaches capable of stimulating the creativity of the involved people (Stasch et al. 1992).

The authors share the vision that more systematic approaches can result beneficial also in this early product development stage (Pahl and Beitz 2007), which is, conversely, pronouncedly entrusted to individual skills (Bacciotti et al., 2013).

According to this objective, the authors propose, in the present paper, an approach to browse the aspects viable to impact customer value, thus supporting the product ideation task. The task is actually challenging, since manifold product aspects contribute to determine value (Cantamessa et al. 2012; Lee et al. 2010; Chen and Yan 2008). The advanced tool, namely Four Dimensions framework (FDf), assumes that all the product characteristics can be schematized into four dimensions: General Demands (GDs) of customers, product Stakeholders (SHs), different stages of product Life Cycle (LCs) and different levels of detail (Systems, SYSs). The generation of original combinations of dimensions' attributions urges designers exploring a wide range of situations, circumstances and working conditions, where new sources of value for customers can be individuated. FDf stands therefore in the backbone of a proposal for proactively generating new product attributes, avoiding employing customer opinions, which generally hinder the identification of new needs to be satisfied (Bacciotti et al., 2013).

In order to show how FDf works and obtain some feedback about its applicability, the authors have employed a case of study concerning one of the most successful PC developed by Apple Inc., i.e. the iMac. The known evolution of its characteristics allowed understanding to which extent FDf, if applied to the first PC model, would support the identification of the new features appearing as time progressed.

The second section of the article introduces the concept of value, highlighting and discussing the dimensions that represent possible sources of value generation for customers. Then, the third section presents an overview of methods that support the idea generation phase, shedding light on their capability of exploring the introduced dimensions of value. Subsequently, the fourth section describes the proposed tool and the step by step application to the considered case study, revealing the main outcomes arisen by the example. Eventually, the most remarkable results and the future research directions are summarised and discussed in the fifth section, which concludes the paper.

2. The dimensions of value

The central goal in New Product Development is to create a product with superior value for the customer so that his/her needs will be satisfied (e.g. Van Kleef et al. 2005). However, the concept of customer (or user) value can assume different meanings, according to the research field (Boztepe 2007). The authors refer to the capability of designed product properties to engender customer satisfaction, satisfy needs and generate benefits for users. In this sense, a value proposition strategy pursues the objective of differentiating the company's offer from the industrial standard, with the attempt of developing new products and services that enhance customer satisfaction through additional benefits and unprecedented experiences (Kim and Mauborgne 2005). Such a kind of value innovation strategy fundamentally redefines the market boundaries by identifying new product characteristics.

Several sources are acknowledged in literature as opportunities for the generation of customer value, according to them, the idea generation phase should be carried out by exploring the following value dimensions:

- General Demands (GDs): they refer to the existing, emerging or unspoken needs perceived by the customers and satisfied through the benefits generated by the product features. The recalled benefits are generally defined as Product Attributes (PAs) (Borgianni et al. 2013). Hence, in the remainder of the paper, the authors will indicate with this term the distinctive tangible (e.g. quickness and speed in performing the functions, ergonomics, storability) or intangible (e.g. aesthetics, fun and adventure, ethics) characteristics of a product that generate value for the customer. This first value dimension can be specified and explored by the other three following dimensions that identify actors, life cycle phases and systems involved in the value generation process.
- Stakeholders (SHs): they are all the actors that interact with the product during its life cycle. The concept of "customer" is extended from buyer to user, beneficiaries, service recipients and outsiders, with the aim of identifying new opportunities to increase the delivered value. As stated by (Cantamessa et al.

2013), buyers and users might be different individuals (e.g. parents and children) and the actor(s) that will ultimately benefit from the product might be different from either the buyer or the user.

- Life Cycle phases (LCs): they concern the circumstances that may occur along the different stages of product existence, from the moment in which any stakeholder begins to interact with the product, to the end of product functioning. By analysing all these situations, several scenarios where any stakeholder may perceive value can be identified (Rotini et al. 2012). Hence, it can be deduced from this that SHs and LCs dimensions are strictly related (Cantamessa et al. 2013). This investigation is crucial to avoid focusing only on the phase of product's use, losing several opportunities to identify sources of value for the customer.
- Systems (SYS): this dimension suggests analysing the product at different levels of detail, including the "super-system" (Altshuller 1984) in which the product will be situated along its life cycle (operative environment, working conditions, surroundings, matching systems). The design of the product taking into account different hierarchical levels of the systems (from the external environment to their parts and components) is viable to enhance customers' value.

The authors believe that the research direction in this field should be oriented towards an integrated analysis of all these value aspects that are strictly linked.

3. Overview of idea generation tools

The idea generation task is one of the main activities of the Product Planning phase, as seen in the first Section, and allows identifying attributes, features or general ideas of the product to be developed (Alam 2006; Riel et al. 2013). The authors have recently presented an overview of methods to support this activity (Bacciotti et al. 2013), limiting their focus on approaches to be employed during Product Planning, so excluding techniques tailored for other design phases (e.g. requirement checklists or Quality Function Deployment). The authors will now try to remark to which extent and in which ways the investigated methods support the exploration of the dimensions of value, briefly introduced in the previous Section.

(Liberatore and Stylianou 1995), as well as (Matsatsinis and Siskos 1999) suggest a set of statistical tools to combine the inputs coming from customer surveys, expertise of internal personnel and market analysis, in order to generate a list of the most beneficial GDs. These methods focus on the end user, overlooking other potential SHs; in addition, they analyse only some of the LCs and the SYSs. For instance, (Matsatsinis and Siskos 1999) considers only the phases of purchasing and use of the product and focuses on two SYSs, i.e. the product and its packaging. Therefore, only the analysis of the GDs value dimension can be considered effectively supported by these tools.

(Chan and Ip 2011) proposes a method that follows a different procedure, if compared to the previous contributions. The design team has to assess, on the basis of experience, the most beneficial GDs for the end user. Subsequently, these GDs are matched with those coming from customer surveys, in order to obtain the best set of GDs. Although the analysis of the GDs is better managed than the previously cited methods, this approach shares the same weaknesses. Indeed, it considers only the end user and the same LCs (i.e. purchasing and use) and SYSs (i.e. product and packaging) of (Matsatsinis and Siskos 1999), without using a systematic approach to explore these value dimensions.

(Lee et al. 2010) proposes a method that involves design teams striving to identify the GDs of potential stakeholders through scenario-based analysis. This technique allows analysing several circumstances occurring during LCs, however it does not consider the SYSs dimension, because the focus is exclusively on the product. Although three out of four value dimensions (i.e. GDs, SHs and LCs) can be analysed using this approach, it is characterised by a low systematic level; moreover the method is considerably based on subjective inputs and random processes.

The Lead User Method (Von Hippel 1986; 2005), does not consider neither design teams nor group of generic customers, but only pioneer users (lead users) of a product. Pioneers have spent more time in using the product with respect to the rest of the customers, so that they can suggest new GDs still latent for many potential clients. This approach focuses only on the end user, supports the analysis of the phase of use and it can consider more SYS, without using a systematic approach.

Within Blue Ocean Strategy (Kim and Mauborgne 2005), the most useful tool to support the designer during the idea generation process is the so-called Six Paths framework (Borgianni et al. 2012). The instrument is articulated in six suggestions (i.e. look across alternative industries, look across strategic groups within industry, redefine the industry buyer group, look across to complementary product and service offerings, rethink the functional-emotional orientation of the product, participate in shaping external trends over time) that support the analysis of the SHs (according to the first three paths) and implicitly of GDs (considering all the paths). Conversely, LCs and SYSs dimensions cannot be analysed using this approach, because the method does not provide any hints to explore these value dimensions. In addition, this tool offers only mere qualitative indications that are not sufficiently systematic to support the professionals during Product Planning (Aspara et al. 2008).

(Chen and Yan 2008) illustrates a method that supports the designer in the process of product ideas generation, based on the hybridization of existing products features. The SYSs dimension is well investigated, analysing the product and all its parts, components and accessories. However, the approach does not support the exploration of SHs and LCs dimensions. Therefore the designer could probably consider only the end user and the phase of use of the product.

According to the performed review, the considered techniques do not comprehensively support the exploration of the whole set of value dimensions, since each contribution is tailored on specific aspects. Furthermore, almost all the analysed approaches are poorly systematic. Therefore, the authors developed a tool that tries to guide the designer, in a structured way, in the exploration of all the dimensions of value, supporting the idea generation with a systematic process.

4. Exploring the dimensions of value: description and application of the Four Dimensions framework

The objective of FDf is to support the analysis of the value dimensions defined in Section 2, with the aim of eliciting product attributes and individuating new sources of value for stakeholders.

In the following Subsections, the tool is shown providing details about the objectives of the constituent activities and the expected outcomes. Furthermore, the description of the proposed approach is combined with its application to a case study concerning Apple iMac. The authors choose this case because of the well-documented evolution of the product and its attributes from 1998 up to 2013. The option to apply the developed tool to a new product has been discarded, because it would require too much time in order to obtain preliminary results.

iMac has undergone notable changes in the last 15 years (Figure 1), even if it has maintained its main peculiarities. The most evident improvements are related to the technological evolution of the monitor and the electronic components that allowed a reduction of PC dimensions. However, also the software evolution has played an important role in determining the widely acknowledged success of the product.

Figure 1 evolution of Apple iMac (1998-2013) [www.apple.com]

4.1 Step 1: Information gathering

The reference market in which the company wants to perform the new value proposition has to be deeply analysed, in order to get a complete picture of the as-is situation about the currently displayed product features (PFs). Thus, the result of this phase is constituted by a comprehensive list of characteristics capable to represent all the aspects related to existing products in a certain market field.

With respect to iMac, the authors considered all the features of the first model issued in 1998. The required information about the product has been extracted from the 1998 web site, available at the following URL: www.web.archive.org/web/19980509035420/ http://www.apple.com (last access 9th December 2013). Table 1 shows an excerpt of the collected data

	iMac 1998 product features (PFs)
Processor:	233-MHz PowerPC G3
Backside level 2 cache:	512K L2 cache
Memory:	32MB of SDRAM *(expandable to 128MB)*
Hard disk drive:	4GB IDE
CD-ROM drive:	Built-in 24x speed (maximum)
Display:	Built-in 15 inch (13.8-inch diagonal viewable image size)
…	…

Table 1 iMac 1998 collected PFs

4.2 Step 2: Exploring the value dimension of the general demands

4.2.1 Step 2.1: Translate the collected product features into product attributes

The product features collected in the previous step have to be now expressed in terms of product attributes (PAs). According to the Pas' definition introduced in Section 2, the user has to identify the benefits perceived by the customers for each PFs. The translation of PFs into PAs can be carried out through the following questions:

- which reason or scope motivates the presence of the <product feature> in the existing products?
- which benefit(s) for the customers can be achieved through this <product feature>?

Table 2 shows the results of the conversion of an illustrative iMac product feature into the related product attributes.

Product features (PFs)	**Product attributes (PAs)**
Memory (RAM): • which reason or scope motivates the presence of the ***memory (RAM)*** in the existing products? • which benefit(s) for the customers can be achieved through the ***memory (RAM)***?	Fast application launches
	Expandability/improvements of PC efficiency

Table 2 conversion of PFs into PAs

4.2.2 Step 2.2: Group the product attributes according to general demands

In this step, the identified PAs have to be grouped, according to the GDs they fulfil; in such a way, it is possible to identify which are the needs already satisfied in the reference market, through the characteristics offered by the existing products. The translation of PAs into GDs can be carried out through the following questions:

- which needs for the customers can be achieved through the <product attribute>?
- which reason or scope do the product attributes have in common?

In addition, a suitable approach to guide the reasoning involved in this task is the Customer Requirements Checklist (CR Checklist) (Becattini et al. 2011; Rotini et al. 2012), showed in Table 3. The recalled checklist consists in a record of hints, comprising a wide range of GDs. The list, although not claiming to be exhaustive, has resulted sufficiently large within the experiences carried out by the authors in the field of Product Planning. The GDs are listed according to:

- direct benefits perceived by the end user, namely useful functions (i.e. first row of Table 3);
- strategies aiming at eliminating or attenuating undesired effects commonly associated with the product functioning, namely harmful functions (i.e. second row of Table 3);

- properties leading to the reduction of the resources to be channelled by the buyer or the end user of the system, namely resources (i.e. third row of Table 3).

Hence, the user can analyse this list looking for the answers to the previous questions. For instance, considering the iMac's PAs of Table 4, the application of CR Checklist leads to the identification of the general demand "quickness and speed in performing the functions".

Useful functions • the advantages arising from the exploitation of the product, which can be referred to the quality and the quantity of the desired output; • the amount of users for whom such benefits are met, thus the flexibility of the product according to different customer demands; • the capability of the product to meet the customer needs within the requested time; • the adaptability of the product when working in diverging conditions with respect to the designed preferred ones; • the stability of the product performances when subjected to external perturbations; • the chance to effectively control the system in order to obtain the expected outcomes; • the possibility to expand or upgrade the range of product functioning; • the opportunity provided to advantageously employ the product for not standard users or disabled people; • the possibility to customize the product or certain properties according to the user tastes and tendencies; • the possibility to use the system for different employments after the termination of main product functioning, the collection of matching items; • the aesthetical requirements and the emotional dimension of the product, the style, the fashion content, what it evokes in the user, the lifestyle that the object implies, the prestige it generates for the owner as a feeling of distinction and recognition; • the fun and adventure resulting from the use of the system.
Harmful functions • the integrity of the product itself, its resistance to planned or accidental stress or collisions, the strength against wear or corrosion; • the limitation of damages towards treated objects or neighbouring systems; • the environmental sustainability, the recyclability, the possibility to reuse the system or its parts reducing the amount of waste; • the ethics of the product as a distinguishing factor; • the safety and innocuousness for human health and people's psychological and social conditions; • the absence of bother for the user employing the product or for surrounding people, the comfort of use, the ergonomics, the manageability; • the reliability, the limited frequency of system failures; • the duration, the expected life of the product.

Resources

- the limitation of occupied space, the lessening of the encumbrance, the accessibility, meant as a shrunk quantity of space required to allow the users to employ, store, transport, maintain and dismantle the product;
- the working speed, the reduction of time to be waited before the functioning of the product delivers the expected outcomes, including the duration of the period to be waited before physically benefiting of the bought item or service after the purchase;
- the limitation of the time required to maintain or fix the product, to change accessories, to dismantle the system, to learn how to use it, to administer or to accomplish the involved bureaucracies;
- the reduction of the information and skills to be gathered in order to correctly use and control the product, the ease of employment, the user friendliness, the limitation of required training;
- the ease of acquiring the product, due to market penetration and distribution policies;
- the ease of managing, maintaining, assembling, disassembling, upgrading, substituting components or accessories;
- the ease of choosing and individuating the product in the marketplace, according to recognizable features, due to technical, aesthetical or communication issues;
- the lightness and the portability;
- the independence from the use of different materials, instruments, technical systems;
- the absence or limitation of the consumption of consumable items or materials;
- the reduction of auxiliary functions to be delivered in order to use, install, dismount or dispose the system;
- the limitation of the required energy needed for the product working, maintaining, installing, disposing, recycling; its efficiency;
- the decrease of the human power needed to use or transport the product;
- the additional services provided in order to attenuate the consumption of individual resources, as those listed in the previous bullets, the customer care.

Table 3 CR Checklist

<table>
<tr><th>General demand</th><th>Product attributes</th></tr>
<tr><td rowspan="6">Questions:
• which needs for the customers can be achieved through the <product attribute>?
• which reason or scope do the product attributes have in common?

Answer: Quickness and speed in performing the functions</td><td>Short boot time</td></tr>
<tr><td>Quick file access</td></tr>
<tr><td>Fast application launches</td></tr>
<tr><td>Fast networking</td></tr>
<tr><td>Speed of browsing the Internet</td></tr>
<tr><td>Fast data transfer</td></tr>
</table>

Table 4 conversion of PAs into GDs

4.3 Step 3: Exploring the value dimensions regarding stakeholders, life cycle phases and system hierarchies

In this step the LCs, SHs and SYSs value dimensions have to be analysed in order to identify:

- current LCs in which GDs are perceived;

- existing SHs that interact with the product;
- existing SYSs that are exploited as value sources for the customer.

4.3.1 Step 3.1: Exploring the LCs dimension

The authors proposed to adopt an appropriate subdivision of the temporal dimension of the product lifecycle, designed to pinpoint the most common situations in which stakeholders can perceive value (Rotini et al., 2012), i.e. purchasing, choice and access activities, before use operations, utilization time, elapsed time before further exploitations, end of the functioning.

The user can analyse the list of collected PAs, in order to identify the LCs in which stakeholders can benefit of each product attribute. For instance, in the iMac 1998, the PA “ease to learn”, which refers to the GD “ease of use”, is perceived in “before use operation”, as shown in Table 5.

General demands (GDs)	Product attributes (PAs)	Life cycle phases (LCs)
Ease of use	Ease to learn	Before use operation
Audio quality	Quality of the voice (microphone)	Utilization time
Video quality	Graphics quality	Utilization time

Table 5 correlation between SHs, PAs and GDs

4.3.2 Step 3.2: Exploring the SHs dimension

Existing SHs can be identified through the information collected in Step 1, also thinking to the LCs dimension. Designers employing FDf can thus analyse the list of collected PAs, as seen for the LCs dimension, in order to establish the SHs benefitting of each product attribute in the given circumstances. A tool for supporting this task is the use, as a checklist, of the four clusters (i.e. buyers, users, beneficiaries and outsiders), suggested by (Cantamessa et al. 2012; 2013). Within these groups of customers the user can identify several subgroups of stakeholders (e.g. old people, left handed individuals, children, etc.).

The application of this step to the iMac 1998 has led to the identification of a wide list of already satisfied stakeholders, for instance the PA “compatibility with several Braille displays”, which refers to the GD “ease of use”, has a relationship with “disabled people (users)”, as shown in Table 6.

<table>
<tr><th>General demands (GDs)</th><th>Product attributes (PAs)</th><th>Stakeholders (SHs)</th></tr>
<tr><td>Ease of use</td><td>Compatibility with several Braille displays</td><td>Disabled people</td></tr>
<tr><td rowspan="3">Audio quality</td><td rowspan="3">Quality of the voice (microphone)</td><td>Educators and Students</td></tr>
<tr><td>General consumers</td></tr>
<tr><td>Disabled people</td></tr>
</table>

Table 6 correlation between SHs, PAs and GDs

4.3.3 Step 3.3: Exploring the SYSs dimension

This activity concerns the identification of environments, products, parts and accessories that stimulate the generation of value for the stakeholders by fulfilling the GDs. In order to support this task, it can be useful to focus separately on three main hierarchical levels, i.e. the environment in which the product is situated, the product itself and, eventually, the parts, components and accessories of the product (Altshuller 1984). The identification of various operating environments can be performed considering all the places where the product can be situated during its life cycle. A tool for supporting this task is the use, as a checklist, of the above mentioned five LCs phases. On the other hand, a suitable approach that could be used to enhance the analysis of the low level (i.e. product's parts and accessories), is the Design Knowledge Hierarchy (Chen and Yan 2008), which uses a tree diagram to such an aim. Eventually, the user can exploit the same approach showed for the analysis of the LCs and SHs dimensions, in order to determine which SYS fulfils each product attribute. For instance, in the iMac 1998, the PA "ease to use peripherals", that underpins the GD "ease of use", emerges from the consideration of the product sub-systems "keyboard" and "mouse", as shown in Table 7.

General demands (GDs)	Product attributes (PAs)	Systems (SYSs)
Ease of use	Ease to use peripherals	Keyboard
		Mouse
Audio quality	Quality of the voice (microphone)	Audio output system
Good View (monitor)	Monitor focus	System to show video output

Table 7 correlation between SYSs, PAs and GDs

4.4 Step 4: Combination of the four value dimensions

This final step represents the core of the proposed idea generation tool. The collected lists of GDs, SHs, LCs and SYSs have to be combined in order to create a wide range of new situations the practitioner can investigate for generating new sources of value. The investigation schema suggested by the FDf compels the user to ask himself the following question:

Are there any circumstances related to the <general demand>, occurring during the <life cycle phase> and concerning the <system> that generate value for the <stakeholder>, resulting as inputs for the design of a new product?

Thus, the tool can be employed as a collection of questions, supporting the scope of systematically browsing the possible sources of value offered by the product. Subsequently, the individuated sources of value have to be appropriately elaborated and interpreted in order to elicit new product attributes. New attributions of any dimensions of value with respect to the gathered terms can undoubtedly result effective for the scopes of generating new PAs. However, FDf has been initially tested with the terms monitored in the as-is situation, in order to show the applicability of the approach in a systematic way. Conversely any unguided widening of the dimensions would jeopardize the systematic level of the technique, since e.g. the kinds of SHs may be countless.

The possible combinations of the individuated elements for the four value dimensions include new and existing combinations (Figure 2). All of them can potentially support the identification of new PAs, however the new combinations have more chances to generate scenarios potentially disclosing breakthrough product ideas. Therefore, the authors suggest to primarily focus on this group of combinations, in order to identify innovative sources of value for the stakeholders.

Figure 2 four value dimensions combinations

Considering the iMac case study a possible question is:

*Are there any circumstances related to the **ease of use**, occurring during the **purchasing, choice and access activities** and concerning the **PC** that generate value for the **general customer** (end user), resulting as inputs for the design of a new product?*

An answer to this question can be found considering the new iMac, indeed Apple has introduced free workshops and on-line tutorials with the aim of training the end users.

4.5 Main outcomes

In order to understand the capability of FDf to lead to new meaningful product attributes, the authors performed a comparison between the iMac version sold in 1998 and the current PC. For the sake of clarity, it has been simulated the employment of the FDf in 1998 and observed how this application could lead to the definition of product attributes actually implemented in the iMac 2013.

The current iMac has 47 new product attributes if compared to the first model. 26 out of these 47 new PAs can be identified applying the FDf with the mapped elements for the four value dimensions in the "as-is" situation (1998). Therefore, the obtained results show that the 55% of the new product attributes offered by iMac 2013 can be generated by exploring and conveniently combining the dimensions of value of iMac 1998. In addition, extending the four value dimensions by adding new GDs, SHs, LCs and SYSs to the existent set, FDf could even support the identification of the whole set of new PAs.

The wide range of new circumstances identified by the authors analysing the first iMac, not only allowed to find out several attributes implemented in the 15-years-later PC model, but also provided insights for generating new sources of value. For instance, an emerged question is:

*Are there any circumstances related to the **minimal amount of space**, occurring during the **elapsed time before further exploitations** and concerning the **system to connect peripherals** that generate value for the **general customer** (end user), resulting as inputs for the design of a new product?*

An answer to this question can be found considering a way to minimize the amount of space of the power supply cord, e.g. using a wireless energy transmission.

5. Discussion and Conclusion

The idea generation phase plays a key role in the product development process and some methods have been developed in order to support the designer in this critical activity. However, they suffer from an insufficient monitoring of the aspects of value that can be delivered to the end users. In order to develop a comprehensive idea generation technique considering all sources of value for the customer, the present paper presented a new tool, namely Four Dimensions framework (FDf). The proposal maps a wide range of situations, circumstances and working conditions, with the aim of individuating new sources of value for the customer. It considers four dimensions that contribute to the success of the product: General Demands (GDs) of the customers, product Stakeholders (SHs), different stages of product Life Cycle (LCs) and different levels of detail (Systems, SYSs) related to the product. The combination of these aspects allows systematically browsing a wide set of sources of value, thus supporting the identification of new product ideas.

In order to show how FDf works and draw some preliminary feedback about its functionality, the authors applied the tool to a successful product whose attributes evolution (from 1998 up to 2013) is known, i.e. Apple iMac. The obtained results are satisfactory, since 55% of the new attributes introduced by iMac 2013 could be potentially identified by applying FDf to the 1998 model. The outcome is even more interesting, considering that electronic products are subjected to rapid obsolescence and hard competition (Haigh 2011). However, the usability and reliability of the method in the industry has to be still demonstrated with real industrial applications. In addition, further research is needed for identifying possible ways to systematically extend the dimensions of value to be explored through FDf. This could make more exhaustive the search of new value opportunities. Moreover, further investigation is required to understand how the large number of combinations can be managed, in order to provide an effective idea generation method. Furthermore, the authors invite other researchers to propose additional value dimensions to be integrated in the developed approach. Eventually, the authors consider the possibility to extend the developed idea generation tool with criteria or methods that support the idea selection phase of the Product Planning.

References

Alam I (2006) Removing the fuzziness from the fuzzy front-end of service innovations through customer interactions. Industrial Marketing Management 35(4):468-480

Altshuller GS (1984) Creavity as an exact science. The Theory of Solution of Inventive Problems. Gordon & Breach Science Publishers, New York

Aspara J, Hietanen J, Parvinen P, Tikkanen H (2008) An Exploratory Empirical Verification of Blue Ocean Strategies: Findings from Sales Strategy. Eighth International Business Research (IBR) Conference, Dubai

Bacciotti D, Borgianni Y, Rotini F (2013) Overview Of Methods Supporting Product Planning: Open Research Issues. International Conference On Engineering Design, ICED13, Sungkyunkwan University, Seoul

Becattini N, Cascini G, Petrali P, Pucciarini A (2011) Production processes modeling for identifying technology substitution opportunities. Proceedings of the TRIZ-Future Conference 2011, Dublin

Borgianni Y, Cascini G, Rotini F (2012) Investigating the patterns of value-oriented innovations in blue ocean strategy. International Journal of Innovation Science 4(3):123-142

Borgianni Y, Cascini G, Pucillo F, Rotini F (2013) Supporting product design by anticipating the success chances of new value profiles. Computers in Industry 64:421-435

Boztepe S (2007) User value: Competing theories and models. International journal of design 1(2):55-63

Cantamessa M, Cascini G, Montagna F (2012) Design for Innovation. International Design Conference - DESIGN 2012, University of Zagreb/The Design Society

Cantamessa M, Montagna F, Messina M (2013) Multistakeholder Analysis of Requirements to Design Real Innovations. International Conference On Engineering Design, ICED13, Sungkyunkwan University, Seoul

Chan SL, Ip WH (2011) A dynamic decision support system to predict the value of customer for new product development. Decision Support Systems 52(1)178-188

Chen CH, Yan W (2008) An in-process customer utility prediction system for product conceptualisation. Expert Systems with Applications 34(4):2555–2567

Haig M (2011) Brand Failures. Kogan Page, London

Kim WC, Mauborgne R (2005) Blue Ocean Strategy. Harvard Business School Press, Cambridge

Lee CW, Suh Y, Kim IK, Park JH, Yun MH (2010) A Systematic Framework for Evaluating Design Concepts of a New Product. Human Factors and Ergonomics in Manufacturing & Service Industries 20(5):424-442

Liberatore MJ, Stylianou AC (1995) Toward a Framework for Developing Knowledge-Based Decision Support Systems for Customer Satisfaction Assessment: An Application in New Product Development. Expert Systems with Applications 8(1):213-228

Matsatsinis NF, Siskos Y (1999) MARKEX: An intelligent decision support system for product development decisions. European Journal of Operational Research 113(2):336-354

Pahl G, Beitz W, Feldhusen J, Grote KH (2007) Engineering Design – A Systematic Approach. Springer, London

Riel A, Neumann M, Tichkiewitch S (2013) Structuring the early fuzzy front-end to manage ideation for new product development. CIRP Annals-Manufacturing Technology

Rotini F, Borgianni Y, Cascini G (2012) Re-engineering of Products and Processes. Springer, London

Schilling M (2008) Strategic Management of Technological Innovation. McGraw-Hill, New York

Stasch SF, Lonsdale RT, La Venka NN (1992) Developing a framework for sources of new product ideas. Journal of Consumer Marketing 9(2):5-15

Ulrich KT, Eppinger SD (2008) Product Design and Development. McGraw Hill, New York

Van Kleef, E., van Trijp, H., Luning, P (2005) Consumer research in the early stages of new product development: a critical review of methods and techniques. Food Quality and Preference 16(3) 181-201

Von Hippel E (1986) Lead users: A source of novel product concepts. Management Science 32(7):791-805

Von Hippel E (2005) Democratizion innovation. The MIT Press, Cambridge

D.2 A CAD tool to support idea generation in the Product Planning phase

D. Bacciotti, Y. Borgianni and F. Rotini

Abstract

The work described in the paper is motivated by the lack of computer-aided tools to support Product Planning and, more specifically ideation processes of New Product Development (NPD) initiatives. The domain is populated by software applications aimed at managing and organizing Product Planning activities, thus poorly contributing to the definition of new product characteristics, and models to stimulate novel ideas. The latter face limitations in terms of overlooked implementation with CAD tools supporting the following NPD phases and poor exploration of the design space. The authors propose an original method and software prototype capable to provide a wide range of stimuli, whose testing demonstrated much better results than traditional approaches in terms of quantity and variety of generated ideas.

1. Introduction

CAD tools provide an essential aid to designers in New Product Development (NPD) processes by accelerating and easing activities, which required consistent time resources decades ago. Besides, the scientific community claims advantages with respect to the integration of all the phases of the design process (Cugini et al. 2009). More specifically, research efforts have been addressed to link the activities pertaining to the front end, i.e. Product Planning and Conceptual Design, and the back end, i.e. Embodiment Design and Detailed Design, (Pahl and Beitz 2007). The diffusion of CAD instruments to support the latter represents a way with no turning back in the industrial world. Hence, any integration of all design phases cannot disregard the employment of computer platforms.

Unfortunately, the integration is slowed down by the difficulty of identifying repeatable patterns (translatable in algorithms) in front end phases and the lack of shared models among front end and back end phases. Indeed, it is widely acknowledged in the literature that these phases typically involve random process and "ad hoc" decisions based on intuition, observations, discussions or accidents (Flint 2002; Montoya-Weiss and O'Driscoll 2000). This is why the term "Fuzzy Front End" (FFE) (Smith and Reinertsen 1991) has been coined to describe the earlier phases of the design process. Besides, the lack of replicable actions to perform the FFE ranges among the causes of products' commercial failure (e.g. Haigh 2011) and determines the unpredictability of the costs occurring during the whole product development cycle (Ulrich and Eppinger 2011).

Some CAD tools have been proposed to support Conceptual Design (Cao and Fu 2011; Cardillo et al. 2013; Sapidis and Kyratzi 2005), which is acknowledged as a fundamental step towards the definition of original, novel and sustainable technical solutions (Al-Hakim et al. 2000). In addition, the literature shows a growing trend in the proliferation of CAD software for Conceptual Design, as it results evident from the manuscripts published in a recent special issue devoted to outline next-generation of CAD platforms (e.g. Becattini et al. 2012; Fuge et al. 2012; Goel et al. 2012; Komoto and Tomiyama 2012). Conversely, the exploitation of Artificial Intelligence is so far marginal to ease the execution of Product Planning tasks. According to Pahl and Beitz (Pahl and Beitz 2007) and several other scholar of Engineering Design field, these tasks can be summarized as it follows:

- identification of customer needs to be fulfilled;
- analysis of current lacks in the products available in the market;
- ideation of new product functions, features and properties capable to fulfil customer expectations;
- selection of the most promising new product ideas.

Therefore, the main outcome of Product Planning is constituted by the product idea, expressed in terms of a requirements list. Since the information coming out from the considered phase represents the reference for the subsequent design activities, the undertaken decisions strongly impact the success likelihood of the new product development initiative. Notwithstanding the strategic role played by Product Planning, insights from literature show how even few acknowledged methods effectively support the above recalled tasks (Bacciotti et al. 2014; Soukhoroukova et al. 2012), as shown in Section 2. Moreover, whereas these methods have been implemented in computer frameworks, the scope was never considered of integrating the developed software with CAD tools supporting other design phases. As a result, a negligible set of software applications is tailored to aid the ideation process of Product Planning, by e.g. taking the review of computer-aided innovation tools described in (Hüsig and Kohn 2009) as a reference. Section 2 will elucidate too the scopes of diffused commercial software applications that ease the execution of Product Planning, remarking the little attention dedicated to the generation of new ideas.

The authors have attempted to extrapolate repeatable patterns within Product Planning and developed a computer aided tool, namely iDea, to support designers during idea generation processes. Section 3 describes the software prototype and its underlying methodology. The aim of the proposal is overcoming the limitations of the most diffused methods for idea generation, by benefitting of Artificial Intelligence capabilities to offer designers a complete set of stimuli for generating original product attributes.

In order to assess the effectiveness of developed tool, a test has involved 24 MS students of Mechanical Engineering (Section 4). In the experiment, the authors have compared the outcomes of iDea with those emerging from the employment of a more known tool, i.e. Six Paths Framework (Kim and Mauborgne 2005). The latter supports the idea generation activity providing some hints to guide an individual "Brainstorming" process. The choice of this instrument leant upon the need of picking up a successful technique, besides diffused in industry, which however suffers from the lack of patterns allowing a useful computer implementation.

