Università degli Studi di Firenze

Dipartimento di Meccanica e Tecnologie Industriali

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XXIII Ciclo

Tesi di Dottorato di Ricerca

Re-engineering of Products and Processes through a value oriented approach

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(SSD ING-IND/15)

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Abstract

During the last twenty years a multitude of methods has been developed with the aim of supporting business process reengineering activities. Most of these methods are focused on pursuing time and cost reduction policies in order to preserve the competitiveness of products and services on the market place. A deep analysis of the literature shows that such kind of business process initiatives failed in pursuing this objective, since redesign efforts should be focused not only on cost and time reduction, but also on those aspects mostly impacting the customer perceived value. Starting from the evidences of this analysis, the research activity performed in this doctorate was aimed at defining a roadmap to support business process initiatives swivelled on the value generated for the end user. The Thesis describes the roadmap and its implementation according to the class of business process re-engineering problems to be addressed. The methodology is a systematic approach with manifold tasks, that links New Product Development, new value proposition strategies and Business Process Re-engineering issues. Three exemplary applications are described in order to clarify its customized application for different business re-engineering problems, coming from different industrial sectors.

The contents are organized in 7 main Chapters. Chapter 1 introduces the scientific context of the research and describes the pursued objectives. In the Chapter 2 a critical review of the existing tools and methods in reference to the methodological objectives, is presented. Chapter 3 is specifically dedicated to the description of the roadmap, by providing for each step, the suitable tools for the implementation, on the basis of the kind of industrial re-engineering problem under investigation. Chapter 4 illustrates the application of the method to different case studies. Chapter 5 reports the description of the experimentation that has been executed to verify the robustness and repeatability of the key steps of the roadmap. In Chapter 6, discussions are presented about the effectiveness of the method, the achievement of the methodological objectives and possible future research activities that can be developed starting from the results obtained by this research. Eventually, in Chapter 7 the conclusions are drawn.

Contents

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 reports a critical analysis of the methods to support re-engineering tasks of products and processes with the aim of highlighting the main open issues and consequently illustrating the motivations underlying the present research. Section 1.2 focuses on the addressed problems and clarifies the objectives of the work. Eventually, Section 1.3 provides useful definitions of some important key concepts with the aim to facilitate the reading and understanding of the topics related to such thesis.

1.1. Context of the research and scientific background

The concept of "business process" was born in the early 1990s as a means to identify all the activities that a company performs in order to deliver products or services to their customers. The need of describing and formalizing the actions performed to turn resources into benefits for the customer was strongly perceived in those years since companies started worldwide to radically reorganize their activities in the attempt to regain the competitiveness lost during the previous decade. The "business process" concept has been defined by several authors in the literature with the aim of providing a reference for modelling and analysis tasks. Davenport [1.1] stated that it is:

"a structured, measured set of activities designed to produce a specific output for a particular customer or market. It implies a strong emphasis on how work is done within an organization, in contrast to a product focus's emphasis on what. A process is thus a specific ordering of work activities across time and space, with a beginning and an end, and clearly defined inputs and outputs…. Processes are the structure by which an organization does what is necessary to produce value for its customers."

Thus, according to Davenport, a business process is identified through clear boundaries, inputs, outputs and activities ordered in time and space: the purpose of the process is the transformation of inputs into outcomes having value for the customer.

Hammer and Champy [1.2] give a more general definition focused on the process outcomes according to the customer perspective:

"a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer"

Eventually Johansson et al. [1.3] emphasizes on the creation of links and interrelations among the activities and on the transformation that takes place within the process, highlighting the value chain concept:

"a set of linked activities that take an input and transform it to create an output. Ideally, the transformation that occurs in the process should add value to the input and create an output that is more useful and effective to the recipient either upstream or downstream."

There are so many other definitions but in essence all are the same: business processes are relationships between inputs and outputs, where inputs are transformed into outputs throughout a series of activities, which add value to the inputs.

According to the cited contributions, a business process should be therefore characterized by:

- clearly defined boundaries, inputs and outputs;
- activities ordered in time and space;
- a clearly identified receiver of the process outcomes, i.e. the customer;
- the transformation taking place within the process that is meant to add value to the inputs;
- an organizational structure;
- one or more functions to be performed.

Such properties suggest that the business process can be considered as a technical system able to generate value by manufacturing products or delivering services under certain boundary conditions such as market demand, raw material availability, product requirements, technology and know-how resources, etc. When the process is not able to exploit the available resources according to their potentialities, its capability to survive market competition decreases dramatically, due to a disadvantageous balance between the provided benefits and the involved costs. Thus any organization has to pursue continuous business improvements through a regular evolutionary path in order to preserve its competitiveness; this evolution can involve the business at different levels and it requires resources of knowledge dispersed across different fields and disciplines. For such reasons, the analysis of process bottlenecks and the identification of suitable reorganization strategies is a challenging task to be performed.

During the last twenty years, many methods have been suggested to address the redesigning and innovation of business processes. In the management field, but also in the scientific literature, such reorganization tasks were defined as Business Process Re-engineering (BPR). Several definitions of BPR are available but one of the most acknowledged is that provided by Hammer and Champy [1.2]:

BPR consists in "*the fundamental rethinking and radical redesign of a business processes to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service, and speed*".

The companies have pursued BPR strategies, by taking into account a wide range of product features, such as price, lead-time, delivery conformance, performance, quality and reliability, sources of risk, environmental factors and life-cycle costs. Consequently, different approaches have been developed, characterized by the priorities assigned to one or more of the previously listed features, meant as the main triggers to successfully perform the product and process development [1.4, 1.5].

For example in [1.6] an integrated multidimensional process improvement methodology has been proposed to address the yield management, process control and cost management issues for a production process. Total Quality Management (TQM) is used to manage the cost of the system according to the quality requirements and a discrete event simulation is employed to achieve process re-engineering and improvement.

A method has been presented in [1.7] based on a heuristic approach which supports the practitioners in developing a new improved business process starting from the current design. The method has been extrapolated from different successful and acknowledged best practices to carry out BPR tasks. These heuristics have been synthesized in a checklist for process redesigning with the objective of contemplating and harmonizing different management approaches: Total Cycle Time compression, Lean Enterprise and Constraints Management.

Cameron and Braiden [1.8] have performed an investigation of BPR methodologies employed in different companies which manufacture products on Engineering To Order (ETO) basis; this segment typically exploits business opportunities according to the ability to meet customer requirements. The results show that BPR methodologies cannot be applied to such kind of companies since they are not able to manage different business units as in the case of collaborating companies.

Herron and Braiden [1.9] have developed a methodology to assist the user in identifying the most appropriate lean manufacturing tools and techniques to address the problems of a particular company through a quantitative compatibility assessment. The results confirm that lean manufacturing tools may have a major impact only on specific areas of the business, but they are not a panacea for any kind of problems. Typically, companies experienced problems in areas such as under capacities, scheduling and innovation in products and processes, which represent issues that are not directly influenced by lean manufacturing methods.

The approach based on Balanced Score Card (BSC) [1.10] focuses on providing a systematic tool for BPR, combining financial and nonfinancial performance indicators in a coherent measurement system. Four metrics are constructed according to a predefined strategy, and the company's processes are aligned towards this strategy. The company is evaluated according to indicators belonging to four different areas: the financial perspective; the customer satisfaction; the internal business process view based on the concept of the value chain; a final index taking into account the innovation and the learning perspective. As stated in [1.11] BSC suffers from limits based on invalid assumptions about the innovation economy: its rigidity, its conception of knowledge and innovation as a routine process, its focus on the internal processes of the company determine biased evaluations since the relationships with the environment are neglected. Such limitations make the BSC performances poor by the viewpoint of understanding the innovation economy.

A considerable amount of works approach the problem of dealing with concurrent issues in terms of costs management and product requirements; a recent example is [1.12], where the integration of Value Engineering and Target-costing techniques is proposed to support the product development process in an automotive company. Such a methodology was applied to a case study aimed at improving costs and performances of a vehicle engine-starter system, according to customer and company needs.

Notwithstanding the research in the BPR field has brought to numerous contributions, several works in literature argue that BPR has failed to meet its expectations; among the others, Holland and Kumar [1.13] noted that 60–80% of BPR initiatives have been unsuccessful. The most frequent and harsh critique concerns the strict focus on efficiency and technology and the disregard of people in the organization that are subjected to a reengineering initiative. Very often the label BPR was used for major workforce reductions with the aim of decreasing organizational and production costs, instead of suggesting any kind of improvement based on process innovation.

Moreover the analysis performed by Hall et al. [1.14] suggested that in order to obtain successful BPR initiatives, redesign efforts should be focused not only on cost and time reduction but mainly on the areas of the business process having the most direct impact on customer value. These results show that managers must reengineer their core processes starting from the customer perspective, since, in a competitive context, a reengineering task cannot be limited to lean cycles to reduce costs and robust procedures to ensure quality.

As well, as remarked by Kim and Mauborgne [1.15], all traditional industries are already very competitive and capable to oversupply the current demand. Seeking to 'beat the competition' typically leads to ever-finer segmentation and specialization, price pressure and negative effects on margins. Their proposal to avoid head-to-head competition and to build a Blue Ocean Strategy (BOS), consists in finding new demand/market opportunities in order to make the competition irrelevant through a careful analysis of the possible aspects of value that customers might care about. This criterion brings very often to the definition of product characteristics that determine an unprecedented value curve that strongly differs from the one representing the industrial standard. In these cases a breakthrough in the business process is required and the consequent reorganization of phases and resources has to be oriented on the fulfilment of the product requirements that generate brand new value for the customer.

Thus the task related to the identification of value bottlenecks has to take into consideration the required productivity issues, the product performances to be enhanced, the new functions to be performed, new properties or features of products and services.

Recently Product Service Systems (PSSs) [1.16] and Service Product Engineering (SPE) [1.17] have been developed addressing the needs of manufacturing and service companies, with the aim of generating additional value for products. These methodologies address a growth strategy based on innovation in mature industries, by augmenting the overall value for the customer thanks to increased servicing and service issues. However there are few examples of complete PSSs tasks designed on a life cycle basis in companies. This is due to a number of uncertainties concerning the characteristics of the PSSs, among the others:

- readiness to adopt the PSSs into a company's strategic decisions. The shift from selling products to providing PSSs entails substantial changes in the companies' structure and organizational frameworks, production and marketing strategies;
- readiness to accept the PSSs by consumers. Little research has been conducted on evaluating the impact of PSSs paradigms and their profitability for consumers. In order to overcome these limits a general

methodological framework for PSSs design and implementation still requires to be developed.

The scientific background described so far shows that a systematic and robust approach to perform the analysis of a business process focusing on the customer perspective is still absent. One of the main issues to be addressed concerns the identification of the relationships among the process phases, the products attributes and their contribution to the generation of the customer satisfaction, capable to highlight strong points of the business process, value bottlenecks and innovation priorities. In order to define reorganization activities based on the value innovation criteria these crucial issues remain open and the present research aims at providing a contribution in such context.

1.2. Research objectives

According to Pahl and Beitz [1.18], the need to develop new products or services arises from different stimuli which may be internal or external to an organization. They can be summarized as in the following:

- *the market*: new customer needs to be fulfilled, new functionalities to be delivered, product maturity, etc.;
- *the company*: new ideas and results coming from research and development activities, availability of new manufacturing technologies, needs of performance improvements, etc.;
- *other*: new policies, environmental issues, etc.

Typically such stimuli deal with unsatisfied and unspoken needs of the customers and they represent greater potential inputs for individuating new business opportunities. Besides, the further exploitation of such stimuli may result in under capacities of the process in terms of delivering the new elements of value to the customer. It is, thus, straightforward that the recognition of the limitations in delivering the maximum benefits to the end users, is a crucial issue to be addressed in order to carry out successful reorganization initiatives. In addition, notwithstanding the realized products or the delivered services are viable to occupy promising market space, novel business ideas often cannot be developed or show relevant problems to access market due to a large amount of factors related to the resources availability.

Moreover, the implementation of suitable technical solutions able to cover these deficiencies, is a difficult task as well, since it involves knowledge dispersed across many disciplines including engineering, resources management, information technology, marketing, etc.

Thus, the problems to be solved in order to obtain successful re-engineering activities based on the Value Innovation criterion, can be summarized through the following main questions:

1. what should be changed in the process in order to guarantee or increase the customer satisfaction?
2. What should be changed in the product or service characteristics in order to deliver superior value to the customer with respect to products and services currently in the marketplace?
3. Which activities aimed at resource reorganizations, should be prioritized for implementing the new product and/or service ideas?

Such problems can be easily summarized through the models depicted in Figure 1.1.

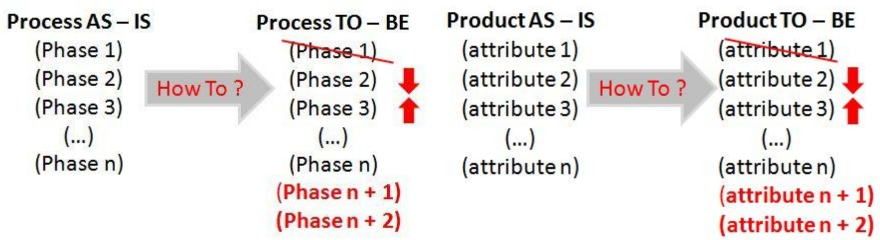


Figure 1.1: Models of the problems to be solved in a BPR initiative based on Value Innovation.

With reference to those product or service features having a high impact on customer perceived value, it may happen that one or more phases of the process provide a marginal contribution, show poor performances or consume too many resources. In further circumstances, especially when the business should be reorganized around a new product or service, the lack of proper functions that are not available in the AS-IS situation (i.e. manufacturing phases, design activities, etc.), hinders the satisfaction of the customer. Indeed, in these cases, the process is not capable to accomplish one or more important attributes of the new product or service delivering superior value. Thus, facing such a problem with a focus on the value delivered to the customer, means to analyze the contribution of each phase in generating the product/service attributes. Such task has to take into account the impact of the phases in determining the customer satisfaction, considering as well the involved resources in delivering such contribution. On the basis of this analysis, the main value bottlenecks can be individuated and the suitable reorganization actions can be prioritized in order to overcome the emerging deficiencies.

Subsequently, the process can be re-engineered by identifying the proper technical solutions that implement the individuated actions.

As briefly recalled, products/services themselves can experience problems related to the perceived customer value, consequently impacting the whole business. The limited delivered value can be due to a modification of customer needs, demands, expectations or preferences. In such case the product or service should be re-engineered by individuating and providing the required new elements of value and/or the enhanced performances, as expected by the customer.

This task involves the identification of the features of the AS-IS product/service whose performances should be enhanced or reduced, those to be removed since the customer is no longer interested in, and those to be created due to the new customer needs. It is straightforward that a radical transformation in the value offered by the product may subsequently involve disruptive changes in the process, since the required level of product performances and/or the new created product/service characteristics might be provided at an unsatisfactory extent with the available technologies, know how, financial resources, assets, etc.

According to the above mentioned issues, the general objective of the present research is the definition of a methodological approach capable to lay the value bottlenecks bare and to support the definition of new process and/or product characteristics. Moreover, a further objective of the present research stands in providing suitable tools for the implementation of the identified re-engineering actions, upon the technical and business domains. As a whole, the current study is thus addressed at offering models and methodologies viable to support the following tasks:

1. Performing the analysis of the AS-IS business process at both the economical and technical levels.
2. Identifying the value bottlenecks, according to the internal or external stimuli.
3. Identifying new schemes and/or product technical solutions capable to overcome the bottlenecks and/or the poor customer value, according to the available resources.

The attainment of such objectives requires the definition of:

- suitable modelling techniques capable to summarize the whole set of information and data pertaining to different domains;
- proper value assessment metrics by which perform the analysis of the business process focusing on the value delivered to the customer;
- tools to support new value proposition tasks for products and services;
- tools to support the technical implementation of the re-engineering initiatives.

1.3. Definitions

Definitions of some key concepts used in this thesis:

- *Benefit:* Desirable attribute of a good or service, which a customer perceives he or she will get from purchasing.
- *Competing factors:* Product or service attributes on which the competition is played in the reference market.
- *Customer perceived value:* Customer's opinion of a product's value to him or her.
- *Customer Requirements:* Particular characteristics and specifications of a good or service, as implied by the customers' intention to fulfil certain need, see also "Product attributes".
- *Customer satisfaction/dissatisfaction:* Measure of how products and services supplied by a company meet/don't meet the customer expectation.
- *Functional Feature:* Functional role that a product attribute plays within customer perception of the products and services, i.e. positive outcomes, limitation of undesired effects, reduction of required resources.
- *New Value Proposition:* Offer that describes the quantifiable benefits that individuals or organizations promise to deliver to a customer through new products or services.
- *Performance*: Accomplishment of a given function/activity measured against preset standards of accuracy, completeness, cost, and speed.
- *Product attributes:* Characteristics or features of a product that are thought to appeal to customers, see also "Customer Requirements".
- *Product profile*: The whole set of attributes characterizing a product or service.
- *Resource:* A resource is any physical or virtual entity of limited availability that needs to be consumed to obtain a benefit from it.
- *Value:* Extent to which a good or service is perceived by its customer to meet his or her needs or wants, measured by customer's willingness to pay for it. It commonly depends more on the customer's perception of the worth of the product than on its intrinsic value.
- *Value bottleneck*: Function, activity, or resource already working at its full capacity and which, therefore, cannot handle any additional demand placed on it.
- *Value elements*: Product attributes.
- *Value Innovation*: It is intended as a business strategy based on the radical improvement of the customer perceived value, through the proposition of unprecedented product/service attributes.

2. State of the Art

In this Chapter a brief literature review is showed, aimed at describing tools and methods which are pertinent with the objectives of the current research.

Section 2.1 reports an analysis of the business process modelling techniques, while Section 2.2 describes the metrics for the value assessment and tools to support new value proposition tasks. Eventually, in Section 2.3 a critical discussion aimed at highlighting matching and contradicting issues of the considered tools and methods, is performed according to the research objectives presented in Chapter 1.

2.1. Tools for Business Process modelling

Efficient design, analysis and optimization of enterprise operations require notations, formalisms, methods and tools to depict the various facets of a business organization. All the aspects of this modelling activity are collectively called Enterprise Modelling (EM) as stated by Vernadat [2.1]. In this context, process modelling is very important: models are used to understand how the current system is evolving, to define the main characteristics of the re-engineered system and to guide implementation and monitoring activities.

The goal of EM is to make knowledge explicit so that it could add value to the enterprise or can be shared by business applications and users for improving the performance of the enterprise. EM contributes to solving interoperability difficulties by increasing the shared understanding of the enterprise structure and behaviour. Furthermore, EM provides methodologies for the identification of connected roles and objects within enterprises from different perspectives. In studying process models, Curtis et al. [2.2] identified four main perspectives: functional, behavioural, organizational and informational. The functional perspective represents a process in terms of what activities are being performed and which information flows are needed to link these activities. The behavioural perspective depicts when and how activities occur, by using mechanisms such as iterations and triggers. The organizational perspective describes where activities are performed, and by whom. Eventually, the informational perspective provides a view of the system in terms of the produced or manipulated entities, such as documents, data and/or products. These perspectives allow distinct and complementary representations, and each one considered by itself, only gives a partial and incomplete view. Therefore, multiple modelling methods may be required to produce an integrated and complete representation of a business process. Many languages and tools (more than 300) have been developed in the last thirty years in order to support EM with partially overlapping approaches. Aguilar-Saven [2.3] performed a comprehensive survey of the available modelling techniques, highlighting strengths and weaknesses of each approach. Giaglis [2.4] proposed a well established and recognized taxonomy aimed at assisting decision-makers in selecting the suitable modelling tool depending on the characteristics and requirements of the business process. Here in the following a brief review of the most acknowledged modelling methods is presented, taking the above mentioned contributions as literature references in the field.

Flowchart [2.5] is one of the first graphical modelling techniques, dating back to the 1960s. It was initially developed to provide computer program logic representation, subsequently, due to its generic nature, it has been used in many other application areas, including business process modelling. The advantages of flowcharts lie in their capability to show the overall structure of a system, to trace the flow of information and work, to depict the physical media on which data are input, output and stored, and to highlight key decision points. The process model is constituted by symbols that are used to represent operations, data, flow directions and equipments, in order to perform the definition, analysis, or solution of a problem. A sequential flow of actions are employed to represent the activities while the formalism doesn't allow their breakdown in other sub functions. The Flowchart is acknowledged as a very easy tool to use; moreover it is assessed that it does not require a very long time to draw a model. In addition, thanks to its flexibility, a process can be described in a wide variety of ways. The most recognized weakness of this standard is that the boundaries of the system appear unclear and inaccurately defined. Moreover the diagrams tend to be very big, as well as they do not highlight the distinction among main tasks and sub-activities, resulting in severe limitations about their readability. Since the diagrams do not foresee any sub-layers, it is hard to navigate the schemes and it is difficult to find information in the chart. Flowcharting is no longer a dominant modelling technique because it can provide only basic facilities in representing processes. Therefore, it is nowadays used as a simple, graphic means of communication, to support narrative descriptions.

Role Activity Diagrams (RADs) [2.6] are diagrammatic notations that are focused on the modelling of individual or group roles, their activities and interactions, along with external events and logic that determines what activities are carried out and when. RADs differ from other diagrammatic techniques, since they adopt the roles as primary unit of analysis in process models rather than activities. Thus, RADs are mainly suitable for organisational contexts where the human element is the critical resource on which the changes are focused. However, they don't allow the explicit representation of the functional and informational perspectives, hence having a complementary role in the context of BPR.

Data Flow Diagramming (DFD) is a technique for graphically representing the flow of information among external entities, internal activities, and database in a business process [2.7]. DFDs are focused on the flow of data inside and outside the system boundaries. In that respect, DFDs are comparable to flowcharts, differing from them basically in the focus of the analysis (DFDs focus on data, instead of activities and control). DFDs have been widely used for data modelling and have become a popular notation for process analysis and design. However, they present several limitations. Firstly, they focus primarily on data and they do not provide formalisms for the representation of workflows, involved people and other elements. Secondly, they do not provide any information on decisions and event sequences. Eventually, DFDs are static representations of the system's functions that are used to manipulate the flows of information, and therefore they are not suitable to support decision-making tasks. In order to make DFDs useful for supporting process analysis activities, they are complemented by structured textual descriptions of procedures in which data are to be used, these descriptions are called process specifications.

Role Interaction Diagrams (RIDs) are a modelling technique resulting from the combination of RADs and Flowchart [2.8]. A matrix summarizing the activities in the columns and the roles in the rows, is used to represent functions-roles relationships, while proper formalisms are employed to represent the process. RIDs are intuitive to understand, easy to read but quite hard to build. A strong weakness of the model consists in the fact that it doesn't allow the representation of inputs and outputs of each activity, thus important information misses. When editing an existing diagram, it can be hard to introduce new activities or roles. Since each activity is linked to a performer, the responsibilities and the involved knowledge are well defined.

The Integrated Definition for Function Modelling (IDEF) [2.9] is a family of methods that supports the modelling of an enterprise and its business areas. It is used according to different applications, respect which they are distinguished in: IDEF0, IDEF1, IDEF1X, IDEF2, IDEF3, IDEF4 and IDEF5. However, for business process modelling, the most used versions are IDEF0 and IDEF3.