Eventually, Section 5 concludes the paper by introducing expected future developments of the proposed tool. In addition, it highlights the core findings of the present research, as well as its main limitations.

2. Background

A deep survey of procedures and techniques that support idea generation is out of the scope of the present paper. Readers can find detailed information about academic and industrial approaches to Product Planning in other sources, such as (Adams et al. 1998; Bacciotti et al. 2013). With respect to the objectives of the manuscript, it is sufficient to point out how the most diffused approaches refer to stimuli or hints that proactively allow identifying new product ideas. As a result, the most appropriate software applications to support Product Planning consist in enhanced techniques that favour communication within design teams. Still with reference to (Pahl and Beitz 2007), they include digital Brainstorming and Crowdsourcing tools. These instruments provide virtual environments in which designers and or/customers can share, improve and assess ideas generated through intuition and personal experience. Hence, the employment of Artificial Intelligence is devoted to ease the management of the treated design activities, but it can hardly give rise to better product ideas than the methods that are basically implemented in computer frameworks.

Some approaches provide guidelines to support individual (Kim and Mauborgne 2005) or collective (Lee et al. 2010) Brainstorming sessions. For instance, Six Paths Framework (Kim and Mauborgne 2005) is a set of strategic suggestions to explore new opportunities in a reference industrial field. For the sake of completeness, the recommendations stand in the option to:

- look across alternative industries;
- look across strategic groups within industry;
- redefine the industry buyer group;
- look across to complementary product and service offerings;
- rethink the functional-emotional orientation of the product;
- participate in shaping external trends over time.

Although this approach offers only mere qualitative indications (Aspara et al. 2008), it is observing, at least, a partial acceptability in industry (Lindič et al. 2012). It is straightforward that a wide exploration of the design opportunities is not well supported by procedures that entrust individual or collective intuition, or provide very few directions to reflect upon, as for the case of Six Path Framework. In addition, as already remarked in the Introduction, we can claim that the development of the recalled stimulation techniques has a weak relationship with CAD frameworks, especially from the viewpoint of integrating these tools in environments supporting the whole NPD cycle. Contributions discussing the link between Product Planning methods and CAD systems refer rather to software applications enhancing the sketching capabilities during brainstorming sessions, still without providing any functionality for stimulating the creativity of participants (Robb et al. 2009).

The weaknesses of Product Planning methods with respect to the scope of introducing idea generation capabilities into CAD environments have pushed the authors to investigate the opportunities provided by commercial software in addition to literature sources. In order to take into account the most diffused software supporting Product Planning, it was required to build a representative sample of tools to be further examined. To this scope, the authors picked up the computer applications emerging from the first 50 results by performing in February 2015 a Web Search through Google search engine with the following keywords:

- New Product Development software;
- Innovation software;
- Fuzzy Front End software;
- New Value Proposition software;
- Product Planning software.

The Web Search led to the identification of 41 computerized tools, which the authors classified according to four categories standing for the kind of supported activities in the initial phases of NPD tasks. Table 1 reports the computer applications in alphabetic order and associates them with the pertinent groups. Said categories, listed in the followings, merge the classifications provided by two different studies that used very similar taxonomies (Monteiro et al. 2010; Rangaswamy and Lilien 1997):

- Idea Generation: tools to stimulate new ideas, bundles of idea sources, brainstorming and creativity enhancement models;
- Knowledge Management (KM): tools devoted to the management of information regarding the product sphere and customer preferences;
- Decision Support Systems (DSS): tools for evaluation of products and projects, techniques for decisions undertaking;
- NPD Management: tools for managing innovation processes and patent policies, assessing risks, facilitating collaboration and communication activities.

Software	*Link*	*Idea Generation*	*KM*	*DSS*	*NPD Management*
Accept360	www.accept360.com			•	•
Aha!	www.aha.io			•	
beCPG	www.becpg.net			•	•
Blueprinter 4.0	www.newproductblueprinting.com			•	
BoardPacks	www.whitecapcanada.com				•
Brightidea	www.brightidea.com			•	•
Business 360°	www.software-innovation.com			•	•
Changepoint Project Portfolio Management	www.changepoint.com			•	•
Daptiv	www.daptiv.com			•	•
DataStation	www.datastation.com			•	•
EXAGO	www.exago.com			•	
Genius Project	www.geniusproject.com			•	•
GenSight NPD PPM	www.gensight.com			•	•
GrowthCloud	www.growthcloud.com			•	
HYPE GO! & HYPE Enterprise	www.hypeinnovation.com	•		•	
Idea Spotlight	www.wazoku.com			•	•
Idearium	www.idearium.com				•
IdeaScale	www.ideascale.com			•	•
IHS Goldfire	www.ihs.com			•	•
Imaginatik	www.imaginatik.com	•		•	•
Induct	www.inductsoftware.com			•	•
Innovation Factory	www.innovationfactory.eu				•

Innovation framework	www.innovation-framework.com	•		•
Inova suite	www.inova-software.com		•	•
Kindling	www.kindlingapp.com			•
Mindjet SpigitEngage & MindManager	www.mindjet.com	•	•	•
Oracle Instantis	www.oracle.com	•		•
PD-Trak	www.elite-consulting.com			•
Planview Enterprise	www.planview.com		•	•
Powersteering	www.powersteeringsoftware.com			•
ProductPlan	www.productplan.com		•	•
ProductVision	www.asdsoftware.com		•	
PTC Windchill	www.ptc.com		•	
Qmarkets	www.qmarkets.net	•		
SAP	www.sap.com		•	•
Sciforma	www.sciforma.com		•	•
Sopheon Accolade	www.sopheon.com	•	•	•
Strategyzer	www.strategyzer.com		•	
Valkre Render	www.valkre.com		•	•
Wellspring Sophia	www.wellspring.com		•	
Windows SharePoint	www.microsoft.com			•

Table 1 sample of innovation software applications classified according to the activities they support within Product Planning

At first, the investigation shows that Idea Generation activity is the least supported. Indeed, just 7 applications include capabilities to stimulate new ideas, whereas the quantity of tools classified as KM, DSS and NPD Management is 31, 23 and 31, respectively. From this viewpoint, even though the performed search cannot be surely considered as a thorough survey, the obtained results suggest that the development is overlooked of computerized tools for individuating new ideas in engineering design tasks. Secondly, an insightful analysis of the 7 identified software applications shows that these tools are aimed at providing platforms for collaborating in shaping new ideas or offer strategies for enhancing the creative thinking. Moreover, none of them interplays with CAD systems; hence, they are conceived as creativity aids with no particular reference to design issues. In this sense, the investigated commercial software mirror the problems that were highlighted for the tools directly implementing Product Planning techniques, i.e. being constrained in the exploration of the design space and besides unsuitable to the scope of creating a CAD environment supporting users along the whole NPD cycle.

The objective of the paper is illustrating a preliminary proposal that aims at overcoming the above gap.

3. An original method and software prototype to support idea generation

This Section provides a deep description of iDea tool. More in particular, Subsection 3.1 summarizes the fundamentals on which the system is grounded with the aim of offering a brief overview of the adopted logic. Eventually, Subsection 3.2 describes an illustrative application aimed at showing software implementation, functioning and generated outputs.

3.1 Overview of iDea tool

A preliminary research conducted by the authors (Bacciotti et al. 2014) has allowed schematizing the design space to be explored during Product Planning. According to the obtained outcomes, four main directions, namely Value Dimensions, can be investigated in order to identify new product features or ideas that generate value for customers:

- General Demands (GDs): distinct tangible (e.g. quickness and speed in performing the functions, ergonomics, storability) or intangible (e.g. aesthetics, fun and adventure, ethics) customer needs;
- Life Cycle phases (LCs): circumstances that may occur along the different stages of product existence from its market launch to the end of its life;
- Stakeholders (SHs): all the actors that interact with the product during its lifecycle;
- Systems (SYSs): different hierarchical levels of the product, ranging from the environment in which the artefact is situated to its parts and inner components.

According to these Dimensions and their further articulation, the authors developed combination algorithms that allow designers to figure out possible scenarios or circumstances, capable to provide useful hints for the development of new products. In other terms, the authors have individuated possible patterns that can stimulate the creativity of product planners.

The claimed advantage with respect to existing procedures stands in the possibility to explore systematically design opportunities by taking into account a comprehensive set of scenarios. A computer implementation of the stimulation process was necessary to articulate the large quantity of proposed hints.

The developed algorithm allows selecting and customizing the above Dimensions and automatically generating a set of questions that guide the designer during the idea generation task.

More in details, the user has to choose, from the default list of 20 elements shown in Table 2, those that are relevant for his/her NPD project.

Value Dimensions			
GDs	SHs	LCs	SYSs
• Fulfilled needs • Versatility of use/ adaptability • Reliability/ safety • Ease • Aesthetics/ style/ethics • Quickness • Cheapness • Comfort/ ergonomics	• Buyers • Users • Beneficiaries • Outsiders	• Purchasing, choice and access activities • Before use operations • Utilization time • Elapsed time before further exploitations • End of the functioning	• Environment in which the product is situated • Product or service level • Parts, components and accessories

Table 2 list of default GDs, SHs, LCs and SYSs available in iDea

Three idea stimulation logics have been introduced, in order to fulfil different project's needs:

- simple logic: it collects the selected elements of SHs, LCs and SYSs and asks the user to focus on all possible demands related to these elements, in order to identify new product ideas. This algorithm is useful when ideas shall be generated in little time. Indeed, it provides at most 12 questions like: *Do you identify any new idea considering the <SH/LC/SYS>?*, whereas the term into the brackets is one of the elements chosen from the default list of SHs, LCs and SYSs.
- standard logic: it combines the selected elements of GDs with chosen elements of SHs, LCs and SYSs. In this case the user sequentially focus on each GD together with each SH, LC and SYS and tries to identify new product opportunities. In this case, the maximum number of generated questions is 96 and they have the following form: *Do you identify any new idea considering the combination of <GD> and <SH/LC/SYS>?*
  Even if this logic can require more time to reflect upon the questions than the previous one, it provides more specific hints, which result likely useful to explore the design space.
- advanced logic: it allows customizing the chosen Value Dimensions in order to fit with the specific NPD project. Therefore, the user can provide suitable specifications and the algorithm combines them using the same procedure of the previous logic. In order to simplify the customization process, the authors identified a set of 114 specifications that represents cross-sectorial concrete examples of common characteristics linked with the list of elements of Table 2 (see an excerpt in Table 3). These specifications can be used as a starting point to customize the selected Dimensions. This algorithm allows focusing the ideation process on some specific directions that the user considers particularly relevant and interesting for the faced NPD project and the number of questions (and required time) can extremely vary according to the number of specifications provided by the user.

Specifications of Value Dimensions			
GDs	SHs	LCs	SYSs
Fulfilled needs: - Quality of the expected outcomes; - Quantity or extent of the expected outcomes; - Duration of the expected outcomes; - Fun and adventure. …	Buyers: - Manager, decision maker; - Parents or tutor; - Reseller; - Professional; - Agent. …	Purchasing, choice and access activities: - Identifying the product on the web; - Identifying the product on leaflets, brochures; - Comparing with similar products …	Environment in which the product is situated: - Weather conditions; - Tools or matched machinery - Matched or surrounding items …

Table 3 list of suggested specifications for customizing the default GDs, SHs, LCs and SYSs

Therefore, as shown in Figure 1, the exploration of ideas space can be enlarged or narrowed according to the needs of user. This opportunity provides a flexible approach to support the idea generation activity in various industrial contexts.

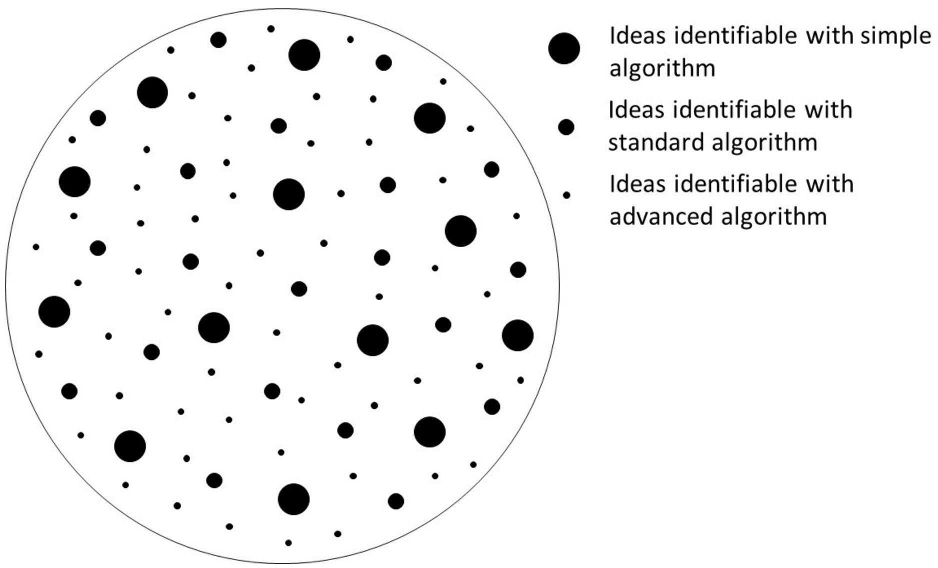

Figure 1 representation of the design space explorable with the three suggested logics

For instance, if the user selects the GD "comfort/ergonomics", specifying the need of storability, and the SYS "parts, components and accessories", by focusing on the latter, a possible question is:

Do you identify any new idea considering the storability of product accessories?

This hint can suggest the possibility of integrating the functions of the accessories or redesigning the shape of the product in order to contain said accessories, as shown in the example of Figure 2.

Figure 2 example of a new idea identified considering the need of "storability" together with "product accessories": a screwdriver with a bit set integrated into the handle

Figure 3 shows the implemented algorithm of iDea, while the next Subsection depicts the architecture of the software and provides an illustrative application to show how it actually works. For more details, the developed tool and a guide, reporting the main functions of iDea, can be downloaded from the link http://goo.gl/AwzZHF.

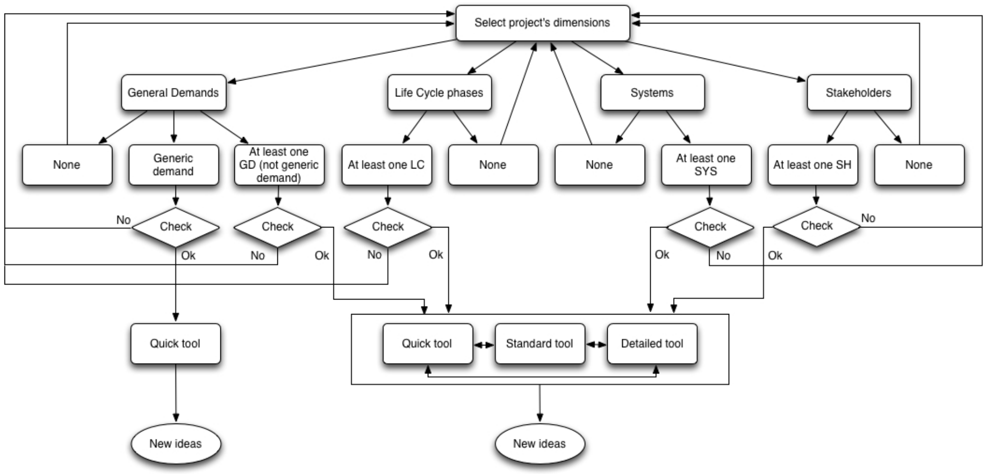

Figure 3 main algorithm of iDea tool. GD, LC, SYS and SH stand for General Demands, Life Cycle phases, Systems and Stakeholders, respectively

3.2 System implementation: an illustrative application

The developed software prototype is a multi-screen GUI that includes a first window (Figure 4), in which the user has to select the Dimensions that are pertinent for its NPD project and further windows (Figures 5-6-7-8) in which the above mentioned idea stimulation algorithms have been implemented. The three logics described in the previous Subsection, i.e. "simple", "standard" and "advanced", are implemented in different modules, named "quick", "standard" and "detailed", respectively.

With the aim of providing an illustrative example of the developed software, iDea has been used to generate new features for a common and simple product, i.e. a door handle.

In the first selection page, Dimensions can be chosen by ticking the related boxes. If

"Generic demand" is selected, all the other GDs are automatically deselected and the unique module that can be used is the "quick" one. In the example, all the items concerning the four Value Dimensions were considered pertinent in the given industrial field and none of them has been consequently deselected, as shown in Figure 4.

After the selection of Dimensions, idea stimulation tools can be used by clicking on the buttons activated on the top of the windows. They can be exploited separately and the user can switch from one to another whenever he/she wants.

The "quick" and "standard" windows are very similar (Figures 5-6). They include the generated hints in a left box and allow collecting a semantic description of new ideas in a text field available on the right side of the window. For instance, in the "quick" module, the LC "before use operation" has led to the identification of three new ideas concerning the case study (Figure 5), and the combination of the GD "Reliability/safety" and the SH "outsiders" in "standard" module led to the generation of three further ideas (Figure 6).

Subsequently, the first window of the "detailed" module allows customizing the selected GDs. The default list of terms can be modified adding or removing elements. By clicking on the "next" button, the same procedure can be repeated for the other three Value Dimensions. For instance, Figure 7 shows a case in which the default SYS "parts, components and accessories" has been customized. Finally, the last click on the "next" button opens a window that has the same layout of the other two modules (Figure 8), i.e. it provides hints on the left side of the window and allows collecting new ideas in the right box. With respect to the case study, the combination of the GD "The lightness and the portability" with the SYS "outside lever/knob" has supported the identification of additional ideas (Figure 8).

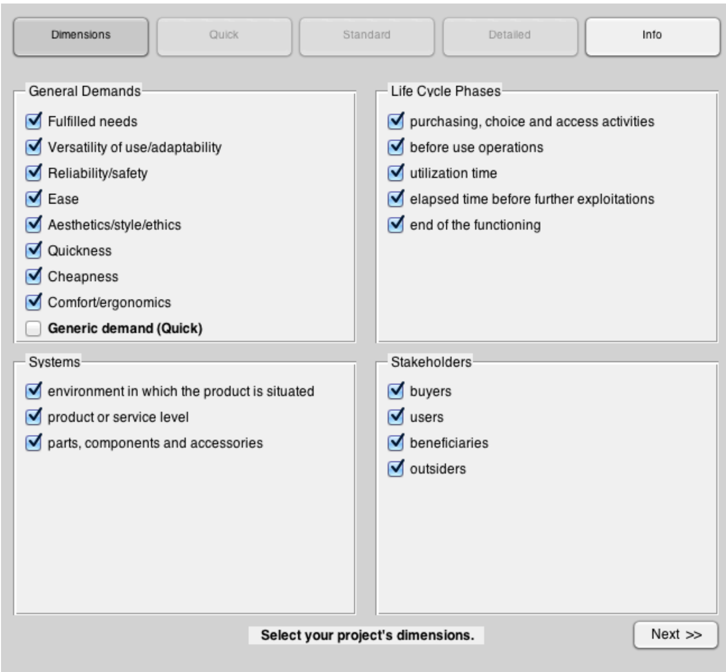

Figure 4 screenshot of the Dimensions' selection page of iDea. All the terms have been selected for the case study

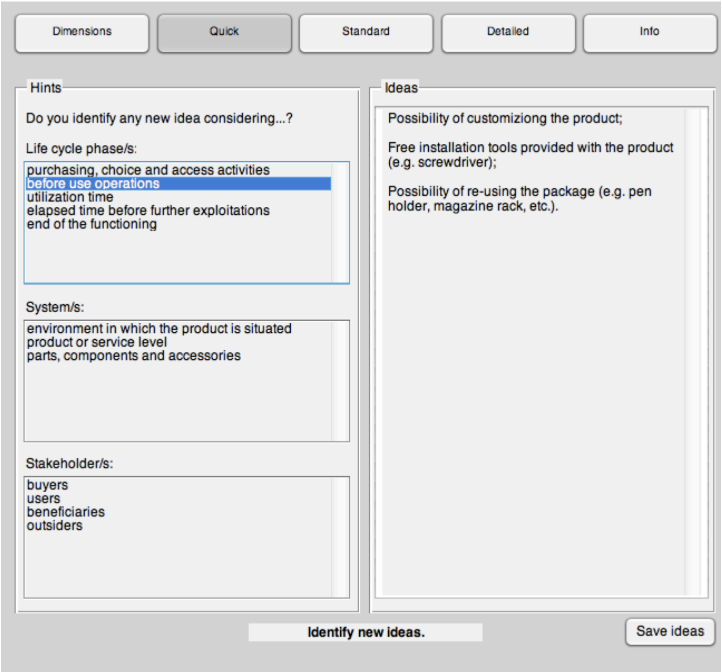

Figure 5 screenshot of the quick module of iDea that shows the ideas stimulated in the case study by the LC "before use operations"

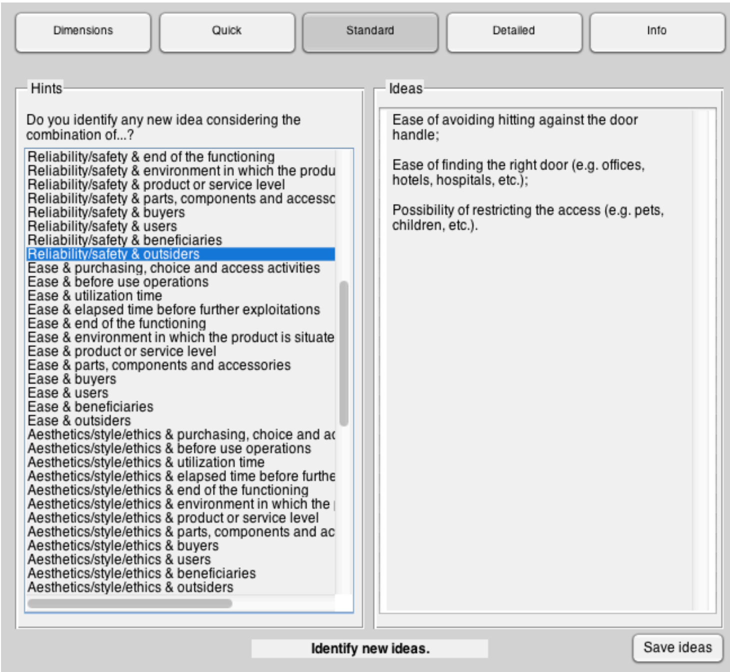

Figure 6 screenshot of the standard module of iDea that shows the ideas stimulated in the case study by the combination of the GD "Reliability/safety" and the SH "outsiders"

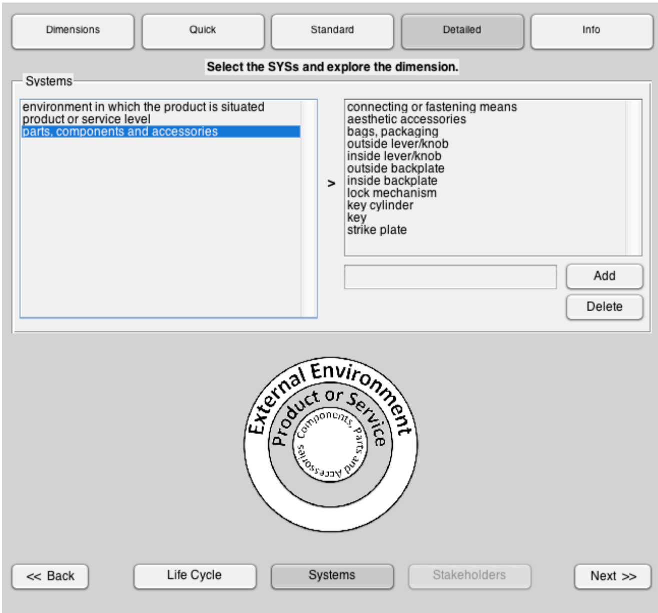

Figure 7 screenshot of the detailed module of iDea. The default SYS "parts, components and accessories" have been customized according to the case study

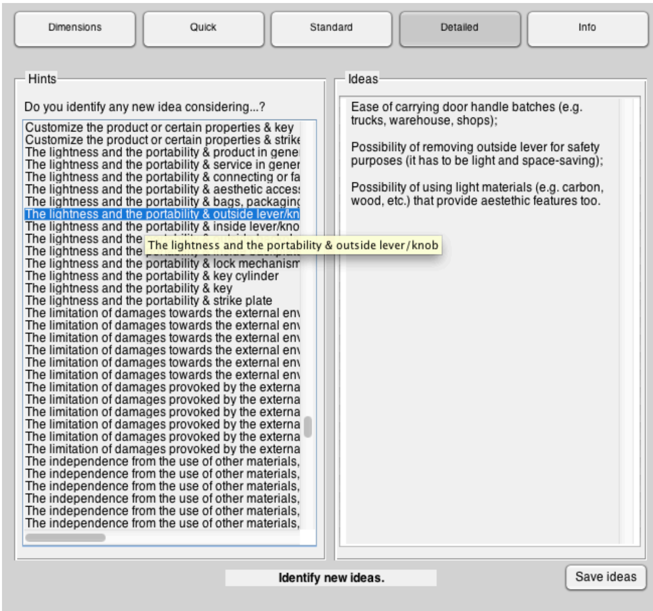

Figure 8 screenshot of the detailed module of iDea that shows the ideas stimulated in the case study by the combination of the GD "The lightness and the portability" and the SYS "outside lever/knob"; long strings are currently highlighted through pointing procedures

Projects and generated ideas can be saved and loaded in order to support both knowledge management and the possibility of sharing information.

4. Test to assess the proposed software application

In order to measure the effectiveness of iDea, the authors organized a test campaign with the objective of comparing its performances with those of an acknowledged Product Planning method. The mentioned Six Path Framework was chosen as a reference, due to its capability to stimulate new product ideas and intrinsic way of working that does not require a computer implementation.

The test has involved 24 MS Students at the faculty of Mechanical Engineering, University of Florence (Italy). They have been properly trained about the logic and the use of the two tools and then randomly divided in two groups (A and B). The test has been structured in two 3-hours sessions, in which students had to work on their own, trying to identify as many ideas as possible in the field of cameras and domestic coffee makers. In the first session, all the students used the Six Paths Framework and group A dealt with cameras, while group B analysed domestic coffee makers. In the second session, the students carried out the idea generation activity employing iDea and dealing with the theme that was not examined in the first session.

The two categories of products have been chosen because they represent everyday devices. Hence, the students could start the idea generation process from the very beginning, without requiring preliminary information gathering to understand products' as-is scenario. Two widely acknowledged metrics in the literature have been used to assess the outcomes of the experiments (Shah et al. 2003):

quantity of ideas: it allows assessing the ability of generating as many ideas as possible in a predefined amount of time;

variety of ideas: it assesses the ability of exploring the design space, identifying ideas that are very different from one to another.

The first metric can be easily investigated by counting the number of generated ideas. In order to assess the variety, the reference approach developed by Shah et al. (2003) has been followed. Although this method has been originally developed to assess technical solutions, it can be easily adapted to Product Planning. The authors required to introduce ad hoc categories to shape a "genealogy tree", which is suitable to characterize the design space of Product Planning instead of Conceptual Design. The authors used the above mentioned four Value Dimensions to differentiate ideas at the highest hierarchy. Further detail levels refer to elements (Table 2) and specifications (see the excerpt of Table 3) that characterize the value provided by new product features with a decreasing degree of abstraction.

For instance, the set of ideas generated in the first session by the student identified as "id14" working with coffee machines (Table 4), has been structured through the "genealogy tree" of Figure 9.

Student	Group	Test	List of ideas
id14	B	1	• Rollaway device, integrated into kitchen furniture; • Direct link to the water supply network; • Possibility of washing the cups directly into the device; • Easy management of the device through Wi-Fi connection; • Integration into the device of an alarm clock that wakes up in the morning and automatically prepares coffee.

Table 4 list of ideas generated in the first session of the test by the students "id14", belonging to the group B. The reference topic was the ideation of new domestic coffee makers

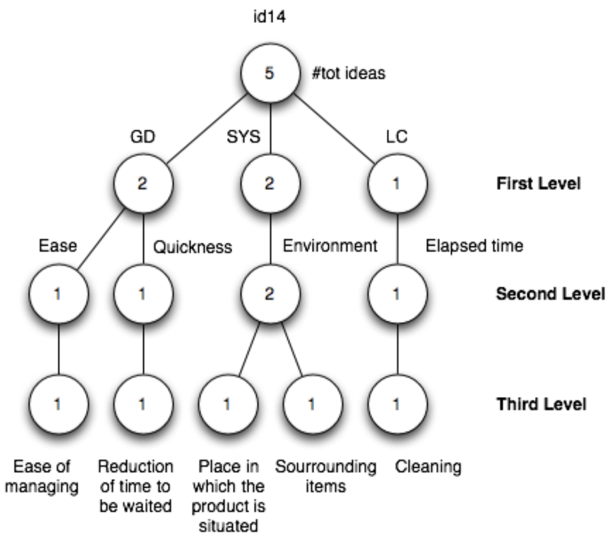

Figure 9 tree diagram used to divided the ideas generated in the first session of test by the students "id14". The reference topic was the ideation of new domestic coffee makers. GD, LC, SYS and SH stand for General Demands, Life Cycle phases, Systems and Stakeholders, respectively

The reference formula proposed by Shah et al. (2003) to assess variety is:

$$V_i = \sum_{j=1}^{3} S_j \times B_j / V_{max} \tag{1}$$

whereas Vi is the variety assessed for the ideas generated by the i-th tester; Sj is the score assigned for the level j (suggested scores are 9, 3, 1 for General Demands, elements and specifications, respectively); Bj is the number of branches at level j; Vmax is the greatest possible variety score. This value is a constant, according to the proposed classification of ideas. Indeed, it can be calculated using the numerator of formula (1) and considering the number of Dimensions (four), elements (twenty) and standard specifications (one hundred-fourteen) included in the model (Vmax=210). For instance, the following extent of variety, expressed in terms of the fraction of the maximum achievable value, is calculated for the above sample of ideas (Table 1):

$$V_{14} = \frac{9\times3 + 3\times4 + 1\times5}{210} = 0{,}2 = 20\% \tag{2}$$

The obtained results have been analysed considering each case study independently. A normal distribution of data has been hypothesized, calculating mean and standard deviation of the samples.

The main outcomes of the test are summarized in Table 5.

		Quantity		Variety	
Case studies	**Tools**	**μ**	**σ**	**μ**	**σ**
Camera	Six Paths Framework	4	2,2	15%	6%
	iDea	20,7	9,4	40%	7%
Domestic Coffee Maker	Six Paths Framework	5	2,1	16%	5%
	iDea	19,8	9,4	39%	10%

Table 5 main results of the test. The table shows mean and standard deviation of the quantity and the variety of ideas generated in the test. The two case studies, i.e. cameras and domestic coffee makers, have been analysed separately

The results show a considerable growth of quantity and variety of ideas for both industrial domains by using iDea. It is worth noticing that a quick overlook of the data is sufficient to individuate very similar variations for both the examples. The increase of quantity and variety is so conspicuous that no statistical test has been conducted to reveal the significance of administering the developed software in order to perform idea generation. The observed increment of standard deviations in sessions using iDea infers that this tool is likely capable to highlight the differences among the personal skills of users.

5. Discussion and Conclusions

Both the literature and the industry witness the lack of CAD tools capable to support the designer in the initial phase of the design process, i.e. Product Planning. In this work, the authors present a tool, namely iDea, supporting the main activity of Product Planning, i.e. idea generation. This tool has been tested against a well-known approach, i.e. Six Paths Framework, by 24 MS students of Mechanical Engineering and obtained promising outcomes in terms of quantity and variety of generated ideas. In addition, the test provided interesting outcomes, deemed worth of future research:

- the possible independence of the obtained outputs (in terms of quantity e variety) from the type of the product to be innovated;
- the fact that iDea can deeply highlight the differences among the personal skills of users.

Despite the evidences arisen from the experiment, further research is required to fully validate the major inspiring capabilities of the developed framework and prototype software tool. Additional evaluation criteria should be introduced to estimate the suitability of iDea in real design tasks. Diffused evaluation procedures include other metrics that require the judgements provided by a representative sample of experts (Kaufman et al. 2007), such as:

- quality of ideas: it is related to the technical feasibility of proposed ideas (Shah et al. 2003) and allows understanding how many ideas could be actually implemented in new products;
- novelty/creativity of ideas: it allows to assess the originality (Shah et al. 2003) and creativity (Amabile 1996) of generated ideas.

Further tests will involve design teams, according to the current collaboration trend (Red et al. 2010), in order to understand how the outputs change from individuals to groups. Moreover, authors will focus on some implementation issues to improve software usability and efficacy. From this point of view, two main aspects should be addressed as further developments of the suggested approach, which concern improvement of creativity stimulation and reduction of boring effects on users. Both the recalled issues deal with the design of a GUI capable to ease the interaction with users. A possible solution that authors are assessing is the integration within the system of images that depict exemplary product features, which appear together the demands that the algorithm generates. In such a way, users can benefit of information that clarify demands meaning as well as get further visual stimuli which make the creative process more fruitful. Indeed, exemplary features can leverage the creative process by urging users thinking to analogous solutions in the specific context of the project. Of course, representations and images should avoid the onset on user of design fixation effects that might result deleterious for the ideation process in terms of quantity and variety of generated product ideas (Becattini et al. 2013).

Eventually, authors are designing possible solutions for integrating iDea with CAD tools supporting 3D modelling and sketching, with the aim of accelerating the whole NPD process. As described in Section 3, the system prototype provides just the possibility of recording and storing the generated idea in the form of a semantic description. The authors are now thinking to include into the system an environment that can help users in translating ideas into sketches and models from which to start the subsequent design and developments phases. In other words, the system that the authors plan should not provide only a support for defining the objectives of the NPD activity but also functionalities capable to translate ideas into technical solutions. Currently, some preliminary studies focused on assessing feasibility have regarded the integration of virtual modelling environments of commercial software.

References

Adams ME, Day GS, Dougherty D (1998) Enhancing new product development performance: an organizational learning perspective. Journal of Product innovation management 15(5):403-422. http://dx.doi.org/10.1111/1540-5885.1550403

Al-Hakim L, Kusiak A, Mathew J (2000) A graph-theoretic approach to conceptual design with functional perspectives. Computer-Aided Design 32(14):867-875 http://dx.doi.org/10.1016/S0010-4485(00)00075-0

Amabile TM (1996) Creativity and innovation in organizations (Vol. 5). Harvard Business School, Boston

Aspara J, Hietanen J, Parvinen P, Tikkanen H (2008) An exploratory empirical verification of Blue Ocean Strategies: findings from Sales Strategy, 8th International Business Research Conference, IBR 2008, Dubai, United Arab Emirates, 27-28 March

Bacciotti D, Borgianni Y, Rotini F (2013) Overview of methods supporting product planning: Open research issues. 19th International Conference on Engineering, ICED13, Seoul, Korea, 19-22 August, 389-398.

Bacciotti D, Borgianni Y, Rotini F (2014) Exploring the dimensions of value: the four dimensions Framework. 14th International Design Conference, Design 2014, Dubrovnik, Croatia, 19-22 May, 711-720.

Becattini N, Borgianni Y, Cascini G, Rotini F (2012) Model and algorithm for computer-aided inventive problem analysis. Computer-Aided Design 44(10):961-986. http://dx.doi.org/10.1016/j.cad.2011.02.013

Becattini N, Borgianni Y, Cascini G, Rotini F (2013) Question/answer techniques within CAD environments: An Investigation about the most Effective Interfaces, Computer-Aided Design and Applications, 10(6), 2013, 905-917. http://dx.doi.org/10.3722/cadaps.2013.905-917

Cao DX, Fu MW (2011) A knowledge-based prototype system to support product conceptual design. Computer-Aided Design and Applications 8(1):129-147. http://dx.doi.org/10.3722/cadaps.2011.129-147

Cardillo A, Cascini G, Frillici FS, Rotini F (2013) Multi-objective topology optimization through GA-based hybridization of partial solutions. Engineering with Computers 29(3):287-306

Cugini U, Cascini G, Muzzupappa M, Nigrelli V (2009) Integrated computer-aided innovation: the PROSIT approach. Computers in Industry 60(8):629-641. http://dx.doi.org/10.1016/j.compind.2009.05.014

Flint DJ (2002) Compressing new product success-to-success cycle time: deep customer value understanding and idea generation. Industrial Marketing Management, 31(4):305-315. http://dx.doi.org/10.1016/S0019-8501(01)00165-1

Fuge M, Yumer ME, Orbay G, Kara LB (2012) Conceptual design and modification of freeform surfaces using dual shape representations in augmented reality environments. Computer-Aided Design 44(10):1020-1032. http://dx.doi.org/10.1016/j.cad.2011.05.009

Goel AK, Vattam S, Wiltgen B, Helms M (2012) Cognitive, collaborative, conceptual and creative—four characteristics of the next generation of knowledge-based CAD systems: a study in biologically inspired design. Computer-Aided Design 44(10):879-900. http://dx.doi.org/10.1016/j.cad.2011.03.010

Haig M (2011) Brand Failures, Kogan Page, London

Hüsig S, Kohn S (2009) Computer aided innovation-State of the art from a new product development perspective. Computers in Industry 60(8):551-562. http://dx.doi.org/10.1016/j.compind.2009.05.011

Kaufman JC, Lee, J, Baer, J, Lee S (2007) Captions, consistency, creativity, and the consensual assessment technique: New evidence of reliability. Thinking Skills and Creativity 2(2):96-106. http://dx.doi.org/10.1016/j.tsc.2007.04.002

Kim WC, Mauborgne R (2005) Blue Ocean Strategy. Harvard Business School Press, Cambridge

Komoto H, Tomiyama T (2012) A framework for computer-aided conceptual design and its application to system architecting of mechatronics products. Computer-Aided Design, 44(10):931-946. http://dx.doi.org/10.1016/j.cad.2012.02.004

Lee CW, Suh Y, Kim IK, Park JH, Yun MH (2010) A Systematic Framework for Evaluating Design Concepts of a New Product. Human Factors and Ergonomics in Manufacturing & Service Industries 20(5):424–442. http://dx.doi.org/10.1002/hfm.20193

Lindič J, Bavdaž M, Kovačič H (2012) Higher growth through the Blue Ocean Strategy: implications for economic policy. Research Policy 41(5):928-938. http://dx.doi.org/10.1016/j.respol.2012.02.010

Monteiro C, Arcoverde DF, da Silva FQ, Ferreira HS (2010) Software support for the fuzzy front end stage of the innovation process: A systematic literature review, 5th IEEE International Conference on Management of Innovation and Technology, ICMIT2010, Singapore, 2-5 June, 426-431. http://dx.doi.org/10.1109/ICMIT.2010.5492781

Montoya-Weiss MM., O'Driscoll TM (2000) From experience: applying performance support technology in the fuzzy front end. Journal of Product Innovation Management 17(2):143-161. http://dx.doi.org/10.1111/1540-5885.1720143

Pahl G, Beitz W, Feldhusen J, Grote KH (2007) Engineering design: a systematic approach. Springer, London

Rangaswamy A, Lilien, GL (1997) Software tools for new product development.

Journal of Marketing Research 34(1):177-184

Red E, Holyoak V, Jensen CG, Marshall F, Ryskamp J, Xu Y (2010) ν-CAx: A Research Agenda for Collaborative Computer-Aided Applications, Computer-Aided Design and Applications 7(3):387-404. http://dx.doi.org/10.3722/cadaps.2010.387-404

Robb DA, Flora H, Childs P (2009) Sketching to solid modelling skills for mechanical engineers, 11th International Conference on Engineering and Product Design Education, E&PDE09, Brighton, United Kingdom, 10-11 September, 275-280

Sapidis NS, Kyratzi, S (2005) Object Definition from a Sketch to Support Concept Development, International CAD conference and Exhibition, CAD'05, Bangkok, Thailand, June 20-24

Shah JJ, Smith SM, Vargas-Hernandez N (2003) Metrics for measuring ideation effectiveness. Design studies 24(2):111-134. http://dx.doi.org/10.1016/S0142-694X(02)00034-0

Smith PG, Reinertsen DG (1991) Developing products in half the time. Van Nostrand Reinhold, New York

Soukhoroukova A, Spann M, Skiera B (2012) Sourcing, filtering, and evaluating new product ideas: an empirical exploration of the performance of idea markets. Journal of Product Innovation Management 29(1):100-112. http://dx.doi.org/10.1111/j.1540-5885.2011.00881.x

Ulrich KT, Eppinger SD (2011) Product design and development. McGraw Hill, New York

D.3 An original design tool for stimulating the ideation of new product features

D. Bacciotti, Y. Borgianni and F. Rotini

Abstract

The manuscript illustrates a method, implemented in a computer application, which supports the identification of new product features in the early phases of engineering design cycles. In the practice, such a task is commonly carried out through cognitive techniques that generate random and unstructured stimuli. These approaches and the computer-aided tools that implement them suffer from a scarce exploration of the design space. This criticality is faced by introducing an original classification of value drivers, thus organizing a large set of concepts consisting in stimuli for generating new product ideas. The proposed method combines the concepts belonging to different categories of the classification in order to identify scenarios in which the product can provide unprecedented benefits for customers and other stakeholders. Experiments in academia and industry show the capability of the developed method and prototype software to increase the volume and the novelty of ideas, reveal previously overlooked drivers for customer satisfaction and enhance the definition of stimulated design requirements.

1. Introduction

The paper illustrates a method and a computer application supporting the ideation of new product attributes. The contribution described in the present manuscript can be seen as the result of treasuring a bundle of stimuli, which have, more or less recently, affected the authors' background and visions. These hints arise from both the literature, with a particular reference to contributions within engineering design, and the interpretation of the needs that emerge by cooperating with industrial partners in various research projects. More precisely, the stimuli stand in grounded assumptions with reference to innovation in industrial contexts, which will be subsequently explained:

- the declared relevance of innovation in the 21st century industry (Cavallucci 2011), which results in an increasing importance of design activities with a special emphasis on those initial New Product Development (NPD) tasks, such as Product Planning, that participate to the definition of the business opportunities to be exploited;
- the claimed need of fine-tuning formal methods supporting the above design activities;
- the focus on individuals' creativity to achieve new products and services offering greater value for customers;
- the expected growing participation of computers in the creative phases of innovation activities;
- the need of building computer-based applications tailored to aid initial design phases.

The goal of product innovation gradually shifts from technologies for achieving superior performances to user-centred approaches aimed at including unprecedented sources of value for perspective customers. In this sense, the scope of engineering design is expanding towards the initial NPD phases, more focused on the definition of requirements to be fulfilled (Borgianni et al. 2013). This trend is far from being surprising, if the claimed impact is considered of early design stages, the so-called Fuzzy Front End (FFE), in terms of the success chances of new artefacts (Haigh 2011) and the determination of upcoming product development costs (Lotter 1986; Ulrich and Eppinger 2011). Consequently, the models used to describe design processes tend to encompass user needs and requirements, besides traditionally comprising functions, components, interactions and physical principles (Cascini et al. 2013). Within the FFE, a particular attention is then paid to Product Planning, whose scope is, among the others, identifying and analysing users' needs and translating them into design objectives.

The need of systematically aiding the early design phases has been frequently declared (e.g. Pahl and Beitz 2007), but formal methods are considered still inadequate to the purpose (Barczak et al. 2009; Soukhoroukova et al. 2012). The literature shows that big corporations have introduced best practices for an adequate management of the FFE, but they still require introducing formal instruments for enhancing idea generation (Johansson and Nilsson 1998; Börjesson et al. 2006). By insightfully surveying existing techniques devoted to support Product Planning, it emerges that they face the dichotomy between, on the one hand, disruptiveness of generated ideas and, on the other hand, predictability of market results and feasibility of new products with the available company resources (Bacciotti et al. 2013).

Similarly, it is possible to assess that strictly demand-pull approaches substantially limit the capability of exploration of designers, bringing to the development of poor-valued and scarcely innovative products (Eisingerich et al. 2010). The stimulation of creative thinking is conversely seen as a prerequisite for allowing the generation of breakthrough ideas (e.g. Herstatt and Kalogerakis 2005). Nevertheless, unconstrained stimuli can give rise to bizarre ideas, which are often characterized by noticeably limited utility for customers (Caroff and Lubart 2012) and, therefore, are not viable to correctly address NPD cycles. In this sense, the objective of the research is attempting to build a roadmap for systematically investigating the possible sources of value for customers and the circumstances in which they can emerge. The present proposal provides stimuli to conduct the exploration of said sources and circumstances. An original method has been fine-tuned, intended to leverage these guided stimuli to improve designers' ideation processes.

The following Sections (4.2 more in particular) will lay bare the large number of concepts potentially identifying new sources of customer value. In this perspective, the introduction of computerized tools results critical to support the management of a considerable quantity of stimuli. This aspect is consistent with the predicted increase of ICT involvement in NPD activities (Nambisan 2003) and innovation projects aiming at engendering major value for customers (Močnik 2010). However, the role of computers in initial product development phases has been fundamentally limited to a design partnership supporting communication between multiple parties and data management. This circumscribed contribution contrasts with the extensive development of CAD/CAE systems supporting the Back End of design cycles. To this regard, it is deemed that the goal of reducing new products' time-to-market has pushed the evolution of computer tools capable to shorten design processes by quickening those activities that could be easily faced through routine procedures. This has besides resulted in the disregard of design activities requiring a higher degree of creativity and innovativeness (Van Elsas and Vergeest 1998) and in the erection of inertial barriers in terms of exploring original solutions by hindering the representation of new concept models (Quin et al. 2003; Tovey and Owen 2000). Therefore, on the one hand, it results desirable for commercial CAD systems to allow users to carry out proficiently initial design tasks (Tay and Gu 2002). On the other hand, new ICT instruments for the FFE (and tailored to Product Planning in particular) are viable to observe a shift towards computer coaches according to Lubart's (2005) definitions about the forms of interaction between men and machines.

In this sense, the developed method and computer application work like a coach, since the latter suggests areas to be investigated for the identification of new product attributes, whose way of monitoring can be gradually subsumed in the thinking of perspective users. More specifically, the scrutiny of new features consists in mapping their so-called dimensions, i.e. what characterizes the benefits they provide, and finding unprecedented situations to offer value by asking some classical "*wh* question":

- *what* and *why*: the nature or the essence of the given benefit, the reasons behind its fulfilment (General Demand dimension, labelled as GD);
- *who*: the involved subject within the value chain (Stakeholder dimension, SH);
- *where*: the locus at which an useful interaction takes place (System hierarchy dimension, SYS);
- *when*: the time frame during the product lifecycle in which the benefit occurs (Lifecycle dimension, LC).

It is worth remarking that the *how* aspect has not been taken into account, since it concerns different NPD phases devoted to establish working principles and technologies through which to fulfil initial design specifications.

The article is organized as follows. Section 2 analyses the background of the present research and individuates the requirements and the evaluation metrics to be considered for the scope of fine-tuning an original idea generation tool. Section 3 investigates the attempts to address the ideation of new product characteristics, by surveying both scientific literature and existing software applications. Section 4 describes the proposed approach and its implementation into a prototype software. The verification of their effectiveness is illustrated in Section 5 through a testing campaign involving 24 Master Science (MS) students in Mechanical Engineering. Subsequently, Section 6 documents the outputs of the methodology employment in the industrial field. Eventually, Section 7 summarizes the main findings and draws final remarks and planned future activities.

2. Background

The quality of ideation processes is commonly linked with the capability to explore the design space, generally defined as the count for all possible options to address a posed problem (Ullman 1992). For the scopes of the present paper, treating Product Planning and hence the definition of the objectives a NPD cycle should accomplish, the design space can be intended as the entirety of potential benefits to be offered by a new artefact.

Many literature contributions dealing with ideation issues in design substantially refer to generation of solutions for assigned technical problems or, more vaguely, to initial product development activities. Hence, this branch of literature predominantly focuses on Conceptual Design. However, we can extend the validity of the presented findings to Product Planning, since reference sources are committed to investigate the mechanisms underlying design phases requiring a great extent of individual creativity.

2.1 Analogies in creative design phases

Creativity contributes to the exploration of the design space and subsequently to limit design fixation, which is seen as the most harmful phenomenon at the beginning of NPD cycles. According to in-depth studies, design fixation leads to, among the others, repetitive ideas, small quantities of proposed solutions, imitation of provided examples (Linsey et al. 2010; Moreno et al. 2014). In this sense, we could assume that examples or any kind of stimuli producing analogical thinking give rise to the drop of creativity.

On the contrary, design-by-analogy represents a fundamental process guiding idea generation and problem solving appropriately (Verhaegen et al. 2011). As a result, the research in engineering design witnesses several experiments related to the generation of ideas pushed by various kinds of stimuli, whose consequent manipulation of human memory is studied in (Liikkanen and Perttula 2010). Among the others, examples and descriptions from biology field (Mak and Shu 2008; Wilson et al. 2010) claim to foster creative design solutions. Different experiences consider the exploitation of stimuli pertaining to product domain (Lopez-Mesa et al. 2011) and to examples taken from firms' information repositories (Howard et al. 2011).

Ogot and Okudan (2006) show the growth of ideation effectiveness brought by systematic procedures fostering analogical thinking, already for first-year Engineering Students. More recent studies compare the outcomes of initial design activities undertaken through structured methods and intuitive/cognitive approaches (Chulvi et al. 2012; Gero et al. 2013), showing that the former generate more appropriate solutions, while the latter give rise to more novel ideas. Reviews point out how the number of cognitive approaches is overwhelming in the context of the instruments dedicated to the generation of ideas (Bacciotti et al. 2013; Sowrey 1990; Smith 1998; Martin and Hanington 2012).

Despite the variety of stimulation methods based on analogical thinking, the factors underpinning the success of these techniques are still insufficiently researched (Verhaegen et al. 2011). In this context, an in-depth study is constituted by the work described by Vargas Hernandez et al. (2010), who underline the potential of intuitive ideation methods in terms of the capability to enlarge the design space of exploration. Within intuitive methods, engineering design and cognitive psychology communities share many ideation components, such as Provocative Stimuli, Suspended Judgment, Flexible Representation, Frame of Reference Shifting, Incubation, Example Exposure. The scholars test the effect of these components against metrics that assess the goodness of ideation outcomes. Just Incubation results as a statistically significant driver to guide appropriate ideation procedures. However, it is worth noting that such a factor refers to the timing of ideation processes and cannot be considered as a measure to distinguish between good and bad creative methods.

Tseng et al. (2008) demonstrate that analogies that are more distantly related to the core of the design activity result particularly beneficial when design goals are not well defined yet, hence at the very beginning of NPD cycles. As far-field analogies show considerable advantages (Chan et al. 2011), domain-specific hints should be avoided. Moreover, studies explain how the employment of abstract linguistic representations increase the effectiveness of design-by-analogy (Lindsey et al. 2008). The quantity of offered analogies positively influences the creativity of generated ideas (Dahl and Moreau 2002). In addition, administering manifold and continuous stimuli can give rise to considerable workload and perceptible mental stress that are, in turn, judged as phenomena producing enhanced design creativity (Nguyem and Zeng 2012; Nguyem and Zeng 2014). This circumstance finds confirmation in the effectiveness of analogies in idea generation tasks, which involve designers for a large amount of time, thus avoiding productivity drops observed after approximately 30 minutes (Howard et al. 2010).

With respect to the above theoretical background, an original tool to properly support ideation in Product Planning should:

- foster the exploration of the design space;
- provide a large number of stimuli, in such a way that designers' workload is augmented and analogical thinking is aroused for a long time;
- employ abstract concepts to the greatest extent.

2.2 Metrics to assess idea generation in Product Planning

Despite some criticism (e.g. Nelson et al. 2009), the variables introduced by Shah et al. (2003) represent the most acknowledged factors to judge the effectiveness of ideation processes for design tasks. Thus, the reference metrics include quantity, variety, novelty and quality of generated ideas.

These criteria commonly refer to the output of ideation sessions that aim at finding solutions for posed problems; therefore, they best fit the evaluation of Conceptual Design outcomes. In the followings, the authors clarify the meaning of the criteria and argue about the usability of these metrics for Product Planning.

Quantity stands for the number of generated ideas and it can be plainly used with the same meaning within Product Planning.

Variety represents the extent to which different areas of the design space have been explored. It assesses the distance between concepts according to a predefined taxonomy. For instance, a large amount of variety is implied by the use of two different working principles to solve an equivalent problem. Although it potentially represents a significant indicator for the efficacy of idea generation processes within Product Planning, variety cannot be used because of the lack of an established taxonomy to characterize NPD objectives. In addition, in the investigated phase of engineering design, functions and objectives have still to be formulated, hence a defined problem to solve is missing. In this sense, variety cannot be included within the metrics to evaluate ideation performances.

Novelty stands for the degree to which new ideas differ from existing systems. It ranges among the most acknowledged dimensions of creativity. In many cases, especially within creativity assessment, the measure of novelty is determined through experts' evaluations. However, in order to avoid biases ensuing from subjective estimations, objective metrics are gaining consensus in the academic field. Among the available criteria, the procedure developed by Sarkar and Chakrabarti (2011) allows assessing products' novelty according to the ontological elements for which modifications can be observed with respect to existing artefacts. More in detail, the employed ontology refers to the so-called SAPPhIRE model (Chakrabarti et al. 2005), which defines the product in terms of structures, working principles, functions, environment in which it is collocated, required resources, effects of its use. With regards to observed changes, the assessment of novelty is made through a scale ranging from "none" to "very high".

Eventually, quality measures the degree to which a given problem is solved correctly, by evaluating the appropriateness of solutions with respect to given constraints, environment of use and industrial domain. By missing a predetermined function to be fulfilled in Product

Planning, such a metric cannot be included in the set of criteria to assess ideation performance.

As a result, quantity and novelty stand in the employable metrics for comparing the outcomes of idea generation sessions. This couple of dimensions can be considered sufficient for the scopes of assessing ideation effectiveness in Product Planning, since authoritative contributions describing the performance of ideation experiences exploit just these two criteria, e.g. (Kudrowitz and Dippo 2013; Spanjol et al. 2011).

3. Methods and software tools to stimulate idea generation tasks

The present Section overviews diffused methods and existing software applications that can potentially enhance idea generation within Product Planning. Their pros and cons will be subsequently discussed with a specific reference to the requirements and metrics reported in Section 2.

Some scholars have surveyed the available computer applications that support the FFE (Rangaswamy and Lilien 1997; Hüsig and Kohn 2009). Nevertheless, most of the software tools described in said citations are no longer available and an updated review is therefore needed of the computer-aided instruments for stimulating idea generation. The search criteria are disclosed at the beginning of Subsection 3.2 through which such a survey has been conducted in June 2014. This part is anticipated by the description of diffused models for Product Planning (Subsection 3.1), whose names have been used as terms for carrying out the search. Subsequently, the outcomes of the investigation are presented and discussed in the second part of Subsection 3.2, while Subsection 3.3 clarifies how current criticalities can be overcome by means of an original idea generation method.

3.1 Acknowledged techniques to support idea generation

The best-known idea generation technique is the Brainstorming method, originally developed by Osborne (1953). This approach is diffused in the industrial practice (Geschka 1996; Coates et al. 1997), because it can be easily and intuitively implemented. A group of designers, marketing experts and/or customers is organized in order to discuss about new product ideas. The discussion is generally guided by a moderator, who keeps the focus on the main objective and tries to avoid the excessive influence of any participant on other attendees. Practices and techniques to enhance the performances of brainstorming sessions have been experimented, e.g. Synectics (Gordon 1961), Brainwriting (VanGundy 1984), Mind Maps (Buzan and Buzan 1996), Bodystorming (Oulasvirta et al. 2003), KJ Technique (Kawakita 1982) and so on (see Martin and Hanington 2012 for more details). In addition, several software tools to support brainstorming have been developed in the last years giving rise to the so-called "electronic brainstorming" (Aiken et al.1994; Valacich et al. 1994). Although several variants of the original Brainstorming method can be identified in the literature, companies often employ tailored techniques according to specific needs. This approach observes limitations in terms of the high variability of the results according to the involved subjects, by suffering from a very low systematic level (Simonton 2003; Rietzschel et al. 2006). In addition, some studies highlight that groups employing Brainstorming produce a smaller quantity of ideas (besides less feasible) rather than entrusting idea generation to a plurality of individuals working separately, namely nominal group technique (Rietzschel et al. 2006; Diehl and Stroebe 1991; Rochford 1991; Furnham 2000). Besides, it is claimed that electronic brainstorming, whereas face-to-face interaction is avoided, can improve idea generation both in terms of productivity (number of ideas per participant) and effectiveness (ideas viable to be successfully implemented) with respect to conventional sessions (Rangaswamy and Lilien 1997).

Lateral thinking (De Bono 1968; 2010) is another well-known idea generation technique, with a not negligible diffusion in industry (Coates et al. 1997). This approach, unlike logical “vertical” thinking, pushes individuals or teams to think from different perspectives, overcoming their psychological inertia and generating as many new ideas as possible. Different methods can be used in conjunction with lateral thinking, e.g. Delphi method (Linstone and Turoff 1975; Franklin and Hart 2007) and Six Thinking Hats (De Bono 2009). The main weaknesses of lateral thinking reflect the shortcomings of Brainstorming, especially in terms of its low systematic level (Li et al. 2007).

The scenario-based technique (Lee et al 2010; Kahn 2011) is employed by design teams to identify the potential user needs and product requirements by simulating the most likely scenarios for product use. A remarkable limitation is constituted by the need of involving large design teams, since the members have to exchange views with each other during idea generation to obtain reliable results (as pointed out in Lee et al 2010).

The idea generation task can be supported by the toolkit of Blue Ocean Strategy (Kim and Mauborngne 2005), with a particular reference to the Six Paths framework and the so-called BEC/BUM (standing for Buyer Experience Cycle/Buyer Utility Map). Single users and design teams can exploit both the techniques. The former suggests six ways to think about new strategies analysing new stakeholders, complementary products and services and trends in the reference industrial field. By providing only qualitative indications and hints for idea generation, the Six Path framework is not considered sufficiently capable to support the designer (Aspara et al. 2008). The latter guides the idea generation process through the combined analysis of product life cycle phases and some kinds of customer needs (e.g. simplicity, convenience, fun, environmental friendliness). The limited sample of indicated product attributes can be seen as a constraint of the analogical thinking process.

Approaches to gather and manage ideas from customers and/or employees are widely implemented in the companies. Among the others, the Lead user method (Von Hippel 1986; 2005) points the attention just to ideas generated by pioneer users. Indeed, this category of consumers have spent more time with the product with respect to other customers, hence they are supposed to have accumulated experience and individuated unfulfilled latent needs (Kano 1995). Conversely, all potential customers and/or employees are involved within several approaches, commonly designated as crowdsourcing techniques (Poetz and Schreier 2012). Crowdsourcing is diffusedly incentivized through contests (Hebner et al. 2009; Leimeister et al. 2009; Walter and Back 2011; Bilgram 2013) and/or rewards (Valacich et al. 1994; Toubia 2006), observing an increasing participation of Internet communities (Bayus 2013). It results apparent that neither the Lead user method, nor crowdsourcing can ensure positive outcomes, since the collected users’ ideas might result distant from companies’ expectations.

Random ideation processes and limited design spaces to be explored are the main weaknesses of found methods. This results in design outcomes that greatly depend on users’ creativity and in the potential loss of valuable ideas as a consequence of continuous and unstructured flows of stimuli that do not allow the proper reflection upon thought product benefits. From a different perspective, the most diffused systematic techniques conversely suffer from limited capabilities of developing out-of-the-box solutions. Besides, being they particularly tailored to the conceptual design phase, their names will not be considered as inputs for the survey of computer applications supporting idea generation.

3.2 Overview of the outcomes emerging from the survey of software applications for idea generation

The monitoring of computer applications for idea generation has been performed by browsing the World Wide Web through common search engines and the electronic stores of the most diffused operating systems (Android, Apple and Windows). The keywords for individuating sound results included:

- terms identifying the typology of required tools: software, support system, computer-aided, app/application;
- words featuring the objective to be attained through the above instruments: idea generation, idea stimulation, analogy, creativity, opportunity identification, business opportunity, New Product Development, Product Planning;
- terms standing for the most acknowledged methods or procedures inherent to the very early design stages: Brainstorming, Mind Maps, Blue Ocean Strategy, Lead User, Lateral Thinking, Scenario Model, Crowdsourcing.

According to the results of the survey, the main categories of computer-supported idea generation tools can be identified. Whereas some of them directly descend from the implemented models described in Section 3.1, some of them emerge as new classes. The individuated categories of software applications follow:

- Brainstorming and Mind Maps that support it. Some of the tools include additional features to improve the creative process, e.g. they allow making sketches (mainly in touch screen devices), inserting images and/or photos, attaching virtual sticky notes, developing diagrams, performing analyses through SWOT (Strengths, Weaknesses, Opportunities, and Threats) and SCAMPER (Substitute, Combine, Adapt, Modify, Put to other use, Eliminate, Reverse). In addition, some of them provide generic questions and/or hints to help exploring creative directions and finding new ideas. Furthermore, many of these tools allow sharing generated ideas.
- Patent inspiration tools: they allow browsing patents databases, by simply indicating the main topic in the search bar. The identified patents can belong to different fields with respect to the context of the research and they are claimed to support the generation of new ideas in both Product Planning and Conceptual Design.
- Web inspiration tools: they allow searching on the web new ideas, inventions, concepts, scientific researches, etc. The search can be addressed by terms related to the main topic or work in an unconstrained way. New ideas are inspired by a mix of images, descriptions and links.
- Crowdsourcing: these ICT tools for idea management support the collection and sharing of new ideas generated by employees, customers, and/or generic users. In addition, these applications are capable to put into relationship the individuals participating to the creative NPD tasks, thus taking the form of digital brainstorming instruments.
- Random words and random image, which are combined to stimulate new ideas. Some of these tools even allow moving the generated words and images in the screen, with the aim of organizing them like in a real desk, thus facilitating the creative process. These software applications can support both design processes and other creative activities, such as art and poetry.

- Creative cards, consisting in digital collections of images and/or photos combined with words, descriptions and/or short stories. Some of these cards bundles suggest possible scenarios of use in order to stimulate the creative process. Other decks provide generic hints and, like the previous category of ICT tools, they can be used by artists and writers too. Some literature contributions show successful implementations of Creative cards (Halskov and Dalsgård 2006; Davis 2010), which are however consistently oriented towards the support of Conceptual Design. Halskov and Dalsgård (2006) even claim that this kind of tools is more effective than Lateral thinking, because, in their test, Creative Cards provide a larger number of sources of inspiration. However, their application in the engineering design is too restricted and it is not possible to use these instruments as a starting point for the development of further methods and tools.
- Lateral thinking: the research allowed identifying few tools that support the implementation of Lateral Thinking (and the related Six Thinking Hats approach).
- Blue Ocean Strategy: two mobile applications implementing BOS tools have been individuated. The former supports the sketching of Strategy Canvas, i.e. value curves schematizing new ideas in terms of product attributes and related performances. The curves allow representing an idea and comparing the proposal with competitors' deliverables. The latter trivially implements the BEC/BOM.

A representative collection of the identified tools is presented in Appendix 1, in which these applications have been grouped according to the supported Operating Systems and the categories recalled in the above bulleted list.

3.3 Outcomes of the survey and research objectives

The outcomes of the investigation show a large number of computer-aided applications supporting idea generation in a variety of fields, abundantly crossing the borders of design domain. By focusing on those techniques closer to the engineering world, the research confirms the considerable diffusion of heuristics that leverage human reasoning and analogical thinking in order to conceive new hints for product development. The advantages in using computer-aided systems (instead of the frameworks that are implemented) seem to stand just in favouring the communication between parties and better visualizing the generated ideas. The main limitations of the reference techniques (mentioned in Section 3.1) are conversely not overcome, despite the possibilities offered by Artificial Intelligence.

It emerges that illustrated tools and software applications do not ensure a suitable exploration of the design space. Still with respect to the indications arisen in Section 2, knowledge is missing with respect to the produced workload and to the time the presented stimulation tools can support in proposing analogies. The kind of aroused analogies is remarkably variegated, ranging from very generic tendencies (e.g. Six Path Framework) to random images (e.g. Creative Cards). In some cases, stimulation patterns are not predefined and analogies come out accidentally from group discussions (e.g. Brainstorming). Anyway, the overviewed instruments are not plainly concerned with the need of systematically inducing far-field abstract analogies. With respect to metrics to assess ideation effectiveness, much knowledge is missing. Brainstorming performances represent an exception in this sense, at least in terms of quantity, which is the dimension that Osborne (1953) primarily stressed. Furthermore, as previously mentioned, whereas Brainstorming advocates state that such a method is more effective than entrusting idea generation to a plurality of individuals working separately, other studies reverse this claim.

By observing the shortcomings of and the missing knowledge about existing techniques and ICT tools, the authors have evaluated the opportunity of developing an original method for supporting idea generation in Product Planning. We propose first to scan the opportunities of introducing new product attributes, so to organize a vast collection of useful hints. A structured roadmap displays to designers such hints, expressed through abstract and general terms. The roadmap benefits from a classification of the hints, as it will become more apparent in Section 4, allowing to combine stimuli in order to favour the exploration of design opportunities. The capabilities of computers are employed in order to support the user in searching for said opportunities and organizing the relevant information and the generated ideas.