IDEF0 standard is a functional modelling tool, but it is often used even to represent processes, since the functions that can be represented include activities, actions and operations. IDEF0 models illustrate the relationship of all the functions in a graphical format with “box and arrows”, whereas the boxes are the functions themselves and the arrows stand for the constraints. Within process modelling, IDEF0 is used to represent constituent activities and their transformation of inputs into outputs, along with the controls governing the transformation and the required resources. In the same context, IDEF0 models can be employed with a different formalization: the boxes describe the activities that perform the functions and the arrows stand for the information and the objects that are inter-related in a given system. They are placed in a left to right sequence and connected with the flows, since one activity’s output is used as input by another activity. Drawing the diagram results in an easy enough task. Due to such common application, IDEF0 is considered among the most useful instruments to perform business process modelling, with the possibility to decompose the processes in lower level activities. Furthermore, the very strict rules in IDEF0 allow its implementation in computer software. Moreover, it is possible to highlight a large amount of resources involved in the system (information, instruments, materials, employed people, control rules) and their input and output flows within each activity or phase. Nevertheless, IDEF0 has inherent limitations in terms of capability to describe different aspects of a technical system [2.10] and the literature includes several claims for its modification or integration [2.11, 2.12].

IDEF3 Process Description Capture is used to depict behavioural aspects of a process. It allows different views of how things work within an organization and it can capture the precedence and causality relationships between activities and different events. IDEF3 consists of two modelling modes: the process flow description, which describes how things actually work in the organization, and the Object State Transition Description (OSTD), which summarizes allowable transitions of an object. While IDEF0 is a suitable modelling technique for development and design, IDEF3 is advantageously employed to assist decision tasks during the process execution.

The Object Orientation (OO) methods are techniques to model a process described as objects that undergo transformations, which are performed by function carriers. An object holds a state, represented by one of the possible conditions determined by the values of its properties (attributes) in which it may exist. The state changes are reflected by the behaviour, i.e. how an object acts and reacts on the basis of the set of operations the object can perform on itself, and according to its interface, functions and methods. There are many different techniques based on OO; among them the Unified Modelling Language (UML) represents a collection of engineering practices that have proven successful in the modelling of large and complex systems [2.13, 2.14].

The UML uses a wide array of diagrammatic notations, including: Use Case diagrams, which capture system functionality as seen by the users; Class diagrams, which capture the vocabulary of the system; Behaviour diagrams such as state chart, activity and interaction diagrams; component and deployment diagrams. The underlying reason for the development of the language is simple: although a wide variety of notational languages have long existed for the representation of software systems, many languages are typically aligned with a particular analysis and design method. This wide variety can be a source of complexity and problems of non-compatibility between languages. UML attempts to address this gap by being a 'universal' language, covering everything from business process representation to database schema depiction and software components modelling. However, some may argue that the language is heavily based on the OO paradigm and hence it may not be applicable in situations where the modellers want to follow a more traditional modelling approach.

The above performed review can lead to some interesting observations. Firstly, the various techniques differ significantly in the ability to model different business and system perspectives. Some techniques focus primarily on functions, some others on roles, or on data. Ideally, what might be needed is the development of a single technique that could effectively represent all modelling perspectives in a rigorous and concise fashion, and hence be applicable in all modelling situations. However, the multiplicity of possible modelling goals and objectives makes the development of such technique impractical. It would probably generate complex models, thus reducing the ease of use for any single particular application [2.2, 2.3].

2.2. Tools for the Value assessment and New Value Proposition tasks

In order to implement BPR activities based on Value Innovation, the estimation of the value delivered to the customer is a crucial task. Several approaches facing such issue, have been developed during the years. In the following a brief review of tools and methods for value assessment is presented. It has been narrowed to some peculiar contributions closely connected to the methodological objectives of this research.

Some of these pertain to the engineering field and they were/are used to assess the maturity of a technical system as a criterion to establish when a radical change in delivering a certain function is required. Other relevant contributions pertain to the marketing field and introduce techniques employed to ascertain the expected delivered value by asking the opinion of customer about the features of the product.

A totally different approach is that proposed by BOS, which suggests to perform a new value proposition task by shifting to new product profiles. The core criteria recommend to define new features and radically modify those existent, rather than asking the customer what he/she wants.

2.2.1. Value Engineering and other metrics for Value assessment

Value Engineering (VE) is a systematic method developed by Lawrence D. Miles [2.15] aimed at improving the value of products or services by using an examination of their functions. The metric for the value assessment is defined as the ratio between the delivered benefits and the involved costs [2.16]. Such terms are evaluated as in the following:

- Value methodology takes the cost or price of a product or service and allocates it to each function.
- According to Miles, the function value is determined through its worth, thus by the performance that makes it desirable, useful, or valuable. Often, the function value is ascertained through the market value.

Within the VE, the estimation of industrial processes performance, aimed at BPR, is a very debated subject. In most cases the followed approaches are restricted to specific business segments, or they are limited to qualitative aspects without carrying out any kind of quantitative estimations. As an example of the first case, a formulation of customer value (brand perception) in the branch of e-commerce has been published in Deise et al. [2.17], Smith and Chaffey [2.18], Hales and Barker [2.19]. With respect to the second one, Process Value Analysis [2.20] has been developed in the context of Value Engineering methods. It intends to assign a value to the phases mainly taking in consideration the profitability of the activities. Thus, the Process Value Analysis gave, indeed, origin to Activity Based Costing (ABC). A further proposal for BPR is the Comparative Value Analysis proposed by Dransfield et al. [2.21], which performs comparisons among more enterprises performances, but it doesn’t deal with firms’ internal processes. Although these approaches are viable to provide useful metrics for value assessment, they don’t allow to take into account the contribution of each activity in determining the customer attraction and the potential impact of phase weaknesses in terms of customer dissatisfaction. Moreover, they don’t consider any kind of cost to the fulfilment of the phase tasks through the employed resources.

The integration of Value Engineering analysis with TRIZ has been initiated since the ‘80s [2.22- 2.25]. The fourth TRIZ Laws of Engineering Systems Evolution (LESE) [2.26] states that any Technical System evolves towards an increase of the Ideality expressed as the ratio between provided benefits and spent resources (e.g. amount of material, weight, energy, time etc). Classical TRIZ defines also a number of typical patterns to increase the ideality of Technical Systems, both for products and processes [2.27]. Such a definition of ideality closely resembles the concept of Value defined by Miles [2.15], expressed as the ratio between benefits and costs. In modern TRIZ literature [2.29, 2.30, 2.31, 2.32] the common formulation of Ideality is expressed by the ratio among the sum of the useful functions provided by a certain technical system, and the sum of generated harmful effects and consumed resources. Thus, in its widest meaning, "the degree of ideality indicates a ratio between the value delivered by a certain system and all types of expenses and investments needed to produce this value" [2.33]. Therefore, the estimation of ideality referred to products and devices, relates to performances and the whole range of expenses, while within the assessment of processes, it involves the outputs of entire process or single phases, compared with the resources spent for their accomplishment, such as elapsed time, energy, etc. As in the case of VE, also TRIZ Ideality can be considered a useful metric to perform value assessment tasks devoted to BPR. However, for the objectives of the present research, it requires a more precise definition tailored on the evaluation of the benefits delivered to the customer.

The Theory of Constraint (TOC) by Goldratt E. M. [2.34] performs the identification of the system bottlenecks and determines the effect that any local action has on the improvements of the system, through a metric based on the monetary involved flows . The main terms introduced by TOC are:

- the Throughput (T), i.e. the rate at which the system generates money;
- the Inventory (I), that is represented by all the money the system invests in goods that it intends to sell;
- the Operating Expenses (OE), which stand for the money required by the system to turn I into T.

The criterion followed by TOC to improve the system is to spend as much efforts as possible on activities that tend to increase T primarily and make reduction of I and OE as secondary priority. With TOC it is possible to implement reengineering actions aimed at removing system bottlenecks that limit productivity, so to fulfil unexploited market opportunities. According to this criterion, the metric used to assess the value generated by the system is based only on the process incomes, without taking into account any aspect related to the benefits delivered to the customer; thus TOC tools result pretty useless for Value Innovation tasks.

2.2.2. Approaches based on the Voice of the Customer

Several methods have been developed in the consumer research field, with the aim to capture the so called "Voice of Customer" (VOC); in [2.35] an extensive survey is presented. Many approaches such as those based on Free Elicitation, Laddering, Conjoint Analysis, etc., try to extrapolate the product attributes having major interests for the user by interviewing techniques in which the customers are asked to identify the attributes they consider relevant in the perception of a product. Other methodologies (i.e., Empathic Design, Information Acceleration, etc.) are based on observing the consumer behaviour during the day life. The assumption behind these approaches is that designers can easily identify opportunities for products in response to perceived needs, by examining the consumer behaviour.

According to Ulwick [2.36], even if all these value assessment methods help in gaining knowledge of consumers and their behaviour, they cannot support any new value proposition task, since asking the customers helps just to reveal the needs they are clearly aware, without shedding light on potentially novel valuable attributes.

Quality Function Deployment (QFD) has been applied to several domains such as robust design and BPR [2.37-2.39]. It allows to focus the design tasks on the customer requirements along the whole product development process from conceptual design to manufacturing. During the years several approaches have been developed by researchers in order to employ QFD for product planning tasks. In [2.40] QFD and Design Structure Matrix were used to assist the designers in understanding customer needs and planning for the early stage of product conceptualization. A market-driven design system to integrate QFD technique with marketing analysis was proposed in [2.41]. The suggested approach is focused on concentrating the design efforts on particular product features, which generate maximum benefits for customer satisfaction, as claimed in [2.37]. More recently, Ulrich and Eppinger [2.42] provided a methodological approach for identifying customer needs and for establishing their relative importance, but they didn't provide any guidelines for ranking and selecting needs based on their perceived value, as highlighted in [2.43].

In the above mentioned approach and several others available in literature, QFD is used as a method to relate the customer demands to the engineering requirements in the early stage of New Product Development (NPD), but it cannot provide any useful support in identifying the product attributes having superior value. Thus QFD is used, very often, together with the above cited methods for customer research in order to investigate the end-user needs and to translate them into product attributes.

Kano et al. [2.44] developed a two-dimensional model that classifies the product attributes in three main categories: must-be, one-dimensional and attractive according to the role that a specific product attribute plays on determining the customer satisfaction. The Kano model is widely recognized in literature as an effective tool for categorizing product criteria and requirements, since a design team can determine which attributes should be improved in order to generate the maximum benefits in terms of customer satisfaction [2.45, 2.46]. Although the suggested classification is a powerful tool to perform the analysis of the impact played by product features from the user's viewpoint, the Kano model cannot provide any useful guideline aimed at identifying which performances should be modified in the AS-IS process, product or service and which new attributes should be created.

Hara et al. [2.47] developed the concept of Service Product Engineering (SPE) as a means to provide more value to the customer by offering not only product but also the related services, according to the Life Cycle Engineering (LCE). In their approach, the elements of value are identified by the so called "Persona" model that summarizes personality information about the customer. Then designers collect the voice of customer in the same segment as the "Persona"; subsequently such voices are classified into groups that are independent, they represent the receiver's internal state, which is the metric used for the measurement of the customer satisfaction. Different service product alternatives are evaluated by classifying the functional characteristics through the Kano model and then by determining the impact they have on the receiver's internal state. Even if the LCE perspective allows the identification of relevant value aspects of the product along its life cycle, the evaluation of the impact that both product and service characteristics have on customer satisfaction is still performed on the basis of the VOC approach.

2.2.3. Blue Ocean Strategy

From the business point of view, most of the well-established strategies mainly focus on the ways to achieve competitive leadership and advantage, with a crucial role played by the relationship between the performance and the prices of the manufactured products or the delivered services. On the contrary, the strategy fine-tuned by Kim and Mauborgne aims at looking for new business opportunities, through the definition of an innovative set of features for a company's industry, allowing to create new market space due to a novel value proposition. In this way BOS intends to break the quality/cost trade-off through value innovation, thus "killing" the competition with industry rivals and creating a new business model through the investigation of communalities of different groups of costumers and non-customers. The so built uncontested marketplace is symbolized by a blue ocean in contrast with severe competition, the red ocean infested by bloody sharks.

The reasons of BOS' success, witnessed by acknowledgements [2.48], awards [2.49], quick adoption by the companies looking for innovation tools [2.50], are to be traced, beyond the suggestive picture of the blue ocean [2.48, 2.51], in the attempt to develop and systemize ideas and theories regarding a dynamic market characterized by breakthroughs opposed to incremental improvements [2.52] and pushed by the interplay among needs (functional, emotional, aesthetical, etc.), consumers and firms [2.53]. The advantages of pursuing a blue ocean are pointed out by Kim and Mauborgne through the evidences arising from numerous breakthrough case studies belonging to manifold sectors [2.49]. The widespread applicability of the strategy in the business context has pushed its diffusion. In the literature the case studies regarding the fruitful application of BOS' framework, guidelines and tools, as well strong recommendations for their implementation, range from big companies [2.54] to SMEs [2.55], from the tertiary sector [2.56] to institutions [2.57, 2.58]; the involved industrial fields encompass manufacturing [2.59, 2.60], apparel and footwear [2.61, 2.62], energy and sustainability [2.63], pharmaceutics and biotechnology [2.64-2.66], education [2.67-2.69], communications [2.70, 2.71], logistics [2.72], transportation [2.73], insurance [2.74], financial activities [2.75], healthcare [2.76], entertainment [2.77], tourism [2.78-2.80], agriculture [2.81], husbandry [2.82], constructions [2.83], real estate [2.84].

The aforementioned application of the strategy has been carried out with the direct implementation of BOS fundamentals, as well as employing the suggested tools described in the book [2.85]. Among them, the strategy canvas represents the conceptual framework aimed at summarizing the ideas to perform a successful strategic "move". In the strategy canvas the value curves stand for the graphical representation of the relative performances of products or services, across the relevant factors of competition for the companies and their value propositions in their pertinent business industry.

In the BOS a new curve is built by proper modifications of the current product/service attribute performances and by the introduction of previously ignored properties. The innovative bundle of attributes and performances is obtained by the Four Actions Framework and summarized by the Eliminate Reduce Raise Create (ERRC) Grid. While it is relatively simple to investigate the current relevant product features to be properly removed, worsened or enhanced, by benchmarking the competition, the proposition of new valuable product attributes represents a severe challenge. Within BOS such task can be eased by the Six Path Framework, which represents a set of indications that help in finding new ideas that are viable to break the established market boundaries.

Nevertheless, it has been argued that the strategy canvas represents just a useful visual tool to represent the ideas underpinning the BOS “move”, whilst it misses proper guidelines in order to select successful value propositions among multiple alternatives [2.86]. As a consequence, assessing a strategy canvas results in a difficult matter [2.51, 2.87]. Several scholars [2.58, 2.88, 2.89] have attempted to make the process of building the strategy canvas more robust, taking into account the extent of importance levels attributed to competition factors in terms of customer perceived value. However, these measures can be adopted just after the relevant business features have been identified and defined, so when the range of possible choices has already been consistently reduced and the actions to be applied have just to be prioritized.

A relevant matter consists in the proper actions to be applied to the various product attributes. From Kim and Mauborgne’s description of Four Actions Framework it emerges that the attributes to be investigated are those related to buyer’s perceived value:

- the eliminate action concerns factors the pertinent industry has long competed on and that don’t represent anymore a source of competitive advantage in terms of customer value;
- the reduce action is related to product/service attributes that are overdesigned and that could be provided at much lower performance without affecting perceived value;
- the raise action consists in increasing the performance of certain attributes well above the current industry standard, breaking the compromise with other features of the value curve;
- the create action aims at introducing brand new sources of value for customers.

Thus, the company’s strategy should be reoriented acting on those features that directly affect the buyer’s perception, whereas a performance increase for a certain attribute represents a growth in customer’s value. However, already Ziesak [2.89] has highlighted how Kim and Mauborgne themselves use price in their value curves and how a high score of this attribute results in a low value for customers. Thus the employment of attributes generating dissatisfaction may result misleading especially with reduce and raise actions. The non-prescriptive formulation of the rules has resulted in several applications performed by BOS practitioners that show an incorrect use of the Four Actions Framework. These include the use of features that are not valued by customers [2.57, 2.90, 2.91] and mainly inherent to internal business processes [2.92-2.94], as well as attributes that have a reverse impact on buyers’ perception and satisfaction [2.73, 2.95, 2.96].

Another issue related to BOS tools concerns the need to apply all the four actions in order to create a blue ocean, as recalled by Kim and Mauborgne in the Chapter that introduces the ERRC Grid. However, it is arguable to assess such statement as a constraint, since even in classical BOS application cases, it is not straightforward to clearly individuate factors submitted to all the four actions: examples can be drawn by Siegemund [2.97], who examined Southwest Airlines, and Formule 1's value curve without any newly created attribute, as represented by Kim and Mauborgne [2.98] and subsequently by Narasimhalu [2.88].

Kim and Mauborgne have illustrated a set of case studies from a wide range of industrial sectors, in order to show the strength and the positive outcomes of their strategy. However it has been argued that is not possible to determine whether the examples have contributed to the formulation of the theory or if they have been chosen because they fit the strategy. As well as it is also unclear how exactly the method was developed [2.69], issues arise in terms of BOS' reliability and applicability. The authors provide an example about an unsuccessful value proposition by the combined use of Four Actions and Six Path Frameworks, representing a cross-check that evidences the limited robustness of the tool.

The developers of the BOS themselves point out that business innovation is a complicate task with manifold aspects not to be overlooked; in [2.99] they suggest the example of Motorola Iridium as an acknowledged flop. Such failure represents a characteristic case study employed in the literature to explain ex post the reasons of a business disaster, pointing out strategic and managerial mistakes [2.100-2.103]. Nevertheless, all the previously mentioned scientific sources share a common vision about the customer perception of the newly introduced communication system. Such consensus about the user perception allows to analyze the NVP initiative concerning Iridium through BOS lenses. The investigation insights reveal that the performed value transition could be stimulated by the path "Look across time" (i.e. fulfilling the need determined by increasing people's mobility and exigencies of communication) and by the following bundle of actions and matching value attributes with respect to common cellular telephones:

- Create: possibility to talk wherever (geographically) in the world;
- Raise: reliability in preserving the communication;
- Reduce: lightness, practice of use;
- Eliminate: cheapness, possibility of indoors use.

The example shows that the application of BOS tools itself cannot prevent from business failures and that the achievement of a systematic strategy to support NVP tasks cannot disregard a more careful appraisal of the dynamics followed by successful marketed items and wrong business ideas.

2.3. Discussion

Here in the following, a brief critical discussion of the above performed literature review is presented, with the aim of highlighting strong points and deficiencies of the presented tools, with reference to the objectives of the research described in Chapter 1.

The review performed in Section 2.1 reveals that altogether the different modelling techniques are tailored to represent specific aspects of the business process. However, Flow Chart owns a high communication capability, it is quite simple to understand, but it cannot represent the process in different layers. Moreover, the lack of methods systematizing the construction of the chart, limits the possibility to employ such modelling technique especially for very complex systems. DFDs, RADs and RIDs are quite simple formalisms but their main limitations are related to the set of flows that can be schematized through the model. DFDs can manage only streams of data, RADs deal with flows of individual roles, while RIDs can summarize both of them but they cannot represent inputs and outputs of activities. The OO models are robust and suitable to control, manage and monitor processes. However they often result excessively large and detailed; the information is represented in a fragmented way and they require a lot of time resources to model complex systems.

Among the different modelling techniques, the IDEF family seems to provide the best set of tools for BPR. They are characterized by well defined formalism, rules and notations for model building. This allows to use algorithms and computers for the construction of the model. Moreover, complex activities can be represented by splitting them into sub-layers. Although the IDEF0 can summarize a wide range of information, it doesn't take into account the extent of the flows of energy, time and money involved in the phases, but substantially flows of materials, information and required skills. According to the objectives of such research, IDEF0 is adopted as reference technique for modelling tasks. However, it requires a customization in order to enhance its capability to represent the process in different domains, taking into account also the resources that are neglected. In reference to this need, the integration of the Energy Material and Signal (EMS) modelling [2.104] within IDEF, can provide a suitable formalism. EMS is a classical technique for representing a function of a certain technical system as a black box channelling or converting energy, material and signals, i.e. information, to achieve a desired outcome.

The metrics for value assessment are based on the ratio between the benefits produced by the business process and the involved costs. Generally speaking, the VE assessment metric can be adopted for BPR initiatives based on value innovation. However, for the objectives of the current research, the value assessment requires a shift from the system perspective to the customer viewpoint within the delivered benefits. More precisely, instead of considering the technical performances of the process functions in terms of their worth and resources consumption, the generated benefits should be measured in terms of the delivered customer satisfaction. Such strategy can be carried out by taking into consideration the fulfilled customer requirements, their relevance and role in determining the customer perceived value and by evaluating the impact that each phase has in delivering such product and service attributes.

The identification of the new product/service profiles creating superior value for the user is often demanded to the VOC. Unfortunately, as revealed by the literature, VOC practices cannot support the systematic identification of new attributes, since the consumers don't know exactly what they want and what they could expect. Some of the described methods are useful but not suitable to identify the impact that each product attribute has on the customer satisfaction. Moreover they don't provide any useful indication on the measures to be undertaken in order to shift towards more valuable product profiles. For such reason VOC techniques are useless for the purpose of this research activity.

An alternative approach dealing with the objectives described in Chapter 1, is that proposed by BOS. However, as a consequence of the whole bundle of the above performed observations, the BOS' tools result pretty descriptive, useful to motivate the success of products and services ex post, but don't provide systematic paths to identify the new valuable profiles. Thus, the application of BOS tools for value proposition strategies requires to develop an enhanced formalism in the correct identification of the attributes and subsequently in the actions to be performed.

3. Methodological Proposal

In this Chapter the developed roadmap aimed at supporting BPR activities, is described.

According to the objectives introduced in Chapter 1, the proposed approach allows the identification of the proper metrics for the assessment and the evaluation of the requirements that determine the customer satisfaction. On the basis of such metrics, the impact of each process phase on the perceived value of the product and/or services, is ascertained with respect to the employed resources. The results of this assessment are employed to systematically synthesize suitable guidelines for process evolution, allowing to preserve and improve market competitiveness. Furthermore, suitable tools have been developed to systematize new value proposition tasks. They support the identification of the product/service attributes to be submitted to the Eliminate, Reduce, Raise and Create actions, according to the BOS' Four Action Framework. The research activity that has led to the development of these tools, is reported in the Appendix (A1) that constitutes an integral part of such thesis, whereas in this Chapter the outcomes of the recalled survey are presented for application purposes only.

The following Section depicts the logic and each step of the proposed roadmap for BPR and value-based New Product Development, as well as the integration of the involved tools and models.

3.1. Description of the methodological proposal

As shown in Figure 3.1, the roadmap is constituted by four main steps; the chart shows the list of the main phases, their tasks and the employed tools. Such procedure ranges from information gathering to the individuation of feasible process/product/service innovations. According to the kind of problems stated in Chapter 1, the roadmap summarizes the flow of the prescribed activities, objectives, tasks, and employed tools for their implementation. Here in the following its main features are described, while, in the next sections, each phase and the related tools, are presented in detail.

The identification of the process phases providing poor customer satisfaction is the key step to define innovation tasks aimed at removing business limits and improving the system, according to the customer perceived value. Moreover, the classification of the product/service attributes according to a functional approach based on the customer perspective, and the definition of proper implementation rules for the ERRC model based on such classification, allow the systematic identification of new product/service profiles. Eventually, the integration of different modelling techniques capable to represent the aspects related to both the functional and economical domains, is the key to perform a comprehensive analysis concerning a large amount of common industrial problems. Such a multidimensional approach allows to systematically take into account the cross-disciplinary nature of the business process.

Phase	**Tasks**	**Tools**
Process to Problem	• Information gathering • Business process functional modeling • Identification of the product value profile according to the competing factors in the reference market	• System Operator • Resources Checklist • IDEF • EMS • TOC • ENV • Value Curve
Problem to Ideal Solution	• Identification of what should be changed in the process • Identification of what should be changed in the product or service	• Kano Model • Value Indexes • Functional Features • New Value Proposition Guidelines
Ideal Solution to Physical Solution	• Finding physical solutions for new process implementation • Finding physical solutions for new product/service implementation	• Quick Response Manufacturing • Lean Manufacturing • Just In Time • Value Engineering • TRIZ • Knowledge Management
Physical Solution to Engineering Solution	• Embodiment of the TO-BE business process	• IDEF • EMS • TOC • ENV • Virtual Prototyping

Figure 3.1: The roadmap is constituted by 4 main steps: for each step the involved tasks and tools are summarized.

3.1.1. Process to Problem

Objectives

The aim of the first step is to schematize the business process into a general model of the problem, allowing to perform the subsequent analysis tasks. Such a model should describe how the system works, taking into account both the technical and economical domain, as well as collecting all the involved resources: material, energy and information flows, technologies, human skills and know-how, monetary flows. Also products and services are modelled, highlighting the attributes that generate the customer satisfaction.

In order to accomplish such objective, the “Process to Problem” step requires the implementation of the following activities:

1. *Information gathering*: this activity is aimed at extracting and collecting all the information related to the process and the involved resources.
2. *Business process functional modelling*: this task is aimed at representing the business process with a set of well defined phases each one characterized by inputs, outputs, performances and control parameters.
3. *Identification of the product value profile according to the competing factors in the reference market*: this activity is aimed at identifying the product/service attributes delivered to the customer and their performances, according to the main factors on which the competition is played in the reference market. Such activity allows to highlight the main sources of value for the product/service and how do they differ with respect to the competitors.

Phase implementation

- *Information gathering*

The information gathering is carried out taking in consideration several information sources. At the beginning of the information acquisition, sources like books, reports and manuals play a significant role for the definition of the sector background [3.1]. Subsequently, more detailed and explicit information can be extracted by using several techniques: within this task the consultation of domain experts is a common strategy. It is recommended to interview multiple experts, but appropriate devices must be used in order to solve any conflicting issues coming from overlapping competencies of the involved specialists [3.2].

In order to trigger relevant business improvements, the extraction and codification of tacit knowledge plays a significant role [3.3, 3.4], especially within processes [3.5]. The concept of tacit knowledge was introduced by Polanyi [3.6], who defined it as personal with no possibility to be codified. The possibility of acquiring and disseminating tacit knowledge is a very debated issue. Many scholars, such as Nonaka [3.7], have developed Polanyi's conception of tacit knowledge in a practical direction to enhance organizational knowledge creation and assessing the possibility to elicit it. Coherently to this vision and purpose, the task of acquiring tacit knowledge implies to meet directly the employees at the different organizational levels. The attention on tacit knowledge and the attempt to extract it, are aimed at formalizing a set of control parameters that impact the business process and of evaluation parameters capable to describe the system performances. By eliciting the relations among the various parameters, beyond the phases, it is possible to follow a systematic approach in the analysis of the system, in order to highlight spaces for innovation and possible enhancements.

During the information gathering, all the involved resources should be identified. According to the TRIZ concept of "resources": any substance, field, interaction, characteristic, property, time/space availability within the system not used at its maximum potentiality, constitutes an opportunity to improve the system itself. This task requires:

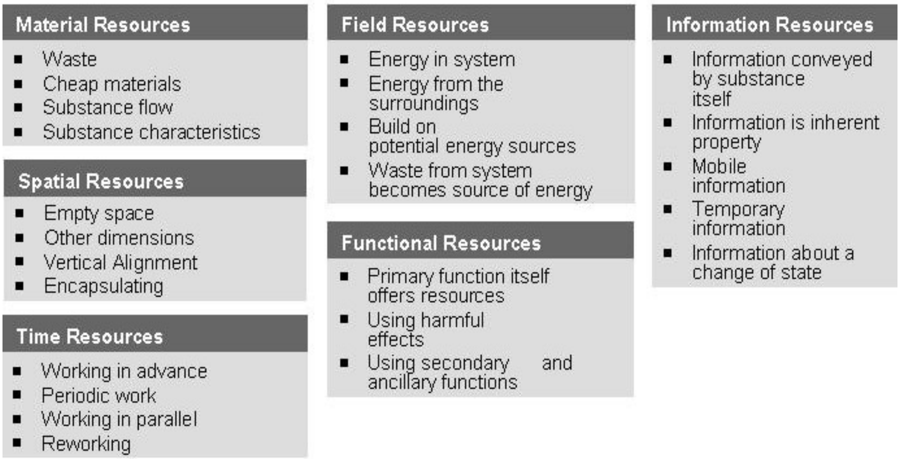
- to analyze each phase and its flows in order to discover if there are resources inside the system that are not exploited. These resources may be used in order to improve the overall efficiency of the system (e.g. the energy lost due to friction in a phase may be used as thermal heating for other phases of the process, etc.).
- to identify the availability of external achievable resources in terms of market opportunities and available materials.

A useful tool to support the identification of resources is the so-called System Operator or Multi-Screen approach [3.8], consisting in a multi-scale analysis to be focused on each time-step/phase (before, during and after the phase is performed) of the process and on the cause-effect relationship existing between its functional interactions (Figure 3.2a). In a few words, the System Operator (typically depicted as a 3x3 matrix of "screens") is characterized by a vertical axis representing the hierarchical level of the analysis and a "Time" dimension constituting its horizontal axis. Any talented analyzer, whatever the Technical System dealing with, recognizes and takes into account the environment and the external objects that the system interacts with (i.e., the super-system), its constituting elements (i.e., the sub-systems), and the past, present and future of each detail level. Depending on the specific situation, the Time dimension can be considered as a historical time (the evolution of certain systems), as a process time (while analyzing a chain of events, even with their cause-effect relationships), or as a life cycle of an element of a system (from its creation to the disposal/recycling stage and as speed or acceleration of an action), if these variables are relevant for the specific situation. It is worth noting that super-system/sub-system relationships and the past/future relationships are just relative concepts; in other terms, the representation of the System Operator as a nine-screen schema, is just conventional, but its dimension should be considered arbitrarily extendible in any direction.

Moreover, in order to systematically look for resources, a Resources Checklist represents a suitable tool that classifies all kinds of them according to their own nature; an example is shown in Figure 3.2b.

RESOURCES	Before the Phase	During the Phase	After the Phase
Super System			
System			
Sub System			

(a)



(b)

Figure 3.2: Tools for the identification of the resources involved in a process: (a) System Operator, (b) an example of resources checklist.

- *Business process functional modelling*

The business process schematization task is carried out through the employment of a multi domain modelling technique. The scheme allows the organization of the whole set of information related to technical and economical domains in an overall model capable of summarizing both the resources and monetary flows, performances of the phases, control parameters, etc. Such model is obtained through the integration of IDEF0, EMS and TOC modelling techniques.

As recalled in Chapter 2, IDEF0 is used to represent constituent activities and their transformation of inputs into outputs, along with the controls governing the transformation and the resources required for the process. It illustrates the relationship of all the functions as depicted in Figure 3.3, whereas the boxes are the functions themselves and the arrows stand for the inputs and outputs flows (i.e. materials), the control (i.e. all the conditions and states governing the function) and the mechanisms (i.e. all the objects implementing the function). A suitable customization of classical IDEF0 model, consists in adding the time required to perform each activity, which is a particularly relevant issue when competition is significantly based on the time to market.

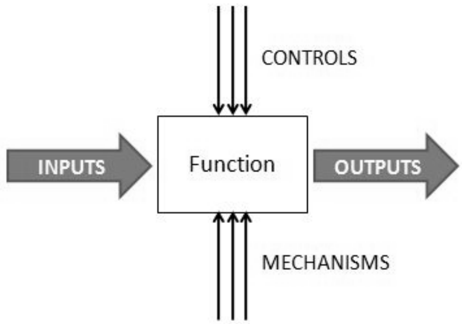


Figure 3.3: IDEF0 formalism for the representation of a process phase. The box stands for the process function or activity (i.e. manufacturing functions, design functions, marketing functions, etc.), the arrows indicate input and output flows and phase constraints.

The EMS model is adopted together with IDEF0 in order to represent also the energy and signal flows of resources. The flows of information and energy in input and output of each phase are represented, but compared with traditional IDEF modelling, a distinction is here suggested between useful and harmful flows, as already proposed in [3.9]. In order to understand the way to determine if a flow should be considered positive or harmful, sufficient or insufficient, it is worth to notice that each elementary phase of the IDEF model is characterized by a function involving a function carrier (in TRIZ terms a "tool"), an action and an object receiving the function. The action is properly defined if it can be expressed as a combination of one among four verbs (increase, decrease, change, stabilize) and the name of a property of the object, in agreement with the Element-Name-Value (ENV) model detailed in [3.10]. The property of the object, e.g. a size, the colour, the electrical conductivity, the shape, is thus set to a certain value e.g. one meter, red, five Siemens per meter, spherical, due to the extent of the function. If the modification of the object property is desired, the function is considered useful, while if the modification of the object property is undesired, the function is considered harmful. Among the useful functions, if the property of the object assumes precisely the expected value, we have a sufficient useful function; besides, if the value of the property is inadequate the function is considered useful but insufficient. With similar criteria, a flow should be considered useful, if its existence is desired in the process, harmful vice versa. Among the useful flows, those with appropriate properties (e.g. quantity, frequency etc) are considered useful sufficient, while inadequate or unacceptably instable flows are marked as useful insufficient. Moreover, all these functions can be tuned according to the specific situation by means of a set of control parameters acting on each phase; the integrated IDEF and EMS model here proposed records also these input physical parameters (e.g. temperature, pressure, frequency of a signal etc.).

Eventually, for the objective of this step, the IDEF0 model should be integrated with the monetary flows involved in the business process. In such a way each activity can be characterized not only in terms of parameters related to the technical domain, but also with economical parameters as costs due to raw materials, tools, labour, investments, energy, financial expenditures etc. The task requires modelling the value of the flows involved within and outside the system and can be suitably performed through the tools provided by the TOC. As briefly described in Chapter 2, according to the TOC, the business process is represented as a technical system constituted by chains of operations, where each ring represents a phase; in Figure 3.4 an example is provided. The streams taken into account in this kind of model are the monetary flows generated by the system that are defined as it follows [3.11]:

- *Throughput (T)*: “The rate of which the entire system generates value through sales (product or service)”: this flow represents the money coming in the system.
- *Inventory (I)*: “All the money the system invests in things it intends to sell”: this is the flow of money that is spent in order to buy raw materials, plants, buildings.
- *Operating Expense (OE)*: ”All the money the system spends turning Inventory into Throughput” this flow of money going out the system to buy labour, utilities, consumable supplies, energy, maintenance, etc.

The monetary flows allow the analysis of the system also in terms of financial and productivity performances. The Throughput analysis performed according to the market demand and its differentiation, could highlight possible margins of improvement of the incomes and the related productivity bottlenecks. Thus, such kind of analysis together with the assessment of the value delivered to the customer, can provide other useful indications about the actions to be undertaken for the process improvement.

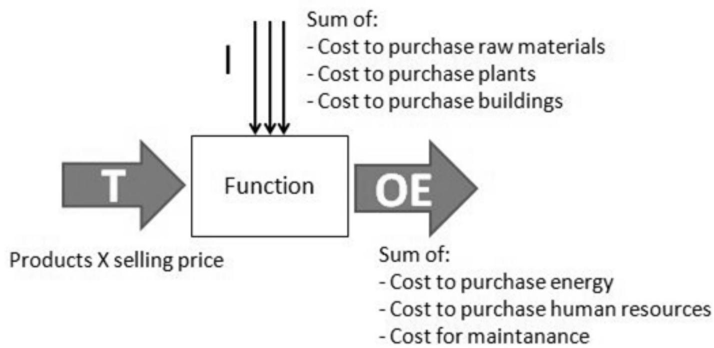


Figure 3.4: Model of a process phase according to TOC paradigm. Throughput is the monetary flow coming into the system through the selling of products whereas Operating Expense is the monetary flow the system spends to produce products. Inventory represents investments on plants and raw materials.

- *Identification of the product value profiles according to the competing factors in the reference market*

Such task is aimed at providing a model capable to highlight and summarize the product or service attributes that are offered to the customer. It is suitable to perform the positioning of the product or service in reference to the competitors and to support subsequent new value proposition activities. With the aim of encompassing all the aspects of possible value for the end-user, the identification of the product attributes on which the competition is played, should be performed along two main dimensions, i.e.:

1. *the product life cycle*: in order to account for possible aspects of value related to different phases of the product life;
2. *different levels of detail*: in order to pinpoint the relevant attributes, through an evaluation of the value sources related to different hierarchical levels of the product/service under investigation, by considering various operating contexts.

Given its flexibility of use, the System Operator can be employed once again as a reasoning tool for mapping a wide range of situations, circumstances and working conditions otherwise neglected, consequently allowing to scout for enhancement opportunities. According to the multi-dimensional nature of the investigation of product attributes, the System Operator is used to individuate known and unknown sources of value for the end-user of the manufactured products or delivered services. It is hereby proposed to adopt a standard subdivision of the temporal dimension according to the Life Cycle perspective:

purchasing and access activities, operations and conditions preceding the employment of the system; the utilization time, the elapsing period before further exploitations; the phases related to the definitive termination of the functions, the disposal, the dismantling. The way of structuring the different levels of detail depends on the complexity of the product or service under investigation (Figure 3.5).

	Buying	**Before use**	**During use**	**After use**	**Disposal**
Super system	Surrounding Environment	Surrounding Environment	Surrounding Environment	Surrounding Environment	Surrounding Environment
System	Product	Product	Product	Product	Product
Sub System	Components	Components	Components	Components	Components

Figure 3.5: The System Operator is subdivided in: purchasing, before use; use, after use and disposal. The rows allow thinking to attributes related not only to the system itself (product) but also to other attributes linked to it: features connected with the environment or context of use (Super system) and/or attributes related to detailed aspects of the product (Sub system).

Once the attributes have been identified, a useful representation of the product value profiles can be performed through the employment of the Value Curve model of BOS [3.12]. Such model stands for a graphical representation of the relative performances of products or services, across the relevant factors of competition for the companies. The Value Curve consists in a two dimensional map whereas the abscissa reports the product attributes generating the customer satisfaction, the ordinate depicts the matching performance level at which each attribute is delivered to the end-user. In Figure 3.6 an example of Value Curve is shown.

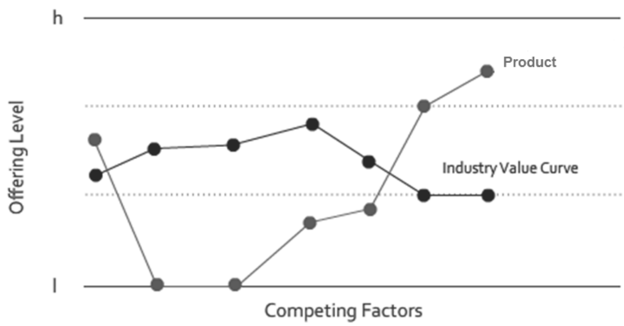


Figure 3.6: An example of Value Curve. In the abscissa there are the product attributes, while in the ordinate the performance at which each product attribute is delivered to the end-user. Such graphical representation allows therefore the positioning of the product with respect to the competitors according to the factors of competition in the reference market.

Eventually, the Relevance index (R) expressing the importance degree that each product/service attribute owns in determining the customer perceived value, is identified by using a scale ranging from 1 to 5. The determination of R is performed by the business sector experts since they are aware of the market and the customer preferences. It is worth noting that a measure of the value delivered to the customer can be preliminarily obtained through the following relation:

$$V_j = \sum_i R_i \times p_{ij}$$

where: Vj is the delivered value of the product or service j, Ri is the relevance index of the attribute i in determining the customer perceived value, pij is the performance of the attributes i of the product or service j.

If the reference market is characterized by a competition played on the differentiation of the attribute performances and all the products present similar value curves, the V index can be used for benchmarking the different items in terms of delivered value. On the contrary, it cannot be used in case of products or services showing very different value curves.

Partial results

The results obtained through the execution of the "Process to Problem" phase are summarized as it follows:

1. *Multi-domain model of the business process*: each phase of the business process characterized by: inputs, outputs, harmful and useful flows of resources, performances, control parameters, monetary flows.
2. *Product value profile*: two dimensional map summarizing the value proposition of the products available in the reference market, according to the factors on which the competition is played.

3.1.2. Problem to Ideal Solution

Objectives

This step is aimed at identifying "what should be changed" in the current reality of the system "AS-IS" in order to improve the benefits delivered to the customer of the manufactured product and delivered services. Generally speaking, such an activity involves the recognition of the process under capacities that hinder the maximization of the customer satisfaction according to the available resources and the market demand. Such an analysis is the key for the identification of proper reorganization activities aimed at improving the value delivered to the end-user.

According to what stated in Chapter 1, the loss of competitiveness of a business process is related, at least, to the following problems:

1. the system is no longer able to provide the value attributes of the product or service;
2. the product or service is no longer able to generate satisfaction due to a change in the customer needs or preferences, which decreases the currently perceived benefits.

Therefore, in reference to the nature of the problem, the actions to be undertaken may regard the process, the product/service or both of them. It is obvious that any change in the performances of the existing attributes and/or the fulfilment of new characteristics, requires a radical modification of the AS-IS process. Indeed the bundle of the current phases, as well as the employed technologies and know-how, may not be able to deliver the new value profile at the proper extent. Thus, solving a problem related to the product or service competiveness through radically changing the value profile, implies a new task aimed at identifying what should be modified in the AS-IS process. Depending on the nature of the problem, this step of the roadmap requires the implementation of the following tasks:

1. *Identification of what should be changed in the process:* this activity is required to solve problems related to the system when it is no longer able to provide the value attributes of the product/service according to the available resources;
2. *Identification of what should be changed in the product or service:* this activity is required if the product or service is no longer able to generate the customer satisfaction.

Phase implementation

- *Identification of what should be changed in the process*

The following steps describe an original approach that has been published in [3.13], named Process Value Analysis (PVA), for measuring the benefits generated by each phase in terms of its own contribution in generating the customer satisfaction.

The method swivels on the set of value adding attributes pertaining the manufactured products or the delivered services. The accomplishment of these attributes along the phases results in customer satisfaction.

The developed approach requires the implementation of four main tasks, summarized below:

1. *Classifying the product attributes according to the Kano model*
2. *Assessment of coefficients expressing customer contentment for the attributes and the process phases*
3. *Comparing benefits and resources of each business process phase*
4. *Identifying directions for value improvement and new values proposition*

1. Classifying the product attributes according to the Kano model

The product or service attributes identified as value elements for the end-user during the “Process to Problem” step, are classified according to the Kano Model of Customer Satisfaction [3.14]. It classifies the product attributes on the basis of their effect on customer satisfaction. Kano Model divides the attributes, defined as Customer Requirements (CRs) in three main categories that play a different role in the product or service perception: Must-Be, One-Dimensional and Attractive.

Must-Be CRs are the attributes expected by the customer; they do not provide an opportunity for product differentiation, since they are commonly accomplished also by the competitors. Decreasing the performance related to these attributes provides diminishing returns due to customer dissatisfaction; their absence or poor performance results in extreme customer dissatisfaction. One-Dimensional CRs are characterized by the extent of customer satisfaction that increases linearly with their performance. Besides, an absent or weak performance attribute determines customer dissatisfaction. Attractive CRs are usually not explicit and unexpected by customers and can thus result in high levels of customer satisfaction, while their absence does not lead to dissatisfaction. These excitement attributes often satisfy latent needs, customers are currently unaware of. In a competitive marketplace where manufacturers’ products provide similar benefits, providing excitement attributes that address “unspoken needs” can determine consistent competitive advantages.

2. Assessment of coefficients expressing customer contentment for the attributes and the process phases

As described above, the attributes of the product/service generated by the business process are classified through Kano CRs categories. It is useful to combine Kano CRs categories into coefficients expressing overall customer value perception of the product or service. Such a practice has been already proposed by several authors as in [3.15, 3.16], introducing:

- Customer Satisfaction (CS), which represents the contribution given by an attribute to provide satisfaction for the product or the service when the related CR is fulfilled;

- Customer Dissatisfaction (CD), which indicates the contribution given by an attribute to avoid dissatisfaction for the product or the service when the related CR is fulfilled.

These CS and CD coefficients are calculated by the following expressions:

$$CS_i = \frac{o_i + a_i}{A + O + M} \quad (1); \qquad CD_i = -\frac{m_i + o_i}{A + O + M} \quad (2);$$

Where:

- CSi and CDi are respectively the Customer Satisfaction and Dissatisfaction indexes for the i-th CR;
- oi, ai and mi are the importance degrees of i-th CR in determining the customer perceived value. The values of these weights are the relevance indexes defined for the product/service attributes that have been identified in the “Process to Problem” step. According to the Kano classification of CRs, the value of oi, ai and mi coefficients are defined as in the following:
  - if i-th CR = “Must be” then mi = Ri, oi=0, ai=0;
  - if i-th CR = “One dimensional” then mi=0, oi=Ri, ai=0;
  - if i-th CR = “Attractive” then mi=0, oi=0, ai=Ri;
- A, O and M are the sum of weights for the i-th CR evaluated as it follows:

$$A = \sum a_i \quad (3); \qquad O = \sum o_i \quad (4); \qquad M = \sum m_i \quad (5).$$

It can be remarked that the CRs having a high CS value are tailored to generate delighting and surprising properties for the product or for the delivered service; besides, the ones with a high CD coefficient (in absolute value) are oriented to fulfil basic and expected characteristics.

In order to relate the business process phases with customer value perception terms, it is hereby remarked that each phase contributes totally or partially to ensure the attributes. In the context of product development strategies, Quality Function Deployment (QFD) [3.17] entails the identification of customer expectations and engineering characteristics that meet these needs. With a similar approach, in the scope of BPR, the proposed procedure requires mapping the features underlying the accomplishment of each CR. Subsequently the phases, properly identified in the “Process to Problem” step, that modify or deal with those features are monitored by the business process experts in order to define their accounted ratios in fulfilling the CRs. The relative contributions addressed to the j-th phase in ensuring the achievement of the i-th CR is indicated with kij. As represented in Figure 3.7, the coefficients kij can be evaluated as a correlation between the properties of the objects modified by each function identified in the multi domain model of the process and the CR of the final product. The ratio gives the possibility to determine for each phase, its own values of Phase Customer Satisfaction (PCS) and Phase Customer Dissatisfaction (PCD) indexes, intended as the potential to bring customer contentment and the contribution in avoiding dissatisfaction. The phase coefficients PCSj and PCDj are calculated as follows through (6) and (7):

$$PCS_j = \sum_i k_{ij} \times CS_i \quad (6); \qquad PCD_j = \sum_i k_{ij} \times CD_i \quad (7).$$

Such values represent consequently the opportunity for a phase to delight customers and the risk to impact harmfully on the product/service perception respectively; the same coefficients indicate, as well, the potentiality to generate unexpected benefits and harm, depending on the accuracy of the phase completion.