Hence, with reference to the fundaments of idea generation processes (Section 2.1), the planned requirements of the method stand in:

- improving the exploration of the design space, that is supposed to be achieved by offering diversified hints;
- augmenting designers' workload, by encouraging the user in reflecting upon a rich collection of stimuli, whose display is potentially long-lasting;
- providing stimuli in abstract forms.

The effectiveness of the proposed Product Planning methodology will be determined in terms of quantity and novelty, as the reference metrics pointed out in Section 2.2.

4. Developed methodology and computer implementation

The goal of scanning the mare magnum of possible product features to be implemented in new deliverables necessitates a taxonomy categorizing the potential sources and circumstances viable to provide value for customers. Indeed, according to authors' vision, it is critical to build clusters of recurring useful stimuli in order to perform a structured investigation as opposed to the random stimulation approach characterizing the cognitive techniques discussed in Section 3. In other words, it is hereby proposed to properly organize the design space to be explored within idea generation activities.

The taxonomy requires being flexible enough to fit any industrial field and situation in which a NPD task has to be tackled, besides including a large number (ideally all-encompassing) of triggers for idea generation. According to authors' knowledge, no shared scheme of fulfilled benefits has been proposed up to now, if popular groupings of human needs (e.g. Maslow's hierarchy (Maslow 1943), List of Values (Kahle et al. 1986), Max-Neef's classification (Max-Neef et al. 1991)) are considered too general to categorize customer requirements. Indeed, since these models are organized in terms of psychological benefits for individuals, they do not clearly refer to a large number of practical needs fulfilled through technical functions (e.g. transporting, data processing, lighting).

Thus, an original abstract representation with the above characteristics has to be built. As already introduced in Section 1, the advanced proposal reflects the nature of customer attributes as typically defined in the Product Planning, i.e. whereas just the core aspects are specified. The description includes the definition of a specific need to be fulfilled in order to delight specific beneficiaries in a certain circumstance which involves different levels of interaction with the developed system. The articulation of product requirements in such terms, although intuitive, is not reported in any previous literature source. However, the following Subsection illustrates how the four ways of characterizing designed benefits (Dimensions onwards) make sense as a driver for searching new development opportunities or distinguishing forms of customer value. More in detail, paragraphs 4.1.1-4.1.5 treat a specific Dimension each, while 4.1.5 shows how illustrative Product Planning approaches can be schematized in terms of the four clusters. The original contribution of the paper lies in the possibility to combine all the presented Dimensions suitably and, more specifically, the items described in Subsection 4.2. Subsection 4.3 presents the combination roadmap and its software implementation, standing for the preferred embodiment of the matching procedure.

4.1 Definition and description of the four Dimensions

4.1.1 General Demands

General Demands (GDs) are meant in the present paper as distinct typologies of benefits that can be delivered by correctly designing a new product. They can be broadly referred to kinds of existing, emerging or unspoken needs, otherwise defined as "value opportunities" (Cagan and Vogel 2001), "utility levers" (Kim and Mauborgne 2005) or "customer perceived value evaluation factors" (Lee et al. 2010) on which Product Planning tasks are set. They represent the basic characterization of product attributes that specifies the met needs or wants (Ulrich and Eppinger 2011) referable to both functional and emotional perception of value.

4.1.2 Stakeholders

The design field is increasingly employing the concept of stakeholders (SHs), by addressing all the subjects that interact with the product, extracting value from the artefact or, generally speaking, are aroused of some interest as a result of the existence of the system. As in (Martin and Hanington 2012), design processes require individuating the reference actors standing for the key constituents of projects. With this meaning, SHs include the individuals that participate to the design task and the company that organizes innovation initiatives to generate turnover. On the other hand, product attributes are planned to satisfy needs of subjects that interact with the deliverables of design and manufacturing processes. From this viewpoint the relevant SHs to classify product features include all the actors that are influenced by the artefact in the lifecycle phases following its market launch. In each case, the concept of "customers", which has been traditionally employed, is extended from buyers to users, beneficiaries, service recipients and outsiders, with the aim of identifying new opportunities to increase the delivered value. As underlined in (Cantamessa et al. 2013), buyers and users might be different individuals (e.g. parents and children) and the actor(s) that will ultimately benefit from the product might be different from either the buyer or the user.

4.1.3 Lifecycle phases

Life Cycle phases (LCs) concern the circumstances that may occur along the different stages of product existence. Coherently with the observation advanced for SHs, the relevant domain to categorize product attributes starts with the market introduction, thus ranging from this moment to the end of product functioning (Cantamessa et al. 2013). By analysing the possible situations to be faced, scenarios where different SHs may perceive value can be identified (Rotini et al. 2012). A correct scrutiny of LCs is deemed crucial to avoid focusing only on the phase of product's use (Aurich et al. 2010), losing opportunities to identify sources of value. Not surprisingly, the correct examination of LCs is traditionally deemed critical within the correct definition of product specifications in engineering tasks (Tseng and Jiao 1998; Weissman et al. 2011).

4.1.4 Hierarchies of systems

This dimension suggests analysing the product at different levels of detail, including the "super-system" in which the product is situated, as indicated by classical TRIZ nine-screen scheme (Altshuller 1984) to individuate valuable suggestions for product development. The design of the product taking into account different hierarchical levels of the systems (SYSs), from the external environment, which strongly characterizes design requirements (Zeng 2004; Chen and Zeng 2006), to parts and components, is viable to guide the individuation of business opportunities (Sheu and Lee 2011). Besides, the literature reports examples concerning the exploitation of products' hierarchical and functional decomposition to deliver customer needs (McAdams et al. 1999) and to generate concepts (Tay and Gu 2002; Chen and Yan 2008).

4.1.5 Characterizing Product Planning approaches with the Four Dimensions

As inferable from Section 3.1, some Product Planning instruments are oriented towards the exploration of a subset of Dimensions. For instance, the mentioned BEC/BUM proposed within Blue Ocean Strategy aims at stimulating ideas by involving a rich collection of LCs and a sample of GDs.

Popular design methods that are expanding their boundaries towards the initial phases of NPD tasks can be interpreted in terms of the proposed Dimensions. Among them, eco-design tools swivelling on Life Cycle Assessment procedures to address Product Planning (Bhander et al. 2003; Kobayashi 2006) take into account a reference GD (i.e. environmental friendliness) and analyse opportunities and threats along a detailed list of LCs. Design methods seeking to fulfil new needs by scrutinizing the User Experience (recently surveyed in Pucillo and Cascini 2014) observe the behaviour of different kinds of users (then a specific typology of SHs) when interacting with products, with a specific emphasis on the utilization phase, hence a well-defined stage constituting the LCs. Besides, with respect to Product-Service Systems, the basic issues to be taken into account for design scopes pertain to subsets of GDs (not otherwise specified needs), LCs, SHs (generally indicated as actors) and SYSs (the employed term "periphery" indicates the surrounding environment and the available infrastructure), at least according to (Müller and Sakao 2010).

The combination of Dimensions is common also for other tasks tailored to support engineering design. For instance, Metzler et al. (Metzler et al. 2014) deliberately employ LCs and SHs in order to integrate systematically cognitive functions into product concepts derived from new ideas and existing artefacts. The ontology proposed in (Oriţă et al. 2013) to organize the knowledge relevant for products and manufacturing processes makes use of GDs (with a particular focus on costs), LCs and SHs, by considering the different expectations of the company and its customers.

4.2 Elements and Specifications to identify new product attributes

The task of stimulating new ideas by contextually considering the four Dimensions requires individuating objects referred to each of them to be favourably combined. As previously clarified, populating the Dimensions with all the possible items represents a challenging task, because of the lack of sources claiming to be all-encompassing to characterize any fundamental issue of the taxonomy.

The authors decided to employ available schemes supposed to provide an exhaustive picture of the terms and the concepts representative for each Dimension. As indicated in Tables 1-4, the items constituting the Dimensions were organized in terms of Elements, i.e. abstract concepts representing large categories of the matched cluster, and Specifications, i.e. more concrete examples of common characteristics linked with the mentioned Elements. With respect to GDs, an available list of objects was found in (Borgianni et al. 2013), whereas a catalogue of needs was employed to estimate the success chances of innovative products. Given the large number of listed typologies of customer requirements, the sample was used to denote GDs' Specifications, subsequently grouped by the authors into a set of Elements (Table 1). On the other hand, the Elements pertaining to SHs, LCs and SYSs were extracted from the representation provided by (Cantamessa et al. 2013), the relevant objects reported in (Ward et al. 2003) and the mentioned TRIZ nine-screen framework, respectively. Specifications for the indicated Dimensions were elaborated by the authors on the basis of empirical observations of innovative aspects shown in successful products (Tables 2-4).

Elements	Specifications
Fulfilled needs	• Quality of the expected outcomes; • Quantity or extent of the expected outcomes; • Duration of the expected outcomes; • Fun and adventure.
Versatility of use/ adaptability	• Suitability of the product according to different demands; • Adaptability of the product in diverging conditions with respect to the designed preferred ones; • Expand or upgrade the range of product functionalities.
Reliability/ safety	• Controllability of the system in order to obtain the expected outcomes; • Integrity of the product itself, its resistance to planned or accidental stress or collisions, the strength against wear or corrosion; • The limitation of damages towards the external environment; • The limitation of damages provoked by the external environment; • The safety and innocuousness for human health and people's psychological and social conditions; • The duration, the expected life of the product.
Ease	• The reduction of the information and skills to be gathered during the product life cycle; • The ease of acquiring the product, due to market penetration and distribution policies;

	• The ease of managing, maintaining, assembling, disassembling, upgrading, substituting components or accessories; • The independence from the use of other materials, instruments, technical systems; • The reduction of auxiliary functions to be delivered; • The additional services provided in order to attenuate the consumption of individual resources, the customer care.
Aesthetics/ style/ethics	• Customize the product or certain properties; • The possibility of benefitting of the product (or its parts) for different employment after the end of its life; • The aesthetical requirements and the emotional dimension of the product, the style, the fashion content; • What the product evokes, the lifestyle that the object implies, the prestige it generates for the owner as a feeling of distinction and recognition; • The environmental sustainability; • The ethics as a distinguishing factor.
Quickness	• The reduction of time to be waited before the functioning of the product delivers the expected outcomes; • The limitation of the time required to perform operations.
Cheapness	• The reduction of the consumption of parts, components or consumables; • The limitation of the required energy (or human power) needed for the product during its lifecycle; • Product/service cheapness; • Accessories cheapness; • Cheapness of various activities during product life cycle.
Comfort/ ergonomics	• The absence of bother for the people; • The comfort of use, the ergonomics, the manageability; • The limitation of occupied space; • The lightness and the portability.

Table 1 elements and corresponding Specifications belonging to the Dimension "General Demands"

Elements	**Specifications**
Buyers	• Manager, decision maker • Parents or tutor • Reseller • Professional • Agent
Users	• Teacher/trainer • Worker, employee • Disabled person • Not-standard user

Beneficiaries	• Community, citizenry • Children • Patients • Animals
Outsiders	• Maintenance technicians or helpers • Third party developers • Assistants • Neighbours • Relatives • Consultants, advisors • Unknown people coming into casual contact with the product

Table 2 elements and corresponding Specifications belonging to the Dimension "Stakeholders"

Elements	**Specifications**
Purchasing, choice and access activities	• Identifying the product on the web • Identifying the product on leaflets, brochures • Identifying the product in the shop • Identifying the product on various kind of advertising • Comparing with similar products • Communicating with the firm • Reaching the shop • Waiting to be assisted • Managing the payment (cash, credit card, etc.) • Using coupons and discounts • Receiving prizes or free accessories/services
Before use operations	• Shipping • Carrying • Unpacking • Training • Assembling • Managing administration issues, bureaucracies • Communicating with the firm
Utilization time	• Switching on/off • Handling • Feeding • Performing other operations in the mean time • Using the product • Using accessories
Elapsed time before further exploitations	• Exploiting the outcomes of the product utilization • Maintaining • Cleaning • Repairing • Storing • Mounting accessories or changing parts • Protecting the product • Carrying

	• Waiting for the system being ready • Receiving assistance
End of the functioning	• Reselling the product and its accessories • Recycling or disposing of the product • Donating the product to needy people • Using the product as a collection item • Using the product for alternative employments

Table 3 elements and corresponding Specifications belonging to the Dimension "Lifecycle phases"

Elements	Specifications
Environment in which the product is situated	• Weather conditions • External environment • Place in which the product is situated (room or virtual space) • Tools or matched machinery • Matched or surrounding items • Other similar or identical systems placed nearby
Product or service level	• Product in general • Service in general
Parts, components and accessories	• Case • Engine and transmission • Connecting or fastening means • Handle • Opening/closing means • Movement means • Expansions • Aesthetic accessories • Bags, packaging • Fuel or consumables • Battery and chargers

Table 4 elements and corresponding Specifications belonging to the Dimension "System hierarchies"

4.3 Combination procedure and computer application

As clarified at the beginning of Section 4, any way of advantageously relating the contents of the Dimensions can be seen as a peculiar procedure to stimulate idea generation through the proposed approach. In this sense, the authors propose a set of preferred combination modes, which were subsequently implemented in a computer application. The manners of linking the Dimensions were preliminarily evaluated in a positive way in terms of the ratio between the benefits in employing the matching mode and the time spent to carefully consider the emerging combinations. It is worth noticing that matching all the Elements and/or Specifications composing the Dimensions would give rise to thousands of combinations, whereof many of them could result meaningless in the majority of industrial contexts. In order to reduce the number of combinations drastically, the authors opted not to consider all the four Dimensions contextually. The combination modes swivel on GDs, seen as a fundamental characterization of product attributes, to which the contents of the other Dimensions are associated to generate ideas. In other words, two concepts are matched simultaneously, whereas one of them refers to GDs' Dimension. More in details, three different combination procedures (to be exploited separately) are proposed:

- quick: any benefit (without indicating any particular content of GDs) with the Elements of SHs, LCs and SYSs;
- standard: Elements of GDs with the Elements of the other Dimensions;
- detailed: a subset of the Specifications of the GDs with particular Specifications of the residual Dimensions, as shown in Table 5. This kind of association is grounded on the observation of GDs' Specifications, which can vary with respect to particular Specifications (e.g. the customization of a product according to different exigencies of different stakeholders). Said Specifications correspond to all the items included in a certain Dimension (indicated with "all" in Table 5) or in tailored subsets.

Specifications of the General Demands	**Specifications combined in the detailed mode: reference Elements they belong to**
Quality of the expected outcomes	-
Quantity or extent of the expected outcomes	-
Duration of the expected outcomes	-
Fun and adventure	LC: Utilization time
Suitability of the product according to different demands	SH: all
Adaptability of the product in diverging conditions with respect to the designed preferred ones	LC: all
Expand or upgrade the range of product functionalities	-
Controllability of the system in order to obtain the expected outcomes	SYS: Product or service level; Parts, components and accessories
Integrity of the product itself, its resistance to planned or accidental stress or collisions, the strength against wear or corrosion	SYS: Parts, components and accessories
The limitation of damages towards the external environment	SYS: Environment in which the product is situated
The limitation of damages provoked by the external environment	SYS: Environment in which the product is situated
The safety and innocuousness for human health and people's psychological and social conditions	SH: all
The duration, the expected life of the product	SYS: Product or service level; Parts, components and accessories
The reduction of the information and skills to be gathered during the product life cycle	LC: all
The ease of acquiring the product, due to market penetration and distribution policies	LC: Purchasing, choice and access activities
The ease of managing, maintaining, assembling, disassembling, upgrading, substituting components or accessories	SYS: Parts, components and accessories

The independence from the use of other materials, instruments, technical systems	SYS: Environment in which the product is situated
The reduction of auxiliary functions to be delivered	LC: all
The additional services provided in order to attenuate the consumption of individual resources, the customer care.	-
Customize the product or certain properties	SYS: Product or service level; Parts, components and accessories
The possibility of benefitting of the product (or its parts) for different employment after the end of its life	LC: End of the functioning
The aesthetical requirements and the emotional dimension of the product, the style, the fashion content	SYS: Parts, components and accessories
What the product evokes, the lifestyle that the object implies, the prestige it generates for the owner as a feeling of distinction and recognition	SH: Buyers; Users
The environmental sustainability	LC: all
The ethics as a distinguishing factor	-
The reduction of time to be waited before the functioning of the product delivers the expected outcomes	LC: Before use operations
The limitation of the time required to perform operations	LC: all
The reduction of the consumption of parts, components or consumables	SYS: Parts, components and accessories
The limitation of the required energy (or human power) needed for the product during its lifecycle	LC: all
Product/service cheapness	-
Accessories cheapness	SYS: Parts, components and accessories
Cheapness of various activities during product life cycle	LC: all
The absence of bother for the people	SH: all
The comfort of use, the ergonomics, the manageability	LC: Before use operations; Utilization time; Elapsed time before further exploitations; End of the functioning
The limitation of occupied space	LC: Before use operations; Utilization time; Elapsed time before further exploitations; End of the functioning
The lightness and the portability	SYS: Product or service level; Parts, components and accessories

Table 5 suitable combinations of the Specifications belonging to the General Demands with those forming the Elements of other Dimensions (detailed mode of association)

Any perspective user of the method and the corresponding matching procedures can accomplish the test manually, by exploiting the lists reported in Tables 1 and 2. The developed computer-aided application supports the task in terms of easing the combination of the items and the management of the generated ideas, making the developed method more usable. Any interested reader can freely download the tool (named iDea) from the Internet at the web address: http://goo.gl/AwzZHF. In addition to the automatic execution of the above combination options, the prototype software allows selecting and customizing subgroups of Elements and/or Specifications in order to fit better the requirements of the industrial context in which the designer operates. Figure 1 presents the flow chart implemented in said ICT tool, shedding light on the possibility to select the contents of the Dimensions to be exploited and to switch between the three combination alternatives. A guide reporting the main functions of the software tool is included in the software application, downloadable from the above link.

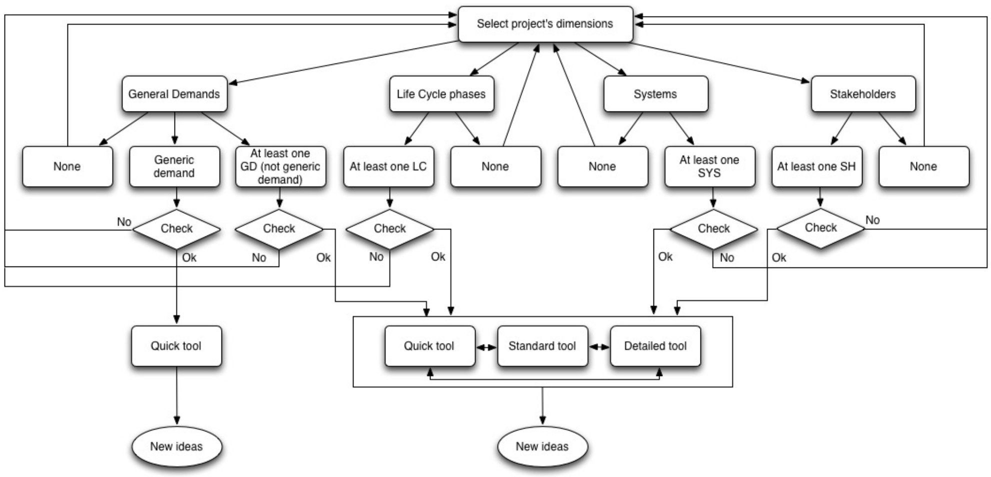

Figure 1 working flow of the prototype software aimed at stimulating ideas by combining concepts organized according to the developed taxonomy of product attributes

5. Testing activity

A testing campaign was required to assess potential advantages and criticalities of the method and the prototype software application. The authors planned the test in order to assess the quantity and the novelty of generated ideas.

By exploiting these metrics, the scope stood in comparing the performances of the presented proposal and those of traditional ideation approaches. The paper has already clarified how most of idea generation processes in industry are essentially entrusted to intuition and random stimuli (e.g. recently consulted information sources, new products of the competitors). Analogies come out accidentally, based on teamwork members' inspiration, personal creativity and talent. Hence, the free and unsupported search for new ideas represents the most proper benchmark for the sake of comparison.

5.1 Organization of the experiment and participants

The conducted experiment has involved 24 volunteer MS Students in Mechanical Engineering, University of Florence (Italy), which were attending the Course in Product Design and Development. The experiment consisted in two individual idea generation sessions, lasting three-hours, during which each participant working individually tried to identify original product features.

Before the first session, the students were trained about the fundaments of Product Planning and the role of information gathering in this design phase. Besides, prior to the first session, the Course had illustrated the cited Blue Ocean Strategy and Brainstorming, thus providing references about individual and group ideation techniques. In addition, the authors had illustrated to the students the opportunity of exploiting Brainstorming strategy by individuals instead of teams, like in the mentioned nominal group technique.

At the beginning of the first session, the students were randomly subdivided in two groups (A and B). The authors, which were supervising the experiment, encouraged both clusters to write down as many new product characteristics as possible, by exploiting personal creativity, any source of information or any notion descending from the themes of the Course. At the end of the generation task, each participant was asked to pick up one or more benefits descending from the generated original features and briefly describe the main traits of a new product consistent with the individuated advantages. The experiment foresaw different reference products to work with; group A dealt with cameras, while group B analysed domestic coffee makers. The two categories of product represent everyday devices, about which students were supposed to have already sufficient information about recent developments, thus avoiding time-consuming information gathering.

Between the two sessions, the basic notions of the proposed methodology and iDea software application were illustrated. The second session was performed with the same format of the first one, with two differences only:

- each participant was asked to use iDea to stimulate new product features, by exploiting one or more combination tools (quick, standard, detailed), according to their preferences;
- the products to deal with were reversed between groups A and B, so as to avoid conditioning from the first session, potentially leading to replicate the results.

5.2 Assessment of quantity and novelty

The first task of the tests, i.e. the generation of new product attributes, aimed at assessing quantity. Indeed, the authors attribute this variable to the number of new product features that students have identified and listed.

The evaluation of novelty represents the objective of the second task of the test, i.e. describing a more elaborated idea treasuring (some of) the identified original product features. It is worth noting that novelty metrics cannot be applied to any of the identified product features, by not including the ontological components foreseen in the SAPPhIRE model. Then, according to the criteria described in (Sarkar and Chakrabarti 2011), the following degrees of novelty were associated to new product ideas:

- None, when there is no difference with respect to already existing products; e.g. a camera with interchangeable covers[1];
- Low, when components or subassemblies are substituted to achieve the same functions through a known behaviour or when parts from other devices are originally integrated to perform the functions they are commonly intended to; e.g. a coffee machine with an integrated radio;
- Medium, when besides changing the disposition or the presence of components, the working principle is modified; e.g. a coffee machine whereas brews are delivered upwards and stored into thermally insulated bins, so to avoid temperature losses as it normally happens to coffee drops falling into mugs by gravity;
- High, when, besides structural and behavioural changes, the delivered function requires different inputs and/or implies consequences or transformations which were not displayed by existing products; e.g. a camera which distinguishes pictured colours and automatically retrieves objects with the same hue on the Web, so to find clothes or other items to be suitably combined with available stuff;
- Very high, when unprecedented functions are displayed; e.g. a coffee machine brewing transparent drinks that do not blemish clothes, paper sheets or other objects in general.

5.3 Outcomes of the test and assessment of the role played by the use of the proposed methodology

The authors gathered the results of the tests and, for each participant, observed the number of identified new product features, as well as determined the degree of novelty for the final ideas. With respect to the former, the analysis took into account just those product attributes clearly not included in commercial products.

Table 6 reports all the results of the two-session experiment. The Table indicates, besides the quantity of features and the novelty of ideas, if each single test (marked by an ID) has treated cameras (if No, the topic is coffee machines) and has benefitted from the use of iDea (if No, it refers to the intuitive session).

Test ID	Camera as a topic	Use of iDea	Quantity of new product features	Novelty of final ideas
1	Yes	No	3	Medium
2	Yes	No	2	None
3	Yes	No	6	Low
4	Yes	No	3	None
5	Yes	No	5	Low
6	Yes	No	3	Low
7	Yes	No	7	Low

[1] See e.g. Canon Powershot D10

8	Yes	No	2	Low
9	Yes	No	3	Low
10	Yes	No	1	None
11	Yes	No	5	High
12	Yes	No	8	None
13	No	No	3	Low
14	No	No	5	Low
15	No	No	3	None
16	No	No	4	Low
17	No	No	5	Low
18	No	No	5	None
19	No	No	3	Low
20	No	No	7	None
21	No	No	10	None
22	No	No	7	None
23	No	No	5	Low
24	No	No	3	None
25	No	Yes	20	High
26	No	Yes	21	Low
27	No	Yes	31	Medium
28	No	Yes	12	Low
29	No	Yes	14	High
30	No	Yes	20	None
31	No	Yes	28	High
32	No	Yes	8	None
33	No	Yes	16	Low
34	No	Yes	7	Low
35	No	Yes	21	High
36	No	Yes	39	Very high
37	Yes	Yes	28	High
38	Yes	Yes	17	High
39	Yes	Yes	15	Low
40	Yes	Yes	13	Low
41	Yes	Yes	19	High
42	Yes	Yes	13	None
43	Yes	Yes	27	High
44	Yes	Yes	34	None

45	Yes	Yes	20	Low
46	Yes	Yes	18	Low
47	Yes	Yes	14	Low
48	Yes	Yes	30	Low

Table 6 outcomes of the experiment in terms of quantity of new generated product features and novelty of described final ideas

By considering students' individual creativity as a random factor, each tests differs in terms of the treated case study and the employed support for Product Planning. These two different conditions represent the applied treatments potentially influencing the results. By using Stata software (release 11.0), the authors built two-predictor regression models assessing the role played by the case study and the idea stimulation support with respect to quantity and novelty. Both the influencing factors were introduced as dummy variables. The statistical models aim at verifying the confidence level to which the predictors can be considered influencers of quantity and novelty, by observing the variability of regression coefficients. As foreseen by the software, the null hypothesis is that each independent variable has no effect (has a coefficient of 0). Hence, by studying the simultaneous effect of the two treatments, null (*H0i*) and alternative hypotheses (*H1i*) can be formulated as follows:

H0a: The subject of the test (i.e. cameras instead of coffee machines) does not affect the results of idea generation processes in terms of quantity
H1a: The subject of the test (i.e. cameras instead of coffee machines) affects the results of idea generation processes in terms of quantity

H0b: The employed tool does not affect the results of idea generation processes in terms of quantity
H1b: The employed tool affects the results of idea generation processes in terms of quantity

H0c: The subject of the test (i.e. cameras instead of coffee machines) does not affect the results of idea generation processes in terms of novelty
H1c: The subject of the test (i.e. cameras instead of coffee machines) affects the results of idea generation processes in terms of novelty

H0d: The employed tool does not affect the results of idea generation processes in terms of novelty
H1d: The employed tool affects the results of idea generation processes in terms of novelty.

The regression results display P-values, showing the probability of mistakes in rejecting the null-hypotheses under a suitable statistical model, which differs according to the chosen typology of regression.

5.3.1 Quantity

The term standing for quantity, which is expressed through a natural number, can be conveniently treated as a continuous variable. Therefore, the authors performed a multivariate linear regression to infer the role of case study and employed method. Table 7 shows the results of the regression (R^2=0,64).

The constant stands for the number of expected new product features, which a designer should generate in a three-hour session by exploiting its individual creativity and by treating coffee machines. The results clearly show how the influence of the case study on quantity is marginal (very low coefficient and very high P-value, *H0a* is accepted). Conversely, the employment of iDea is expected to increase the number of generated features to a remarkable extent (about additional 16 new characteristics on average). Besides, the emerged P-value allows claiming the positive effect of the method on quantity with abundant reliability (the probability of its influence is greater than 99,9%), thus leading to reject *H0b*.

Regressor	Regression coefficient	P-value
Camera	-0,042	0,981
iDea	15,708	0,000
Constant	4,521	0,005

Table 7 results of the linear regression model explaining the effects of independent variables on quantity

5.3.2 Novelty

According to the criteria described in (Sarkar and Chakrabarti 2011), novelty is an ordinal variable. Hence, the authors performed a multivariate ordinal regression to infer the role played by the case study and the proposed methodology. Table 8 reports the results of the statistical model (Pseudo R^2=0,07).

The coefficients associated with the independent variables are the expected increase in log-odds of being in a higher level of novelty, given that the other explanatory factor is kept constant. The constants shown at the bottom of the Table are useful to compute the thresholds where novelty is cut to make the five groups that we observe in our data. For the sake of clarity, with regards to the statistical laws governing ordinal logistic models, we can calculate the ratio between the probability of overcoming a given degree of novelty (*j*) and the probability of obtaining such a level or lower, as follows:

$$\frac{P(Novelty > j)}{P(Novelty \leq j)} = e^{-constant\_j + 0{,}103 \times Camera + 1{,}688 \times iDea} \qquad (1)$$

In the formula, the terms *Camera* and *iDea* represent the introduced dummy variables; thus, the factors in the exponent should hold the value 0 or 1 according to the test conditions.

Regressor	Regression coefficient	P-value
Camera	0,103	0,852
iDea	1,668	0,005
Constant_none	-0,188	
Constant_low	2,098	
Constant_medium	2,231	
Constant_ high	5,034	

Table 8 results of the ordinal regression model explaining the effects of independent variables on novelty

Table 8 highlights that, as in the case of quantity of new product features, the novelty of ideas is positively influenced by the methodology (*H0d* is rejected with a 99,5% probability) and the case study plays an arguable role (*H0c* is accepted).

By assuming the marginal impact of the subject of investigation in idea generation tasks, a new regression was performed viable to isolate the influence of the introduction of the proposed methodology. With reference to the new model, Figure 2 illustrates the 95% range of probabilities in obtaining each level of novelty by exploiting just designers' intuition and benefitting from the presented ideation approach and prototype software. The diagram shows that marginal transformations appear in terms of the percentage of low novelty ideas by using an intuitive approach or the proposed method. Conversely, the employment of iDea allows diminishing the definition of ideas characterized by no novelty and increasing the chances of producing ideas whose novelty ranges from medium to very high.

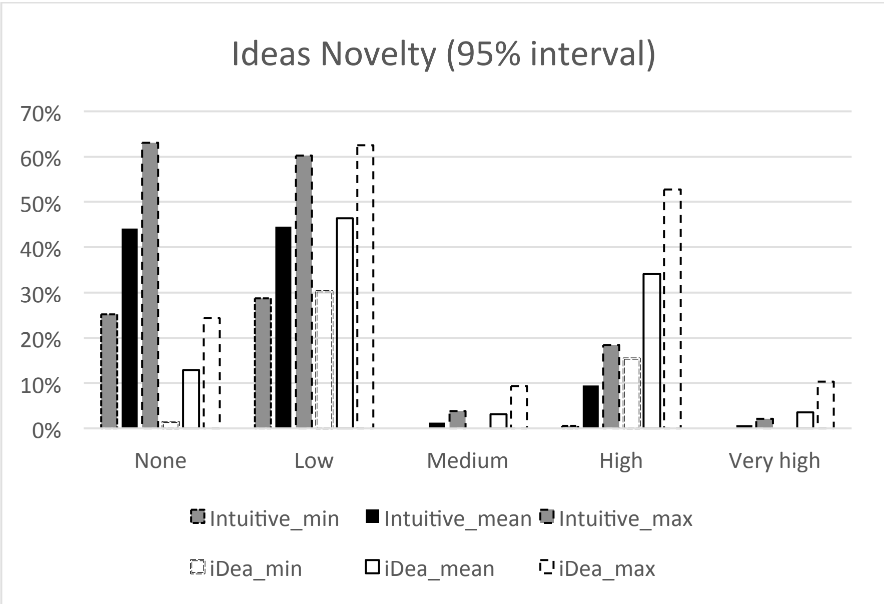

Figure 2 95% interval and mean probability values of observing a given degree of novelty when relying on intuition (black column for the average value, grey columns for interval extremes' values, with dotted and dashed border for the minimum and the maximum, respectively) and exploiting iDea (white columns, continuous border for the average value, dotted border for the minimum, dashed border for the maximum).

5.4 Implications and limitations

The above regression models remark the powerful influence of a methodology attempting to browse a considerable part of the design space in Product Planning. Despite the limited explanatory power of the tool employment in terms of displaying ideas novelty (low R^2), the exploitation of iDea has resulted fully impacting in shaping ideation processes.

In addition to the illustrated outcomes, we can claim the appropriateness of the presented instrument in terms of increasing designers' workload. The authors have observed a growth of the time dedicated to ideation from 106 minutes (on average) for the intuitive session to 148 minutes for iDea session (students were left free to conclude the tests if they thought to produce new ideas no longer).