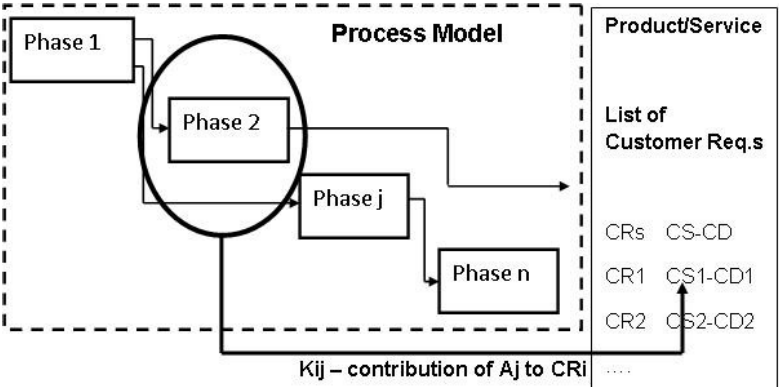


Figure 3.7: The coefficients kij represent the contribution of the jth phase to the satisfaction of the ith customer requirement.

Thanks to PCSj and PCDj it is possible to determine the contribution of each phase to the general customer contentment about the product or the service by means of an indicator named Phase Overall Satisfaction (POS); the one related to the j-th phase will be indicated as POSj. A review of the literature shows that the link of the Overall Satisfaction with terms expressing appreciation or dislike (such as CS and CD, respectively), as well as with positive and negative features, is not univocal. Commonly the impacts of satisfaction and dissatisfaction are related through linear and non-linear equations to the overall satisfaction [3.18]. Among them, a reliable one, obtained through a research work performed by Mittal et al. [3.19], has been adopted by the authors. The employed equation is non-linear and it states the asymmetric influence of positive and negative attributes, with a greater role played by dissatisfaction factors. The POSj can be thus expressed by the (8):

$$POS_j = 0{,}29 \times PCS_j - 0{,}04 \times PCS_j^{\,2} - 0{,}72 \times PCD_j + 0{,}07 \times PCD_j^{\,2} \quad (8).$$

The POS can be assumed as a suitable metric in order to evaluate the benefits arising from each phase of the process in terms of customer satisfaction.

3. Comparing benefits and resources of each business process phase

Within the presented work, the Value of each phase is assessed through the following Indexes:

- the benefits are evaluated with customer value perception indexes (POS, PCS, PCD);
- the expenses and the investments are calculated in terms of involved resources, costs and required times, according to the flows summarized in the multi domain process model.

By using these criteria, the following indexes are calculated in order to compare the benefits delivered to the customer with the involved resources:

- POSj as indicator of the benefits generated by j-th phase:
- RESj as indicator of the general level of employed resources for j-th phase in achieving customer contentment. This index is defined as:

$$RES_j = C_j + T_j \qquad (9).$$

where Cj and Tj are indexes representing costs and time resources spent during the j-th phase.

- Overall Value of the j-th Phase (OVj), expressed as it follows:

$$OV_j = \frac{POS_j}{RES_j} \qquad (10)$$

Other indexes can be likewise introduced, using the coefficients PCS and PCD, giving rise to the Value for Exciting requirements (VEj) and the Value for Needed requirements (VNj). Such parameters, calculated through (11) and (12), represent the suitability of the resources employed along the phases in achieving customer satisfaction through unexpected properties of the product or the service (VEj) and in fulfilling the basic requirements so to avoid strong consumer discontent (VNj):

$$VE_j = \frac{PCS_j}{C_j + T_j} \text{ (11);} \qquad VN_j = ABS(\frac{PCD_j}{C_j + T_j}) \text{ (12).}$$

4. Identifying directions for value improvement and new value proposition

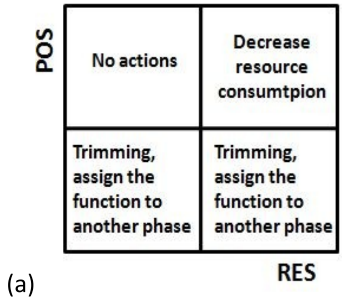
This step provides an interpretation of the previously described value indexes, focusing on the potential directions to increase the business process performance.

The OV index is suitable to identify, through a first evaluation, strong points and constraints among the phases. Those showing a high OV rate can be considered to be tailored to the business process and their employed resources are well spent in generating customer satisfaction, whereas the ones with low scores can represent problematic issues and bottlenecks in the value creation. The analysis of POS and RES indexes can help in identifying the nature of the bottlenecks: when the low OV rate is due to a high denominator, i.e. high expenses of resources, the focus of the BPR must be oriented towards a reduction of the main cost factors. Besides, when the poor OV rate is due to a limited contribution of the related phase to the customer satisfaction, a BPR initiative should evaluate the opportunity either to eliminate such a phase by assigning its role to another phase of the process, substitute the technology adopted so far, assign suitably new functions without a meaningful increase of the needed resources. The “POS vs. RES” chart presented in Figure 3.8a, can be a useful tool to visualize the phase positions according to the actions to be undertaken.

A more detailed analysis of the criticalities can be performed by using the other value coefficients (VE and VN). They can be analyzed independently, but it is even useful to relate them, in order to have additional information for the business process characterization. Such an analysis can be supported by a grid, here named Value Assessment Chart (VAC), where the phases are mapped in terms of VE, VN pairs (Figure 3.8b). Depending on the range of VE and VN rates (high or low value), the phases can be classified in four main areas:

- *Low performance*: the employed resources don’t guarantee an adequate product/service appreciation level and they cannot avoid consumer dissatisfaction. The phases falling in this area thus need strong changes and also the opportunity of their elimination might be evaluated. It has to be carefully investigated whether the low VE and VN rates depend on low benefits or high employed resources. A phase belonging to the former set is often worth to trim, by assigning the same minimal benefits to other existing phases. Besides, if the low value is due to high resources consumption, specific actions aimed at determining a leaner phase should be applied (indeed, this is the case when Lean Manufacturing provides maximum benefits). A further opportunity is to use the excess of resources for generating new attractive properties within the phase.

- *Basic performance*: employed resources don't provide perceivable product/service benefits, but they are well spent to avoid consumer dissatisfaction. Typically, such phases are already optimized and oriented to fulfil the fundamental attributes; they don't need strong modifications and aren't worth of investments.
- *Exciting performance*: in this case, employed resources play an evident role to produce an adequate product/service appreciation level but they cannot avoid consumer dissatisfaction. Such phases are worth of investments in order to maximize their generated benefits; their success is a key to let the product/service to differ from the competitors.
- *High performance*: this quadrant is characterized by phases capable to provide well perceivable sometimes even unexpected benefits, still maintaining an extreme efficiency for fulfilling basic necessary needs. These phases are excellently tailored to the business process and they are worth to be safeguarded due do their high performances.



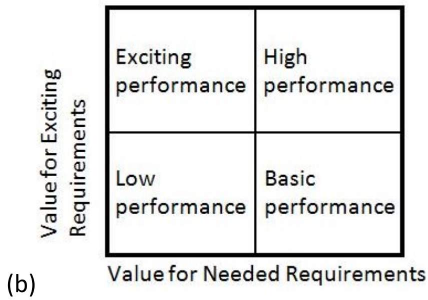


Figure 3.8: (a) POS vs. RES chart can help in identifying the nature of the bottlenecks. (b) The Value Assessment Chart shows at first whether few or many phases are able to deliver value to the business process, coherently with the employed resources.

Further indications can be obtained by taking into account the natural transformation of the needs related to a product or service: according to [3.20, 3.21], needs are first unexpressed, then their accomplishment becomes an attractive element and afterwards they show increasing priority: therefore, Value Assessment Chart areas can be interpreted as a phase characterization in fulfilling requirements entailing different stages of customer wishes evolution. Thus, with the support of market researches, the chart helps in identifying which phases have the adequate features to satisfy any additional requirements. In certain circumstances especially in case of lacking exciting performance phases, new attractive features aimed at ensuring good business performances, have to be taken into account within the process.

- *Identification of what should be changed in the product or service*

As highlighted in Chapter 2, the strategy developed by Kim and Mauborgne results very elegant to describe past successes, but not really prescriptive. Taking into account such limitation, a research activity [3.22] has been performed aimed at making more systematic the BOS logic and structuring its application through Engineering Design tools. Among them, the ERRC model is viable to facilitate the successful transition from the value profile representing the industrial standard to an innovative set of competing factors and related performance levels. The most severe challenge is however the capability, besides poorly supported, to introduce unprecedented and valuable product attributes.

The results of the performed research are reported in the Appendix A1, where an in-depth analysis has been performed, of the successful case studies employed as Blue Ocean Strategy examples, in order to point out common patterns of value evolution. More in detail the survey has individuated which categories of competing factors are preferentially transformed within the treated value transitions with respect to the ERRC actions belonging to the Four Actions Framework. The same attributes have been clustered according to the functional role (in TRIZ terms) they play within customer perception of product and services, i.e. positive outcomes, limitation of undesired effects, reduction of required resources (functional features) and more detailed sub-classifications (sub-functional features).

The output of the research has been the individuation of suitable preliminary guidelines for the definition of product profiles, by observing the evidences of the correlation among BOS actions and product/service attributes. These guidelines are structured as a collection of suggestions in terms of types of new valuable product attributes to create, existing properties to enhance, currents features whose performances are viable to be reduced, and eventually product characteristics to be eliminated without relevant drawbacks.

Here in the following, the developed functional classification of the product attributes and the investigated guidelines are presented in order to explain their application.

1. Functional classification of the product attributes (Functional Features classes)

The application of the developed guidelines, requires the classification of the product/service attributes identified during the “Process to Problem” phase, according to their functional role in determining the customer perceived value. The adopted functional classification refers to the TRIZ Ideality criterion, by which the attributes have been distinguished among outcomes of the useful functions (UF), measures to attenuate or avoid the inconvenience due to harmful effects (HF) and efforts aimed at mitigating the impact of resources' consumption (RES). Due to such definition of the functional features' classes, the increase of each attribute results in a growth of customer perceived value. Furthermore, within each functional class, the attributes have been clustered into sub-classes, as shown in Table 3.1. The UF attributes are distinguished into:

- Threshold achievement (THR), the capability to impact the user at an expected extent;
- Versatility (VER), the capability to adapt the behaviour according to different operating conditions;
- Robustness (ROB), the capability to provide the same desired outcome under varying inputs;
- Controllability (CTRL), the capability to generate the desired outcome according to the user's will.

The HF attributes are classified by considering the direct receiver of the undesired effect, as detailed hereafter:

- the harm impacts the object of the main function of the system (OBJ), e.g. when the mechanism itself adopted to deliver a desired function at the same time causes the undesired side effect;
- the receiver of the undesired effect is the system under investigation itself (SYS), when drawbacks or certain operative conditions jeopardize the integrity and/or reliability of its parts/phases;
- the external environment or some element of the super-system that should be safeguarded (SUP) are harmed, e.g. when dealing with pollution.

The RES attributes are subdivided in terms of the kind of resources needed by the user in order to make the system work correctly. While the classification used didn't include the costs, since these are directly related with the kind of resources that are consumed, the users perceive the amount of expenditures regardless of the motivations of such outlays. Thus the novel categorization differs by adding this item in the RES attributes' sub-classification, specifying however which resources impact upstream for the determination of the costs. Consequently these attributes are distinguished in terms of the diminished consumption of:

- Space (SPA), e.g. the reduced critical dimensions;

- Time (TIME), e.g. quickness in delivering certain operations;
- Information, know-how, need of practice and/or experience (INF), e.g. ease of use;
- Material (MAT), e.g. the avoided employment of tools or substances;
- Energy (ENE), e.g. efficiency;
- Monetary costs (COS), e.g. cheapness

Table 3.1: Functional classification suggested for the product/service attributes.

1st level		**2nd level**	
Useful functions (UF)	positive outcomes delivered by the system to the user	Threshold (THR)	capability to impact the user at an expected extent
		Versatility (VER)	capability to adapt the behaviour according to different operating conditions
		Controllability (CTRL)	capability to generate the desired outcome according to the user's will
		Robustness (ROB)	capability to provide the same desired outcome under varying inputs
Harmful functions (HF)	measures to attenuate drawbacks provoked by the system functioning	on the System itself (SYS)	safeguard of system integrity and functioning
		on the Supersystem (SUP)	limitation of the impact on the surrounding systems and on the environment
		on the Object (OBJ)	limitation of the impact on the user and on the object modified by the system
Resources (RES)	mitigation of the impact due to resources' consumption	Space (SPA)	e.g. the reduced critical dimensions
		Time (TIME)	e.g. quickness in delivering certain operations
		Material (MAT)	e.g. the avoided employment of tools or substances
		Information (INF)	e.g. practice of use, limited skills required
		Energy (ENE)	e.g. efficiency
		Costs (COS)	e.g. cheapness

2. *Guidelines for new value proposition*

At a first glance the main indication provided by the performed research stands in the reduction, within value evolution cycles, of direct benefits and positive outcomes provided by products and services in favour of attenuated impacts of undesired effects and the resources demands requested to customers. The whole set of arisen indication is described in detail in Appendix A1, however the most straightforward for new value proposition tasks are summarized in the following:

- no particular preference is remarked in the implementation of new attributes at the first level of classification; further on, benefits can arise by introducing new features centred on the reduction of employed resources in terms of required information, know how, practice of use;
- within the Raise action it is observed that the meaningful mitigations of the inconveniences due to HF and to the consumption of resources (RES) seem to be recommendable; a leap concerning the cheapness of the system results to be consistently advantageous
- the main trend related to the Reduce action is the drop of the performances defined as UF and specifically of those ranked into Threshold Achievement
- the Eliminate action tends to be applied mainly to the UF attributes; the features that are eliminated or that don't represent anymore competition issues, deal significantly with the versatility and the adaptability of the system, i.e. blue oceans can be found through specialization.

Starting from the whole bundle of the above presented observations, the performed research has led to synthesize eight main guidelines. They help in selecting the functional features to be submitted to the ERRC model. Six out of them recommend the functional classes to be subjected to RAISE, REDUCE and ELIMINATE actions. The other two suggest the functional classes to be considered for the creation of new exciting product or service attributes. Here in the following, such guidelines are briefly described, they have been summarized in Table 3.2:

- the two CREATE actions suggest the creation of an attribute pertaining to the UF THR class and another attribute related to the RES INF class;
- three RAISE actions are applied to the performances of an attribute classified as UF CTRL, one classified as HF OBJ and another one classified as RES INF;
- two REDUCE actions must be applied to the performances of an attribute classified as UF THR and another classified as UF VER;
- the ELIMINATE action must be applied to an attribute pertaining to the UF VER class.

It is worth noting that the number of attributes identified during the "Process to Problem" phase can result greater than the number of guidelines. In such case, it is suggested to select the six attributes pertaining to the functional classes compatible with the guidelines, among those representing well established and competing factors in the reference market.

Table 3.2: Summary of the guidelines for the generation of a new product profile according to the BOS strategy.

Action	**Create**	**Create**	**Raise**	**Raise**	**Raise**	**Reduce**	**Reduce**	**Eliminate**
Feature	UF THR	RES INF	UF CTRL	HF OBJ	RES INF	UF THR	UF VER	UF VER

Partial results

The outcomes of the "Problem to Ideal Solution" phase can be summarized as in the following:

1. *Process*:
    - evaluation of each phase contribution in determining the customer satisfaction and in avoiding the customer dissatisfaction through a set of indexes of value, taking into account all the employed resources.
    - Determination of the evolution paths aimed at obtaining radical process improvements based on the value generated for the customer of the product/service whose business process is under investigation.
2. *Product/service*:
    - Specifications of the TO-BE product in terms of new/modified attributes.

3.1.3. Ideal Solution to Physical Solution

Objectives

This step of the roadmap consists in the application of the appropriate measures to attain the new process/product/service specifications obtained from the "Problem to Ideal Solution" phase. Such goals have to be translated in technical objectives and organizational changes, allowing to put in practice all the needed business process modifications.

Thus, the objective of this step is the identification of the proper functions to be performed and the search of appropriate behaviours for their implementation, such as physical principles and new technologies. Generally speaking, the tasks related to this step are the same involved in a "traditional" Conceptual Design phase of the Product Development Cycle (PDC) [3.23].

Depending on the outputs that are provided by the "Problem to Ideal Solution" phase, the following tasks are implemented:

1. *Finding physical solutions for new process implementation.*
2. *Finding physical solutions for new product/service implementation.*

Phase implementation

Here in the following a set of tools are summarized, useful to offer appropriate guidelines for finding solutions that fit the specifications identified in the previous step. They refer to the search of solutions for the implementation of the new process as well as for the implementation of the new product/service ideas related to the new attributes profile.

- *Finding physical solutions for new process implementation*

According to the outcomes of the "Problem to Ideal Solution", the value indexes help in defining the appropriate strategies for each phase of the business process; the directions to be followed can be classified in three different categories:

1. increasing the phase value through the improvement of its performance and effectiveness or the supply of new CRs;
2. increasing the phase value in terms of efficiency, i.e. through the reduction of the involved resources, while preserving the same benefits;
3. suppressing low value phases or eliminating some of their expected features, with the consequent modification of other process sections that, should fulfil the consequently unsupplied CRs.

Classical TRIZ tools, i.e. the 76 Standard Solutions [3.24], represent suitable instruments to increase the performance or the efficiency of the phases (directions 1 and 2). More precisely, once that the critical function of the phase to be enhanced has been identified, the Standard Solutions allow to increase its effectiveness, through the introduction or modification of appropriate substances and/or fields (standards belonging to class 1.1) or through a more efficient use of the existing resources (standards belonging to class 2).

Many methodologies deal with policies within manufacturing environment and they are mostly tailored to reduce useless resources, so that they address the second direction for phases modifications. In this context, the Lean

Manufacturing [3.25] and Quick Response Manufacturing (QRM) [3.26] provide valuable suggestions for business improvements.

Lean Manufacturing proposes a large set of tools that aim at reducing wastes, meant as those activities carried during the production stages that don't bring any added value. Lean Manufacturing introduces a pull-based supply chain, whereas procurement and production are demand driven and thus coordinated by actual customer orders. The supplying and the purchases are ruled by Just in Time (JIT) strategy, that aims primarily at the reduction of in-process inventory.

Besides, the reduction of the operational times can be obtained through the means of QRM, whose target is the minimization of lead-times. In order to provide further benefits QRM methodology should be applied to the whole supply chain, strengthening the cooperation among the involved firms.

The suppression of phases with the consequent assignment of useful functions to different process stages (third direction) can be done through the employment of Value Engineering, that provides the means for trimming parts of a system, that aren't worthwhile to be kept.

The subsequent assignation of new properties to a certain phase can be supported by the individuation of existing techniques in dedicated knowledge bases. Scientific documents and especially patents represent the widest available source of technical information close to the technological frontier. An efficient approach to speed up the identification of relevant technical contents from articles and patent databases is described in Cascini et al. [3.27, 3.28]. The individuation of proper ways to put in practice additional features of the phases can be done also with a set of function retrieval tools. In the scope of TRIZ, Function-Oriented Search (FOS) [3.29] is especially suitable to find and apply existing functions, also from different technical fields. FOS is an evolution of the TRIZ concept assessing that the shortest path to an effective solution is to use an analogy. The tool leads the user in the identification of the key problem, the formulation of a generalized function to be achieved, the individuation of the most appropriate industrial area to be investigated, the selection of the technologies closest to required functional parameters.

- *Finding physical solutions for new product/service implementation*

According to the results obtained from the previous Section, a new set of product/service specifications in terms of CRs is obtained. Thus, before performing any conceptual design activity, such CRs must be translated in Engineering Requirements (ERs) of the new system, that represent the specifications against which the suitability of the solutions generated in this step can be judged. A useful method used to support the preparation of the ERs list is the QFD [3.30], that helps to translate customer wishes into product requirements. Moreover, through the QFD House of Quality, the designer can have a clear vision of the criticalness related to design problem since it allows the identification of any positive or negative correlation among the product requirements.

According to the nature of the design problem and its complexity degree, it may happen that no inventive step is required to obtain the successful solution, but just the application of the knowledge already available within the design team: the recalled TRIZ 76 Standard Solutions are an excellent structured checklist which allows to browse the team knowledge with a systematic approach. Other suitable methods to support this kind of design task, such as Systematic Search with the Help of Classification Schemes, Design Catalogues, etc. are presented in [3.23].

Besides, if the previous analysis points to the necessity to overcome a trade-off due to conflicting requirements, the design task requires the application of tools for the identification and solution of physical contradictions such as those suggested by the TRIZ Theory. As a result, a conceptual solution is generated in terms of physical properties of the system that allows to satisfy the conflicting requirements according to the available system resources. Recently an implementation of these techniques in a Computer-Aided Inventive Problem-Solving environment has been proposed in [3.31].

Due to the nature of the TRIZ inventive process, the conceptual solution could be derived from any field of application; thus its embodiment into an engineering solution may involve multidisciplinary competences, even external to the design team knowledge. This task can be suitably supported by Knowledge Management (KM) tools, in order to retrieve and analyze relevant technical contents from patents, scientific journals etc. even with limited resources. A viable tool to speed up the identification of relevant technical contents from articles and patent databases may be the already recalled approach that has been presented in [3.27, 3.28].

Partial results

The partial achieved results are the physical solutions for the implementation of both the TO-BE process and the TO-BE product/service.

3.1.4. Physical Solution to Engineering Solution

Objectives

The solutions developed in the previous phase are then evaluated to establish the opportunities for implementation in the business process. A simulation of the TO-BE situation is performed in order to verify the impact of the proposed innovations in terms of functional and economical parameters and to compare the updated Throughput/Operating Expenses with the AS-IS process, according to the market opportunities. Eventually, the conceptual solution identified for the new product/service is hereby embodied in the structure TO-BE.

Phase Implementation

Once again the multi domain modelling techniques presented in the "Process to Problem" step can be advantageously employed to synthesize the TO-BE situation with the new/modified phases, the new monetary and resources flows. For each phase of the TO-BE process both technical and economical evaluation parameters are updated according to the ENV and TOC models respectively. As far as the modifications introduced in the TO-BE model are based on typical engineering solutions, their expected impact can be adopted to perform a benchmark between the TO-BE and the AS-IS model in order to verify both Throughput and performance improvements. Besides, if these technical solutions require the implementation of new technologies, CAE tools and Virtual Prototyping techniques can be also used to perform a preliminary evaluation of their unknown performances.

If a value transition has been carried out through the application of the new value proposition guidelines, a preliminary investigation is required aimed at determining the main process limitations in delivering the new product/service profile. Additionally, a shift of the value offered to the end-user necessarily involves radical modifications of the phase contributions in generating the customer satisfaction or dissatisfaction. Thus, the AS-IS phases must be evaluated with respect to the TO-BE product/service attributes which become the new CRs to be fulfilled. This task can be partially supported by the tools for the identification of "what should be changed in the process" that pertain to the "Problem to Ideal Solution" step of the roadmap. Such assessment may lead to the identification of relevant evolution paths. More in particular, according to the guidelines for new value proposition that have been applied to the product/service attributes, the following scenarios can appear:

1. the product attributes that experienced an Eliminate action can involve the elimination of the phases related to them or their orientation towards the fulfilment of the new aspects of value of the product or the service;
2. the product attributes that underwent the Raise or Reduce actions can involve the reorganization of the related phases in order to deliver the new required levels of performances;
3. the new product attributes arisen through the Create action can require the introduction of new phases and resources. It is indeed expected that

the current process stages are not tailored to fulfil the novel customer requirement.

Once such preliminary assessment has been carried-out, the implementation tasks of the TO-BE process tailored on the new product/service profile can be easily supported by the tools for “Finding physical solutions for new process implementation” already described in the “Ideal Solution to Physical Solution” Steps.