However, despite the underlined role played by iDea in the experiment, the assessment of its utility in the industry cannot be automatically inferred from the presented results. The first testing session has simulated the ideation process of a designer in an industrial context, in which, as observed in many companies, formal Product Planning methodologies have been not introduced and the generation of novel attributes is entrusted to intuition. In each case, this simulation can result inaccurate by considering the differences between the volunteer students and members of R&D departments, e.g. in terms of experience, domain knowledge, motivation. Besides, certain firms can benefit from different idea stimulation techniques or design-by-analogy methods.

Further on, whereas the main purpose of the developed tool consists in enlarging the explored design space, evaluations can be performed in terms of novelty, but not on variety. The expected reduction of design fixation can be thus deducted by observing the good performances of sessions with iDea, but not verified in a rigorous way.

Section 6 documents the application of iDea performed by a scholar with a great experience on NPD techniques and some specific industrial sector and the chief of a start-up enterprise. The results provide a first overview of the capabilities of the proposed methodology in the industrial environment, thus partially filling the gaps of the above-described experiment.

6. Industrial applications of the methodology: description and discussion

The methodology was thus tested through two additional experiments in which the developed prototype software was exploited. In both cases, the authors participated to the test, by providing any explanation requested by the user in terms of procedures to follow and the meaning of the concepts underlying Dimensions, Specifications and Elements. However, the authors did not influence the creative process of the users at all, since their participation substantially aimed at saving the time of experimenters, who should otherwise consult the guide.

The purpose of the tests consisted in verifying the applicability of the proposed instrument and its effective capability to stimulate new product ideas for industrial players too. At the same time, the experiments revealed problems related to the utilization of the tool and not predicted benefits descending from its application, further considered as side results.

More in detail, the first case study was carried out by a scholar with a vast knowledge about design methods and a great experience in the field of household electrical appliances, matured in manifold projects involving branches of big corporations and SMEs working as specialized suppliers in such an industrial domain. The second experiment involved the project coordinator of a start-up firm, named B10nix (see more at www.b10nix.com). The enterprise designs and produces innovative artefacts exploiting the latest advances in Human-Computer Interaction (HCI) field, with a particular focus on wearable technologies. The involved subject currently coordinates B10nix's research team, besides being legal representative and co-founder of the firm after many years of experience in the field of HCI. Whereas the former was mainly thought to evaluate the usability of the tool and assessing its capability to investigate the design space, the latter mostly aimed at estimating its utility in industrial contexts, by drafting a comparison between the developed method and seeded practices. The tests will be widely illustrated in the following Subsections 6.1-6.2, while further considerations will be drawn in Subsection 6.3.

6.1 Test one: household ovens

The tester decided to analyse the field of household ovens, since he has been recently involved in several research activities devoted to innovate this kind of products. Thanks to his active participation in these activities, the experimenter possesses an up-to-date knowledge about the current competing factors of household ovens and the topics of many long-term NPD projects in this industrial domain.

The employment of iDea regarded all the three combination procedures, whereas no item concerning Dimensions, Specifications and Elements was deselected. This choice was performed for a twofold motivation: on the one hand, all the items were considered pertinent in the given industrial field; on the other hand, this could help the developers assessing the reference time for a full exploration of the associated concepts, as proposed by the methodology. The tester decided to take note of all the emerging product attributes, regardless they were seeded in the industry or original. At the end of the whole idea stimulation task, all the emerged competing factors were classified in known properties, benefits which have been already conceived through previous NPD activities (but not implemented yet), totally original characteristics. Table 9 provides an overview of the results, including the quantity of attributes generated through and the time dedicated to the three modules of iDea.

	Already known and implemented competing factors	Conceived competing factors, not implemented yet	Newly emerged competing factors	Spent time (about)
Quick module	29	15	2	40min
Standard module	93	30	15	40min
Detailed module	143	77	39	3h
TOTAL	**265**	**122**	**56**	**4h 20min**

Table 9 overview of the outcomes of the first experiment involving the developed methodology and iDea prototype software in terms of distinct product attributes generated or clearly identified through the three modules

The outcomes reported in Table 9 demonstrate the capability of the instrument to perform an accurate examination of the possible sources of value characterizing an artefact. Unfortunately, such results cannot be compared with any reference list of attributes and, hence, no statement can be formulated about the capability of the instrument to perform all-encompassing explorations. In any case, the usability of the method through iDea computer application has been verified, since the tester has autonomously produced an articulated bundle of competing factors, including original ideas. The new attributes include both benefits that can be easily fulfilled through existing technologies and more bizarre or futuristic ideas. None of them will be revealed, since the tester will employ them as a driver for proposing the new R&D objectives to partner firms.

6.2 Test two: wearable systems to capture and analyse the movement of people

The products offered by B10nix, although being relatively new in the marketplace, follow a continuous innovation process in order to improve their performance and enlarge the context of use of the developed systems. In this sense, the artefacts that are presented in the homepage of the firm well suit the application of instruments intended to individuate new sources of value. In this perspective, the tester decided to exploit iDea to approach the identification of new business opportunities concerning the use of wearable HCI systems in the context of rehabilitation through physiotherapy. More in detail, the analysed artefacts currently stand in arrays of sensors and electrodes hosted in worn garments or tailored bands, capable to assist injured people in performing physiotherapy exercises and evaluating the extent of improvements. Dedicated software gathers relevant data and supports physiotherapists in the post-processing phase.

The experimenter employed the three combination modules, but some items were excluded, because of being deemed not pertinent to the analysed product (at least in its current stage of development), while some group of Elements was customized by introducing specific terms. Although during the discussion many implemented product attributes were clearly revealed, just new product ideas were recorded. New product attributes, likely to be implemented in subsequent versions of the treated HCI system, emerged by using the combination options as follows:

- 4 new ideas with the Quick module (about 25 minutes spent);
- 9 new ideas with the Standard module (about 2 hours spent);
- 4 new ideas with the Detailed module (about 3 hours spent, whereas the duration of the procedure for customizing the items lasted 25 minutes).

It is worth highlighting that some idea was stimulated through different modules and combinations. The above numbers refer to product characteristics that had not previously emerged during the test.

The content of the ideas will not be revealed, since the tester considered them relevant for future developments of the wearable system to monitor people's movement. They regard both new features to improve the functioning of the product and additional services likely to enhance the experience of using the analysed artefact with respect to a variety of stakeholders.

A final interview was conducted to evaluate the applicability of the proposed instrument in industrial contexts and its supposed efficacy if compared with commonly employed Product Planning practices. The design team is currently performing Brainstorming sessions to generate ideas and planning to follow a more customer-oriented approach, by asking potential users for feedback with respect to new products the firm intends to develop. The outcomes of conjoint Brainstorming meetings are variable in terms of both quality and quantity of produced ideas; the main limitation of this approach stands, according to the experimenter, in the generation of very fuzzy concepts that do not undergo sufficient elaboration because of continuous shifts towards different areas of the design space. In these terms, the employment of the methodology and the developed software allows generating a larger number of ideas if the time spent and the human resources are taken into account. The tester greatly appreciated the possibility to write down and subsequently better define the new benefits to be offered. Indeed, it often happened during the test that new ideas were refined by considering different combinations of dimensions at any detail level. Other strengths of the approach were individuated in the capability to perform a very wide exploration of the possible benefits a product should fulfil, by pointing out the full spectrum of main characteristics taken into account during the initial development of the wearable HCI system, lasting four years. Furthermore, the same experimenter revealed the intention to replicate the task both alone and together with other members of the research team and/or perspective customers. In addition, he affirmed to be optimist about the possibility of individually subsuming the approach of the methodology through a learning-by-doing process, gaining more and more confidence with respect to introduced terms and combinations.

6.3 Discussion of the results of the industrial applications

The tests demonstrated the capability of the discussed tool to help identifying new product features and ideas also for people with a great orientation towards the industrial world. In particular, the application of the developed methodology in a real industrial case (second experiment) shows how the proposed approach has qualitatively overcome the performances of common Product Planning practices. If compared with the time and human resources dedicated to idea generation, the employment of the methodology results a brief task, also thanks to the presence of iDea software prototype. Whereas industrial practitioners would not be inclined to modify their established approach to Product Planning, the exploitation of the developed tool would not however result in a significant loss of time (if the common duration of NPD cycles is considered). In another perspective, the described instrument can be seen as a support for Brainstorming sessions, whose idea stimulation is fostered by the systematic way of exploring potential benefits for users and stakeholders. In this sense, more clear indications will emerge from future tests in B10nix, which should involve more designers simultaneously. Sound indications should be obtained however with regards to the time and difficulty in learning how to effectively use the proposed tools, since both tests were carried out with the presence of the authors.

Further on, both tests have remarked the capability of the method to generate a detailed framework of existing competing factors, besides supporting the generation of new ideas. This side result could be exploited when requiring to perform benchmark activities or to carry out innovation initiatives swivelled on the enhancement of current product attributes. A not minor advantage (see experiment 2) has emerged in terms of highlighting potential benefits by providing services matching the functions of a reference product. In this sense, the developed framework is likely to represent a support in the field of designing Product-Service Systems. The capabilities to better structure the emerged ideas has already been pointed out in Subsection 6.2.

With respect to the number of generated ideas, the quantities of new attributes emerging from the two tests clearly differ. Very diverging outcomes concern also the pace of generating new ideas by using the three modules, as highlighted in Table 10. Whereas standard and detailed modules show the best generation frequency in the first experiment, the quick combination strategy results the most prolific within the second test. These varying results do not allow individuating a most suitable matching mode and, hence, additional tests are required to fine-tune the combination procedures.

	Experiment 1	**Experiment 2**
Quick module	20 minutes	6 minutes
Standard module	3 minutes	20 minutes
Detailed module	5 minutes	39 minutes
Overall	5 minutes	20 minutes

Table 10 approximate average time elapsed to stimulate new ideas with the proposed matching modes

The main weakness of the developed instrument, as revealed by both testers, stands in the possibility of provoking a sense of boredom by submitting the user to a very large number of stimuli. According to their comments, this bad feeling is tolerated whereas the motivation in employing the instrument is high, but drops of attention can likely occur also in these cases. This aspect partially conflicts with the effort paid to increase individuals' workload. The experimenters suggested inverting the items standing for the GD and the other Dimension. They believe that thoroughly analysing aspects concerning a LC, SYS or SH would be preferable rather than specifying GDs with respect to all the variants they can assume by simultaneously considering other Dimensions.

Additional strategies, already outlined by the authors stand in:

- enriching the HCI with pictorial communicational;
- changing the modality through which the suggestions for new attributes are offered (e.g. through formats resembling conceptual maps).

7. Main findings and final remarks

The paper describes an original method to be employed in the initial phases of engineering design tasks, specifically to stimulate the individuation of original benefits in the critical activities constituting idea generation within Product Planning. The authors claim the lack of appropriate instruments to browse the possible sources of value for innovative products and propose an approach that monitors the drivers of new ideas by exploiting a schema constituted by four Dimensions and combination rules among them. The structuring of said dimensions in two different detail levels represents a further original contribution of the paper. The association between items belonging to two different dimensions is believed to favour the creativity process of perspective users. A software prototype has been developed to enhance the usability of the approach and to allow customizing the items to employ for the exploration of new value drivers, which have to be subsequently exploited in the design task.

The development of the present proposals has benefitted from the fundaments of ideation processes illustrated in the literature (see Subsection 2.1). More in particular:

- favouring the exploration of the design space was a premise of the work; unfortunately, the lack of suitable metrics to assess variety in the Product Planning does not allow claiming if this objective has been fully achieved;
- the increase of designers' workload has been verified by observing the rise of the time dedicated by MS Engineering students to perform ideation activities when employing the presented methodology;
- the utilization of general and abstract concepts to arouse analogies has been foreseen, besides allowing the authors to fine-tune a general-purpose instrument, usable in multiple industrial domains.

An articulated testing campaign has revealed the capability of the tool:

- to foster the generation of new product features, by drastically augmenting their number if compared to intuitive strategies;
- to increase the degree of novelty of new product ideas that follow the initial conception of the above features;
- to provide a support for industrial players both for mature systems (such as household ovens) and innovative products developed through long-lasting and accurate design processes (such wearable HCI artefacts);
- to browse existing customer requirements, thus easing benchmarking activities.

The first two points of the above bulleted list represent fundamental criteria to evaluate the effectiveness of idea generation techniques (see Subsection 2.2).

The main drawbacks of the shown toolkit seem to stand in the boredom arising from submitting the user to a protracted series of questions and stimuli, despite the benefits of mental stress claimed in the literature. In this sense, some hypothesized measures are described in Section 6, beyond improving the interface of the software by benefitting of studies in the field of HCI.

Despite the manifold outcomes provided by the two-session tests with Mechanical Engineering students and industrial applications, a complete validation activity is still required. It would consist in the exploitation of the emerged value drivers, their industrial implementation and the verification of the success of the so designed innovative products. Hence, such a validation should require long times before observing market results, clearly incompatible with the divulgation of the findings.

Sections 5 and 6 outline open issues about the effective capabilities of the proposed method. More specifically, a major understanding would be required with respect to the usability of the instrument by research teams instead of individuals, the dependence of the results from individual skills, the capability to support more or less creative people, the potential benefits of introducing stimuli through forms of pictorial communication. Eventually, the developed instrument has to be better linked with the subsequent NPD phases, with a particular attention to idea selection tasks, resulting consistently critical as the number of stimulated product attributes grows.

Any interested reader willing to obtain details about the utilization of the method and the software prototype (as well as its installation for Windows and Mac operating systems) can contact the corresponding author.

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References

Aiken M, Krosp J, Shirani A, Martin J (1994) Electronic brainstorming in small and large groups. Information & Management 27(3):141-149. doi:10.1016/0378-7206(94)90042-6

Altshuller GS (1984) Creativity as an exact science. The Theory of Solution of Inventive Problems. Gordon & Breach Science Publishers, New York

Aspara J, Hietanen J, Parvinen P, Tikkanen H (2008) An exploratory empirical verification of Blue Ocean Strategies: findings from Sales Strategy. 8th International Business Research Conference, IBR 2008, Dubai, March 27-28

Aurich JC, Mannweiler C, Schweitzer E (2010) How to design and offer services successfully. CIRP Journal of Manufacturing Science and Technology 2(3):136-143. doi:10.1016/j.cirpj.2010.03.002

Bacciotti D, Borgianni Y, Rotini F (2013) Overview of methods supporting product planning: Open research issues. In Proceedings of the 19th International Conference on Engineering Design, ICED13, Seoul, August 19-22, 389-398

Barczak G, Griffin A, Kahn KB (2009) Perspective: trends and drivers of success in NPD practices: results of the 2003 PDMA best practices study. Journal of Product Innovation Management 26(1):3-23. doi:10.1111/j.1540-5885.2009.00331.x

Bayus BL (2013) Crowdsourcing new product ideas over time: An analysis of the Dell IdeaStorm community. Management Science 59(1):226-244. doi:10.1287/mnsc.1120.1599

Bhander GS, Hauschild M, McAloone T (2003) Implementing life cycle assessment in product development. Environmental Progress 22(4):255-267. doi:10.1002/ep.670220414

Bilgram V (2013) Performance assessment of co-creation initiatives: A conceptual framework for measuring the value of idea contest. In Evolution of innovation management: Trends in an international context, edited by Alexander Brem and Eric Viardot, 32-51. Palgrave Macmillan, Basingstoke

Borgianni Y, Cascini G, Pucillo F, Rotini F (2013) Supporting product design by anticipating the success chances of new value profiles. Computers in Industry 64(4):421-435. doi:10.1016/j.compind.2013.02.004

Börjesson S, Dahlsten F, Williander M (2006) Innovative scanning experiences from an idea generation project at Volvo Cars. Technovation 26(7):775-783. doi:10.1016/j.technovation.2005.01.005

Buzan T, Buzan B (1996) The mind map book how to use radiant thinking to maximise your brain's untapped potential. Plume, New York

Cagan J, Vogel CM (2001) Creating Breakthrough Products: Innovation from Product Planning to Program Approval. Prentice Hall, Upper Saddle River

Cantamessa M, Montagna F, Messina M (2013) Multistakeholder analysis of requirements to design real innovations. In Proceedings of the 19th International Conference on Engineering Design, ICED13, Seoul, August 19-22, 309-318

Caroff X, Lubart T (2012) Multidimensional Approach to Detecting Creative Potential in Managers. Creativity Research Journal 24(1):13-20. doi:10.1080/10400419.2012.652927

Cascini G, Fantoni G, Montagna F (2013). Situating needs and requirements in the FBS framework. Design Studies 34(5):636-662. doi:10.1016/j.destud.2012.12.001

Cavallucci D (2011) A research agenda for computing developments associated with innovation pipelines. Computers in Industry 62(4):377-383. doi:10.1016/j.compind.2010.12.002

Chakrabarti A, Sarkar P, Leelavathamma B, Nataraju BS (2005) A functional representation for aiding biomimetic and artificial inspiration of new ideas. Artificial Intelligence for Engineering Design, Analysis and Manufacturing 19(2):113-132. doi:10.1017/S0890060405050109

Chan J, Fu K, Schunn C, Cagan J, Wood K, Kotovsky K (2011) On the benefits and pitfalls of analogies for innovative design: Ideation performance based on analogical distance, commonness, and modality of examples. Journal of mechanical design 133(8). doi:10.1115/1.4004396

Chen CH, Yan W (2008) An in-process customer utility prediction system for product conceptualisation. Expert Systems with Applications 34(4):2555-2567. doi:10.1016/j.eswa.2007.04.019

Chen ZY, Zeng Y (2006) Classification of product requirements based on product environment, Concurrent Engineering 14(3):219-230. doi:10.1177/1063293X06068389

Chulvi V, Mulet E, Chakrabarti A, López-Mesa B, González-Cruz C (2012) Comparison of the degree of creativity in the design outcomes using different design methods. Journal of Engineering Design 23(4):241-269. doi:10.1080/09544828.2011.624501

Coates NF, Cook I, Robinson H (1997) Idea generation techniques in an industrial market. Journal of Marketing Practice: Applied Marketing Science 3(2):107-118

Dahl DW, Moreau P (2002) The influence and value of analogical thinking during new product ideation. Journal of Marketing Research 39(1):47-60. doi:10.1509/jmkr.39.1.47.18930

Davis J (2010) Generating directions for persuasive technology design with the inspiration card workshop. In Proceedings of the 5th International Conference on Persuasive technology, PERSUASIVE 2010, Copenhagen, June 7-10, 262-273

De Bono E (1968) New think: the use of lateral thinking in the generation of new ideas. Basic Books, New York

De Bono E (2009) Six Thinking Hats, 2nd edition. Penguin, London

De Bono E (2010) Lateral thinking: Creativity step by step. HarperCollins, New York

Diehl M, Stroebe W (1991) Productivity loss in idea-generating groups: tracking down the blocking effect. Journal of personality and social psychology 61(3):392-403. doi:10.1037/0022-3514.61.3.392

Ebner W, Leimeister JM, Krcmar H (2009) Community engineering for innovations: the ideas competition as a method to nurture a virtual community for innovations. R&d Management 39(4):342-356. doi:10.1111/j.1467-9310.2009.00564.x

Eisingerich AB, Bell SJ, Tracey P (2010) How can clusters sustain performance? The role of network strength, network openness, and environmental uncertainty. Research Policy 39(2):239-253. doi:10.1016/j.respol.2009.12.007

Franklin KK, Hart JK (2007) Idea generation and exploration: benefits and limitations of the policy Delphi research method. Innovative Higher Education 31(4):237-246. doi:10.1007/s10755-006-9022-8

Furnham A (2000) The brainstorming myth. Business strategy review 11(4):21-28. doi:10.1111/1467-8616.00154

Gero JS, Jiang H, Williams CB (2013) Design cognition differences when using unstructured, partially structured, and structured concept generation creativity techniques. International Journal of Design Creativity and Innovation 1(4):196-214. doi:10.1080/21650349.2013.801760

Geschka H (1996) Creativity techniques in Germany. Creativity and Innovation Management, 5(2), 87-92. doi:10.1111/j.1467-8691.1996.tb00125.x

Gordon WJ (1961) Synectics: The development of creative capacity. Harper, Oxford

Haig M (2011) Brand Failures. Kogan Page, London

Halskov K, Dalsgård P (2006). Inspiration card workshops. In Proceedings of the 6th conference on Designing Interactive systems, DIS06, University Park, June 26-28, 2-11

Hernandez NV, Shah JJ, Smith SM (2010) Understanding design ideation mechanisms through multilevel aligned empirical studies. Design Studies 31(4):382-410.

doi:10.1016/j.destud.2010.04.001
Herstatt C, Kalogerakis K (2005) How to use analogies for breakthrough innovations. International Journal of Innovation and Technology Management 2(3):331-347. doi:10.1142/S0219877005000538
Howard TJ, Culley S, Dekoninck EA (2011) Reuse of ideas and concepts for creative stimuli in engineering design. Journal of Engineering Design 22(8):565-581. doi:10.1080/09544821003598573
Howard TJ, Dekoninck EA, Culley SJ (2010) The use of creative stimuli at early stages of industrial product innovation. Research in Engineering Design 21(4):263-274. doi:10.1007/s00163-010-0091-4
Hüsig S, Kohn S (2009) Computer aided innovation—State of the art from a new product development perspective. Computers in Industry 60(8):551-562. doi:10.1016/j.compind.2009.05.011
Johansson J, Nilsson L (1998) Product planning at an Electrolux subsidiary. In Proceedingd of the International Conference on Engineering and Technology Management, IEMC'98, San Juan, October 11-13, 425-430
Kahle LR, Beatty SE, Homer P (1986) Alternative measurement approaches to consumer values: the list of values (LOV) and values and life style (VALS). Journal of consumer research 13(3):405-409
Kahn KB (2011) Product Planning Essentials. M.E. Sharpe, New York
Kano N (1995) Upsizing the organization by attractive quality creation. In Total Quality Management, edited by Gopal K. Kanji, 60-72. Springer Netherlands, Dordrecht. doi:10.1007/978-94-011-0539-2_6
Kawakita J (1982) The Original KJ-Method. Kawakita Research Institute, Tokyo
Kim WC, Mauborgne R (2005). Blue Ocean Strategy. Harvard Business School Press, Cambridge
Kobayashi H (2006) A systematic approach to eco-innovative product design based on life cycle planning. Advanced engineering informatics 20(2):113-125. doi:10.1016/j.aei.2005.11.002
Kudrowitz B, Dippo C (2013) When Does a Paper Clip Become a Sundial? Exploring the Progression of Originality in the Alternative Uses Test. Journal of Integrated Design and Process Science 17(4):3-18. doi:10.3233/jid-2013-0018
Lee CW, Suh Y, Kim IK, Park JH, Yun MH (2010) A systematic framework for evaluating design concepts of a new product. Human Factors and Ergonomics in Manufacturing & Service Industries 20(5):424-442. doi:10.1002/hfm.20193
Leimeister JM, Huber M, Bretschneider U, Krcmar H (2009) Leveraging crowdsourcing: activation-supporting components for IT-based ideas competition. Journal of management information systems 26(1):197-224. doi:10.2753/MIS0742-1222260108
Li Y, Wang J, Li X, Zhao W (2007) Design creativity in product innovation. The international journal of advanced manufacturing technology 33(3-4):213-222. doi:10.1007/s00170-006-0457-y
Liikkanen LA, Perttula M (2010) Inspiring design idea generation: insights from a memory-search perspective. Journal of Engineering Design 21(5):545-560. doi:10.1080/09544820802353297
Linsey JS, Tseng I, Fu K, Cagan J, Wood KL, Schunn C (2010) A study of design fixation, its mitigation and perception in engineering design faculty. Journal of Mechanical Design 132(4). doi:10.1115/1.4001110
Linsey JS, Wood KL, Markman, AB (2008) Modality and representation in analogy.

Artificial Intelligence for Engineering Design, Analysis and Manufacturing 22(02):85-100. doi:10.1017/S0890060408000061

Linstone HA, Turoff M (1975) The delphi method. Addison-Wesley, Reading

Lopez-Mesa B, Mulet E, Vidal R, Thompson G (2011) Effects of additional stimuli on idea-finding in design teams. Journal of Engineering Design 22(1):31-54. doi:10.1080/09544820902911366

Lotter B (1986) Manufacturing Assembly Handbook. Butterworths, Boston

Lubart T (2005) How can computers be partners in the creative process: classification and commentary on the special issue. International Journal of Human-Computer Studies 63(4):365-369. doi:10.1016/j.ijhcs.2005.04.002

Mak TW, Shu LH (2008) Using descriptions of biological phenomena for idea generation. Research in Engineering Design 19(1):21-28. doi:10.1007/s00163-007-0041-y

Martin B, Hanington B (2012) Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions. Rockport Publishers, Beverly

Maslow AH (1943) A theory of human motivation. Psychological review 50(4):370-396. doi:10.1037/h0054346

Max-Neef MA, Elizalde A, Hopenhayn M (1991) Human scale development: conception, application and further reflections (Vol. 1). Apex Press, New York

McAdams DA, Stone, RB, Wood, KL (1999) Functional interdependence and product similarity based on customer needs. Research in Engineering Design 11(1):1-19. doi:10.1007/s001630050001

Metzler T, Witzmann M, Deubel T, Lindemann U (2014) Lifecycle and stakeholder-oriented integration of cognitive functions into product concepts. In Proceedings of the 13th International Design Conference, DESIGN 2014, Dubrovnik, May 19-22, 925-934

Močnik D (2010) Achieving Increased Value for Customers Through Mutual Understanding Between Business and Information System Communities. Managing Global Transitions 8(2):207-224

Moreno DP, Yang M, Hernandez A, Linsey J, Wood KL (2014) A Step Beyond to Overcome Design Fixation: A Design-by-Analogy Approach. In Proceedings of the 5th International Conference on Design Computing and Cognition, DCC14, London, June 23-25, 23-25

Müller P, Sakao T (2010) Towards consolidation on product-service systems design. In Proceedings of the 2nd CIRP IPS2 Conference, Linköping, April 14-15, 219-225

Nambisan S (2003) Information systems as a reference discipline for new product development. Mis Quarterly 27(1):1-18

Nelson BA, Wilson, JO, Rosen D, Yen J (2009) Refined metrics for measuring ideation effectiveness. Design Studies, 30(6), 737-743. doi:10.1016/j.destud.2009.07.002

Nguyen TA, Zeng Y (2012) A theoretical model of design creativity: nonlinear design dynamics and mental stress-creativity relation. Journal of Integrated Design and Process Science 16(3):65-88. doi:10.3233/jid-2012-0007

Nguyen TA, Zeng Y (2014) A physiological study of relationship between designer's mental effort and mental stress during conceptual design. Computer-Aided Design 54:3-18. doi:10.1016/j.cad.2013.10.002

Ogot M, Okudan GE (2006) Integrating systematic creativity into first-year engineering design curriculum. International Journal of Engineering Education 22(1):109-115

Oriţă A, Drăghici G, Beney JL (2013) Use of Ontological Classes in the Exploration of User Needs. Applied Mechanics and Materials 371:847-851. doi:10.4028/www.scientific.net/AMM.371.847

Osborne AF (1953) Applied Imagination. Scribner, Oxford

Oulasvirta A, Kurvinen E, Kankainen T (2003) Understanding contexts by being there: case studies in bodystorming. Personal and Ubiquitous Computing 7(2):125-134. doi:10.1007/s00779-003-0238-7

Pahl G, Beitz W, Feldhusen J, Grote KH (2007) Engineering design: a systematic approach. Springer, London

Poetz MK, Schreier M (2012) The value of crowdsourcing: can users really compete with professionals in generating new product ideas?. Journal of Product Innovation Management 29(2):245-256. doi:10.1111/j.1540-5885.2011.00893.x

Pucillo F, Cascini G (2014) A framework for user experience, needs and affordances. Design Studies 35(2):160-179. doi:10.1016/j.destud.2013.10.001

Qin SF, Harrison R, West AA, Jordanov IN, Wright DK (2003) A framework of web-based conceptual design. Computers in Industry 50(2):153-164. doi:10.1016/S0166-3615(02)00117-3

Rangaswamy A, Lilien, GL (1997) Software tools for new product development. Journal of Marketing Research 34(1):177-184

Rietzschel EF, Nijstad, BA, Stroebe W (2006) Productivity is not enough: a comparison of interactive and nominal brainstorming groups on idea generation and selection. Journal of Experimental Social Psychology 42(2):244-251. doi:10.1016/j.jesp.2005.04.005

Rochford L (1991) Generating and screening new products ideas. Industrial Marketing Management 20(4):287-296. doi:10.1016/0019-8501(91)90003-X

Rotini F, Borgianni Y, Cascini G (2012) Re-engineering of Products and Processes. Springer, London

Sarkar P, Chakrabarti A (2011) Assessing design creativity. Design Studies 32(4):348-383. doi:10.1016/j.destud.2011.01.002

Shah JJ, Smith, SM, Vargas-Hernandez N (2003) Metrics for measuring ideation effectiveness. Design studies 24(2):111-134. doi:10.1016/S0142-694X(02)00034-0

Sheu DD, Lee HK (2011) A proposed process for systematic innovation. International Journal of Production Research 49(3):847-868. doi:10.1080/00207540903280549

Simonton DK (2003) Scientific creativity as constrained stochastic behavior: the integration of product, person, and process perspectives. Psychological bulletin 129(4):475-494. doi:10.1037/0033-2909.129.4.475

Smith GF (1998) Idea ‐ Generation Techniques: A Formulary of Active Ingredients. The Journal of Creative Behavior 32(2):107-134. doi:10.1002/j.2162-6057.1998.tb00810.x

Soukhoroukova A, Spann M, Skiera B (2012) Sourcing, filtering, and evaluating new product ideas: an empirical exploration of the performance of idea markets. Journal of Product Innovation Management 29(1):100-112. doi:10.1111/j.1540-5885.2011.00881.x

Sowrey T (1990) Idea generation: identifying the most useful techniques. European Journal of Marketing 24(5):20-29. doi:10.1108/03090569010140228

Spanjol J, Qualls WJ, Rosa JA (2011) How Many and What Kind? The Role of Strategic Orientation in New Product Ideation. Journal of Product Innovation Management 28(2):236-250. doi:10.1111/j.1540-5885.2010.00794.x

Tay FE, Gu J (2002) Product modeling for conceptual design support. Computers in industry 48(2):143-155. doi:10.1016/S0166-3615(02)00014-3

Toubia O (2006) Idea generation, creativity, and incentives. Marketing Science

25(5):411-425. doi:10.1287/mksc.1050.0166

Tovey M, Owen J (2000) Sketching and direct CAD modelling in automotive design. Design Studies 21(6):569-588. doi:10.1016/S0142-694X(99)00027-7

Tseng I, Moss J, Cagan J, Kotovsky K (2008) The role of timing and analogical similarity in the stimulation of idea generation in design. Design Studies 29(3):203-221. doi:10.1016/j.destud.2008.01.003

Tseng MM, Jiao J (1998) Computer-aided requirement management for product definition: a methodology and implementation. Concurrent Eng Res A 6(2):145-160. doi:10.1177/1063293X9800600205

Ullman DG (1992) The mechanical design process (4th edition). McGraw-Hill, New York

Ulrich KT, Eppinger SD (2011) Product design and development. McGraw Hill, New York

Valacich JS, Dennis AR, Connolly, T (1994) Idea generation in computer-based groups: A new ending to an old story. Organizational Behavior and Human Decision Processes 57(3):448-467. doi:10.1006/obhd.1994.1024

Van Elsas PA, Vergeest, JSM (1998) New functionality for computer-aided conceptual design: the displacement feature. Design Studies, 19(1), 81-102. doi:10.1016/S0142-694X(97)00016-1

VanGundy AB (1984) Brain writing for new product ideas: an alternative to brainstorming. Journal of Consumer Marketing 1(2):67-74. doi:10.1108/eb008097

Verhaegen PA, D'hondt J, Vandevenne D, Dewulf S, Duflou JR (2011) Identifying candidates for design-by-analogy. Computers in Industry 62(4):446-459. doi:10.1016/j.compind.2010.12.007

Von Hippel E (1986) Lead users: a source of novel product concepts. Management science 32(7):791-805. doi:10.1287/mnsc.32.7.791

Von Hippel E (2005) Democratizing innovation. The MIT Press, Cambridge

Walter TP, Back A (2011) Towards measuring crowdsourcing success: An empirical study on effects of external factors in online idea contest. In Proceedings of the 6th Mediterranean Conference on Information Systems, MCIS 2011, Cyprus, September 3-5

Ward J, Shefelbine S, Clarkson PJ (2003) Requirements capture for medical device design. In Proceedings of the 14th International Conference on Engineering Design, ICED 03, Stockholm, August 19-21, 65-66

Weissman A, Petrov M, Gupta SK (2011) A computational framework for authoring and searching product design specifications. Advanced Engineering Informatics 25(3):516-534. doi:10.1016/j.aei.2011.02.001

Wilson JO, Rosen D, Nelson BA, Yen, J (2010) The effects of biological examples in idea generation. Design Studies 31(2):169-186. doi:10.1016/j.destud.2009.10.003

Zeng Y (2004) Environment-based formulation of design problem. Journal of Integrated Design and Process Science 8(4):45-63

Appendix 1: Most remarkable results of the survey about software applications to aid idea generation: the classification is based on the source through which they were identified and the kind of logic/approach they implement

Source	Name or web address	Category	Functionalities and additional notes
Web (Google search)	http://coggle.it	Brainstorming and Mind Maps	It allows making Mind Maps
	http://creately.com	Brainstorming and Mind Maps	It allows making Mind Maps, diagrams and SWOT analysis
	http://crowdicity.com	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	http://freemind.sourceforge.net	Brainstorming and Mind Maps	It allows making Mind Maps
	http://hypeinnovation.com	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	http://ideagenerator.creativitygames.net	Random words and random images	
	http://innovation.qmarkets.net	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	http://inspire.quirky.com	Patent inspiration tool	
	http://watchout4snakes.com	Random words	
	http://web.singnet.com.sg	Brainstorming and Mind Maps	It allows making Mind Maps
	http://www.accept360.com	Crowdsourcing	It supports the idea management
	http://www.brainbankinc.com	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	http://www.brainstormsw.com	Brainstorming and Mind Maps	It allows collecting and organising photos and texts

	http://www.brightidea.com	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	http://www.comapping.com	Crowdsourcing	It supports the collaboration during the NPD and allows making digital Brainstorming sessions
	http://www.creax.com	Patent inspiration tool	
	http://www.datastation.com	Crowdsourcing	It supports the idea management
	http://www.debonoconsulting.com	Lateral thinking	It also support the implementation of the Six Thinking Hats approach
	http://www.ideo.com	Creative cards	They have been developed to support NPD processes
	http://www.infinn.com http://www.brainstorming.co.uk	Crowdsourcing, random words and random images	It allows making digital Brainstorming sessions and includes several other tools, e.g. SCAMPER, frame change, etc.
	http://www.innovationportal.eu	Crowdsourcing	It supports the collaboration during the NPD and allows making digital Brainstorming sessions
	http://www.inspiration.com	Brainstorming and Mind Maps	It also allows making diagrams
	http://www.matchware.com	Brainstorming and Mind Maps	It allows making Mind Maps
	http://www.mindgenius.com	Brainstorming and Mind Maps	It allows making Mind Maps
	http://www.mindjet.com	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	http://www.moreinspiration.com	Web inspiration tool	
	http://www.mywebspiration.com	Brainstorming and Mind Maps	It allows making Mind Maps
	http://www.nchsoftware.com (ClickCharts)	Brainstorming and Mind Maps	It allows making diagrams
	http://www.patentinspiration.com	Patent inspiration tool	
	http://www.play-factory.it (Cards)	Creative cards	They have been developed to support NPD processes
	http://www.thebrain.com	Brainstorming and Mind Maps	It allows making Mind Maps

	http://www.thoughtrod.com	Brainstorming and Mind Maps	It provides question and hints to help exploring creative directions and finding new ideas
	http://www.xmind.net	Brainstorming and Mind Maps	It allows making Mind Maps
	https://bubbl.us	Brainstorming and Mind Maps	It allows making Mind Maps
	https://company.podio.com	Crowdsourcing	It supports the collaboration during the NPD and allows making digital Brainstorming sessions
	https://www.stormboard.com	Crowdsourcing	It supports the collaboration during the NPD and allows making digital Brainstorming sessions
	www.inova-software.com	Crowdsourcing	It supports idea management and technology scouting
App Store/iTunes (Apple devices)	Blue Ocean Strategy Visualizer BEC-BOM	Blue Ocean Strategy	It includes the BEC-BOM tool
	Blue Ocean Strategy Visualizer (Strategy Canvas)	Blue Ocean Strategy	It includes the Strategy Canvas tool
	Blue Ocean Strategy Canvas	Blue Ocean Strategy	It includes the Strategy Canvas tool
	BigMind - Mind Mapping	Brainstorming and Mind Maps	It allows making Mind Maps
	Brain squeezer	Crowdsourcing	It supports the collaboration during the NPD and allows making digital Brainstorming sessions
	Brainsparker - Creativity and ideas booster	Random words and random images	
	Brainstorming canvas	Brainstorming and Mind Maps	It allows making sketches and organising sticky notes
	Business Idea Generator	Web inspiration tool, Patent inspiration tool	
	Cell storming	Brainstorming and Mind Maps	It allows making Mind Maps
	Concept	Brainstorming and Mind Maps	It allows collecting and organising photos, texts, sticky notes and making sketches
	Effective mind	Random words and random images	
	Evernote	Brainstorming and Mind Maps	It allows collecting and organising photos, texts and making sketches

	iBrainstorm	Brainstorming and Mind Maps	It allows collecting and organising photos, texts, sticky notes and make sketches
	iBrainstormer	Brainstorming and Mind Maps	It allows making Mind Maps
	Idea Generator	Random words	
	ideaMan	Random words	
	Idea sketch	Brainstorming and Mind Maps	It allows making Mind Maps
	IdeaDeck	Brainstorming and Mind Maps	It allows collecting and organising sticky notes and make SWOT analysis
	Ideas (brainstorming, mindmapping and inspiration)	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts, words)
	Ideas Blitz	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts, words)
	Ideas flux	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Ideator	Random words	
	Ideatron	Brainstorming and Mind Maps	It allows making sketches and notes
	IDEO Method Cards	Creative cards	They have been developed to support NPD processes
	Inkflow Visual Notebook	Brainstorming and Mind Maps	It allows collecting and organising photos, texts and making sketches
	iMindQ (mind mapping) | Brainstorming app	Brainstorming and Mind Maps	It allows making Mind Maps
	iMindMap/iMindMap HD	Brainstorming and Mind Maps	It allows making Mind Maps
	Innovate - Innovation & Creativity Community	Web inspiration tool	
	Inspireme	Random words	
	Intuiti	Creative cards	
	MindNode	Brainstorming and Mind Maps	It allows making Mind Maps
	MindMeister	Brainstorming and Mind Maps	It allows making Mind Maps
	MyInvention	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas

	Popplet	Brainstorming and Mind Maps	It allows making Mind Maps
	Riffer idea generation and brainstorming tool	Brainstorming and Mind Maps	It allows collecting and organising photos, texts, and make sketches
	SimpleMind	Brainstorming and Mind Maps	It allows making Mind Maps
	Super research idea generator	Random words	
Google Play Store (Android devices)	Android Idea Book	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	Brainstorm List: Brainstorming	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	Brainstorming App	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Brainstorming: Dynamic New Way	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Brainstream	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	Business Ideas Pro	Web inspiration tool	
	Connected Mind	Brainstorming and Mind Maps	It allows making Mind Maps
	Create-O-Mat	Random words	
	Creative Ideas (App Innovation)	Web inspiration tool	
	creative ideas (AnaCoder)	Web inspiration tool	
	Creative Thinking	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Creative Thinking Techniques	Lateral thinking	
	Creative Ways Wallpaper	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Creativity Inspire Innovation	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Creator Studio	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas

	Entrepreneur Business Ideas	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Idea (hwkhlp.com)	Crowdsourcing	It supports the collaboration during the NPD and allows making digital Brainstorming sessions
	Idea (Idea App, LLC)	Brainstorming and Mind Maps	It allows collecting and organising photos and texts
	Idea Card	Creative cards	
	Idea Generation MindMap	Brainstorming and Mind Maps	It allows making Mind Maps
	Idea Generator	Random words	
	Idea Growr	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts) and provides hints to help exploring creative directions and finding new ideas
	Idea Napkin	Brainstorming and Mind Maps	It allows making sketches
	Idea Note	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	Idea Share	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	Idea Tracker	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	idea Training	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Ideas by Brightidea	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	iMindMap/iMindMap HD	Brainstorming and Mind Maps	It allows making Mind Maps
	Inspiration	Random words and random images	
	Intuiti	Creative cards	
	MindCanvas	Brainstorming and Mind Maps	It allows collecting and organising photos, texts, and making sketches
	MindMemo	Brainstorming and Mind Maps	It allows making Mind Maps
	Mindomo	Brainstorming and Mind Maps	It allows making Mind Maps

	Random Ideas	Random words	
	SimpleMind mind mapping	Brainstorming and Mind Maps	It allows making Mind Maps
	Thinker	Brainstorming and Mind Maps	It allows making Mind Maps
Store (Windows devices)	Idea Sketch	Brainstorming and Mind Maps	It allows making diagrams
	Think creative	Brainstorming and Mind Maps	It allows collecting and organising photos, videos, texts and making sketches
	Flow Chart Marker	Brainstorming and Mind Maps	It allows making diagrams
	Brainstorming	Brainstorming and Mind Maps	It allows making Mind Maps
	Mind Map	Brainstorming and Mind Maps	It allows making Mind Maps
	Brain_Squeeze	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	Concept Mapper	Brainstorming and Mind Maps	It allows making Mind Maps
	FtsMind	Brainstorming and Mind Maps	It allows making Mind Maps
	MindMaps	Brainstorming and Mind Maps	It allows making Mind Maps
	Simple Thoughts	Brainstorming and Mind Maps	It allows making Mind Maps
	InvulgoMindMapper	Brainstorming and Mind Maps	It allows making Mind Maps
	Mindmap	Brainstorming and Mind Maps	It allows making Mind Maps
	Mapidea	Brainstorming and Mind Maps	It allows making Mind Maps
	Blue Ocean Strategy	Blue Ocean Strategy	It includes the Strategy Canvas and Four Action framework tools
	Evernote	Brainstorming and Mind Maps	It allows collecting and organising photos, texts and making sketches
	M8! –Mind Map	Brainstorming and Mind Maps	It allows making Mind Maps
	Freemind	Brainstorming and Mind Maps	It allows making Mind Maps

D.4 Product Planning techniques: investigating the differences between research trajectories and industry expectations

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Abstract

According to several literature sources, Product Planning is acknowledged as a primary driver of future commercial success for new designed products and it is schematically constituted by the identification of business opportunities and the selection of most promising alternatives. Despite the recalled relevance of Product Planning, it emerges that a marginal quantity of companies have adopted formal methods to carry out this task. The paper attempts to provide a major understanding about such a limited implementation of Product Planning techniques and other open issues emerging from the analysis of the literature concerning the initial phases of engineering design cycles. The presented study investigates the claimed benefits of methods described in the literature, the level to which such tools are diffused through educational programs in Technical Institutes, the expectations and the demands of a sample of enterprises with respect to new tools supporting Product Planning. It emerges that, whereas existing methods strive to fulfil relevant properties according to the perception of the companies, limitations come out in terms of the transfer of the proposed techniques and their perceived reliability.

1. Introduction

The capability to innovate the commercial offer is becoming a key aspect for the survival of companies due to the high competitiveness of the market. In this sense, a crucial role is played by the design activities belonging to the New Product Development (NPD) process.

Actually, several schemes of NPD cycles exist (e.g. Pahl and Beitz 2007; Shinno et al. 2006; Ulrich and Eppinger, 2011; Guo 2012); however, even though quite different terminologies are used, all of them can be represented through the overall model shown in Figure 1.

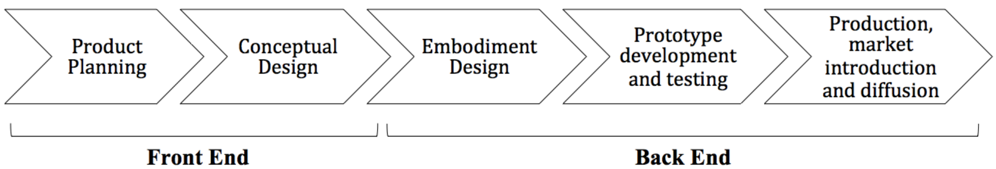

Figure 1 shared phases of the product development process

The first two phases of the product development process, i.e. Product Planning and Conceptual Design, generally constitute the so-called Front End. This initial part of the design process is often referred as "Fuzzy Front End" (FFE); Smith and Reinertsen (1991) have first popularized the term. The adjective "fuzzy" has been attributed to Front End phases, because they typically involve random process and "ad hoc" decisions based on intuition, observations, discussions or accidents (Stasch et al. 1992; Montoya-Weiss and O'Driscoll 2000; Flint 2002).

Conceptual Design is acknowledged as a fundamental step towards the definition of original, novel and sustainable technical solutions (Al-Hakim et al. 2000). Product Planning consists in the identification of customer needs, the analysis of current lacks in the market and the definition of new product characteristics capable of fulfilling customer expectations (Pahl and Beitz 2007). Therefore, the outcome of this phase constitutes the product idea on which companies will concentrate design efforts and resources (Montagna 2011).

As shown in Figure 1, the Back End ranges from Embodiment Design to those activities oriented to the introduction of new artefacts in the marketplace.

The literature pays a growing interest towards initial phases, which are considered critical to carry out innovation initiatives successfully (Kim and Wilemon 2002; Reid and de Brentani 2004; Riel et al. 2013). Indeed, several scholars highlight that a great percentage of product failures is ascribable to inefficient planning activities (Cooper 1999; Shinno and Hashizume 2002; Haig 2011). Moreover, Ulrich and Eppinger (2011) estimate that up to 80% of the forthcoming cost of a product is committed by the decisions undertaken in the initial phases. Furthermore, managers and researchers claim that improvements in the management of the Front End phases are capable of producing benefits far exceeding those resulting from enhancements concerning later stages (Zhang and Doll 2001).

The appropriate accomplishment of the activities at the beginning of design cycles strongly reduces problems in the subsequent product development tasks (Cagan and Vogel 2001; Flint 2002), drives revenues and increases firms' profitability (Dahl and Moreau 2002; Reid and de Brentani 2004; Alam 2006; Kahn 2011). In brief, well-managed initial design phases are the prerequisite to create successful new products (Kim and Wilemon 2002; Ernst 2002; Guo 2012). As claimed by Pahl and Beitz (2007), formal processes through which to perform Front End phases help execute the whole product development cycle effectively. Notwithstanding the critical role they play, initial design phases are still insufficiently supported (Koen et al. 2001; Flint 2002; Soukhoroukova et al. 2012).

In this perspective, plenty of proposals have been advanced to carry out the design of new products advantageously. However, despite some decades of research focused on NPD processes, those attempts have not obtained the expected results (Flint 2002), especially from the viewpoint of introducing formal practices and methodologies in industry.

Nijssen and Frambach (2000) remark problems about poor awareness in companies of methods supporting NPD, as well as they highlight that practical results are sometimes arguable. On the one hand, unsatisfying results may arise as a consequence of the wrong implementation of NPD methods in industry, e.g. by making reference to incorrect NPD phases for which the proposed techniques are designed (Yeh et al. 2010). On the other hand, misalignments can be explained by the fact that methods presented by academicians lack industrial validation and/or are developed with no real connection with business settings in plenty of cases (Cantamessa 2003). López-Mesa and Bylund (2011) include the cited issues among the causes that provoke the insufficient implementation of academic methods in industry. They investigated previous literature sources in preparation to an ethnographic study conducted in Volvo Car Corporation, which assesses similarities and differences between effectively employed decision-making strategies (considered as a crucial design activity) and procedures suggested by academic NPD methods. In-depth studies of industrial practices and questionnaires surveying the diffusion of academic methods are the most diffused means to investigate the implementation of formal NPD techniques. Graner and Mißler-Behr (2012) have recently conducted a critical analysis of the studies published in authoritative design journals and aimed at evaluating the degree to which proposed NPD methodologies are employed in industrial environments. The survey emphasizes the descriptive approach of most of the treated papers, which follows the varying quantity of investigated enterprises. A large number of studies is restricted to verify the awareness of companies with respect to a sample of design techniques. With regard to these samples, it is claimed that the heterogeneity of the methods populating such sets represents a considerable limitation to the creation of specific knowledge in the field. Therefore, still with reference to Graner and Mißler-Behr (2012), it is recommended to adopt a systematic approach in selecting the methods subjected to investigation. Besides, Blessing and Seering (2016) point out how successful applications of design research refer to specific NPD tasks.

Consistently with these indications, the present paper addresses the investigation of a specific phase of NPD cycles, i.e. the crucial stage referred as Product Planning, with respect to the problems concerning the implementation of methods in industry. Information about the diffusion and the proficiency of specific tools and techniques can be extracted through the numerous literature sources available, by trivially selecting, among the surveyed methods, those that are useful in Product Planning. This is not considered sufficient to explain the lack of practices based on academic findings. In this sense, the present research investigates the adequacy of existing methods in terms of fulfilling companies' needs and the context factors that are supposed to foster or hinder the adoption of academic proposals. It is hereby proposed to achieve such an outcome by discussing and comparing:

- the hot topics and the open issues of the literature about Product Planning, with a particular attention to what concerns the suitability of methods for industrial settings;
- the benefits that are claimed by the developers of Product Planning methods; from this viewpoint, no review has been performed according to authors' knowledge;
- the factors that enable the diffusion of said methods, with a particular reference to their adoption in University courses;
- the priorities assigned by enterprises; to this regard, the authors are aware that a large number of factors can be subsumed by previous studies conducted within industrial environments. However, the knowledge is extremely dispersed, the ways through which information is extracted is hardly comparable and, therefore, no specific reference can be adopted to extract such priorities, at least for what concerns Product Planning.

Section 2 is devoted to describe the research approach followed in the present paper to provide a clear vision about these specific topics. Section 3 digs into the specific research objectives emerged as a consequence of scrutinizing the literature about Product Planning. The emerged research questions are further discussed in Section 4 where strengths and weaknesses of Product Planning methods are compared with NPD practices in a sample of industrial firms and a survey of contents taught in relevant courses in a range of highly ranked technical schools. Section 5 presents an articulated discussion about the new findings of the paper with respect to the treated topics. Eventually, Section 6 closes the paper by recalling the main achievements and indicating authors' future research intentions.

2. Research methodology

As mentioned in the introduction, the overall goal of this paper is to investigate the appropriateness of academic research outcomes on Product Planning for the real needs of industry and to highlight possible mismatches and suggested directions for further research. The overall study has combined literature analysis, investigation of relevant courses in academia and daily practices in a sample of companies.

In this perspective, it was first necessary to perform an in-depth review of Product Planning literature. A preliminary survey of the main topics addressed by the ongoing research brought evidence to the specific objectives that have attracted the biggest attention by researchers in the field. Such a naïve investigation has been then examined by means of statistical text mining tools, so as to highlight the most debated research threads in quantitative terms and to identify their evolution in time.

On the one hand, the study based on text statistics has confirmed the validity of the open issues emerged from the initial literature survey. On the other hand, it has pinpointed specific aspects requiring further investigation.

The second phase of the study concerned the extraction of some properties suitable for comparing methods for Product Planning and, through them, the punctual, despite qualitative, assessment of the numerous methodologies proposed in literature, thus remarking their strengths and weaknesses. As anticipated, a preliminary review of Product Planning methods was carried out to extract said properties.

Thereafter, with the specific aim of analysing the diffusion of Product Planning methods, the authors have conducted a survey of academic courses dealing with NPD in worldwide high-ranked technical institutions. The underlying assumption is that methods and tools taught in leading schools should constitute a common background of future practitioners. In this perspective, it should not be surprising that contents not proposed in academic curricula, despite debated in scientific publications, have produced a negligible impact on industrial practice.

The last phase of the study moved to industry. As already underlined in the Introduction, industry-based surveys and hands-on investigations represent the standard for extracting information from the business domain. Whereas the former are commonly conducted in a large number of companies in order to achieve statistically significant results, the latter, which is abundantly more time-consuming, is carried out in few representative firms. By sharing the thought of Maurer and Widmann (2012) and several others, the authors believe that a standard questionnaire-based survey does not allow to realise to which extent the academic studies conducted so far fulfil the real needs of companies. Therefore, the authors decided to choose a sample of enterprises and to perform an ethnographic investigation of their standard practices for NPD, in order to assess the relevance and the suitability of the aforementioned properties of Product Planning methods. It is evident that the small sample of enterprises involved in this study cannot be considered as fully representative of the industrial sphere. Nevertheless, the authors argue that the issues strongly emerging in most of the analysed firms are good candidate topics for a scientific discussion.

The overall outcomes of this study and the related conclusions emerge as a combination of all the insights and suggestions produced through the above-mentioned activities, as described in the following sections.

3. Analysing the literature about Product Planning: treated themes and overlooked issues

3.1 Role and objectives of the Product Planning in the Fuzzy Front End

Many professionals and researchers do not judge FFE as a structured process because of its intrinsic ambiguity and uncertainty (Koen et al. 2001; Kim and Wilemon 2002; Alam 2006). This circumstance partially motivates the fact that many companies have neither adopted a structured approach to follow, nor do they entrust formal methodologies (Reid and de Brentani 2004; Achiche et al. 2013). On the contrary, a great number of organizations focus their attention on Back End activities, for which acknowledged methods are more diffused, by primarily aiming at reducing manufacturing errors. According to Cagan and Vogel (2001), this strategy is however hazardous, because the disregard of the FFE can lead to product failures or anyway to great expenditures for revising decisions, which dramatically increase as the design process progresses (Kim and Wilemon 2002; Cousineau et al. 2004; Achiche et al. 2013).

Some scholars (Flint 2002; Alam 2006; Soukhoroukova et al. 2012) suggest that FFE can become much less "fuzzy" if customers are involved in the initial stages of NPD. This thought is however not shared by other authors (e.g. Ulwick 2002), who argue that customers fundamentally focus on already fulfilled needs and consequently the opportunities that potentially emerge from the exploration of new market domains get lost. Computer applications supporting FFE are not considered reliable yet and require additional and more specific empirical research (Hüsig and Kohn 2009; Monteiro et al. 2010). Further on, proposals to manage FFE better include organizing teams in an appropriate way to conduct FFE activities (Kim and Wilemon 2002), managing in different ways the fuzziness related to customers, technology and competitors (Zhang and Doll 2001), focusing on the available resources of company (Achiche et al. 2013). Besides, studies about management of early stages of NPD cycles (Adams et al. 1998; Ramesh and Tiwana 1999; García et al. 2008) and strategic positioning of development projects (Balachandra and Friar 1997; Henard and Szymanski 2001) have already brought to clear evidences. According to these sources, key aspects to achieve commercial success lie in internal collaboration between different units of the company, attention dedicated to manifold organizational issues, trust in fostering cross-functional integration, R&D effectiveness, managers' experience. Thus, acknowledged success factors of the product development process do not pertain to what is directly designed, manufactured and marketed. It emerges that few efforts have been conversely devoted to analyse those activities that directly involve the product and its distinguishing features (Page and Schirr, 2008), although, according to Hicks (2016), product-led research has a greater economic impact than process-led research. In this perspective, more knowledge should be acquired about best practices and means for carrying out Product Planning.

In literature, the term "Product Planning" has been adopted to define different design activities. Some scholars (Lee et al. 2010; Li et al. 2012) affirm that the main purpose of Product Planning is the translation of identified client wishes into product technical requirements using the Quality Function Deployment, QFD (Akao 2004). Other authors claim that the main objectives of Product Planning are the assessment and selection of alternative product concepts (Jetter and Sperry 2013). Kahn (2011) defines Product Planning as the process of envisioning, conceptualizing, developing, producing, testing, commercializing, sustaining and disposing of organizational offerings, i.e. he considers the whole product lifecycle. Beyond these definitions, it is widely accepted (Shinno et al. 2006; Pahl and Beitz 2007) that the main objective of Product Planning is the identification of new product features capable of fulfilling customer expectations in order to exploit new market opportunities.

With this meaning, one of the main outputs of Product Planning is the list of product requirements that has to be taken into account in the subsequent design phases for defining, selecting and developing the most valuable technical solutions. In the residual of the paper, the authors will employ such a concept of Product Planning, which is the most popular. At the same time, by referring to customer expectations, Product Planning has to take into consideration the benefits generated by both physical goods and intangible services (Flint 2002; Alam 2006). For the sake of brevity, the authors will use the term "product" diffusely in this paper for indicating any commercial offer or deliverable of industrial processes that includes characteristics pertaining to both products and services (thus physical artefacts, pure services, mixes of tangible products and related services).

More specific scopes of Product Planning process emerge by considering its main constituent activities, currently standing in the generation of ideas about the new product to develop and the subsequent selection of alternatives.

The idea generation, sometimes called Opportunity Identification stage (Cagan and Vogel 2001; Achiche et al. 2013), allows to identify attributes, features or general ideas of the new product. For this reason, some scholars consider idea generation the basic task of Product Planning and a primary source of commercial success. However, many companies do not allocate sufficient resources to carry out this stage accurately, since they perceive it as a random process. As a result, even recent proposals about structuring the FFE disregard the ideation process; (Riel et al. 2013) is among the few exceptions. Appendix 1 summarizes the views of scholars with respect to functions and role played by idea generation. Each reported statement is linked with the references that claim the given argument.

Idea generation usually gives rise to several options. Hence, this divergent activity must be followed by a convergent idea selection task (Rietzschel et al. 2006). The idea selection, named Opportunity Analysis stage in some sources (e.g. Koen et al. 2002), constitutes the decision-making phase of the Product Planning that allows to choose the alternatives to be further developed. Also this activity is supposed to be insufficiently supported, as well documented in Appendix 2 that reports literature claims about idea selection.

Other activities, beyond idea generation and selection, play a not negligible role in the commencing stages of product development, by supporting the management of available resources. All these tasks, reported in Appendix 3 together with the related literature references, are out of the scope of the present work, because they mostly concern the management of innovation projects.

3.2 A general view on the literature about the initial design stages and specific objectives of this study

The presented overview about objectives and criticalities of the FFE (and more specifically to the design activities of Product Planning) has given rise to a framework characterized by conflicting views and a tangled network of problems. According to what has been discussed so far, the most relevant issues seem to regard:

- the possibility of effectively individuating business opportunities through tailored design methodologies;

- the most suitable means to limit the fuzziness of initial NPD phases;
- the capability of customers to unveil impacting new product characteristics;
- the identification of success factors concerning the product directly, rather than the management of the NPD process.

In order to provide a clearer picture of the themes faced in the scientific arena, the authors opted to examine the selected literature sources through a statistical tool of textual analysis. The objective of such an analysis is twofold:

- identifying further arguments that have not been sufficiently highlighted by authors' overview;
- observing the increasing/declining interest of the scientific community towards specific issues by clustering the literature sources according to their publication dates.

3.2.1 Performed analysis: examined body of knowledge and employed software instrument

The authors carried out the above task through the employment of an available computer application, i.e. Provalis Research products (http://provalisresearch.com/). More specifically, the activity required the combined use of the software tools named QDA Miner 4 and Wordstat 7 for the scope of analysing texts and obtaining statistical information of terms' frequency.

The selected sources were the articles cited in this paper from Section 1 to 3.1 (including the related Appendixes), considered as a relevant body of scientific knowledge concerning the initial design phases. The analysis did not include books, because their whole contents (besides normally more extended than papers) did not focus specifically on the treated subject, hence the outcomes of data elaboration could result misleading. It was subsequently verified which full-text articles the software could handle. With respect to these texts, the authors subdivided the articles into groups, characterized by papers' publication dates, of approximately the same time length and including a similar quantity of manuscripts. This measure was deemed necessary to perform a balanced comparison between different publication periods.

More in detail, the groups are structured as follows:

- Group 1: 12 papers published from 1996 to 2001;
- Group 2: 13 papers published from 2002 to 2007;
- Group 3: 16 papers published from 2008.

3.2.2 Main evidences of the linguistic analysis

Among the various outputs of statistical analysis of the terms included in the reference papers, the employed software tool produced the representation reported in Figure 2. This chart was judged as an effective overall view of the themes that are treated by the benchmark articles belonging to the three groups. It shows the extent to which the most popular 30 terms in the whole body (displaying from 434 to 3183 occurrences) of the text characterize the publication time, according to the closeness to the labelled quadrants in which the associated intervals are reported. The Figure remarks how few terms or abbreviations (e.g. NPD) are shared by the three periods in a balanced way, while several words basically feature single clusters.

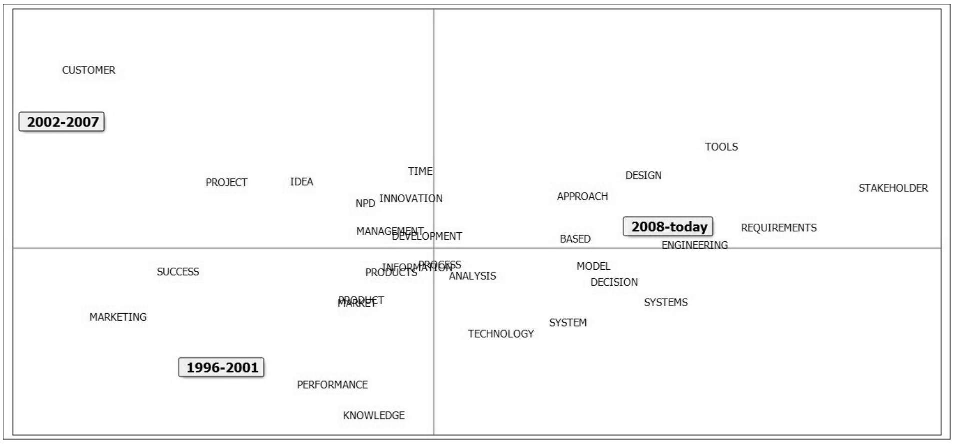

Figure 2 characterization of three subsequent timespans according to the main themes treated in published papers focusing on the initial phases of New Product Development cycles

According to this representation, the literature discussion seems to shift from successful product development practices oriented on performance enhancing strategies exploiting marketing knowledge (1996-2001) to customer-centred projects (2002-2007) and finally to engineering design tools and decision support models attempting to fulfil the requirements requested by multiple stakeholders (2008-today).

3.2.3 Issues to be further investigated and specific objectives of the present research

This picture of the literature debate clearly does not answer the posed questions reported at the beginning of Subsection 3.2. Conversely, it reveals a continuous change of themes that did not emerge from the overview of Subsection 3.1. It can be noted that this shift does not entail a deeper investigation of raised arguments, but, on the contrary, new problems are faced. Such dynamics can be explained by alternative hypotheses:

- the initially posed themes have been sufficiently explored and are not worth investigating further;
- the problems faced by past papers do not impact NPD practices, because of structural modifications of the competition among industries;
- the proposed solutions have not resulted in successful applications and, hence, new attempts are currently experienced.

Unresolved matters and further questions arising from the presented linguistic analysis suggest carrying out additional research on Product Planning, in order to elucidate:

- whether scientific and industrial arenas acknowledge any established Product Planning practice, irrespective of its arguable suitability for a worldwide competition framework increasingly focused on innovation;
- the claimed advantages deriving from the implementation of Product Planning methods;
- pros and cons of involving customers and product stakeholders during the FFE;
- the effective benefits of diffusing and implementing Product Planning models in industry;

- whether rigorous proposals have been advanced to identify successful new product characteristics regardless the followed NPD process.

The issues reported in the above bulleted list constitute specific objectives of the present paper.

With the aim of defining the baseline for investigating the above points, the authors opted to perform a state-of-the-art analysis of Product Planning methods, which follows in Section 3.3.

3.3 Review of Product Planning methods

A survey is presented hereafter of models and techniques to support the main activities of Product Planning, i.e. idea generation and selection, which are more closely connected with intrinsic characteristics of innovative products. The Subsection is introduced by a first characterization of the approaches for executing Product Planning in terms of the role assigned to the customer. The review criteria to individuate relevant contributions are then defined, so as to obtain a collection of methods to support Product Planning. The identified instruments are characterized according to the mentioned categorization. By scrutinizing such tools, it was possible to extract a preliminary set of properties pertaining to Product Planning methods, consisting in the declared scopes or strengths that literature highlights.

3.3.1 An acknowledged classification of Product Planning approaches

It is well-acknowledged that the key to achieve organizational goals is to be more effective and efficient than competitors in identifying and satisfying the needs of target markets (Narver et al. 2004; Kotler 2007), developing and delivering products that are valued by customers (e.g. Kim and Mauborgne 2005; Atuahene-Gima et al. 2005). According to this objective, two main categories of Product Planning approaches can be identified in the literature: responsive and proactive methodologies (Narver et al. 2004; Atuahene-Gima et al. 2005).

The former consider the industrial standard as a reference for identifying lacks in offered product features and delivered performances. Responsive methods swivel on marketing surveys whose results are used as input information to define a new product idea. Hence, the task of pointing out desired improvements is almost entirely entrusted to the end user, who becomes the factual decision-maker. For this reason, the term "market (or demand) pull" is often used to define this kind of strategies (Schön 1967; Chidamber and Kon 1994; Brem and Voigt 2009; Di Stefano et al. 2012), while the innovation strategy implemented through these approaches is mainly based on the fulfilment of expressed needs. Therefore, the team in charge of Product Planning has to collect, analyse, interpret customers expressed needs and translate them into product requirements. The first three activities are typically managed by the marketing professionals, whereas the fourth one is often delegated to designers.