Partial results

The results of this phase are the prototype of the TO-BE process updated with the new phases and the new resources and monetary flows. Another output of this phase is the prototype of the new product/service.

4. Test of the method

In this Chapter the application of the proposed methodology to several case studies involving different BPR problems is presented with the aim of verifying the effectiveness and the usability of the overall approach.

In Section 4.1 the steps 1, 2 and 3 of the roadmap are applied to the Italian accessible fashion footwear industry in order to identify business process reorganization activities aimed at preserving the competitiveness in a sector, characterized by a fundamental role played by the timeliness on the market. The Section 4.2 presents the application of the whole methodology to the Italian industry of wood bio-fuel that experiences process under capacities in satisfying the market demand of wood pellets due to poor performances of the adopted technologies. Eventually, an exemplary application aimed at demonstrating the use of the new value proposition guidelines, is presented in Section 4.3: the case study concerns a new value proposition initiative regarding the professional hair dryers. For each case study a brief discussion of the achieved results is performed according to the specific objective of the testing activity.

4.1. The Italian accessible fashion footwear industry

The methodology has been applied to a branch of the Italian footwear industry. The sector has strongly contributed to the Italian industrial growth in the last decades of the 20th century and played a significant role in the success of products marked “Made in Italy”, synonym of prestige, glamour and fashion. The footwear branch is however facing a crisis period, although the style of the Italian shoes is still successful. The data available from 2000 to 2006 (provided by ANCI, Italian National Shoe Factories Association) highlight a decrease in turnover (from 8,269.3 to 7,198.7 million Euro), active firms (from 7,570 to 6,657) and employees (from 113,100 to 94,143).

In order to invert the trend, a project, named Just In Time for Shoes (JITS), funded by Tuscany Region and coordinated by PQuadro, a consultancy society for the enterprises with a wide experience in the footwear industry, indicates a potential help for a large share of fashion shoe factories in quick response strategies, that individuate speed as the key competitive factor for the enterprises strategic repositioning. The quick response methodologies rose during the 80s in the apparel sector [4.1, 4.2], that has first expressed the need to speed up the items market introduction. Few efforts in the adoption of quick response policies have been done also in the footwear industry with remarkable results [4.3], especially in the cases that the whole supply and retailing chain has been involved.

Within the JITS project, the developed roadmap was applied with the aim to analyze the whole footwear business process in order to rank its phases and to remark the greatest lacks and the most promising opportunities for implementing quick response strategies and for increasing the firms competitiveness.

This Section first describes the problems faced by the Italian footwear sector, with a special focus on the so called "accessible fashion firms", and then all the steps leading to the comparative value analysis among the business process phases in charge of the shoe factories. This case study has been already published in [4.4].

4.1.1. General overview of the business process

The yearly activity of the footwear industry is mainly based on two market seasons (summer and winter). This feature strongly influences the set-up of production and manufacturing activities; the main phases of the process may be summarized as follows:

1. Samples manufacturing stage: a collection of samples is created according to style and relevant features of the shoes, that are attributed by a stylistic staff on the basis of the fashion trends. The factories sell their items on the basis of these samples, whose production requires three-dimensional models and prototypes, that imply several tests. The output of the prototyping is also the bill of materials for each model of shoe of the collection, that is required for the manufacturing stage scheduling, for the purchases planning and by the determination of the prices.
2. Selling stage: this task, that is preceded by the prices determination on the basis of the shoes expected cost and potential commercial success, is carried-out by selling agents and through sector fairs. In this phase the factories receive selling orders of shoes on the basis of which they manufacture these items. During this stage the agents and the sellers

continuously update the factory about the sold batches, so that the manufacturing is scheduled on the basis on more and more reliable forecasts.

3. Supplying and manufacturing stage: all the process swivels on the manufacturing and purchasing planning; the manufacturing organizer and the purchases responsible have an overview on the rate of production, on the accuracy and the timeliness of the operations. The shoes manufacturing is constituted by several sub-tasks (production of working tools such as dies and shoe lasts, leather, heels and components purchasing, uppers manufacturing and sewing, assembling etc.), most of them, due to economic convenience, are carried by subcontractors (usually both offshore and onshore). The produced shoes are then shipped to the retailers. The shoe factory has to put attention on the flawed products along the whole manufacturing stage.

Figure 4.1 provides a graphical representation of the main activities involved in the shoe factories' business process.

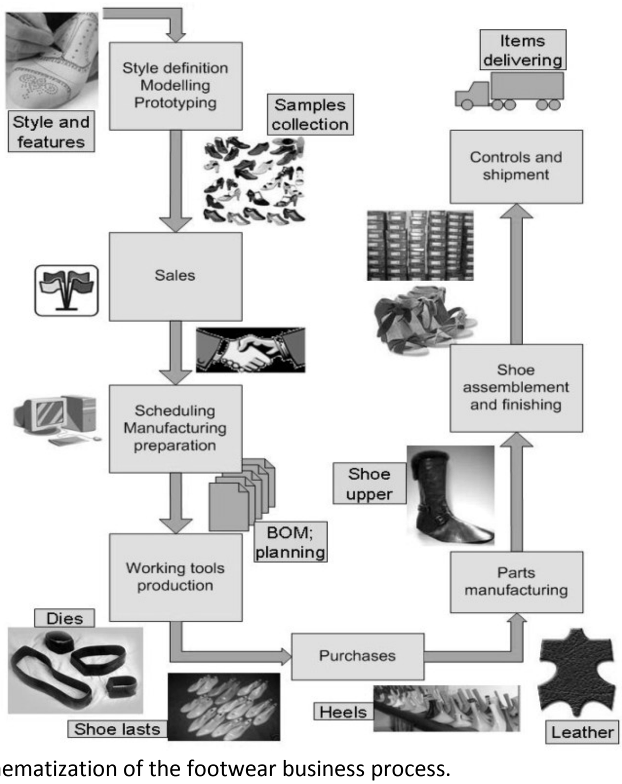


Figure 4.1: Schematization of the footwear business process.

The Italian footwear sector comprises a group of famous brands (e.g. Gucci, Prada, Dolce & Gabbana, Just Cavalli, Patrizia Pepe Firenze, etc) and a multitude of accessible fashion factories. The brands belong mostly to luxury market segment and determine or somehow strongly influence the emerging fashion trends. These high fashion industries show a good market share, since their success is based on the customers' fidelity due to their identification with the brand. The products of the accessible fashion factories address the consumers of a large income bracket. These firms cannot rely their competitiveness on low prices of the items due to the higher margins of cost reduction characterizing the emerging countries where the labour is much cheaper. Among the others, the worldwide market of discount shoes is dominated by Chinese products and the economical trends highlight further reductions of Western productions in this market sector.

The same accessible fashion factories cannot aspire to enter the high-end market, because they miss the means, the organizational structure and the know-how of the brands. Due to the characteristics of the actual business process the collection of shoe samples must be produced much before than the shoes are effectively sold to the end users. In the meantime, the powerful influence of the brands induces strong changes in the vogue trends, resulting in a mismatch between the tastes of the final consumers and the stylistic features of the items produced by many shoe factories. This generates large amounts of unsold goods coming from the accessible fashion shoe factories, leading to retailers' dissatisfaction towards these firms and influencing negatively repurchasing intentions. As a consequence the accessible fashion firms lose relevant market shares. In such context the steps 1, 2 and 3 of the roadmap have been applied in order to identify relevant BPR guidelines for the industrial sector.

4.1.2. Application of the method

Process to Problem

The information gathering of the business process has been carried out in several stages, in order to get a reliable outline of the sector, focusing on accessible fashion shoe factories.

At first, a general background of the common business processes related to the sector has been obtained through the consultation of the technical publications in the field, so creating a first functional model of the business process, that has been then repeatedly enriched and updated.

The second stage has been carried out through interviews with sector experts who cooperated at the project (a business process analyst with 20 years of experience in the field and three entrepreneurs), in order to receive further information about the well-established practices regarding the business and manufacturing processes. The information coming from the different sources has been compared and some contradicting issue has been clarified. The resulting business process model has been then confirmed through the interview of the production managers and the visit of the shop floors of three shoe factories. This last stage has provided further information, such as:

- common problems faced in the business planning;
- constraints related to the manufacturing stage (i.e. common production capacity of the devices, sequence of the operations to be performed, rules to be followed);
- extent of the involved resources in terms of costs;
- employed personnel and tasks;
- common duration of the phases.

Such additional information represents the core of the uncodified knowledge, that allows do determine the most meaningful parameters concerning the business process (care of the stylistic features, timeliness of the subcontractors, success of the manufacturing planning, flows of material to be reworked, etc.). The information gathering process has been stopped when process control parameters and performance assessment means have been properly codified and correlated. More precisely, each activity described by the industrial partners has been investigated in order to elicit the preferred criteria to measure the degree of satisfaction end the technical parameters impacting the process performance.

The whole information has been reorganized through multi domain process model in order to describe each phase of the business process through its activities and their input/outputs. All the companies analyzed within the JITS project are characterized by a substantially similar production process; therefore, it is possible to perform a single analysis capable to provide relevant directions to the whole sector. Thus, the detail level of the model has been limited to the representation of the common structure of the analyzed processes. It is clear that some phases could be further segmented (e.g., the purchasing activity and the manufacturing stage), but the employment of the resources of the sub operations is strongly dependent on the specific firm. Indeed the kind of shoes (classical shoes, sandals, boots, moccasins etc.), the characterizing stylistic features (use of accessories, presence of decorations and seams), the reference markets (South Europe, North Europe, USA, Russia, Japan etc.), the sex of the end users, the collection (summer or winter) heavily influence the process practices, resulting in noticeably different use of resources (financial commitments, duration of the activities, employed labour, carefulness in operations performing).

Moreover, also the benefits arising from the business process and the link between the phases and the attributes of the manufactured items and of the service delivered to the retailers, have been analyzed. Thanks to collaboration with the sector experts, 14 CRs have been individuated as competing factors in the sector, they are summarized in Table 4.1 (see p. 75).

The functional model of the business process is shown in the Figures 4.2 – 4.5 (see pp. 71-74); the main representation includes also the retailing stage, but this won't be subsequently considered, because of being out of the influence of the shoe factory. Figure 4.6 (see p. 75) illustrates the activities duration (whereas the periods are referred to the production of a summer collection) and Table 4.2 (see p. 76) summarizes for each phase the indicative involved costs and elapsed times, in terms of dimensionless quantities as expressed by the rates in the (1) and (2).

$$\text{Cost\_rate} = \frac{\text{Phase\_cost}}{\text{Whole\_variable\_costs}} \quad (1); \qquad \text{Time\_rate} = \frac{\text{Phase\_duration}}{\sum \text{Phase\_durations}} \quad (2).$$

It is worth noting that the Inventory and Throughput flows have been neglected since they are useless in reference to the objective of the current BPR. Indeed, as stated in the previous section, the business process problem it isn't related to productivity bottlenecks. Also the Value Curve of the product is useless thus it has been omitted. In fact, the problem of competitiveness is related to some inefficiencies of the process itself.

Eventually, the relevance indexes Ri expressing the contribution of each CR in determining the customer perceived value, have been identified by the business sector experts. They are summarized in Table 4.3 (see p. 76).

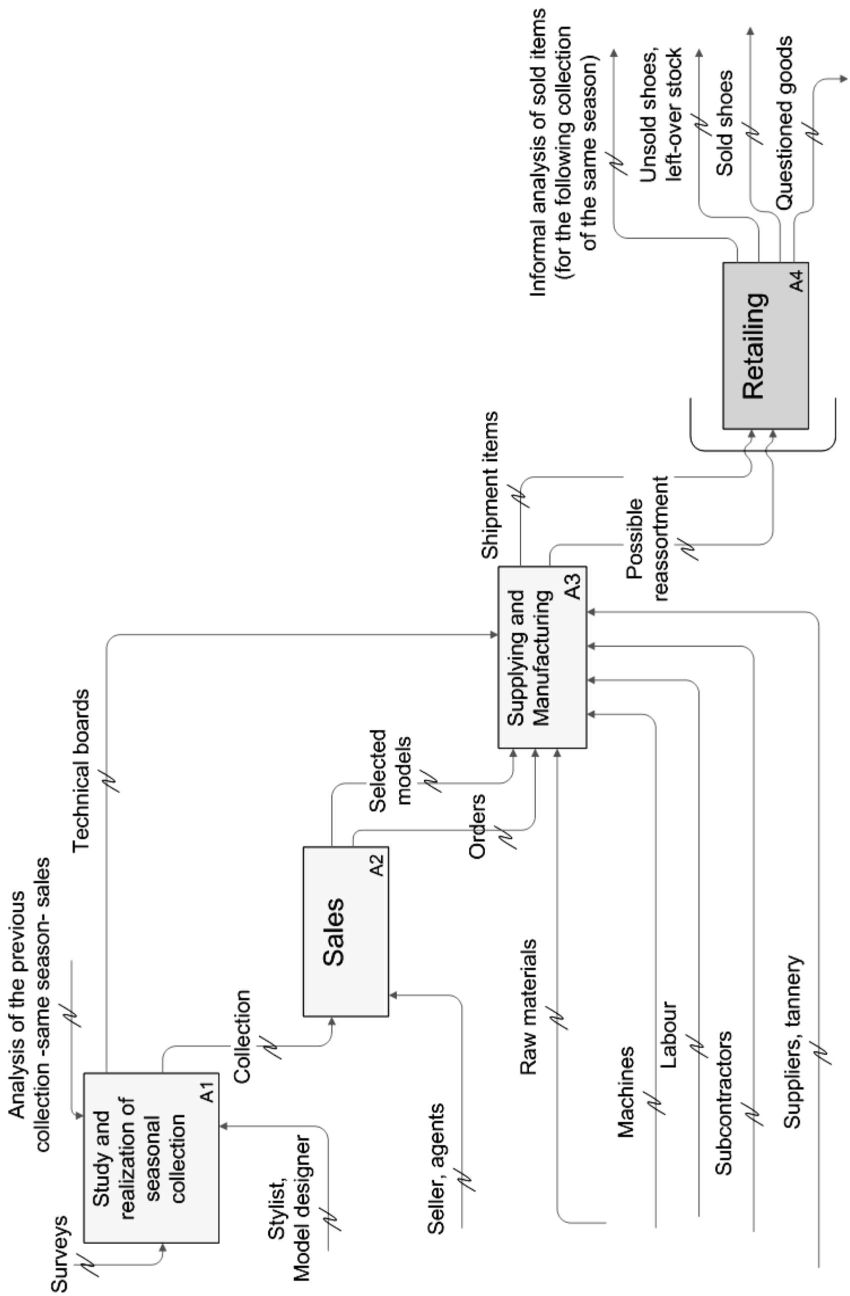


Figure 4.2: Functional schematization of the footwear business process (first level diagram).

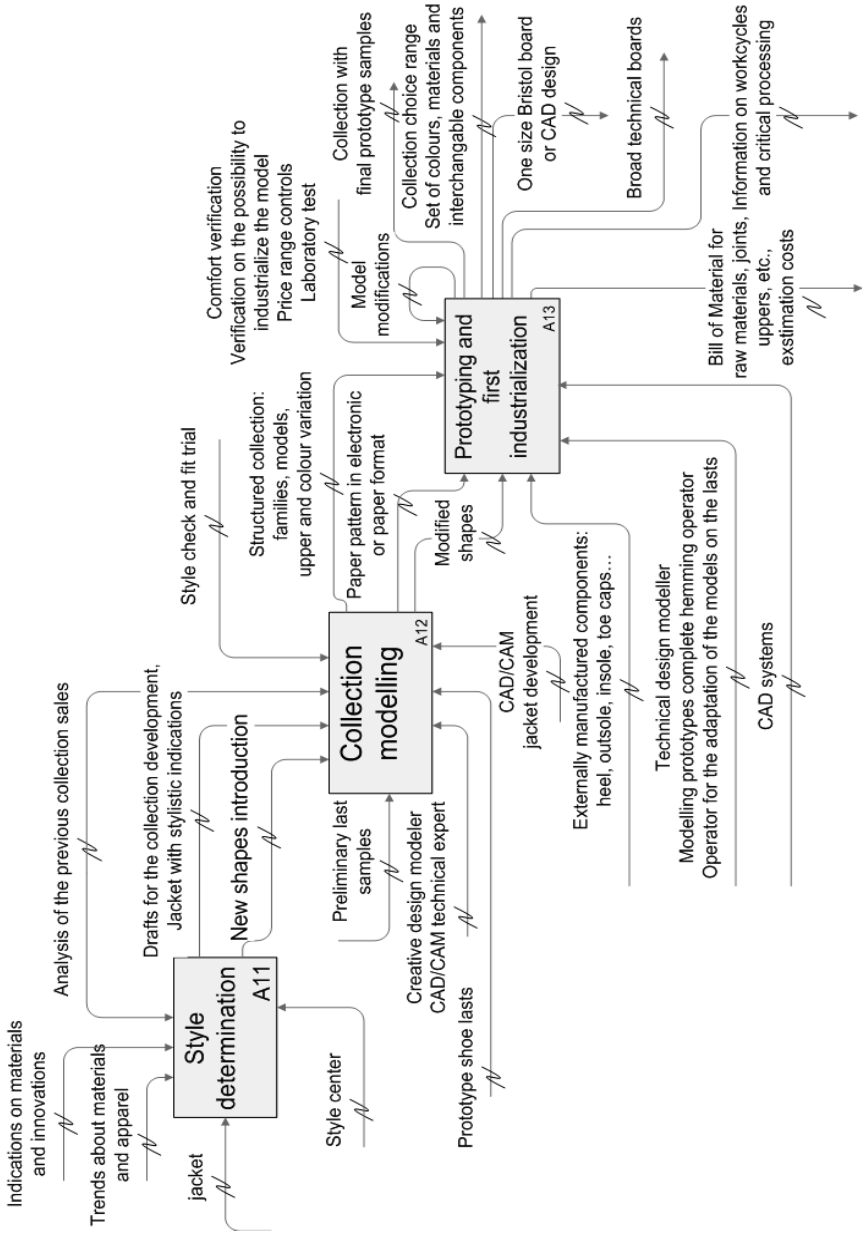


Figure 4.3: Functional schematization of the footwear business process (second level: detail of the study and realization of the seasonal collection).

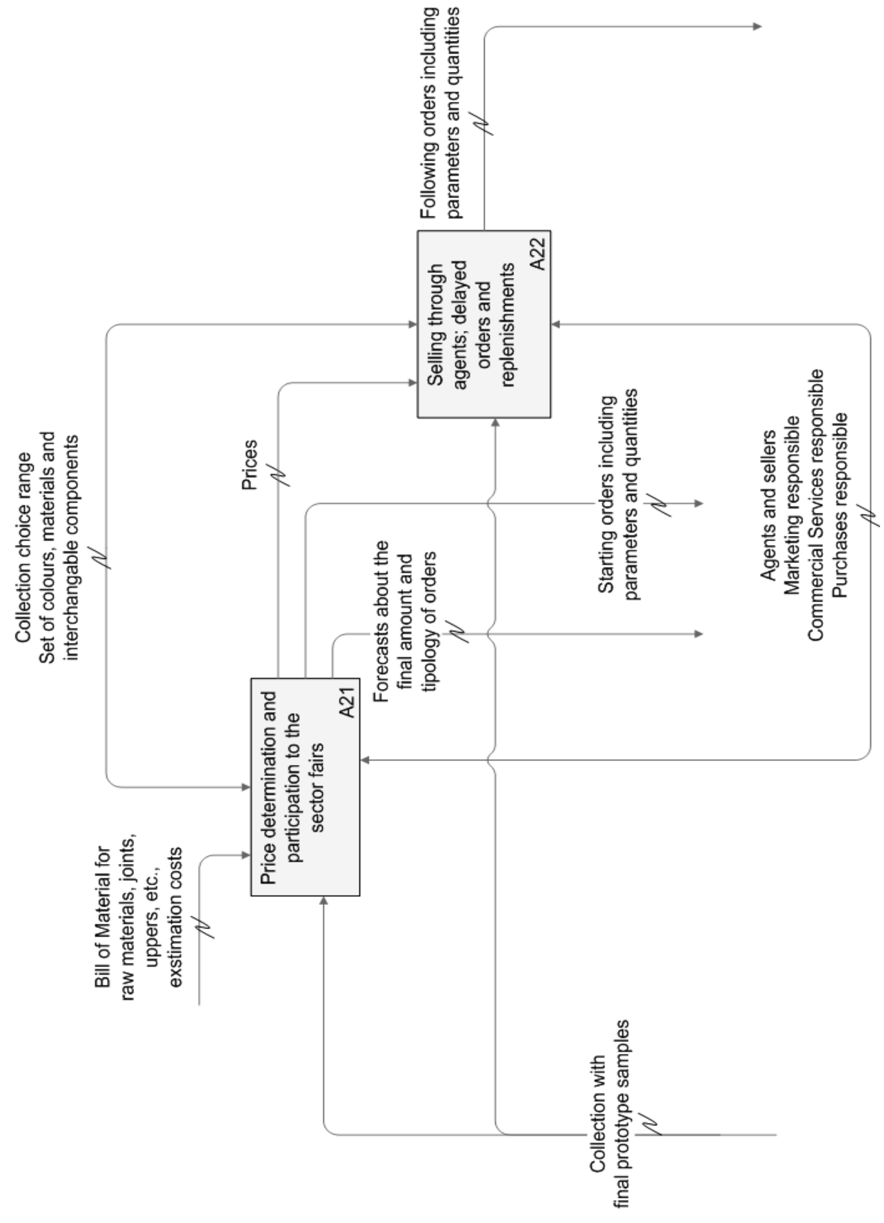


Figure 4.4: Functional schematization of the footwear business process (second level: detail of the sales stage).

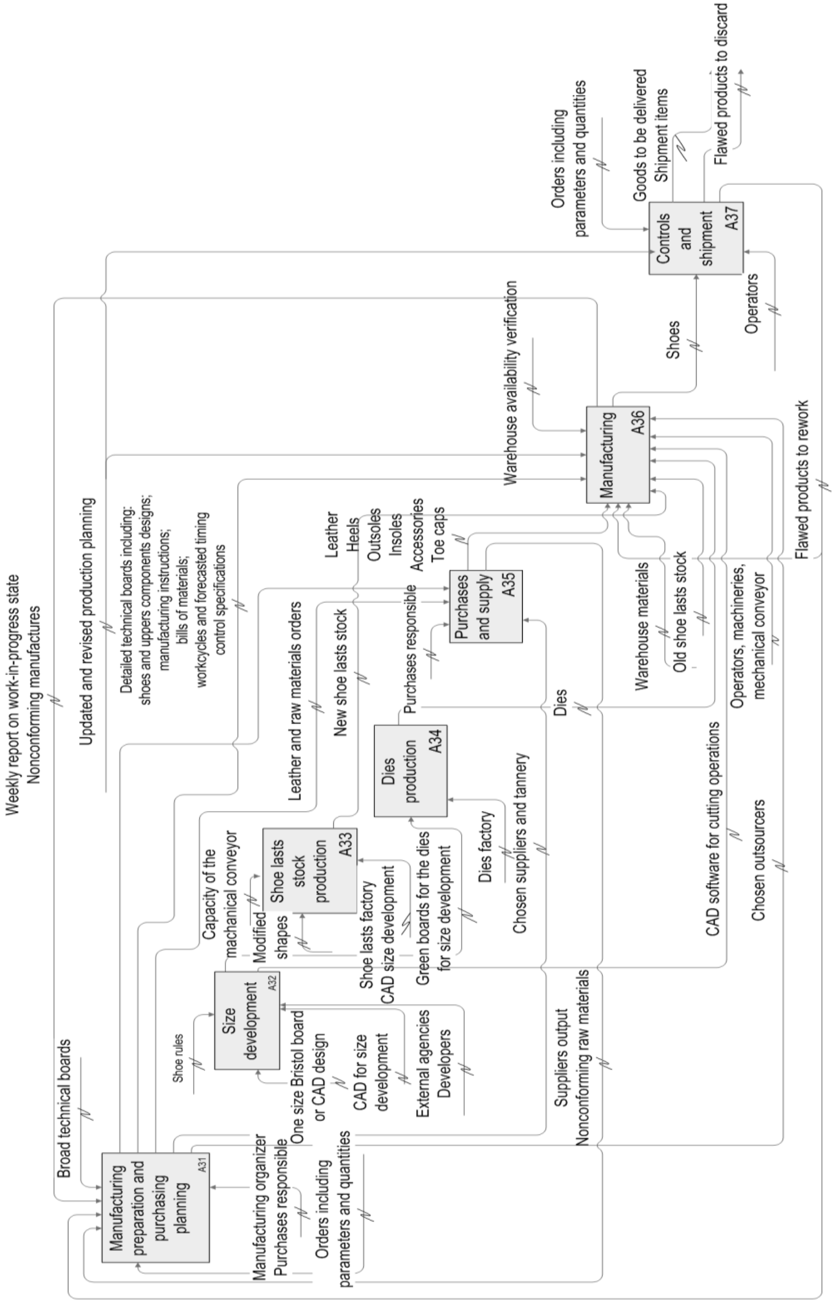


Figure 4.5: Functional schematization of the footwear business process (second level: detail of the manufacturing stage).