Proactive methods attempt to capture unspoken wants of customers or even induce new needs for end users. They aim at developing product ideas radically different from the industrial standard. Therefore, these methods do not involve the end user in the investigation of the aspects that could represent potential innovation opportunities. Benchmarking analyses, usually performed by marketing experts, are used to analyse the business context, while the decisions about definition and selection of the most promising product ideas are in charge of design teams. This category of methods includes the so-called "technology push" strategies (Chidamber and Kon 1994; Rohrbeck et al. 2008; Brem and Voigt 2009; Di Stefano et al. 2012), in which emerging technologies can be exploited as driving forces for disruptive innovations (Wall et al. 2013). However, the use of a new technology is not generally sufficient to ensure market success (Leinsdorff 1995; Flint 2002; Haig 2011). Therefore, a balanced R&D-marketing coordination is strongly recommended to carry out proactive approaches (Gupta et al. 1986; Leinsdorff 1995). Despite the marginal role assigned to customers, investigated proactive strategies do not comprise methods based on design-driven innovation (Verganti, 2008), because they basically aim at changing existing products' meaning (Battistella et al., 2012) instead of developing original artefacts.

Besides the recalled typologies of methods, the existence cannot be overlooked of contributions that actually merge peculiarities of both responsive and proactive approaches. They essentially try to discover and fulfil customers' latent needs by involving the end-users of products or the recipients of services in the idea generation process. Indeed, users provide feedback about the new product ideas that are generated by the design team and/or collaborate in proposing new ones. Due to this evidence, the authors introduce in the paper a further category of approaches, named "Hybrid", through which to classify all the methods that present both responsive and proactive characteristics.

3.3.2 Research criteria

By limiting the scope of the state-of-the-art to idea generation and selection, the review does not comprehend studies which emphasize the importance of the corporate image (e.g. Fombrun 1996), brands (e.g. Park et al. 1986), advertising (e.g. Drumwright 1996), retailing (e.g. Grewal et al. 2010), pricing (e.g. Nagle and Holden 1995). It includes methodologies that support planning activities besides idea generation and selection, but just their contribution to the recalled tasks will be discussed. In addition, the authors have not considered generic approaches for representing and monitoring the design process, e.g. Stage-Gate (Cooper 1990), or tools that support the management and the description of the outputs originating from the Product Planning, e.g. business model canvas (Osterwalder and Pigneur 2010) and strategy canvas (Kim and Mauborgne 2005).

The analysis comprises formal methods, i.e. more or less systematic procedures, and software tools to support Product Planning. For the sake of completeness, the survey has been limited to those methods that support the user in defining the list of competing factors (or in identifying the basic information to intuitively obtain it), which consequently allow to carry out product development cycles in the industrial practice. Such features include both current product characteristics and new attributes, commonly introduced to satisfy emerging or unspoken needs. In the remainder of the paper, the authors indicate with the term "latent needs" the complex of unprecedented customer requirements that are discovered, stimulated or aroused.

Furthermore, for the scope of this research, the authors considered only contributions showing the applicability of the proposed methods in industry or documenting real case studies.

The literature search has been essentially oriented to literature sources within engineering design and, more in general, to innovation management, yet with a focus relevant for a discussion from an engineering design perspective. More in details, the survey has included different research sectors dealing with Product Planning and considered different jargons according to scholars' field of expertise. Besides "Product Planning", the main keywords for performing the research follow, indicating reference works that extensively use the matching terms:

- Fuzzy Front End (Guo 2012; Riel et al. 2013);
- New Product Development (Pahl and Beitz 2007; Ulrich and Eppinger 2011);
- New Value Proposition (Kim and Mauborgne 2005);
- customer needs and satisfaction analysis (Urban and Hauser 1993; Kano 1995);
- company general planning (Kahn 2011; Cooper 2011);
- product innovation (Cagan and Vogel 2001; Tripsas 2008);
- analysis of product success factors (Ayers et al. 1997; Ernst 2002);
- idea generation (Alam 2006; Soukhoroukova et al. 2012).

3.3.3 Identification of the methods to support Product Planning

The outcomes of the survey allowed to individuate 17 distinct methods to perform idea generation and/or selection. Table 1 shows the list of contributions, by specifying whether they belong to responsive, proactive or hybrid approaches. Whereas the developers have not assigned a specific name of the proposed technique, the authors have added the topic of the reference instrument.

Kind of approach	Name (or general topic) of the methodology	Reference Source
Responsive	DSS for Customer Satisfaction Assessment	Liberatore and Stylianou 1995
	SW for Marketing Surveys Analysis	Matsatsinis and Siskos 1999
	DSS based on Experts and Customer Surveys	Chan and Ip 2011
	Marketing Survey with Persona Model	Liao et al. 2008
	Kano Model (classic)	Kano et al. 1984
	Kano Model Evolution	Nilsson-Witell and Fundin 2005
Proactive	Scenario model	Lee et al. 2010
	Blue Ocean Strategy	Kim and Mauborgne 2005
	Lateral thinking	De Bono 1985
	Value Assessment Metric	Borgianni et al. 2013
Hybrid	Brainstorming	Osborne, 1953
	Lead Users Method	Von Hippel 1986
	Selection from New Product Ideas Database	Büyüközkan and Feyzioğlu 2004
	Kansei Engineering	Nagamachi 1995
	System for product conceptualization and customer surveys	Chen and Yan 2008
	Customer value model for service design	Kimita et al. 2009
	Virtual Customer Integration	Füller and Matzler 2007

Table 1 list of identified methods to support idea generation and selection in Product Planning

4. Effects brought by the research on Product Planning

In order to fulfil the research objectives of the paper, the present Section introduces new elements of knowledge with respect to the information directly available from the literature. In particular, in Section 4.1, the authors classify the collected methods for Product Planning according to some properties, which clearly emerged from the above in-depth review (omitted for the sake of brevity). Further on, the authors have performed an analysis of the syllabi of product development academic classes held in the top 30 technical universities worldwide according to Quacquarelli-Symonds rankings (Section 4.2). Such an investigation aims at verifying the popularity of the gathered methods for Product Planning, and, consequently, the degree to which engineers and technicians are expected to master these tools effectively. Eventually, Section 4.3 reports an insightful analysis of Product Planning approaches followed by a sample of convenience of firms. This activity intends to provide a preliminary evaluation of the interest paid by industrial subjects towards the capabilities of available Product Planning methods.

4.1 Properties of Product Planning methods

In order to compare the collected methods and tools, the authors have identified a set of properties. These properties include features originated from the research criteria, distinguishing factors of the analysed methods on which developers focus, clearly desirable characteristics. The latter encompass evaluation criteria with regards to the reliability, the systematic level and the accuracy of the investigated instruments within the support of Product Planning.

4.1.1 Focus on the manifest properties of the tools supporting Product Planning

Table 2 summarizes the whole sample of properties, their description and meaning within the Product Planning phase. The reference numbers of each characteristic are exploited in the following description by using curly brackets.

At first, the scrutinized methods can be distinguished into those with an initial focus on general product ideas {1} and approaches that consider customer requirements {2} as a starting point for innovation initiatives. In the second option, product features can be subsequently articulated in order to create an innovative product profile, i.e. a bundle of attributes associated with their matching offering levels to be transformed into an original product architecture. Conversely, turning general product ideas into a list of product characteristics is extremely helpful in the subsequent design phases.

The intuitiveness of a Product Planning method {3} can represent a basic requirement to allow the implementation of the tool in industrial environments. It is hereby supposed that extensive human resources requested to introduce new NPD approaches can prevent the effective exploitation of the benefits possibly descending from the use of a new methodology. According to the extant trend of assigning an increasing role to Artificial Intelligence also in the design field, the availability of software applications implementing the surveyed methods {4} can result in a substantial strength. User-friendly computer applications emphasize the already discussed ease of use.

A specific benefit of some Product Planning instruments stands in the capability to individuate latent needs {5}. As already highlighted, this chance allows to develop products showing a substantial diversification with respect to the artefacts populating the industry. Differentiation strategies can be likewise supported by methods that include or allow to represent a general picture of the competition in the reference market {6}. Careful competitors' analyses are likely to ease the display of overlooked product performances. Taking into account the relentless modifications of customer preferences {7} brings an additional strength of Product Planning methods for achieving superior performances at the right time. Indeed, it can happen that long NPD cycles determine the market launch of products that are not valued anymore by customers, due to alterations of priority needs to be fulfilled.

The capability of new products to thrive in the marketplace is somehow related to the reliability of the employed Product Planning method {8}. Previous properties {5-7} definitely range among the drivers that allow to develop successful products. However, the trustworthiness of the tool is not hereby considered in terms of rigour in correctly considering multiple factors affecting NPD, but by taking into account how a given method has proved to give rise to profitable results. Hence, Product Planning methods are considered reliable when, regardless their way of functioning, many practical implementations are documented leading to successful new products. The repeatability of positive outcomes within different industrial sectors has to be considered as an ultimate demonstration of methods' reliability.

The majority of the gathered methods support idea generation, potentially giving rise to many new product alternatives. This divergent phase must be followed by a convergent stage, capable of distinguishing the most successful options. In this sense, the existence of means to perform idea selection {9} represents a desirable property of Product Planning methods. It has to be noted that, however, several decision strategies exploit information that is extremely subjective or unreliable. It then comes out that it is preferable to opt for decision criteria not requiring a big amount of individual judgements and uncertain data {10}.

#	Property	Description	Relevance of the property
1	*Initial focus on products attributes*	Predominant attention on the identification of the attributes and features of the product to be developed. Subsequently, these attributes can be articulated in order to create an innovative product profile.	The analysis of the single features of a new product allows to perform insightful evaluations of customer preferences. It favours the process of developing the requirement list.
2	*Initial focus on general product ideas*	Approach aimed at identifying from the beginning new general product ideas, without analysing single attributes.	The capability of framing a general product idea from the very beginning of the design process avoids the need to reconcile single and potentially conflicting customer requirements.
3	*Quickness and easiness of the method/tool*	It features methods resulting easy, quick and intuitive for the user, who has to learn, implement and use them.	It is important to support quickly and easily the Product Planning phase, in order to reduce the companies' committed resources.

4	*Development of computer applications*	It features those methods that have been implemented in a computer-aided tool	Computer applications can effectively support the Product Planning in an easy and quick way; software tools are essential instruments in the present industrial context.
5	*Effective support in the individuation of latent needs*	It considers the capability of effectively aiding the search of customer latent needs.	The discovery and fulfilment of latent needs supports the development of breakthrough products and allows to avoid head-to-head competition.
6	*Integrated competitors' analysis*	Characteristic possessed by the methods that include an analysis of the competition.	The analysis of the reference industry can help to individuate the competition factors and to seek a differentiation strategy.
7	*Consideration of customer preferences dynamics*	It features those methods that consider the variations in the time of the customers' preferences and tastes.	Customer preferences vary in time and it is important to consider their dynamics in a right market at a right time.
8	*Reliability of the approach*	Level at which the presented contributions have been verified or validated through practical applications in differentiated industrial fields.	It is desirable to employ reliable and tested methods that can be beneficially exploited in a large range of industrial contexts.
9	*Support in selecting the most beneficial product idea*	It considers the capability of selecting the most beneficial product idea that should be developed by the company.	It is fundamental to support the last decision-making phase of the Product Planning, because it evaluates which product idea has the greatest chances to be turned into a potential market success.
10	*Independence from inputs subjectivity*	It refers to the limited employment of personal judgments or uncertain inputs, which can alter the final results of the Product Planning.	Such feature influences to a considerable extent the robustness and repeatability of the method or tool.

Table 2 description of the properties through which to compare Product Planning methods

4.1.2 Classification of the collected methods in terms of the emerged properties

With the aim of classifying the collected methods according to the above properties, the authors used the information provided by the scholars and/or further indications achievable from the literature. Table 3 shows the comparison among the reference methods and tools, listed according to the order they appear in Table 1, besides indicating their reference to responsive, proactive and hybrid approaches. The assigned name of the properties are not reported, but the numeration of Table 2 is exploited. A trivial dichotomous system (i.e. yes/no) is insufficient to describe all the methods according to each property, because, in some circumstances, the surveyed contributions fulfil certain requirements just partially. The superscripts in the cells of Table 3 clarify the cases in which the association of the properties to the methods is not straightforward and add further details; they have to be read as follows:

1) the information has been extrapolated, by considering potentially time-consuming activities such as the collection of customer/stakeholders interviews and the elaboration of the extracted data;
2) the instrument is not readily usable if historic information is not available; using it from the beginning requires customer interviews conducted in different years;
3) creative sessions using these tools can have very different durations;
4) the method requires potentially long-lasting iteration cycles due to multiple interactions between the company and its customer;
5) elucidated attractive customer requirements can be considered as uncovered latent needs;
6) lead users are expected to individuate latent needs also with respect to other customers' wants;
7) the number of practical case studies reported in the literature cannot be considered sufficient to infer a significant reliability of the methods across various industrial domains; some methods suffer from a development pattern performed outside of the industrial environment and subsequent adaptations to face companies' challenges;
8) subjective inputs are required, but the use of statistical instruments allows to estimate which evaluations can be considered sufficiently reliable.

		Property # (from Table 2)									
Kind of approach	**Methodology**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Responsive	DSS for Customer Satisfaction Assessment	Yes	No	No	Yes	No	Yes	No	Partially[7]	Yes	Partially[8]
	SW for Marketing Surveys Analysis	Yes	No	No[1]	Yes	No	Yes	Yes	Partially[7]	Yes	Partially[8]
	DSS based on Experts and Customer Surveys	Yes	No	No	Yes	No	No	Yes	Partially[7]	Yes	Partially[8]
	Marketing Survey with Persona Model	Yes	Yes	No[1]	Yes	No	No	No	Partially[7]	Yes	Partially[8]
	Kano Model (classic)	Yes	No	No[1]	No	Yes[5]	No	No	Partially[7]	Yes	Partially[8]
	Kano Model Evolution	Yes	No	No[2]	No	Yes[5]	No	Yes	Partially[7]	Yes	Partially[8]
Proactive	Scenario model	Yes	No	Partially[3]	No	Yes	No	No	Partially[7]	Yes	No
	Blue Ocean Strategy	Yes	No	Partially[3]	No	Yes	Yes	No	Partially[7]	No	No
	Lateral thinking	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	No
	Value Assessment Metric	Yes	No	Yes	No	Yes	Yes	No	Partially[7]	Yes	No
Hybrid	Brainstorming	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
	Lead Users Method	Yes	Yes	Yes	No	Yes[6]	No	No	No	No	No

	Selection from New Product Ideas Database	No	Yes	No[1]	Yes	Yes	Yes	No	No	Yes	No
	Kansei Engineering	Yes	Yes	No	Yes	Yes	No	No	Partially[7]	Yes	Partially[8]
	System for product conceptualization and customer surveys	Yes	No	No	No	No	No	Yes	Partially[7]	Yes	Partially[8]
	Customer value model for service design	Yes	No	No[1]	No	Yes	No	No	Partially[7]	Yes	Partially[8]
	Virtual Customer Integration	Yes	Yes	No[4]	Yes	Yes	No	Yes	Partially[7]	Yes	Partially[8]

Table 3 comparison of the collected methods according to the distinguishing properties of Product Planning tools. Superscripts refer to the explanations of the assigned judgments

4.1.3 General discussion about diffused strengths and weaknesses of Product Planning methods and approaches

Table 3 shows that a large majority of the collected methods starts focusing on products attributes. In each case, most of the hybrid methods have the capability to take into account both the validity/feasibility of general product ideas and the role played by product attributes. It might be inferred that such a kind of methods, which involve the customer in various stages of the Product Planning, own a higher level of versatility for the designer.

As a whole, hybrid methods best support also the individuation of latent needs, but do not integrate the analysis of the competitors diffusely. It has to be underlined that, when this kind of investigation is made, it is commonly not aimed at providing a clearer picture of the competitiveness in the industry, but it basically provides inputs and factors needed for exploiting the methods themselves.

A recurring lack of the surveyed methodologies for the Product Planning is the absence of a quick and easy way to implement and use them. Such a matter can potentially hinder, in industrial contexts, the diffusion of reliable techniques developed in academia. The disregard of intuitiveness particularly affects responsive and hybrid methods, since they require individuating new needs to fulfil and performing customer surveys.

Overall, the most diffused weaknesses of the collected methods concern the subjectivity of the inputs, the scarce reliability and the absence of a dedicated analysis aimed at considering the rapid changes in users' preferences. The first problem is connected with the widespread use of experts' judgments as a main driver to define and assess new product ideas. The methods that exploit statistical analyses are less affected by this problem, because they analyse a wide sample of data and provide therefore a more general view of the opinions expressed by experts and decision makers. However, they imply the commitment of a large amount of time and resources in order to obtain a reliable sample of data. The scarce reliability of the collected methods is mainly due to the focus on specific application fields and to the limited quantity of industrial case studies shown so far. On the one hand, it is worth noting that the development of some of them has not started with the objective of directly supporting industrial tasks, but they rather aim at fostering people's creativity regardless the final scope of idea stimulation. On the other hand, significant enhancements are expected for the examined methods, especially because most of them lie in the early development stage and own an algorithmic structure that might be implemented in computer-aided tools. Hence, in order to achieve more consistent feedback, the most recent methods are worth testing further.

Finally, the selection of the most beneficial product idea is included in the majority of the surveyed methods, although they mostly support generation activities.

4.2 Investigating the diffusion of Product Planning methods

The diffusion of Product Planning methods has been investigated through the analysis of the courses offered by some of the top technical universities worldwide. Indeed, universities represent the bridge between academic research and industry. The observation of offered courses can highlight whether and how Product Planning approaches and methods are taught to future practitioners.

The authors considered the top thirty technical universities ranked by topuniversities.com (last access on January 30th, 2015) based on the combination of different indexes, such as reputation, capability to attract students and professors from abroad, scientific productivity.

The study has analysed universities' websites by focusing on master degree, graduate studies and PhD courses concerning engineering, marketing and innovation management. In particular, the authors selected all the subjects that relate to Product Planning, such as product and service development/management, engineering design, innovation/technology management, marketing/consumer behaviour, creativity and innovation, entrepreneurship, business strategies. Available syllabi and/or descriptions of identified courses have been collected and analysed.

Two universities (i.e Tsinghua University and Shanghai Jiao Tong University) could not be considered, because no information of offered courses was shown in English on their websites at the time of the survey.

The survey allowed to identify about 302 pertinent courses, among which 294 included syllabi or detailed descriptions of the contents. Table 4 shows the main obtained results, by indicating the quantity of courses and Institutes that fulfil the conditions reported in the left column. According to these data, about one-third of collected courses are quite irrelevant with respect to the contents of the paper. Another third (roughly) highlights the importance of the treated topics, but no specific method or approach to support Product Planning is reported in the courses' syllabi and/or descriptions. Eventually, the residual of the courses highlights the importance of paper's contents and include the description of one or more methods or approaches listed in Table 1.

In this last group:

- 47 courses, taught in 19 different universities, concern generic responsive approaches based on the so-called Voice of the Customer (VoC);
- 18 courses, taught in 13 universities, include one or more hybrid approaches;
- 8 courses, taught in 8 universities, show one or more proactive methods.

4 universities (out of the 28 for which information is available) do not include any course with at least one proactive, responsive or hybrid approach; however, they offer at least one course remarking the importance of the topics treated in the present paper.

Eventually, focusing on specific methods, Brainstorming results the most diffused one (9 courses in 7 universities), followed by scenario-based techniques (5 courses in 5 universities), Lead user method (5 courses in 4 universities). Further identified techniques concern only one or two courses/universities as illustrated in Table 4.

The extracted data show that a very limited number of lectures held in technical institutes concerns the description of strategies to generate and select new product ideas. Nevertheless, at the same time, the topic of the paper is outlined in the majority of the reference universities. This allows to conclude that most of trained engineers and technicians are aware of the challenges posed by Product Planning, but lack notions about the methods to perform it, their underlying theory and the practical effects they can bring.

	Number of courses	
Identified courses	302	
Analysed courses with available syllabus/course descriptions	294	
Courses whose contents are irrelevant in light of the topic of the paper	103	
Courses that highlight the importance of treated topics, but no method or approach to support Product Planning is reported in the syllabus and/or description	119	
		Number of universities
Courses that include generic responsive approaches	47	19
Courses that include at least one proactive approach	8	8
Courses that include at least one hybrid approach	18	13
Courses that present Brainstorming	9	7
Courses that present scenario-based techniques	5	5
Courses that present the Lead user method	5	4
Courses that present BOS	2	2
Courses that present Lateral Thinking	1	1
Courses that present Kansei Engineering	1	1
Universities in which no responsive, proactive or hybrid method is included in the academic programs, even if they offer at least one course that shows the importance of the topics treated in the present paper	-	4

Table 4 main results of the survey that analyses the courses of top 30 technical universities worldwide

4.3 Congruence of the benefits claimed by Product Planning methods with respect to industrial needs: an exploratory study on a sample of enterprises

In order to approach the investigation of Product Planning in the industrial domain, the authors performed an in-depth analysis of six companies characterized by well-established NPD processes. The quantity of involved firms is clearly insufficient to draw statistically significant conclusions about the difficulties encountered by organizations during Product Planning. Nor can the sample be considered representative of the variety of enterprises that can potentially benefit of methods and tools for Product Planning. However, three main reasons motivate the choice of accurately analysing few companies, rather than obtaining basic information from a greater number of firms (e.g. through on-line questionnaires):

- a detailed (and consequently time consuming) analysis of a focus group of enterprises can provide more valuable results if compared with quick questionnaires administered to a large sample of industrial subjects, as inferable from the discussion about investigation methods included in (Ulrich and Eppinger 2011);
- companies often highlight their strengths and hide their weaknesses (Bell, 2008), therefore the use of questionnaires without interacting with the firms and/or observing how they act can provide unreliable results;
- the relationship of trust with the selected firms, due to frequent partnership with authors' research teams, is supposed to provide a good understanding about their point of view with respect to Product Planning, as well as the actual strengths and weaknesses of their strategies. The authors have not included in the investigation other industrial partners, because of their lack of autonomy in undertaking decisions concerning the FFE, minor degree of mutual trust, supposed hurdles in sharing the intended concept of Product Planning due to fully unstructured and rather haphazard design processes. The lower reliability of the outcomes provided by other companies, although available to participate in the survey, could potentially lead to misleading conclusions.

Despite the limited number of analysed companies, the sample is characterized by great variety (see Table 5) in terms of:

- industrial sectors: from traditional mechanics to electronic products and ICT;
- the reference market: from mass market products to niches;
- the size of the firms: from few tens of employees (companies 1,2, 3 and 5 are SMEs) up to branches of multinational corporations (firms 4 and 6);
- the turnover: from few to thousands of Mio. Euros.

Besides, all the involved enterprises have developed large market networks that allow them to sell their products worldwide; as a result, they have matured a wide vision about threats and opportunities in their industrial sector. With respect to the recalled variety and the entrepreneurial capabilities of the involved industrial subjects, the survey can disclose a first set of not negligible shared needs concerning Product Planning practices.

	Industrial field	**Turnover (about)**	**European classification according to the number of employees (Small Enterprise: <50 employees; Medium Enterprise: <250 employees; Large Enterprise: >250 employees)**	**Business strategy (B2B = business to business; B2C = business to customer)**
Company 1	Electronic systems	3 Mio. €	Small Enterprise	B2B
Company 2	ICT	3 Mio. €	Medium Enterprise	B2B
Company 3	Audio systems	30 Mio. €	Medium Enterprise	B2B/B2C
Company 4	System providers for food and energy processes	5000 Mio. €	Large Enterprise	B2B
Company 5	Glass System Technology	5 Mio. €	Small Enterprise	B2B/B2C

Company 6	Powered appliances for kitchen, cleaning and outdoor use	15000 Mio. €	Large Enterprise	B2C

Table 5 main features of investigated companies

The survey has been conducted starting with an interview driven by several open questions (Appendix 4), to which respondents were invited to answer by adding digressions and examples. Additionally, at least one of the authors attended some Product Planning activities. The first task allowed to understand companies' strategies and their basic needs. The second activity examined in-depth actual demands.

With respect to the information that originates from the industrial investigation, the residual of the paper does not make reference to its extrapolation from questionnaires or direct observations of the authors.

4.3.1 Brief description of surveyed companies' Product Planning approaches

In company 1, the Product Planning phase is entrusted to a multidisciplinary innovation team that analyses customer needs (collected through social networks, Internet portals, industry trade fairs and professional associations) and new emerging technologies, in order to identify new opportunities. The most promising product idea is selected according to team's experience and company available resources (assets and know-how). Eventually, the company drafts a business model, which summarizes the new idea, the required technologies and includes a market analysis.

Unlike the previous firm, company 2 involves all the employees in Product Planning phase. The idea generation task is stimulated through collective thinking sessions, company internal contests and thematic workshops. Identified ideas are then tested and improved through virtual interaction tools (Internet platforms) that allow to gain valuable feedback from potential customers. Eventually, the selected idea is structured through the *business model canvas* (Osterwalder and Pigneur 2010) that summarizes the new offer, required resources and potential customers.

In company 3, Product Planning is exclusively entrusted to the technical department. Engineers identify the main opportunities through the analysis of the VoC and try to satisfy emerging requirements through the implementation of the desired features into new products.

Company 4 is a large enterprise with several divisions in Europe and it organizes internal innovation contests in order to collect new product ideas from all local groups and select the most promising ones. Innovation teams use a technology-push strategy, primarily based on patent analysis, in order to support the idea generation phase. In addition, they perform benchmarking analyses and study customer preferences dynamics with the aim of supervising competitors' offers and trying to anticipate future consumers' needs. The central European board of managers selects the best ideas according to the expected development costs and efficiency of new products.

In company 5, some engineers identify new product ideas through industry trade fairs, web searches and primarily from the VoC (customers, suppliers and contractors). In addition, they carry out extensive analyses of competitors and patents, in order to deepen the knowledge of the reference industry. In a second instance, idea selection is mainly entrusted to the CEO and it is based on expected revenues.

Eventually, company 6 manages the Product Planning phase with a market-driven Stage-Gate approach (Cooper 1990). Idea generation is entrusted to market analysts that study customer behaviour and trends of preferences. In addition, marketing experts benchmark competitors' products, by monitoring sales, features and performances. Hence, the identified opportunities are compared with competitors' deliverables in order to select a subgroup of promising innovative ideas. Eventually, the company develops prototypes and tests them with a sample of potential customers. If a product obtains positive feedback, its development will be further carried out.

The strategies implemented by the analysed firms are summarized in Table 6, which remarks the followed kind of Product Planning approach, according to the involvement of customers in the process.

Company	Product Planning strategy	Kind of approach
Company 1	General approach based on the VoC	Responsive
Company 2	Virtual interaction	Hybrid
Company 3	General approach based on the VoC	Responsive
Company 4	Scenario technique	Proactive
Company 5	General approach based on the VoC	Responsive
Company 6	Scenario technique and selection approach similar to Kansei	Hybrid

Table 6 approaches used by analysed companies

4.3.2 Main results of companies' survey

Table 7 summarizes the main outputs of companies' survey in terms of the most pressing exigencies related to Product Planning activities, as they emerged in at least half of the surveyed firms. The authors qualitatively considered that the needs expressed by this fraction of the sample do not arise randomly, but they are somehow relevant for a not negligible portion of industrial contexts. In order to stress the relevance of these kinds of demands within product innovation activities, the last column of the table reports illustrative literature sources that agree upon the need of considering these aspects in industry as a result of insightful investigations or meaningful experiences. Other needs represent peculiar features of the Product Planning (as indicated in italics). Hence, such methods' requirements cannot be documented in other sources in view of the lack of specific analyses of this design phase (at least in authors' knowledge).

Companies' needs	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Firm 6	Sources
Quickness and easiness of the method/tool*	•	•	•	•	•		Chai and Xi (2006), Thia (2005)
Effective support in the individuation of latent needs*	•	•				•	Yeh et al. (2010)
Competitors' analysis*	•	•		•	•	•	Chai and Xi (2006)
Independence from inputs subjectivity*	•	•		•		•	Evanschitzky et al. (2012)
Consideration of customer preferences dynamics*	•	•		•		•	*Peculiar of Product Planning*

Reliability of the approach*			•	•	•	•	Thia (2005)
Support in selecting the most beneficial product idea*		•		•		•	Reich (2010)
Use of computer applications*	•	•		•	•		Araujo et al. (1996)
Possibility of involving customers in design activities		•	•	•	•	•	Graner (2016)
Possibility of entrusting multidisciplinary teams	•			•	•		Cooper (1999)
Possibility of schematizing the identified ideas formally	•	•			•		*Peculiar of Product Planning*

Table 7 companies' shared needs during Product Planning activities; the final column explains whether these requirements are considered relevant in other industry-oriented research contributions

The needs marked with a star in Table 7 have a strict relationship with the properties described in Table 2. Hence, it is possible to claim that the development directions of Product Planning methods identify the exigencies of industrial subjects suitably, at least according to the considered sample.

From the perspective of single firms, Table 3 allows to individuate literature techniques that can satisfy companies' expressed needs.

In addition to already defined properties, the survey elucidated three diffused demands:

- possibility of involving customers in the Product Planning activities: this need is strictly related to the possibility of minimizing the risks related to the development of new products. It can be fulfilled by all the hybrid methods, because, as seen above, they involve customers in idea generation or selection;
- possibility of entrusting the Product Planning phase to multidisciplinary teams: this demand starts with the assumption that multidisciplinary teams can provide more point of views, which supports the successful development of innovative products. Although methods' developers do not claim this aspect as a peculiar strength, several mapped tools allow to involve multidisciplinary teams. In particular, Scenario techniques, Lateral thinking, Brainstorming, service design methods developed by Chan and Ip (2011) and Chen and Yan (2008) can satisfy this demand fully;
- possibility of schematizing the identified ideas formally: this need is related to the demand of formalizing, saving and sharing generated ideas. Among the collected literature methods, BOS provides a specific tool, namely Value Curves, that allows to schematize new product ideas in terms of attributes and related performance levels that designers plan to offer.

4.3.3 Further information emerging from surveyed firms

The above comparison between industrial demands and properties of Product Planning methods highlights a good fit between research trajectories and companies' expectations. However, it can be remarked that certain relevant properties are fulfilled just partially or by a small subset of methods. The lack of industrial validation of Product Planning methods, implying their scarce reliability, can be considered as a significant weakness in the landscape of academic research on the topic. Indeed, many surveyed companies have underlined the perception of the uncertainty about efficiency and efficacy of what is developed in the academics. This implies that no analysed enterprise is aware of the specific methods that have been illustrated in Subsection 3.3. More in particular, still according to the viewpoint of involved firms, the main reasons of the unsuccessful industrial implementation of methods developed in the academics can be summarized in:

- scholars' "dogmatic" approach;
- communication problems;
- insufficient promotion of research results (several firms do not know scholars' works);
- cultural problems;
- distance from the business world and its needs;
- supposed unsuitability of the methods' outcomes in certain industrial fields.

In this sense, the above issues clearly mirror claims by López-Mesa and Bylund (2011) about the unsuitability of NPD methods. According to this vision, scholars should start promoting their works and reinforcing the links with industry. In this way, they could achieve a better understanding of firms' needs and develop more suitable tools.

Regardless of the implemented approaches, the surveyed companies have highlighted organizational constraints that imply significant repercussions in terms of new potential procedures to be adopted to support Product Planning. Another possible constraint, at least for some organizations, stands in the higher trust towards methods tailored for their specific industrial field, which are supposed to be significantly more reliable than general-purpose tools.

A further relevant aspect regards the disposition of enterprises towards the required changes of their current Product Planning approaches. Whereas many companies would not reject radical transformations a priori, a very structured firm claims the impossibility to introduce meaningful alterations of its well-established organizational structure.

5. Discussion

5.1 Considerations on the reasons behind the poor adoption of Product Planning methods

The results obtained from the performed investigations allow to draw some considerations about the impact of the research in Product Planning on industrial and educational fields.

On the one hand, the analysis of technical universities highlighted a widespread interest of scholars towards issues and problems belonging to the FFE activities of the NPD cycle and specifically related to Product Planning. However, the body of knowledge taught in regular courses considered for the survey includes specific methods to a negligible extent. Also when training about Product Planning is done, it is centred on transferring approaches generically based on the VoC. Hence, the taught approaches are quite vague and less formalized than the methods debated in scientific literature.

On the other hand, the comparison shows a good correspondence between exigencies related to Product Planning activities and the features offered by literature methods. Indeed, many needs raised by the surveyed companies might be satisfied by the considered Product Planning approaches, or at least, they mirror relevant research objectives. From this viewpoint, the present study draws a parallel with the outputs of the research conducted by López-Mesa and Bylund (2011), centred on decision-making practices during the whole NPD cycle. In other words, industries' practices reflect structures and approaches of Product Planning methods to a considerable extent, despite their poor adoption and awareness. Other companies' demands do not match the claimed strengths of the methods closely; however, they can be fulfilled adequately by a significant set of tools. A strong limitation has emerged in terms of the direct usability of the surveyed methods for industrial purposes, capability of integration and implementation within the firm context and impact on the outcomes of the design process.

In this sense, a partial conclusion is that, besides being poorly promoted already at educational level, formalized Product Planning methods require a stronger orientation towards industrial environments and, first of all, a full demonstration of their operational efficacy. The limited diffusion of the treated methods is likely to reflect both scarce efforts to disseminate their underlying concepts to novel technicians and engineers and intrinsic limitations in terms of their usability.

5.2 Discussion on the research questions

The present Subsection discusses the specific research issues that have emerged in Subsection 3.2. While the presented manifold investigations have fully addressed some of these questions, others require further studies and likely different research approaches or experiments.

Whether scientific and industrial arenas acknowledge any established Product Planning practice

Both the educational field and the industrial domain show a preferential orientation towards responsive approaches or strategies that foresee a strict synergy with customers. With respect to what is discussed in Section 3.3, it is arguable establishing if these approaches are capable of leading firms towards radical product improvements, which better feature a competition oriented on innovation, rather than based on quality and customer satisfaction.

The claimed advantages deriving from the implementation of Product Planning methods

The research issue has been largely addressed in Section 4.1 by showing the most remarkable properties of Product Planning methods and then classifying the tools according to all these features (Table 3).

Pros and cons of involving customers and product stakeholders during the FFE

The difference between proactive and responsive approaches has been already treated in several literature sources. The lack of industrial experiments cannot properly address the debated questions about the suitability of responsive methods to produce fundamental product enhancements and the reliability of proactive strategies. A new group of methods, the hybrid approaches introduced by the authors in the present paper for the sake of convenience, represents a sort of trade-off between responsive and proactive techniques. However, strengths and weaknesses are likewise combined.

The effective benefits of diffusing and implementing Product Planning models in industry

Subsection 5.1 has widely pointed out the poor diffusion of formalized Product Planning paradigms in industry, thus confirming the findings of a large number of studies aimed at elucidating the real impact of NPD and engineering design methods on the business world. The present investigation points out an insufficient transfer of Product Planning methods at the educational level, an incomplete demonstration of their utility, diffused scepticism in industrial environments with regards to academics' work (at least with reference to the topics treated in the paper). These issues are deemed to represent a subset of the reasons behind the limited implementation of said methods. Besides, the scarce information about industrial experiences does not allow to demonstrate whether the claimed benefits of Product Planning methods are verified in practice. Nevertheless, the outcomes of future adoptions are promising if we take into account the fit between the industrial demands exposed by a small set of companies and the advantages Product Planning methods claim to achieve.

Whether rigorous proposals have been advanced to identify successful new product characteristics regardless the followed NPD process.

Acknowledged contributions have not arisen. Conversely, firms tend to adopt strategies that involve customers, whose judgments are seen as a fundamental driver to tackle decisions throughout NPD processes. Three different hypotheses emerge that would require further studies. First: firms are structurally permeated by a customer-focused culture and cannot figure out strategies that do not rely on consumers to a considerable extent. In this sense, the goodness of product features just depends on customers' evaluations. Second: companies' expectations about Product Planning basically lie in enhancing the management of NPD initiatives. It is worth noting that many emerged demands, also beyond the properties of the Product Planning methods, regard the management of intrinsically responsive approaches and the way of organizing innovation processes. While the awareness of Product Planning techniques is very poor, some formal management frameworks (e.g. *business model canvas*) are implemented also within the small set of investigated firms. Third: proactive product-oriented strategies are so poorly reliable that, in each case, it is preferable to trust customers and/or consultants. The limited documentation available from the literature could somehow disguise a certain awareness of industrial subjects with respect to this kind of strategies.

5.3 Limitations of the performed investigation about Product Planning

The evidences presented in this paper originate from considerations extracted from the literature (and authors' interpretation of identified contributions), the syllabi of academic courses, the examination of a small sample of enterprises. Information arising from these sources can be biased by the partiality of these investigations. In particular:

- authors could have omitted relevant literature contributions or overlooked some of the methods' distinguishing features;
- the courses held in the most prestigious technical universities, chosen as a sample of convenience, could be poorly representative of the NPD-related contents taught in universities worldwide;
- the quantity of investigated firms is surely limited and their belonging to a specific geographical area could affect the reliability of the outcomes. In this sense, the investigation in the industrial field suffers from one of the limitations identified by Graner and Mißler-Behr (2012) with respect to studies about NPD methods. The authors have already clarified (Section 2 and Subsection 4.3) the reasons behind preferring to analyse few companies in-depth rather than obtaining less focused outcomes from a richer group of organizations. However, in order to temper the described biases, just demands emerging from a significant share of companies have been considered for the subsequent analysis and discussion.

In this sense, we encourage any reader to extend the present research on Product Planning strategies, by expanding the domain of the investigation, so to confirm or put into discussion the inferred conclusions.

6. Conclusions

With the aim of assessing the suitability of academic contributions for innovation in industry, the present paper builds upon previous literature findings about the adoption of developed NPD formal methods. Such an issue is tackled by investigating a relevant stage of engineering design tasks, i.e. Product Planning, instead of the whole NPD cycle and by introducing an original approach based on the popularity of methods' claimed benefits, rather than considering methods themselves. These choices have been made with reference to individuated lacks of previous literature sources, as remarked in Section 1. The authors have focused on methods' strategies to innovate firms' deliverables, rather than successful managerial practices that greatly affect the FFE, by considering the latter largely debated in specialized literature. However, firms' aptitude to consider aspects peculiar to NPD processes has raised issues that partially overlap with the research field investigating success factors in Product Planning management, e.g. Cooper (1999). In particular, the relevance attributed to and the reliability of customers' indications for the scope of innovating products is a focal point of the present study.

Not surprisingly, in order to characterize the Product Planning methods from which claimed advantages have been extracted, the authors have classified them into three broad categories according to the role played by customers. This categorization can help companies to identify the most suitable techniques according to the planned involvement of their consumers or other stakeholders. The study has attempted to put into relationship the trajectories of research into the early stages of NPD cycles, the benefits and limitations of existing approaches, the effort paid by technical universities in diffusing the fundamental concepts of Product Planning, the perceived needs of industrial subjects. The latter was deemed necessary because of the mare magnum of NPD success factors claimed by numerous literature sources, besides poorly focusing on early design stages. This allowed to lay bare peculiar aspects of Product Planning which had not emerged through studies on methods concerning the whole NPD cycles.

Overall, the main findings of the present work can be summarized as follows:

- Product Planning methods can be characterized with respect to a set of remarkable properties, which appear to range among the most meaningful factors that determine the adoption of these tools;
- the main problems affecting the diffusion of Product Planning methods are supposed to stand in a limited role played by the University world as a catalyst to enlarge the knowledge about their benefits and the low number of applications demonstrating their efficacy in industry;
- industrial subjects tend to implement responsive approaches, despite their argued performances in supporting the generation of disruptive innovations. The reasons behind this emergence require additional research efforts.

As highlighted in Subsection 5.3, these results require an ultimate demonstration by broadening the field of the investigation. Despite this limitation, the authors are currently evaluating the presented outcomes in order to develop original Product Planning frameworks, intended to overcome the weaknesses of existing methods and specifically tailored to ensure industrial usability and usefulness.

References

Achiche S, Appio FP, McAloone TC, Di Minin A (2013) Fuzzy decision support for tools selection in the core front end activities of new product development. Res Eng Des 24(1):1-18. doi: 10.1007/s00163-012-0130-4

Adams ME, Day GS, Dougherty D (1998) Enhancing new product development performance: an organizational learning perspective. J Prod Innovat Manag 15(5):403-422. doi: 10.1111/1540-5885.1550403

Agouridas V, McKay A, Winand H, de Pennington A (2008) Advanced product planning: a comprehensive process for systemic definition of new product requirements. Requir Eng 13(1):19-48. doi: 10.1007/s00766-007-0055-z

Akao Y (2004) Quality function deployment: integrating customer requirements into product design. Productivity Press, New York

Alam I (2006) Removing the fuzziness from the fuzzy front-end of service innovations through customer interactions. Ind Market Manag 35(4):468-480. doi: 10.1016/j.indmarman.2005.04.004

Al-Hakim L, Kusiak A, Mathew J (2000) A graph-theoretic approach to conceptual design with functional perspectives. Comput Aided Design, 32(14):867-875. doi: 10.1016/S0010-4485(00)00075-0

Araujo CS, Benedetto-Neto H, Campello AC, Segre FM, Wright IC (1996) The utilization of product development methods: a survey of UK industry. J Eng Design 7(3):265-277. doi:10.1080/09544829608907940

Atuahene-Gima K, Slater SF, Olson EM (2005) The contingent value of responsive and proactive market orientations for new product program performance. J Prod Innovat Manag 22(6):464-482. doi: 10.1111/j.1540-5885.2005.00144.x

Ayers D, Dahlstrom R, Skinner SJ (1997) An exploratory investigation of organizational antecedents to new product success. J Marketing Res 34(1):107-116. doi: 10.2307/3152068

Balachandra R, Friar JH (1997) Factors for success in R&D projects and new product innovation: a contextual framework. IEEE Trans Eng Manag 44(3):276-287. doi: 10.1109/17.618169

Barczak G, Griffin A, Kahn KB (2009) Perspective: trends and drivers of success in NPD practices: results of the 2003 PDMA best practices study. J Prod Innovat Manag 26(1):3-23. doi: 10.1111/j.1540-5885.2009.00331.x

Battistella C, Biotto G, De Toni AF (2012) From design driven innovation to meaning strategy. Manag Dec 50(4):718-743. doi: 10.1108/00251741211220390

Bell S. (2008) International Brand Management of Chinese Companies: Case Studies on the Chinese Household Appliances and Consumer Electronics Industry Entering US and Western European Markets. Springer, Heidelberg

Blessing L, Seering W (2016) Preparing for the Transfer of Research Results to Practice: Best Practice Heuristics. In: Chakrabarti A, Lindemann U (eds) Impact of Design Research on Industrial Practice, Springer International Publishing Switzerland, Cham, pp. 3-21

Borgianni Y, Cascini G, Pucillo F, Rotini F (2013) Supporting product design by anticipating the success chances of new value profiles. Comput Ind 64(4):421-435. doi: 10.1016/j.compind.2013.02.004

Brem A, Voigt KI (2009) Integration of market pull and technology push in the corporate front end and innovation management-Insights from the German software industry. Technovation 29(5):351-367. doi: 10.1016/j.technovation.2008.06.003

Büyüközkan G, Feyzioğlu O (2004) A new approach based on soft computing to accelerate the selection of new product ideas. Comput Ind 54(2):151-167. doi: 10.1016/j.compind.2003.09.007

Cagan J, Vogel CM (2001) Creating Breakthrough Products: Innovation from Product Planning to Program Approval. Prentice Hall, Upper Saddle River

Cantamessa M (2003) An empirical perspective upon design research. J Eng Design 14(1):1-15. doi:10.1080/0954482031000078126

Cascini G (2012) TRIZ-based anticipatory design of future products and processes. J Integr Des Process Sci 16(3):29-63. doi: 10.3233/jid-2012-0005

Chai KH, Xin Y (2006) The application of new product development tools in industry: the case of Singapore. IEEE Trans Eng Manag 53(4):543-554. doi:10.1109/TEM.2006.883708

Chan SL, Ip WH (2011) A dynamic decision support system to predict the value of customer for new product development. Decis Support Syst 52(1):178-188. doi: 10.1016/j.dss.2011.07.002

Chen CH, Yan W (2008) An in-process customer utility prediction system for product conceptualisation. Expert Syst Appl 34(4):2555-2567. doi: 10.1016/j.eswa.2007.04.019

Chidamber SR, Kon HB (1994) A research retrospective of innovation inception and success: the technology-push, demand-pull question. Int J Technol Manage 9(1):94-112.

Cooper RG (1990) Stage-gate systems: a new tool for managing new products. Bus Horizons 33(3):44-54. doi:10.1016/0007-6813(90)90040-i

Cooper RG (1999) The invisible success factors in product innovation. J Prod Innovat Manag 16(2):115-133. doi: 10.1111/1540-5885.1620115

Cooper RG (2011) Winning at new products, 4th edition. Basic Books, New York

Cousineau M, Lauer TW, Peacock E (2004) Supplier source integration in a large manufacturing company. Supply Chain Manag 9(1):110-117. doi: 10.1108/13598540410517629

Dahl DW, Moreau P (2002) The influence and value of analogical thinking during new product ideation. J Marketing Res 39(1):47-60. doi: 10.1509/jmkr.39.1.47.18930

De Bono E (2010) Lateral thinking: Creativity step by step. HarperCollins, New York

Di Stefano G, Gambardella A, Verona G (2012) Technology push and demand pull perspectives in innovation studies: current findings and future research directions. Res Policy 41(8):1283-1295. doi: 10.1016/j.respol.2012.03.021

Drumwright ME (1996) Company advertising with a social dimension: the role of noneconomic criteria. J Marketing 60(4):71-87. doi: 10.2307/1251902

Eckert C, Bertoluci G, Yannou B (2014) Handling subjective product properties in engineering, food and fashion. 13th International Design Conference, DESIGN 2014, Dubrovnik, Croatia, 19-22 May 2014

Ernst H (2002) Success factors of new product development: a review of the empirical literature. Int J Manag Rev 4(1):1-40. doi: 10.1111/1468-2370.00075

Evanschitzky H, Eisend M, Calantone RJ, Jiang Y (2012) Success factors of product innovation: An updated meta-analysis. J Prod Innovat Manag, 29(S1):21-37. doi:10.1111/j.1540-5885.2012.00964.x

Feldman LP, Page AL (1984) Principles vs. practice in new product planning. J Prod Innovat Manag 1(1):43-55. doi: 10.1016/S0737-6782(84)80042-9

Flint DJ (2002) Compressing new product success-to-success cycle time: deep customer value understanding and idea generation. Ind Market Manag 31(4):305-315. doi: 10.1016/S0019-8501(01)00165-1

Fombrun CJ (1996) Reputation: Realizing value from the corporate image. Harvard Business Press, Boston

Füller J, Matzler K (2007) Virtual product experience and customer participation-A chance for customer-centred, really new products. Technovation 27(6):378-387. doi: 10.1016/j.technovation.2006.09.005

García N, Sanzo MJ, Trespalacios JA (2008) New product internal performance and market performance: evidence from Spanish firms regarding the role of trust, interfunctional integration, and innovation type. Technovation 28(11):713-725. doi: 10.1016/j.technovation.2008.01.001

Gausemeier J, Brink V, Ihmels S, Kokoschka M, Reymann F (2009) Strategic product- and technology-planning with the innovation-database: a field-proven approach from the marketoriented product idea up to an operational development roadmap. IEEE International Conference on Industrial Technology, ICIT 2009, Gippsland, Australia, 10-13 February 2009, pp 1-6

Graner M (2016) Are Methods the Key to Product Development Success? An Empirical Analysis of Method Application in New Product Development. In: Chakrabarti A, Lindemann U (eds) Impact of Design Research on Industrial Practice, Springer International Publishing Switzerland, Cham, pp. 23-43

Graner M, Mißler-Behr M (2012) The use of methods in new product development–a review of empirical literature. Int J Prod Dev 16(2):158-184. doi:10.1504/IJPD.2012.049063

Grewal D, Krishnan R, Levy M, Munger J (2010) Retail success and key drivers. In: Krafft M, Mantrala, MK (eds) Retailing in the 21st Century. Springer Berlin Heidelberg, Berlin, pp 15-30

Guo W (2012) A research on fuzzy front end of npd in Chinese equipment manufacturing firms: A theoretical model. IEEE Control and Decision Conference, CCDC 2012, Taiyuan, China, 23-25 May 2012, pp 493-497

Gupta AK, Raj SP, Wilemon D (1986) A model for studying R&D. Marketing interface in the product innovation process. J Marketing 50(2):7-17

Haig M (2011) Brand Failures. Kogan Page, London

Henard DH, Szymanski DM (2001) Why some new products are more successful than others. J Marketing Res 38(3):362-375. doi: 10.1509/jmkr.38.3.362.18861

Hicks B (2016) Patterns and Paths for Realising Design-Led Impact: A Study of UK REF Cases Studies. In: Chakrabarti A, Lindemann U (eds) Impact of Design Research on Industrial Practice, Springer International Publishing Switzerland, Cham, pp. 45-65

Hüsig S, Kohn S (2009) Computer aided innovation-State of the art from a new product development perspective. Comput Ind 60(8):551-562. doi: 10.1016/j.compind.2009.05.011

Jetter AJ, Sperry RC (2013) Fuzzy cognitive maps for product planning: using stakeholder knowledge to achieve corporate responsibility. IEEE Hawaii International Conference on System Sciences, HICSS 2013, Wailea, Hawaii, 7-10 January 2013, pp 925-934

Johne FA, Snelson PA (1988) Success factors in product innovation: a selective review of the literature. J Prod Innovat Manag 5(2):114-128. doi: 10.1111/1540-5885.520114

Kahn KB (2011) Product Planning Essentials. M.E. Sharpe, New York

Kano N (1995) Upsizing the organization by attractive quality creation. In: Kanji GK (ed) Total Quality Management. Springer Netherlands, Dordrecht, pp 60-72

Kano N, Seraku N, Takahashi F, Tsuji S (1984) Attractive quality and must-be quality. J Jpn Soc Qual Control 14(2):39-48.

Kim J, Wilemon D (2002) Focusing the fuzzy front–end in new product development. R&D Manage 32(4):269-279. doi: 10.1111/1467-9310.00259

Kim WC, Mauborgne R (2005) Blue Ocean Strategy. Harvard Business School Press, Cambridge

Kimita K, Shimomura Y, Arai T (2009) A customer value model for sustainable service design. CIRP J Manuf Sci Technol 1(4):254-261. doi: 10.1016/j.cirpj.2009.06.003

Koen P, Ajamian G, Burkart R, Clamen A, Davidson J, D'Amore R, Elkins C, Herald K, Incorvia M, Johnson A, Karol R, Seibert R, Slavejkov A, Wagner K (2001) Providing clarity and a common language to the" fuzzy front end". Res Technol Manage 44(2):46-55.

Koen PA, Ajamian G, Boyce S, Clamen A, Fisher E, Fountoulakis S, Johnson A, Puri P, Seibert R (2002) Fuzzy Front End: Effective Methods, Tools and Techniques. Wiley and Sons, New York

Kotler P (2007) Marketing Management, 12th edition. Prentice Hall, Englewood Cliffs

Krishnan V, Ulrich KT (2001) Product development decisions: a review of the literature. Manage Sci 47(1):1-21. doi: 10.1287/mnsc.47.1.1.10668

Lee AH, Kang HY, Yang CY, Lin CY (2010) An evaluation framework for product planning using FANP, QFD and multi-choice goal programming. Int J Prod Res 48(13):3977-3997. doi:10.1080/00207540902950845

Lee CW, Suh Y, Kim IK, Park JH, Yun MH (2010) A systematic framework for evaluating design concepts of a new product. Hum Factors Ergon Manuf 20(5):424-442. doi: 10.1002/hfm.20193

Leenders MA, Wierenga B (2002) The effectiveness of different mechanisms for integrating marketing and R&D. J Prod Innovat Manag 19(4):305-317. doi: 10.1111/1540-5885.1940305

Leinsdorff T (1995) Buying behavior and product planning. Int J Prod Econ 41(1):237-239. doi: 10.1016/0925-5273(95)00068-2

Li Y, Wang J, Li X, Zhao W (2007) Design creativity in product innovation. Int J Adv Manuf Tech 33(3-4):213-222. doi: 10.1007/s00170-006-0457-y

Li YL, Tang JF, Chin KS, Luo XG, Pu Y, Jiang YS (2012) On integrating multiple type preferences into competitive analyses of customer requirements in product planning. Int J Prod Econ 139(1):168-179. doi: 10.1016/j.ijpe.2012.03.031

Liao SH, Hsieh CL, Huang SP (2008) Mining product maps for new product development. Expert Syst Appl 34(1):50-62. doi: 10.1016/j.eswa.2006.08.027

Liberatore MJ, Stylianou AC (1995) Toward a framework for developing knowledge-based decision support systems for customer satisfaction assessment: An application in new product development. Expert Syst Appl 8(1):213-228. doi: 10.1016/0957-4174(94)E0011-I

Llinares C, Page AF (2011) Kano's model in Kansei Engineering to evaluate subjective real estate consumer preferences. Int J Ind Ergonom 41(3):233-246. doi: 10.1016/j.ergon.2011.01.011

López-Mesa B, Bylund N (2011) A study of the use of concept selection methods from inside a company. Res Eng Des 22(1):7-27. doi:10.1007/s00163-010-0093-2

Matsatsinis NF, Siskos Y (1999) MARKEX: An intelligent decision support system for product development decisions. Eur J Oper Res 113(2):336-354. doi: 10.1016/S0377-2217(98)00220-3

Maurer C, Widmann J (2012) Conceptual Design Theory in Education Versus Practice in Industry: A Comparison Between Germany and the United States. ASME 2012 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Chicago, Illinois, 12-15 August 2012, pp. 277-283. doi:10.1115/DETC2012-70079

McAdam R, McClelland J (2002) Individual and team-based idea generation within innovation management: organisational and research agendas. Eur J Innovat Manag 5(2):86-97. doi: 10.1108/14601060210428186

Mishra S, Kim D, Lee DH (1996) Factors affecting new product success: cross-country comparisons. J Prod Innovat Manag 13(6):530-550. doi: 10.1111/1540-5885.1360530

Montagna F (2011) Decision-aiding tools in innovative product development contexts. Res Eng Des 22(2):63-86. doi: 10.1007/s00163-011-0103-z

Monteiro C, Arcoverde DF, da Silva FQ, Ferreira HS (2010) Software support for the fuzzy front end stage of the innovation process: a systematic literature review. IEEE International Conference on Management of Innovation and Technology, ICMIT 2010, Singapore, 2-5 June 2010, pp 426-431

Montoya-Weiss MM, O'Driscoll TM (2000) From experience: applying performance support technology in the fuzzy front end. J Prod Innovat Manag 17(2):143-161. doi: 10.1111/1540-5885.1720143

Nagamachi M (1995) Kansei engineering: a new ergonomic consumer-oriented technology for product development. Int J Ind Ergonom 15(1):3-11. doi: 10.1016/0169-8141(94)00052-5

Nagle TT, Holden RK (1995) The strategy and tactics of pricing. Prentice Hall, Englewood Cliffs

Narver JC, Slater SF, MacLachlan DL (2004) Responsive and Proactive Market Orientation and New-Product Success. J Prod Innovat Manag 21(5):334-347. doi: 10.1111/j.0737-6782.2004.00086.x

Nijssen EJ, Frambach RT (2000) Determinants of the adoption of new product development tools by industrial firms. Ind Market Manag 29(2):121-131. doi:10.1016/S0019-8501(98)00043-1

Nilsson-Witell L, Fundin A (2005) Dynamics of service attributes: a test of Kano's theory of attractive quality. Int J Serv Ind Manag 16(2):152-168. doi: 10.1108/09564230510592289

Osborne AF (1953) Applied Imagination. Scribner: Oxford

Osterwalder A, Pigneur Y (2010) Business model generation: a handbook for visionaries, game changers, and challengers. John Wiley & Sons: Hoboken

Page AL, Schirr GR (2008) Growth and Development of a Body of Knowledge: 16 Years of New Product Development Research, 1989–2004. J Prod Innovat Manag 25(3):233-248. doi: 10.1111/j.1540-5885.2008.00297.x

Pahl G, Beitz W, Feldhusen J, Grote KH (2007) Engineering design: a systematic approach. Springer, London

Park CW, Jaworski BJ, Maclnnis DJ (1986) Strategic brand concept-image management. J Marketing 50(4):135-145

Ramesh B, Tiwana A (1999) Supporting collaborative process knowledge management in new product development teams. Decis Support Syst 27(1):213-235. doi: 10.1016/S0167-9236(99)00045-7

Reich Y (2010) My method is better! Res Eng Des 21(3):137-142. doi:10.1007/s00163-010-0092-3

Reid SE, De Brentani U (2004) The fuzzy front end of new product development for discontinuous innovations: a theoretical model. J Prod Innovat Manag 21(3):170-184. doi: 10.1111/j.0737-6782.2004.00068.x

Riel A, Neumann M, Tichkiewitch S (2013) Structuring the early fuzzy front-end to manage ideation for new product development. CIRP Ann-Manuf Techn 62(1):107-110. doi: 10.1016/j.cirp.2013.03.128

Rietzschel EF, Nijstad BA, Stroebe W (2006) Productivity is not enough: a comparison of interactive and nominal brainstorming groups on idea generation and selection. J Exp Soc Psychol 42(2):244-251. doi: 10.1016/j.jesp.2005.04.005

Rochford L (1991) Generating and screening new products ideas. Ind Market Manag 20(4):287-296. doi: 10.1016/0019-8501(91)90003-X

Rohrbeck R, Steinhoff F, Perder F (2008) Virtual customer integration in the innovation process: evaluation of the web platforms of multinational enterprises (MNE). IEEE Portland International Conference on Management of Engineering & Technology, PICMET 2008, Cape Town, South Africa, 27-31 July 2008, pp 469-478

Rubenstein AH (1994) At the front end of the R&D/Innovation process: idea development and entrepreneurship. Int J Technol Manage 9(5-6):652-677. doi: 10.1504/IJTM.1994.025595

Schön DA (1967) Technology and change: the new Heraclitus. Delacorte Press, New York

Shinno H, Hashizume H (2002) Structured method for identifying success factors in new product development of machine tools. CIRP Ann-Manuf Techn 51(1):281-284. doi: 10.1016/S0007-8506(07)61517-0

Shinno H, Yoshioka H, Marpaung S (2006) A structured method for analysing product specification in product planning for machine tools. J Eng Design 17(4):347-356. doi:10.1080/09544820600647734

Smith PG, Reinertsen DG (1991) Developing products in half the time. Van Nostrand Reinhold, New York

Song XM, Parry ME (1996) What separates Japanese new product winners from losers. J Prod Innovat Manag 13(5):422-439. doi: 10.1111/1540-5885.1350422

Song XM, Thieme RJ, Xie J (1998) The impact of cross-functional joint involvement across product development stages: an exploratory study. J Prod Innovat Manag 15(4):289-303. doi: 10.1111/1540-5885.1540289

Soukhoroukova A, Spann M, Skiera B (2012) Sourcing, filtering, and evaluating new product ideas: an empirical exploration of the performance of idea markets. J Prod Innovat Manag 29(1):100-112. doi: 10.1111/j.1540-5885.2011.00881.x

Sowrey T (1990) Idea generation: identifying the most useful techniques. Eur J Marketing 24(5):20-29. doi: 10.1108/03090569010140228

Stasch SF, Lonsdale RT, La Venka NN (1992) Developing a framework for sources of new product ideas. J Consum Mark 9(2):5-15. doi: 10.1108/07363769210036980

Thia CW, Chai KH, Bauly J, Xin Y (2005) An exploratory study of the use of quality tools and techniques in product development. TQM Magazine, 17(5):406-424. doi:10.1108/09544780510615924

Toubia O (2006) Idea generation, creativity, and incentives. Market Sci 25(5):411-425. doi: 10.1287/mksc.1050.0166

Tripsas M (2008) Customer preference discontinuities: a trigger for radical technological change. Manage Decis Econ 29(2-3):79-97. doi: 10.1002/mde.1389

Ulrich KT, Eppinger SD (2011) Product design and development. McGraw Hill, New York

Ulwick AW (2002) Turn customer input into innovation. Harvard Bus Rev 80(1):91-97

Urban GL, Hauser JR (1993) Design and marketing of new products, 2nd edition. Prentice Hall, Englewood Cliffs

Van Kleef E, van Trijp H, Luning P (2005) Consumer research in the early stages of new product development: a critical review of methods and techniques. Food Qual Prefer 16(3):181-201. doi: 10.1016/j.foodqual.2004.05.012

Verganti R (2008) Design, Meanings, and Radical Innovation: A Metamodel and a Research Agenda. J Prod Innovat Manag 25(5):436-456. doi: 10.1111/j.1540-5885.2008.00313.x

Verma D, Fabrycky WJ (1997) Systematically identifying system engineering practices and methods. IEEE Trans Aerosp Electron Syst, 33(2):587-595. doi: 10.1109/7.588377

Von Hippel E (1986) Lead users: a source of novel product concepts. Manage Sci 32(7):791-805. doi: 10.1287/mnsc.32.7.791

Wall M, Gausemeier J, Peitz C (2013) Technology push–based product planning-future markets for emerging technologies. Int J Tech Market 8(1):61-81. doi: 10.1504/IJTMKT.2013.051965

Yang CC, Yang KJ (2011) An integrated model of value creation based on the refined Kano's model and the blue ocean strategy. Total Qual Manag Bus 22(9):925-940. doi:10.1080/14783363.2011.611358

Yeh TM, Pai FY, Yang CC (2010) Performance improvement in new product development with effective tools and techniques adoption for high-tech industries. Qual Quant 44(1):131-152. doi:10.1007/s11135-008-9186-7

Zhang Q, Doll WJ (2001) The fuzzy front end and success of new product development: a causal model. Eur J Innovat Manag 4(2):95-112. doi: 10.1108/14601060110390602

Appendix 1: facts about idea generation

The Table illustrates the literature sources discussing the characteristics, the role and the practices concerning idea generation

	Statements about idea generation					
	Idea generation plays a key role in the NPD process	Creativity stimulation holds a high relevance in idea generation	There is a strong correlation between idea generation and commercial success	Not sufficient resources are allocated by companies to perform the idea generation accurately	Companies perceive idea generation as a random process	It is important to structure the ideation activity in the NPD process
Feldman and Page 1984				•		
Sowrey 1990				•		
Rochford 1991	•					
Stasch et al. 1992					•	
Ayers et al. 1997			•			
Ernst 2002			•			
McAdam and McClelland 2002		•				
Alam 2006	•			•	•	
Pahl and Beitz 2007					•	•
Riel et al. 2013	•					•

Appendix 2: facts about idea selection

The Table shows the literature sources discussing the role and the practices regarding idea selection

	Concepts about idea selection				
	Companies lack coherent or formal process for selecting ideas	Companies have difficulties to distinguish lucrative from poorly beneficial alternatives	Long time and vast human resources are currently dedicated to fulfil idea selection (due to the great number of ideas to be assessed)	Difficulties lie in assessing radical innovative ideas (due to greater uncertainties about potential market results)	There is a strong correlation between idea selection and commercial success
Johne and Snelson 1988				•	
Mishra et al. 1996				•	
Song and Perry 1996					•
Ayers et al. 1997					•
Ernst 2002					•
Rietzschel et al. 2006		•			
Toubia 2006			•		
Barczak et al. 2009	•				
Cascini 2012			•		
Soukhoroukova et al. 2012	•		•	•	

Appendix 3: Additional Product Planning activities

The Table lists the literature sources individuating activities to carry out Product Planning, other than idea generation and selection

	Additional Product Planning activities			
	Monitoring the financial position of the company	Allocating resources and planning timing	Analyzing existing and potential new technologies	Identifying legal regulations and patents
Verma and Fabrycky 1997				•
Shinno et al. 2006	•		•	
Agouridas et al. 2008				•
Gausemeier et al. 2009	•		•	
Montagna 2011	•	•	•	
Ulrich and Eppinger 2011		•	•	

Appendix 4: Product Planning Questionnaire

Question 1
How frequently does the company define new product/service features in your firm, or do you decide to rethink the existing offered ones?

Question 2
Who manages this activity in your company?

Question 3
How do/es he/she/they manage this activity? Do/es he/she/they use any method and/or tool to identify the basic features of new products or services?

Question 4
How are the most promising ideas selected (in the case that in the previous step more than one idea have been identified)?

Question 5
Are you satisfied with your current product/service idea generation and idea selection approaches? Why?

Question 6
What are the main lacks of your approach/es according to your point of view?
What could be primarily improved?

Question 7
Do you know other methods (also implemented in software application) that can support the product/service idea generation and selection, besides the approaches that the company has adopted?
*(if the answer is **YES**) Why aren't they employed in the firm?*

Question 8:
What are the reasons, according to your point of view, of the unsuccessful transfer to the industry of product/service idea generation and selection methods developed in the academic world?