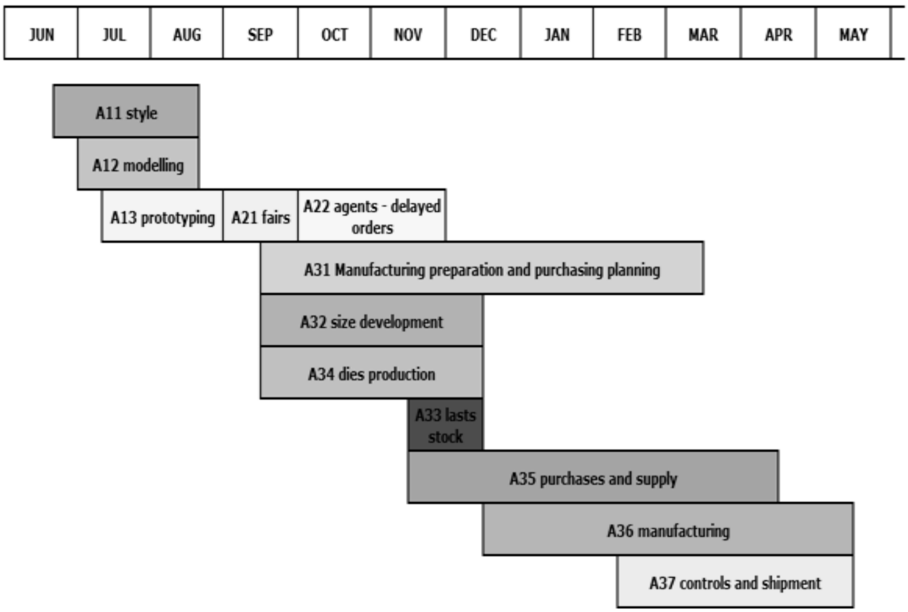


Figure 4.6: Phases duration in the business process for a summer collection.

Table 4.1: Customer Requirements in the footwear business process.

CR	Business process attributes
CR1	Customization possibility
CR2	Link with the apparel sector
CR3	Comfort
CR4	Technical and healthy properties
CR5	Standard dimensions availability
CR6	Resistance and duration
CR7	Components completeness
CR8	Manufacturing care
CR9	Care in the order fulfilment
CR10	Non-standard dimensions availability
CR11	Appeal, lines, shapes
CR12	Colours and materials variety
CR13	Possibility of developing faithful customers
CR14	Offer potentiality

Table 4.2: Cost and time rates for business process phases.

Phase Code	Phase	Cost rate	Time rate
A11	Style determination	0,01	0,06
A12	Collection modelling	0,02	0,05
A13	Prototyping and first industrialization	0,02	0,05
A21	Price determination and participation to the sector fairs	0,01	0,03
A22	Selling through agents; delayed orders and replenishments	0,09	0,06
A31	Manufacturing preparation and purchasing planning	0,03	0,17
A32	Size development	0,00	0,09
A33	Shoe lasts stock production	0,01	0,03
A34	Dies production	0,02	0,09
A35	Purchases and supply	0,36	0,15
A36	Manufacturing	0,42	0,15
A37	Controls and shipment	0,01	0,08

Table 4.3: Classification of the customer requirements and determination of the customer contentment indexes.

CR	Kano category	Rilevance Index (1 - 5)	a_i	o_i	m_i	CS_i	CD_i
CR1	Attractive	4	4	0	0	0,10	0,00
CR2	Attractive	3	3	0	0	0,08	0,00
CR3	Must-be	2	0	0	2	0,00	-0,05
CR4	Must-be	1	0	0	1	0,00	-0,03
CR5	Must-be	2	0	0	2	0,00	-0,05
CR6	Must-be	1	0	0	1	0,00	-0,03
CR7	Must-be	5	0	0	5	0,00	-0,13
CR8	Must-be	2	0	0	2	0,00	-0,05
CR9	Must-be	4	0	0	4	0,00	-0,10
CR10	One-dimensional	1	0	1	0	0,03	-0,03
CR11	One-dimensional	5	0	5	0	0,13	-0,13
CR12	One-dimensional	4	0	4	0	0,10	-0,10
CR13	Attractive	3	3	0	0	0,08	0,00
CR14	One-dimensional	3	0	3	0	0,08	-0,08

Problem to Ideal Solution

According to the objective of this BPR initiative, the problem of competitiveness in the reference industrial sector, is related to the process itself, thus in this step, the identification of what should be changed in the process has been performed.

Classifying the customer requirements according to the Kano model

Thanks to the collaboration with the sector experts, the CRs summarized in Table 4.1, have been characterized by Kano categories with an importance levels ranging from 1 to 5, all the data are shown in Table 4.3.

*Definition of coefficients expressing customer contentmen*t

The attributes ensured during the business process have been matched with the phases, depending on their contribution in fulfilling such requirements. The business experts have indicated the coefficients kij that are the fractions addressed to each phase in ensuring the achievement of the CRs, they are shown in Table 4.4 (p. 79). Then the collected data have been used to calculate the customer contentment indexes CS and CD for each CR that are shown in Table 4.3, and those related to the phases PCS, PCD and POS, that are presented in Table 4.5 (p. 80), by using the relations presented in the Section 3.1.2.

Comparing benefits and resources of each business process phase

Through the relation presented in the methodological chapter, the value indexes that express the phases performance compared with the employed resources have been calculated. The overall efficiency of the phases is evaluated through OV. At the same time VE and VN point out the phases' contribution to achieve delighting and basic product/service properties, respectively. The results, ordered by decreasing Overall Value scores, are shown in Table 4.6 (p. 80).

As explained in the methodological part, the phases can be also characterized through the relation between their VE and VN indexes, so to get additional information about their performance. Figure 4.7 (p. 81) shows the grid where the points representing the phases have been drawn. The average values of VE and VN (both around 0,6) have been chosen to discriminate the four performance areas. In Figure 4.8 (p. 82) the low performance area is shown more in detail.

Identifying directions for value improvement and new values proposition

The Overall Value index shows that the main critical issues concern the phases dealing with the manufacturing, the supply chain and the working tools production. These phases, that take place after the items engineering, represent a bottleneck in the value chain creation process showing a growth in the employed resources.

The charts of Figures 4.7 and 4.8 show that several phases belong to the low performance area; this means that technological and organizational changes should be applied along many stages of the business process. Conversely some phases are tailored to ensure both the basic properties and those product/service attributes, which are unexpected and generate a higher level of customer value perception.

The phase attending the shoes line style is marked by High Value, but the fulfilment of exciting features is strongly predominant. Only manufacturing preparation and purchasing planning phases belong to the Basic Value area; this stage is mainly constituted by management activities and control operations aimed at dispatching correctly the orders. Among the phases in Low Value area, the ones with the worst value indexes are characterized by prevalent orientation towards the necessary features and by large resources utilization; the dies production process shows even limited benefits.

As a consequence, on the basis of the meaning attributed to the four value areas, the following evolution paths and guidelines about the business process reengineering have been identified:

- the phases belonging to high and Basic Value area have to be safeguarded and no deep change should be applied;
- the position of the phases A12, A32 and A33 is doubtful, straddling the low and basic benefits areas; in each case although their low value these operations aren't the ones requiring the greatest attention;
- the phase A34 regarding dies production and showing very low benefits is worth to apply technological changes;
- the phase A37 concerning controls and shipment with low benefits is difficult to be modified, unless deep transformations in the business process are applied; however its development can be oriented just in the performance maximization towards basic requirements fulfilment;
- the phase A22, selling through agents, is situated in the centre of the Low Value area and it is the only one showing the opportunities to jump in the region of Exciting Value;
- the manufacturing stage A36, still in Low Value area, is markedly orientated towards the basic properties accomplishment, showing a big amount of involved resources; the phase is fragmented and the coordination of its inherent activities results difficult and time consuming, especially when the participation of offshore outsourcers occurs, because of transportations and exponentially increasing delays in case of mistakes or flawed semi-finished goods to be reworked or remade;

- the phase A35 concerning purchases belongs to area A because of a high range of consumed resources; if the reduction of raw materials cannot be pursued in the shoe factory's sphere of influence, a reduction in time resources is possible, so to approach the phase towards the Basic Value region;
- no phase is currently situated in the Attractive Value region and there's a need to investigate the emerging trends and the successful issues in the footwear sector, thus leading to revise the business process phases or even to add new ones; the main tendency in footwear, although cross-sectorial, is related to mass customization phenomenon, whereas already in the past years a research [4.5] reveals that shoe consumers "are curious about the customization concept and do realize the related benefits"; moreover the potential success of customized fashion items is deliberately assessed [4.6, 4.7].

Table 4.4: Phases contribution (kij) in fulfilling the customer requirements.

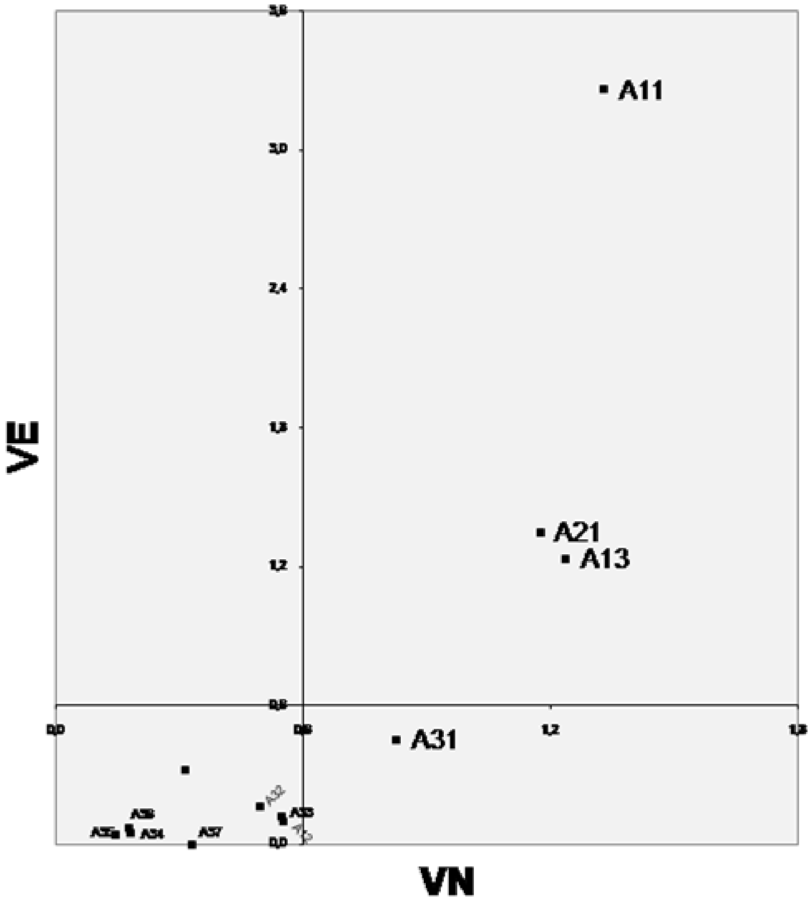
CR Phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A11	0	1	0	0	0	0	0	0	0	0	0,7	0	0,7	0
A12	0	0	0,2	0,2	0	0,2	0	0,2	0	0	0,05	0	0	0
A13	0,1	0	0,2	0	0	0	0	0	0	0	0,25	0,4	0	0
A21	0	0	0	0	0	0	0	0	0,05	0	0	0	0,15	0,5
A22	0	0	0	0	0	0	0	0	0,1	0	0	0	0,15	0,5
A31	0,5	0	0	0	0	0	0,6	0	0,5	0	0	0,4	0	0
A32	0	0	0	0	0,6	0	0	0	0	0,6	0	0	0	0
A33	0	0	0	0	0,2	0,1	0	0,1	0	0,2	0	0	0	0
A34	0	0	0	0	0,2	0	0	0,1	0	0,2	0	0	0	0
A35	0,1	0	0,3	0,4	0	0,3	0,2	0,1	0	0	0	0,1	0	0
A36	0,3	0	0,3	0,4	0	0,4	0,2	0,5	0,05	0	0	0,1	0	0
A37	0	0	0	0	0	0	0	0	0,3	0	0	0	0	0

Table 4.5: Contribution of the phases in achieving customer satisfaction.

Phase	PCS_j	PCD_j	POS_j
A11	0,22	-0,09	0,12
A12	0,01	-0,04	0,03
A13	0,08	-0,08	0,08
A21	0,05	-0,04	0,04
A22	0,05	-0,05	0,05
A31	0,09	-0,17	0,15
A32	0,02	-0,05	0,04
A33	0,01	-0,02	0,02
A34	0,01	-0,02	0,02
A35	0,02	-0,07	0,06
A36	0,04	-0,10	0,08
A37	0,00	-0,03	0,02

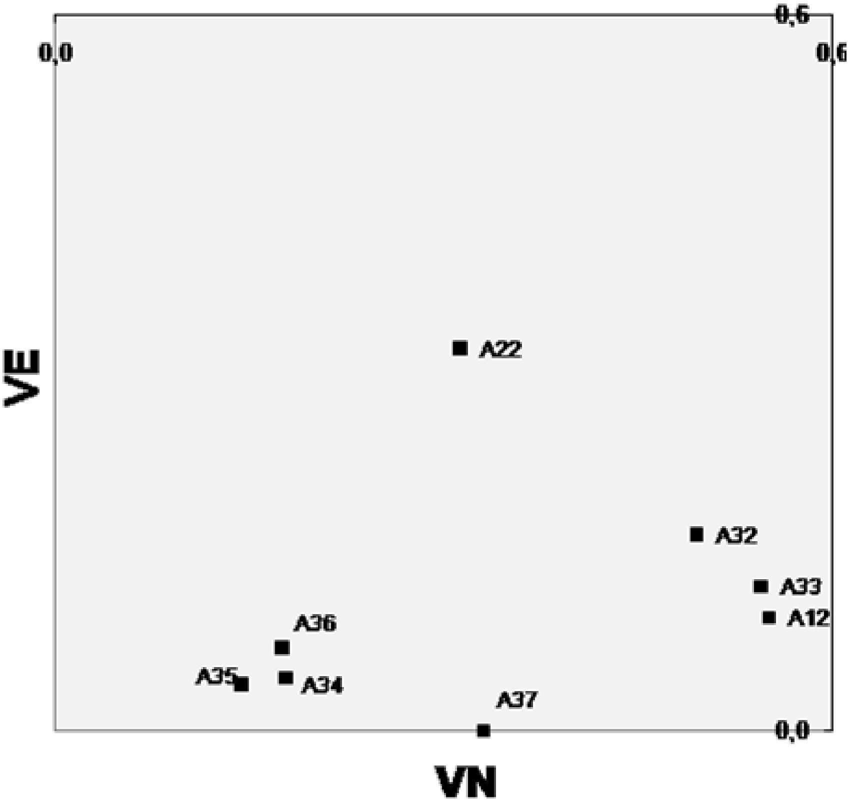
Table 4.6: Comparative value analysis for the business process phases.

Phase	OV	VE	VN
A11	1,88	3,26	1,33
A13	1,25	1,23	1,23
A21	1,24	1,35	1,17
A31	0,73	0,45	0,82
A33	0,43	0,12	0,54
A12	0,43	0,09	0,55
A32	0,41	0,16	0,49
A22	0,32	0,32	0,31
A37	0,24	0,00	0,33
A36	0,15	0,07	0,17
A34	0,14	0,04	0,18
A35	0,12	0,04	0,14



A11	Style determination
A13	Prototyping and first industrialization
A21	Price determination and participation to the sector fairs
A31	Manufacturing preparation and purchasing planning

Figure 4.7: VE-VN grid.



A33	Shoe lasts stock production
A12	Collection modelling
A32	Size development
A22	Selling through agents; delayed orders and replenishments
A37	Controls and shipment
A36	Manufacturing
A34	Dies production
A35	Purchases and supply

Figure 4.8: Low-performance area in VE-VN grid.

Ideal Solution to Physical Solution

This Section introduces the technical and the organizational needs to be satisfied in order to follow the business process improvement directions ensuing from the analysis of the phases' value.

The main implications of the previous analysis indicate the need of new market and organization strategies rather than technological update. The possibility to reduce the time resources, as already suggested by the basic idea of the JITS project, represents the focus of the process improvement, since it would allow strategic phases (at first purchases and manufacturing) to be repositioned. In order to reach this goal, dead times have to be strongly shortened and a correct approach has to be taken in consideration. Thus the means of QRM, implying the minimization of lead times, are in this context the most appropriate.

The analysis of existing technologies, policies and methods provides further indications about single phases. In detail:

- phase A34: its functionalities, thanks to CAD/CAM systems and automated cutting machines, can be integrated in the sizes development phase, so providing additional benefits for the A32 phase; moreover, the limit of the new technologies is the low speed in dying operations opposite to short set-up times, but the decreasing dimensions of the batches encourages their introduction;
- phase A22: the introduction of attractive features could be done through continuous replenishments during the market seasons offering updated models of the collection in accordance with the current fashion trends; thus the increase of the phase performance should be carried within a deep reorganization of the ideation and selling stages implying at first the continuation of the stylistic activity along the business process;
- phase A36: the engagement of offshore subcontractors should be limited in order to reduce the phase duration and to ensure the commitment timeliness; moreover, researches show that onshore manufacturing and the creation of domestic partnerships are more profitable for a certain share of produced items [4.8];
- phase A35: the firms can carry out the purchases of the materials with a higher supplying time (especially leather), before the sales stage and on the base of a forecasted quantity with a safety margin; this is however possible just with the products that can be reused, recycled or reworked, unless the firm accepts high entrepreneurial risks;
- shoes customization: several European projects, such as EUROShoeE [4.9] and Ergoshoe [4.10], aim at developing tools and strategies to introduce in the footwear industry personalized products; their results offer also a

framework about the existing technologies for designing and manufacturing customized shoes.

4.1.3. Discussion

A successful application of some of the recalled indications for process improvement, refers also to the experience of a firm that has applied several of the indicated measures regardless of the approach used in this research.

The Italian shoe factory BASE [4.11], located in Castelfranco di Sotto, is a small enterprise that operates just in the foreign market and it is specialized in the middle quality women shoes segment, although other kind of items are produced. The production of BASE is characterized by limited lead times considering the average elapsed duration between the orders acquisition and dispatching (about 60 days, while commonly the current business process employs between 3 and 4 months), the elimination of dead times, continual replenishments, offshore outsourcing applied just for few low quality items, anticipated purchase of the leather, improved coordination of the supply chain. Thanks to these business choices, the shoe factory hasn't suffered the crisis in the sector and unlike the general trend, the turnover of firm has almost doubled from 2004 to 2007.

It is worth to notice that all these strategic actions meet the guidelines that have been identified through the proposed approach in the context of the JITS Project.

4.2. The Italian industry of woody bio-fuel

In this Section the application of the methodology to a manufacturing process in an emerging field is presented, i.e. the woody pellet production process. This sector presents high business opportunities in Italy since the market demand of such kind of energy sources has grown dramatically in the last five years. Besides, the poor performance of the industrial processes implemented so far, that are still under development, doesn't allow the complete exploitation of the biomass resources. As a consequence, the market demand of woody fuels remains unsatisfied.

In such context, the applicability of the developed approach also for industrial processes experiencing such kind of under capacities, as well as concerning not yet established business ideas, has been tested.

This case study has been published in [4.12, 4.13].

4.2.1. General overview of the business process

Solid bio-fuel obtained by the sustainable exploitation of forest resources represents a relevant complementary source of energy to oil and its derivatives. In the last two years the market demand of solid bio-fuel in Italy has dramatically grown and it represents a business opportunity for a lot of its rural areas: one of these is the Appennino Tosco-Emiliano, a mountainous territory in the north-central part of the country. Two different kinds of solid bio-fuel are obtained by the exploitation of the forest resources and sawdust:

- wood chips: pieces of wood having overall dimensions of 25 x 30 x 20 mm, maximum moisture content of 20% in weight, average market price 70 €/Ton;
- pellets: cylinders of pressed sawdust having a diameter of 6 or 8 mm, height of 35 mm, moisture content of 10% in weight, average market price 180 €/Ton.

Table 4.7 shows an example of local exploitation of biomass resources, referring to a small area located in the Appennino Tosco-Emiliano. In this region the amount of biomass obtained by the sustainable exploitation of forests during a year, may constitute an energy source able to satisfy the needs of about 6600 housing units making them almost independent from the oil derivatives. The available resources are: wood sawdust having a very low content of moisture coming from wood industry and wood waste obtained by the maintenance operations of the forests and the urban green, that is supplied in form of pieces of tree and has a high moisture content.

Table 4.7: Woody biomass resources available in the Appennino Tosco-Emiliano (tons/year).

Origin	Moisture content (in weight)	Estimated availability	Estimated availability after 10 years
Wood coming from industry processes	10%	5000	6000
Wood coming from forest management	35-50%	25000	50000
Wood coming from urban green management	45-50%	2000	10000

A preliminary analysis of the business process showed that the wood waste is used mainly to manufacture wood chips, while pellets are just manufactured from sawdust. As shown in Table 4.7, the yearly availability of the wood coming from sawmills is smaller than the amount coming from forest and urban management. Actually the business process related to the production of woody fuels is able to satisfy the market request of wood chips, while a big deal of pellets market demand is still unmet.

From a technological point of view, the pellet manufacturing process still adopts technologies coming from industrial fields that are strongly different from the wood industry. As it will be further detailed in the next Sections, the process is constituted by three main functions to be performed: trituration, dewatering and pressing of the wood.

The trituration is performed through hammer mills which are meant to crush brittle dry materials in fine particles. Unfortunately, when such systems are used to crush the wet wood, they clog due to the formation of a dough that interrupts the flow of the material inside the machine.

The dewatering phase is performed by a thermal dehumidification in "traditional" ovens burning oil or methane. Due to the high moisture content that has to be removed from the wood, this phase requires a high energy consumption. Moreover, the temperature that the biomass reaches inside the oven is a critical process parameter. If the temperature is high, the dewatering phase can result in the reduction of the energetic content of the wood because of the detaching of volatile substances such as alcohols. On the contrary, if the temperature inside the oven is low, the dehumidification process is not able to properly reduce the moisture content of the wood.

Eventually the pressing of the sawdust is performed by machines developed within the animal feed industry in which the raw material has properties strongly different from wood. Thus these imported technologies have demonstrated low performances and efficiency.

By considering the illustrated deficiencies, the wood pellet production constitutes therefore a suitable case study to test the applicability of the developed methodology in the context of industries experiencing under-capacities.

4.2.2. Application of the method

Process to Problem

The system modelling determines the segmentation of the process in six phases: A1 Trituration, A2 Purification, A3 Dewatering, A4 (second) Trituration, A5 Pelletizing, A6 Cooling and packaging.

The process used to produce the wood chips starts with the trituration (called "chipping") of the wood biomass in order to obtain chips having overall size of less than 30 x 30 x 30 mm. The next phase is aimed at purifying the obtained wood chips by removing any kind of impurities (such as solid particles, glass, iron, etc.). In order to avoid fermentation, the moisture content is reduced to 20% in weight: dewatering is performed using thermal heating and at the end of the process the wood chips are cooled in air. In the next phase the wood chips are further triturated up to the size of the sawdust for the pelletizing phase. The pelletizing of the sawdust produces a not negligible heat due to the high friction of the extrusion die, thus the pellets require to be cooled at the end of the process before the final packaging.

The resources to make the system work properly range from energy to labour and space occupied by tools and machinery. In Table 4.8, the cost involved in each phase of the process for the production of wood chips and pellets, is surveyed. The dewatering phase requires a high energy consumption in order to reduce the moisture content of wood chips from 50% to 20% in weight, the thermal process usually requires 3600 MJ for each ton of removed water. Also different relevant resources are indicated in the same table, that shows that the pelletizing is accounted to a large involvement of human skills in terms of labour, experience and know how, while the machines addressed to perform the dewatering stage show the largest size. The availability of the raw materials is summarized in Table 4.9.

According to the modelling phase, also the T, I and OE flows generated by the current reality of the system have been evaluated. At present, while the market demand of wood chips is entirely covered by the production, the pellets demand is not satisfied at all. Under these boundary conditions the monetary flows that may be generated by the process are those reported in Table 4.10. The required investments for the plant assessment are also summarized and productivity, Net Profit and Return Of Investment (ROI) are evaluated for each product. The analysis of the system performed on the basis of the ROI criterion, suggests to focus the production just on pellets from sawdust, without taking into account the use of wood; in other words, according to the ROI criterion, the use of wood to produce pellets is not worthwhile. On the contrary, the analysis of the monetary flows according to TOC principles shows that selling one ton of pellets more (that means one ton of wood chips less, according to the available resources) produces an increment of the Throughput of the whole system. So throughput analysis of TOC contradicts the ROI criterion since the throughput suggests to improve the pellet from wood process instead of to use only sawdust. Thus the main problem of the current reality is that while the process is able to satisfy the market demand of the wood chips, it is not able to produce more pellets to be sold. The negative effect is that the market demand of pellets cannot be satisfied.

The functional model of the process is presented in Figure 4.9 (p. 89). As depicted, there are some output flows of energy wasted from several phases of the process that constitute unexploited internal resources of the system (such as: the heat content discharged by the cooling phases, the heat content of the air ejected from the dewatering furnace, etc.) as well as the materials extracted by the purification process and the water obtained during the dewatering operations. While the materials extracted by the purification phase may constitute market opportunities, the thermal flows discharged during the process show temperatures that don't allow their convenient recycle for other tasks of the process.

Table 4.8: Energy, labour and space resources involved in the whole process, expressed in €/ton.

Phase	A1	A2	A3	A4	A5	A6
Cost of energy for wood chips production	3	2	20	-	-	-
Cost of energy for pellet production	3	2	38	3	11	1.5
Cost of the involved personnel	2	2	6	2	10	2
Cost of the involved space	1	2	3.5	1	1	1.5

Table 4.9: Raw materials availability.

	Moisture contents %	Dimensions (mm)	Availability (Ton/Year)	Cost (€/Ton)
Sawdust	10	2	5000	5
Renewable Wood	50	>100	30000	25

Table 4.10: Monetary flows (millions of €) generated by the system in a year.

	Wood chips from wood	Pellets from Sawdust	Pellets from wood
T	2.10	1.10	5.40
OE	1.05	0.12	2.48
I	0.95	0.04	1.05
Investment	0.40	0.10	1.00
Productivity (T/OE)	2.00	8.98	2.18
Net Profit (T-OE-I)	0.11	0.94	1.88
ROI (NetProfit/Investment)	0.26	9.40	1.88

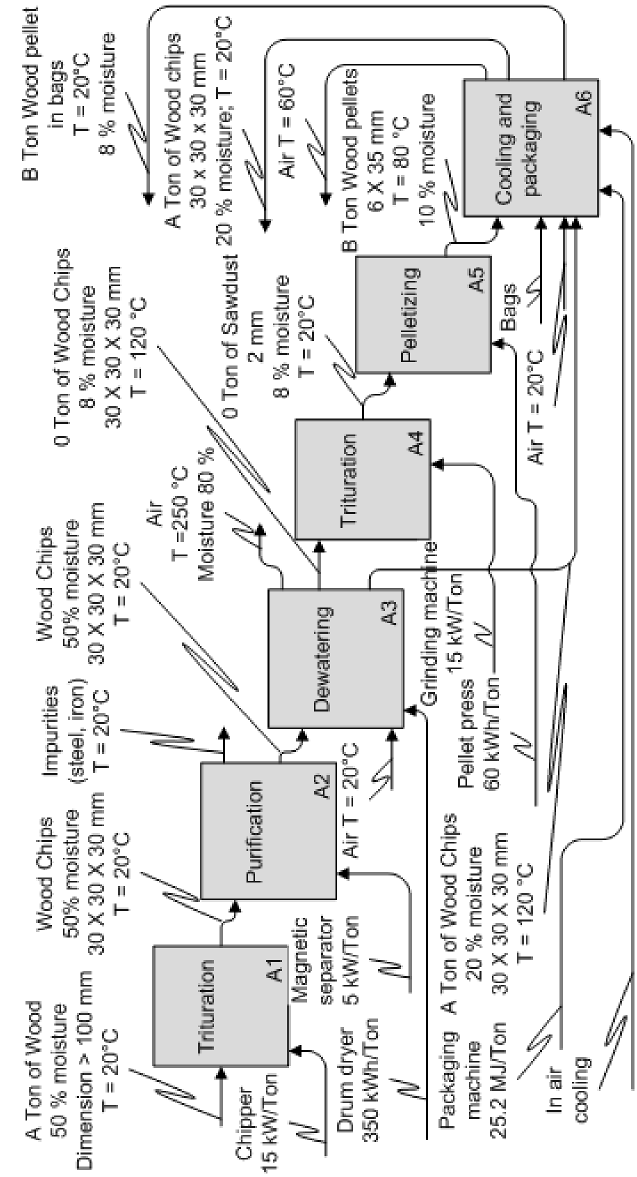


Figure 4.9: The functional model of the solid bio-fuel production process. For the sake of clarity only the flows of materials and energy involved in the process have been indicated together with the technologies employed in each phase.

As last task of the process to problem step, the identification of the competing factors in the market reference, has been performed. In the current process, the set of the critical features to access market is constituted by five requirements imposed by the regulations and the market standards established in this domain. Once that these “must be” requirements are satisfied, no extra attractive features are necessary to sell the product.

The main CRs to be satisfied are the followings: a suitable lower heating value, LHV (CR1), representing the main performance of both wood chips and pellet, since it is intended to deliver the main function of providing heat. The sector experts have identified some other characteristics referred to the licensing laws, such as size (CR2), mechanical resistance (CR3) and capability to preserve the heating characteristics (CR4). At last, only for the wood pellet, the availability in bags (CR5) represents a further attribute for the manufacturing process. Table 4.11 summarizes the requirements and their relevance indexes R in determining the customer perceived value.

Table 4.11: Competing factors in the wood bio-fuel sector and their accounted relevance Ri.

Attribute	***Ri***
CR1 – LHV	5
CR2 - Size	3
CR3 – Mechanical resistance	3
CR4 – Capability to preserve the heating characteristics	3
CR5 - Availability in bags	1

Eventually the value curves related to pellet and wood chips according to the above listed CRs, are shown in Figure 4.10. As shows the pellet owns a high LHV with respect the wood chips. It has also a reduced size that allows its combustion in systems and plants having different scale. Such versatility cannot be offered by the wood chip. Even the mechanical resistance of the pellet is slightly less than that offered by the wood chip, its capability to preserve the heating energy is very high.

According to such analysis the value curves of pellet and wood chip refer to very different market strategies, however, notwithstanding the pellet superior value, its market demand is still unsatisfied due to the recalled process limitations.

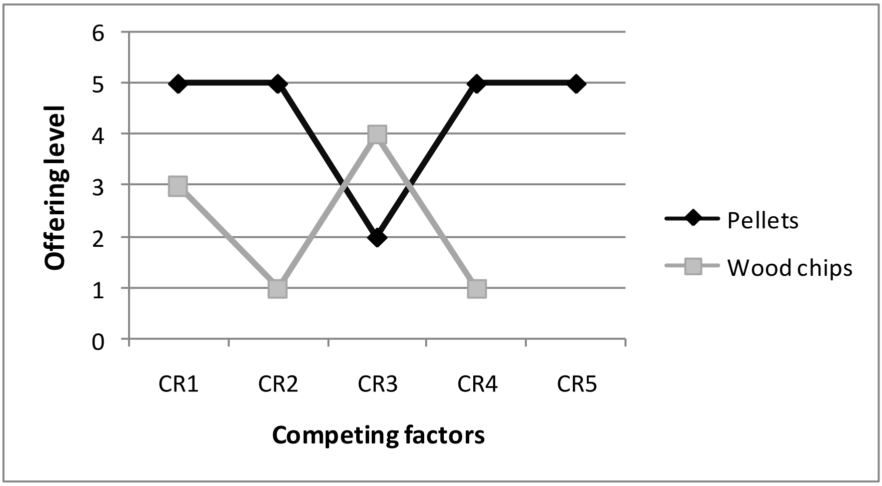


Figure 4.10: Value curves of pellet and wood chip in the reference market. In the ordinate the performances of the related product attributes, are reported.

Problem to Ideal Solution

The task related to this step of the roadmap is the identification of the main process bottlenecks that hinder the satisfaction of the pellet market demand. Thus the tools suggested by PVA are applied in order to highlight the main process under capacities. However, since the set of the critical features to access market is constituted by five main requirements imposed by the regulations and the market standards, the PVA methodology has been customized, with respect to its original formulation described in Chapter 3.

Classifying the product attributes according to the Kano model

In the proposed methodology the CRs are classified according to their contribution in determining the customer satisfaction by means of Kano model. Nevertheless, as demonstrated in the previous step, the present case study is a manufacturing process characterized just by “must-be” requirements, imposed by regulations and standards or “dictated” by the current performances of the products on the marketplace. In such cases the Kano categories lose their significance, more in general this happens in the presence of business processes characterized by:

- targets that are established by different players participating to the value chain (e.g. suppliers, third-parties), and/or
- fulfilment of the requirements to access the marketplace, beyond mandatory product/service features.

This set of industrial processes represents a class of value-related problems that can be easily faced by means of the proposed roadmap where the coefficients expressing the Customer Satisfaction (CS) and Customer Dissatisfaction (CD), are substituted by a relative relevance index (R) representing the extent at which, each product/service requirement contributes to let market access and to boost customer perceived value. A scale from 1 to 5 will be adopted for this purpose, whereas 5 represents the highest importance.

According to this scale, the LHV attribute holds the biggest importance in determining the customer satisfaction thus, the correspondent relevance degree is 5, the sector experts have accounted with an importance level equal to 3 the size (CR2), mechanical resistance (CR3) and capability to preserve the heating characteristics (CR4), while the availability in bag (CR5) has been accounted for a minimal degree of relevance (thus, 1). The R coefficients, defined for each CR, are summarized in Table 4.11 (p. 90).

Definition of coefficients expressing customer contentment

The estimation of the kij indexes, expressing the contribution of each process phase in determining each CR, revealed that the most relevant CR (lower heating value), is determined mainly by the dewatering phase, while the first trituration phase gives a minor contribution. The assessment can be explained through the parameters influencing the performances of the dewatering process based on thermal heating (quantity of the evaporated water and the productivity): dimensions of the raw material at the inlet of the furnace and temperature of the process. CR2 (Size), CR3 (Mechanical resistance), CR4 (Capability to preserve heating characteristics) are determined mainly by pelletizing since in this phase the sawdust is pressed and shaped up to the dimensions of the pellet. CR5 (Availability in bags) depends mostly on packaging and on the size of the pellet, determined by the pelletizing and the second trituration.

Once the kij have been determined, it is possible evaluate for each phase its own Phase Overall Satisfaction (POS), representing its extent to bring customer contentment and to gain market acceptance. It is necessary to highlight that, since the distinction between Customer Satisfaction and Customer Dissatisfaction loses its meaning and can be omitted when all the CRs belong to the same Kano category (“must be”, “one dimensional” or “attractive”), the phase coefficients POSj are calculated as it follows:

$$POS_j = \sum_i k_{ij} \times R_i \tag{3}$$

where:

- kij is the relative contributions addressed to the j-th phase in ensuring the achievement of the i-th CR.
- Ri represents the relative relevance index of the i-th attribute.

Table 4.12 summarizes kij coefficients, while Table 4.13 shows the calculation of POSj indexes (expressed in a non-dimensional form and as a percentage) through (1), exploiting the values of Ri shown in Table 4.11.

Table 4.12: contribution of wood pellet production phases to fulfil the system requirements (kij coefficients).

Phase	CR1	CR2	CR3	CR4	CR5
A1	0,4	0,1	0	0	0
A2	0	0	0,1	0,2	0
A3	0,6	0	0	0	0
A4	0	0,2	0	0	0
A5	0	0,7	0,9	0,8	0,1
A6	0	0	0	0	0,9

Table 4.13: Accounted satisfaction (POS indexes) arising from each phase of wood pellet manufacturing process.

Phase	*POSj*	*POSj*(%)
A1 - Trituration	2,3	15,33%
A2 - Purification	0,9	6,00%
A3 - Dewatering	3,0	20,00%
A4 - Trituration	0,6	4,67%
A5 - Pelletizing	7,3	48,67%
A6 - Cooling and packaging	0,9	5,33%

Comparing benefits and resources of each business process phase

The study of the pellet production process has highlighted the main resources involved in the system.

The time to market doesn't represent a critical factor for the analyzed business process; moreover, the manufacturing of pellets from wood waste doesn't show remarkably longer times than their traditional production from sawdust. Thus the duration of the production phases is not considered relevant for the examined value creation process, as well as the undesired effects of the manufacturing phases (e.g. noise, vibrations, maintenance, etc), that aren't actually pointed out. Therefore the phases' value estimation has neglected operating times and drawbacks, focusing the attention just on the employed resources.

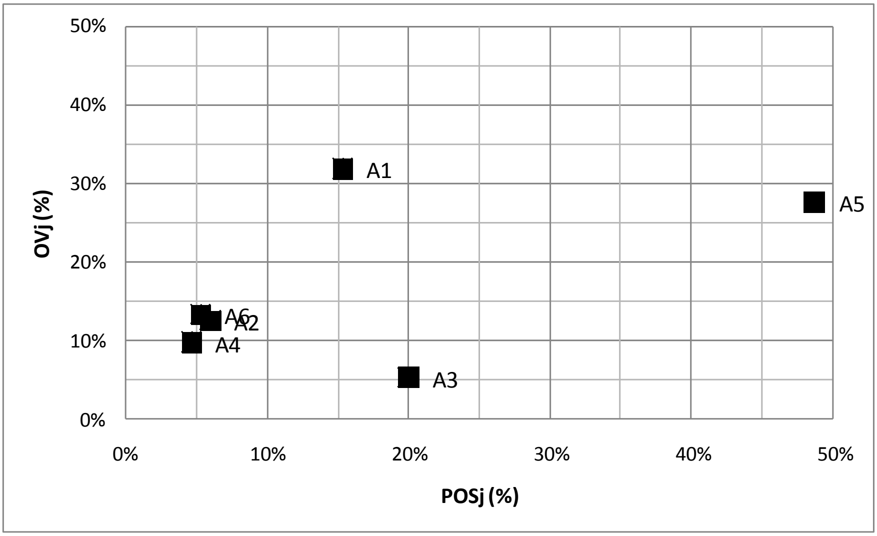
The resources consumption has been normalized assuming a reference production of 1 ton of pellet from renewable wood. More specifically, the analysis has included the expenditures for energy, labour and space occupied by the plant. The energy costs have been calculated with reference to the consumption of each phase in the treatment of 1 ton of wood pellets and to the current price of the electric power. The expenditures accounted to the labour for each phase have been calculated through the accounted involvement of the personnel in the production of 1 ton of wood pellets and the hourly cost of the employed workers. The costs involved for the space occupied by the plant have been calculated dividing the monthly amount of real estate expenditures for the industrial site by the potential production of the plant in the same period, in terms of 1 ton wood pellets batches. Then, such expenditures have been split to calculate the amount accounted to each process step taking into consideration the ratio of the space occupied by the machinery utilized to perform the phases.

Table 4.14 shows the results of estimated expenditures for the exploited resources, together with the percentage of their inverse total indexes (1/RESj), and the phases Overall Values OVj, consequently calculated through the relation presented in Chapter 3 and subsequently normalized in order to obtain a percentage score.

Table 4.14: Overall value OVj of each production phase, estimated as the ratio between the contribution to the customer perceived value (POSj) and the resources consumption. Energy, labour and space resources are expressed in €/ton; in grey the most critical process phase.

Phase	*POSj*	Energy	Labour	Space	*RESj* (total)	1/*RESj* (%)	*OVj*
A1	2.3	3	2	1	6	21.74%	31.81%
A2	0.9	2	2	2	6	21.74%	12.45%
A3	3	38	6	3.5	47.5	2.75%	5.24%
A4	0.7	3	2	1	6	21.74%	9.68%
A5	7.3	11	10	1	22	5.93%	27.54%
A6	0.8	1.5	2	1.5	5	26.09%	13.28%

With the aim of providing a clear representation of the business process analysis, Figure 4.11 and Figure 4.12 show bi-dimensional maps of the phases accounted percentages of value, satisfaction and inverse of the required resources (whereas high values of this parameter indicate phases with a low consumption of resources). The figures show the mutual links between the indexes OVj and the factors determining their values (thus POSj and 1/RESj), thus remarking for low valued phases the main issues to be addresses in a reengineering project (low contribution for the customer satisfaction or high expenditures).



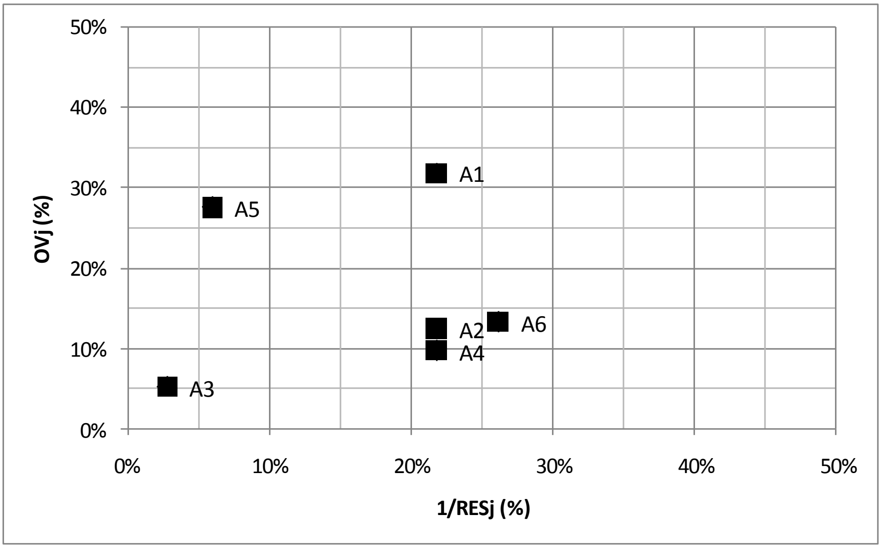


Figure 4.11: Phases ratios in terms of OVj and POSj and in terms of OVj and the inverse of phase required resources (1/RESj).

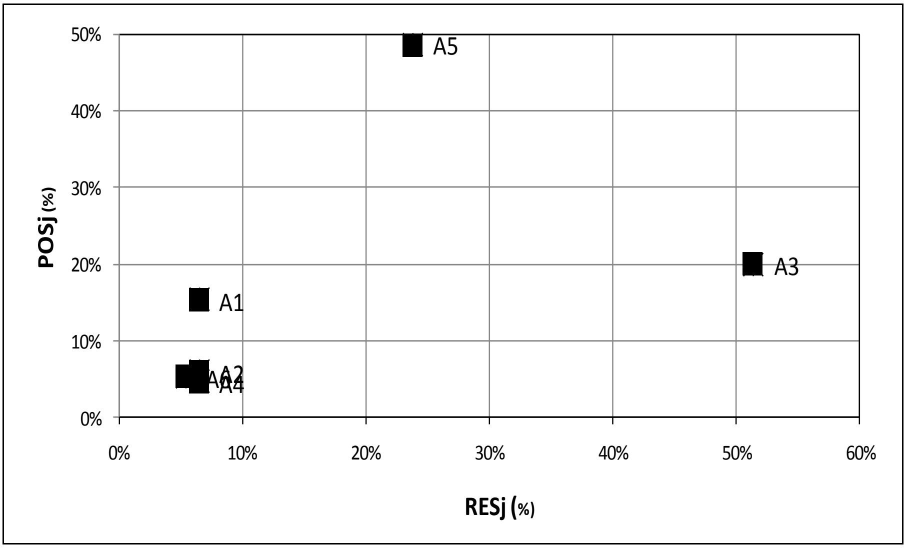


Figure 4.12: Phase positioning in terms of POSj and RESj indexes.

Identifying directions for value improvement and new values proposition

As shown in Table 4.14, the dewatering (A3) has the smallest OV index, thus it represents the most critical phase of the business process, since its contribution to the creation of the benefits for the end-user, compared with the other phases of the same manufacturing process, is not proportioned to its consumption of resources. Moreover, the OV indexes show that the second critical phase is the trituration (A4). According to Figures 4.11 and 4.12, the phase (A4) together with purification (A2), packaging (A6), and first trituration (A1), presents a low contribution in determining the customer satisfaction as well as a low consumption of resources. Eventually the pellettization (A5) give an high contribution to the customer satisfaction.

A more detailed analysis of the process revealed that some important limits of the pellet production starting from wood waste, are due to technologies that are not able to treat, in an efficient way, biomass having high an moisture content. In order to obtain pellet with a high energetic yield, the moisture content in the green biomass (approximately 50% in weight) must be drastically reduced. The technologies based on thermal dewatering use rotating or fluid bed furnaces that are fed by methane, oils, or a part of the raw biomass. This involves high fuel consumption, due to the meaningful amount of water that should be extracted. The efficiency of the dewatering phase could be strongly improved if the size of the biomass could be reduced at the inlet of the furnaces but unfortunately current systems for wood trituration are not able to treat biomass having a high moisture content. Moreover the pressing technologies used for the pelletizing of the sawdust are not able to dewater the biomass.

The OV indexes suggests as a mandatory fundamental action, the improvement of the dewatering phases by developing convenient manufacturing technologies for wood pellet production. Moreover, since the second trituration phase gives a low contribution in determining the customer satisfaction and has also a low consumption of resources, it may be removed from the process by integrating its function with other phases. Such indications are also valid for the (A1), (A2) and (A6) phases that are related to low performances areas of the process as well as the (A4) phase. Even if the pellettization has an high OV, the performed analysis reveals that it is the first phase in determining the customer benefit and the second phase in terms of resources consumption (Figure 4.12), thus its performances may be improved through the adoption of new customized technologies.

Ideal Solution to Physical Solution

The directions for process improvements identified in the previous step, have led to definition of two well defined technical problems:

- how to dewater chips from 50% to 8-12% of moisture with minimum energy consumption?
- how to triturate the chips into 2.5 mm diameter particles during the dewatering phase?

While the second task is somehow achievable with already well established technologies, dewatering is actually left to thermal dehumidification that is a high energy consumption, poor efficiency process. The efficiency depends on the dimensions of the processed material: dewatering sawdust requires less energy than dewatering wood chips. So the problem is that actual technologies for trituration are not able to work properly with wet materials, while thermal dewatering is more efficient with small size materials.

A deeper analysis of the problem has revealed a number of concurrent contradictions both in heat dehumidifiers and in triturating machines. Among them, the latter have a relevant evolutionary potential in terms of contributing to moisture reduction: high speed mechanical energy is a powerful resource to separate water from wood particles during the milling process.

A research of principles performed through FOS, focused on finding physical solutions for implementing the dewatering and trituration functions, has demonstrate that if ultrasonic waves are generated by means of high speed shocks, they can further contribute to moisture reduction as claimed by Duke and John [4.14], Smith [4.15] and Berger [4.16]. A specific patent search to validate such a conceptual solution has revealed three patents Sand et al. [4.17], Sand et al. [4.18], Hamm et al. [4.19], adopting the same physical principle to pulverize and dry raw material.

At least one of these patents has been converted into a real product called Kinetic Disintegration System (KDS) by First American Scientific Corp.: a rotor equipped with chains or knifes operates the trituration of the material, by shooting the particles towards the walls of the machine. The impact transforms the kinetic energy of the particle into impact energy that makes the particles and the water vibrate: this allows the separation of the different materials. According to the datasheet supplied by the producer, such a system is able to reduce the moisture content from 60% to 10% and the particle size up to 1 mm. The most relevant property of this technology is the energy consumption of three times less than a traditional heat based dehumidification.

Physical Solution to Engineering Solution

A novel TO-BE process has been simulated under the assumption to integrate this technology and the model diagram presented in Figure 4.13 (p. 100) has been developed. Thanks to the features of this system, secondary trituration and dewatering phases become a single phase in the new process. The first trituration phase is used in order to perform a size reduction of the biomass according to the dimensions required in input to a KDS-like technology.

In Table 4.15 the costs of the TO-BE process are summarized. According to these results the whole process has gained value in terms of costs and efficiency by removing the limitations due to the poor dewatering phase. Indeed the OE of the dewatering/trituration phase has been strongly reduced since the requested energy is three time less than the AS-IS process. This allows to exploit the available biomass resources according to the actual market demand by giving to the process the opportunity to produce pellets also starting from green wood. In such a way the T of the system can be always maximized.

Unluckily KDS system is not suitable to be used during forestry operations since it has dimensions and weight that don't allow transportation and management in the forest areas. With the aim to overcome this limit a new mechanical system implementing the same physical principle of the machine produced by First American Scientific Corp., obtained through a different system architecture so to avoid patent infringement, has been designed and developed by the industrial partners involved in the project. Such system has dimensions that allow its transportation and installation in the forest areas where forestry operations take place. A first real prototype of the machine is able to produce 300 kg/h of dried sawdust having a moisture content of 15% in weight starting from green wood; the power consumption has been measured as 540 MJ/Ton. This technology is less expensive than the traditional one in terms of investments, operating and maintenance costs. Moreover it may be used also to produce dried wood chips since it allows different biomass sizes in output. The output dimensions depend on both the number of milling steps that biomass undergoes in the machine and its setup, at least, starting from wood chips, only two steps are required to obtain fine chips while fine sawdust can be produced in four milling stages. Tests also revealed that the fine biomass can reach the required moisture content for pellet production after very few milling/dewatering cycles. Eventually the implemented technology allows a productivity that can be easily scaled according to the production needs without significant loss of efficiency.

According to these features a benchmark among the AS-IS and TO-BE pellet production processes, has been performed in terms of business generated during a year, the results are presented in Table 4.16. As shown the innovative technology has a not negligible impact on the business opportunities since all the economical parameters of both processes have been strongly improved.

Table 4.15: Production costs (€/Ton) of solid bio-fuel for each phase of the TO-BE process.

Phase	A1	A2	A3+A4	A5	A6
Cost of energy for wood chips production	3	2	12	-	-
Cost of energy for pellet production	3	2	21	11	1.5
Cost of the involved personnel	2	2	2	10	2
Cost of the involved space	1	2	2	1	1.5

Table 4.16: Benchmark of the business generated in a year among TO-BE and AS-IS pellet production processes starting from wood (T, OE and I are expressed in millions of €).

	AS-IS	TO-BE	Benchmark
T	5.40	5.40	=
OE	2.48	1.41	-43.0%
I	1.05	0.98	-7,1%
Investment	1.00	0.80	-20.0%
Productivity (T/OE)	2.18	3.82	+74.4%
Net Profit (T-OE-I)	1.88	3.01	+60.2%
ROI (NetProfit/Investment)	1.88	3.77	+100.3%

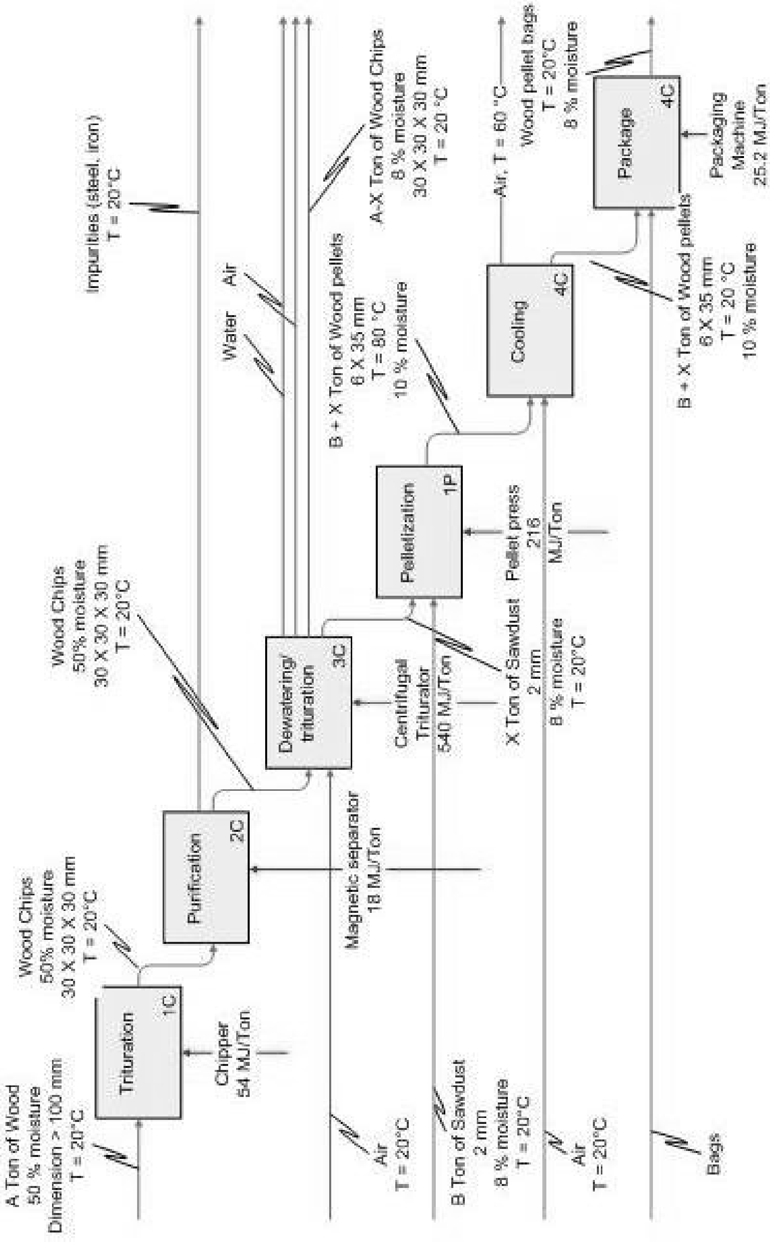


Figure 4.13: TO-BE process.

4.2.3. Discussion

The analysis of the scientific and technical literature in the field of renewable energy confirms that the drying of the woody biomass is a critical phase in the production process of pellet starting from green wood.

In [4.20, 4.21] it is clearly explained that the drying process based on thermal heating has a not negligible impact on both quality and production costs of wood pellet and new drying systems should be developed in order to make more efficient the pellet manufacturing process in terms of energy consumption and product characteristics delivered to the final customer.

In [4.22] it is claimed that in wood manufacturing industry, drying is considered the most relevant matter determining problems in process controllability and high energy expenditures. Several studies have been carried out and several technologies have been introduced to improve this phase in wood industry, as it is summarized in [4.23].

Therefore, the aforementioned researches widely confirm the results obtained by the application of the proposed methodology.

4.3. New value proposition in the professional hair dryer industrial sector

In this Section a new value proposition task in the field of professional hair dryers is presented with the aim of providing an exemplary application of the new value proposition guidelines. The products available in the market are scarcely differentiated in terms of attributes and performances. The industrial sector of professional hair dryers is characterized by well established competing factors. Indeed, since the products present very similar value curves, the market experiences a high level of competition among the players.

The objective is the definition of an innovative profile of a professional hair dryer, whose new features and performances are viable to lead to a shift in the value delivered to the end-user. According to this purpose, the tools suggested in step 1 and step 2 of the roadmap for defining a new product profile have been applied. Thus the following tasks have been performed:

1. definition of the product attributes offered to the customer according to the competing factors;
2. classification of the product attributes through the functional features;
3. application of the new value proposition guidelines.

Here in the following the application of the tools suggested by the road map to perform such activities are described.

4.3.1 Application of the method

Identification of the competing factors in the reference industrial field

Such task has been performed with the support of the System Operator, thanks to its supposed capability to drive the user in a detailed investigation of the items and conditions influencing the systems' functioning. According to the life cycle perspective, the designer should investigate the features of the product that are relevant for the customer during the buying/choosing phase, before the use, during the use, after the use and in event of disposal. In order to reveal a complete set of attributes, such an investigation should be advantageously performed taking into account also the different "hierarchical levels" of the relevant features with reference to the system taken in consideration, i.e. the hair dryer, the stylist, the salon customer. Such hierarchy has to be structured in terms of the operative zone of the objects that perform the functions, the impact towards surrounding systems and people, the link with different situations and working conditions for the products, etc. The features can be therefore ranked according to their impact with:

- the environment of the product will be during its life cycle (super-system);
- the operative zone of the system;
- one or more parts of the product (sub-system).

E.g., along the purchasing and set-up phases:

- the product can be offered with transportation and installation services (features related to the super-system);
- the cheapness and aesthetic quality are product attributes of the system itself;
- the offering of a set of wires for different connections, rechargeable batteries, etc. are all properties related to product components (thus to the subsystems).

According to this logic, the search of the main aspects characterizing a professional hair dryer has been carried out revealing current and potential areas of value for the investigated product; the results are summarized in Table 4.17. A crucial issue in performing the identification of the product attributes that are relevant in the reference market, is represented by the analysis of several documents such as technical documents, product catalogues, product reviews available in the database of the producers and in the specialized literature. In order to speed up such an activity and to make more robust its outcomes, the knowledge management tools can give a valuable contribution for the data extraction and classification. Starting from the main areas of value summarized in the Table 4.17 and from the analysis of the documents in the field of hairdryers, several attributes have been identified. They are listed in Table 4.18.

Table 4.17: System Operator summarizing the main aspects of value for the hair dryer according to its life cycle and to different level of detail.

	Buying	Before use	During use	After use	Disposal
Super system	Service for transportation, installation, training	Customer, Salon facilities	Use suitable for the stylist, Salon facilities, Customer	Customer, Cleaning Hair health	Salon renovating
System	Cost, Efficiency, Durability, Design and aesthetical quality	Hair washing and cutting	Hair drying and styling, Combinated use with hairbrush, Controllability and versatility of the hair drying, Use of energy, Hair dryer connection	Storing, Maintaining, Repairing	Disposing, Recycling Reusing
Sub system	Components	Components according to hairstyle	Components during use	Components after use, refilling	Disposed components and materials

Table 4.18: Attributes representing the main factors of competition in the professional hair dryer industrial sector.

Hair dryer attributes
- design and esthetical qualities; - cost; - efficiency; - ergonomic grip; - controllability of the air jet; - versatility of the air jet; - temperature range; - durability; - ease of handling; - ease of maintaining; - ease of repairing; - drying power; - energy consumption; - stability of performances during the use; - avoiding vibrations; - limited noise; - strength against shocks.

Classification of the product attributes in functional features

The attributes listed in Table 4.18 have been classified according to the functional features. Six of them have been submitted to the new value proposition guidelines. They represent well established and recognized relevant competing factors in the market of professional hair dryer. Here in the following the six attributes considered for the new value proposition task are described according to the performed functional classification.

The “controllability of the air jet” is a traditional feature in the market of the professional hair dryers. The possibility to control the air jet is offered at a medium level without no differentiation among the competitors, it concerns the regulation of the intensity and the direction of the flow. The “limited noise” during use and the “ease of handling” are other traditional features in the existing products even if they are offered at a low level of performance. The first one is related to a harmful function that the system performs against the end-user, the second one is related to the practice of use. The “drying power” is intended as the capability to perform the drying as fast as possible, such attribute is offered at a high level and the trend of the competitors is to further increase this performance of the system. The “temperature range” and the “versatility of the suitable air jet” stand for the possibility to adapt the drying conditions according to the hairstyle that should be obtained; also these performances are offered at a high level since they have a not negligible impact on the result of the hairdo.

The market presents a strong competition since the performance level of these attributes is scarcely differentiated among the players; therefore the value offered to the end-user of professional hair dryer can be summarized through a single value curve that can be considered the standard of the industrial sector, as depicted in Figure 4.14.

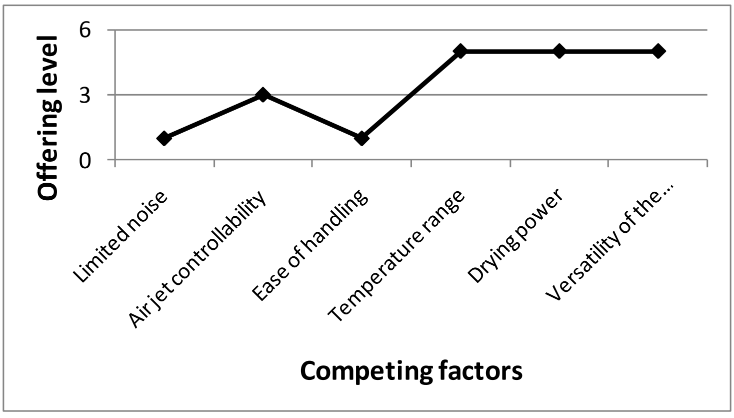


Figure 4.14: Value Curve of the professional hair dryer industrial sector. The scale of the performance levels is: 1 = Low, 3 = Medium, 5 = High.

The "limited noise" pertains to the HF OBJ class since it is a features related to the mitigation of a harmful function that the system performs against the end-user in a direct way. The "ease of handling" may be classified as RES INF since it is related to the practice of use required by the hairdressers (such as hi/hers knowledge, his/her skill in the movements, the employed human power, etc.). Eventually, the "controllability of the air jet", the "temperature range", the "versatility of the air jet" and the "drying power" have been classified as attributes pertaining to the useful function class since all of them are directly related to the main outcome delivered by the system. The "controllability of the air jet" is a product attribute that regards the possibility to manage some parameters of the air jet during the drying, thus it pertains to the UF CTRL class. According to the second level of the functional classification, "temperature range" and "choice of the air jet" are both features allowing an enhanced versatility of the system and thus they have been clustered as UF VER. At last, the "drying power" is an UF THR attribute since it directly relates to the capability of the system to correctly achieve the hairdo requested by the customer. The proposed classification is summarized in Table 4.19.

Table 4.19: The classification in functional features of the hairdryer attributes.

Attribute	Functional Feature
Noise	HF/OBJ
Ease of handling	RES/INF
Air jet controllability	UF/CTRL
Temperature range	UF/VER
Choice of the air jet	UF/VER
Drying power	UF/THR

Application of the new value proposition guidelines

The guidelines for the value transition have been applied with respect to the above defined functional classes; Table 4.20 summarizes the directions for obtaining a new product profile.

According to them, it is suggested to apply three RAISE actions to the attributes classified as UF CTRL, HF OBJ, RES INF. This means that the new hair dryer should present a strongly increased controllability of the air jet (for example by integrating sensors measuring the conditions of the air jet and instruments for the automatic or semiautomatic regulation of the flow according to the needs of the stylist). Moreover, the blow dryer should be more silent and lighter, with a mass distribution tailored to the movements of the stylist hands and arms.

Table 4.20: Application of the new value proposition guidelines to the profile of the hairdryer.

Action	Functional Feature	Attribute
CREATE	UF/THR	Integrated design
CREATE	RES/INF	Ease of use thank to the elimination of the front wire
RAISE	HF/OBJ	Limited noise
RAISE	RES/INF	Ease of handling
RAISE	UF/CTRL	Air jet controllability
REDUCE	UF/VER	Temperature range
REDUCE	UF/THR	Drying power
ELIMINATE	UF/VER	Versatility of the air jet

The guidelines don't suggest any criterion about the selection of what functional feature classified as UF VER should undergo the REDUCE or the ELIMINATE action. The "temperature range" has been chosen for the REDUCE action, while the "versatility of the air jet" has been submitted to the ELIMINATE action. Consequently, the second REDUCE action has been applied to the "Drying power" that is classified as an UF THR attribute. Thus, the resulting product profile offers a reduced possibility for the stylist to set the temperature at which to perform the hair drying, as well as a strongly decreased capability to perform faster such operation. Moreover the guidelines indicate the elimination of the air jet versatility, from the set of competing factors; thus such characteristic will be no longer available in the product.

Eventually the two CREATE actions, in compliance with the new value proposition guidelines, have led to the identification of two new attributes. The first one is the "integrated design" consisting in the integration of the hair dryer in the salon facilities; such feature pertains he UF THR functional class. The other selected attribute viable to be introduced is the "ease of use" through the elimination of the front wire connection (for example by appending the hair dryer to the ceiling), to be classified as RES INF.

In Figure 4.15, the value curve of the new product profile is depicted together with the old one. It is worth noting that the guidelines have led to the definition of a strongly differentiated bundle of offered values with respect to the competitors. Such situation fits therefore the application of the 4 Actions Framework model of the Blue Ocean Strategy.

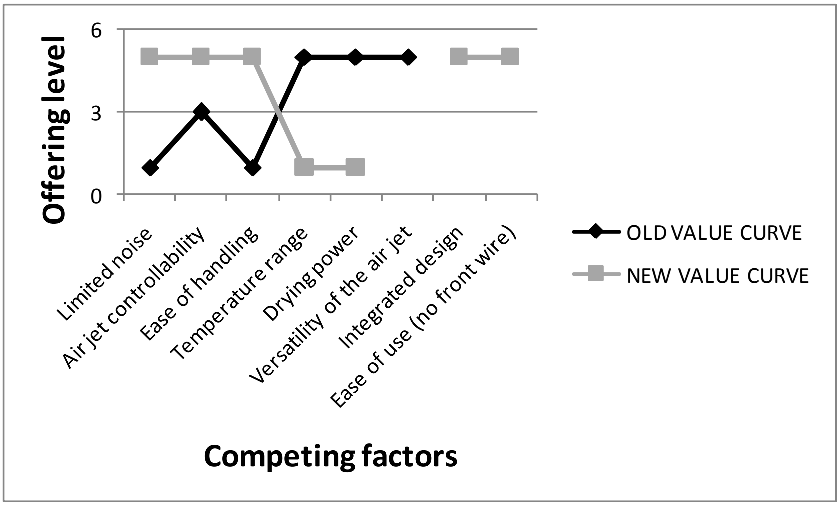


Figure 4.15: The new Value Curve obtained through the application of the value transition guidelines to the professional hair dryer. It is strongly differentiated respect with the old value curve according to the Blue Ocean thinking. The scale of the performance levels is: 0 = Absent attribute, 1 = Low, 3 = Medium, 5 = High.

4.3.2. Discussion

The exemplary application has demonstrated that the proposed new value proposition guidelines give some more prescriptive directions for the implementation of the ERRC model. The application of the guidelines is based on the classification of the attributes according to a customer centred perspective. It allows the link between product/service attributes and end-user functional needs. However, at the present stage of development, further investigations are needed to strengthen some aspects of this tool, that still results poorly systematic.

The new hair dryer profile has been submitted to several hair stylists in order to know their opinion. Such an activity was aimed at verifying if the proposed value transition model presents a logic suiting the Blue Ocean Strategy. Thus, 28 hair stylist have been interviewed by presenting them the new hair dryer profile and asking to answer to the following questions:

1. Do you think that the increased lightness and easy handling of the hair dryer, the elimination of the front wire connection and an improved limitation of the noise, may be perceived as improved benefits by the hairdresser?

2. Do you think that the insertion of one or more parts of the hairdryer within the salon facilities such as the chair or other accessories could allow an integrated and harmonious design of the saloon?
3. Do you think that the elimination and/or the strong reduction of some traditional performances, such as the drying power, can be accepted by the hairdresser?

The investigation reveals that:

1. 26 out of 28 hair stylists think that an improvement of the lightness and of the easy of handling, the elimination of the front wire and the limitation of the noise can be perceived as consistent benefits; 1 out of 28 hair stylists answered negatively while 1 of them believe that such improvements are not relevant within the beauty sector.
2. 21 out of 28 hair stylists believe that the insertion of one or more parts of the hair dryer within the salon facilities could lead to a more harmonious design of the saloon; 5 out of 28 answered negatively; 2 out of 28 didn't answer.
3. 11 out of 28 hair stylists agree with the elimination or the reduction of the traditional performances; 13 out of 28 answered negatively; 4 out of 28 didn't answer.

The results of the opinion poll have been summarized in the diagrams shown in Figures 4.16-4.18. According to these results, it appears that the new and improved attributes are widely accepted by the hair stylists, while half of them didn't agree with a reduction of the traditional performances offered by the hair dryer industry. A deeper analysis of these answers reveals that among the traditional performances, the "drying power" plays a relevant role in determining the perceived benefits since it impacts the waiting time of the client as well as the productivity of the hairdresser. For several hairstylists owning beauty salons and offering spa treatments, long waiting times for the customers aren't considered relevant drawbacks. Very often, men and ladies exploit the opportunity of the hairstyle also to perform public relations, social exchange, etc. and make use of other treatments for their beauty and care. On the contrary, with respect to hairdressers offering just the hairstyle service, the low waiting time is a "must", since the client is uniquely interested in performing the hairdo as fast as possible.

The BOS bases its logic on creating a new business opportunity by breaking the existing market boundaries and by extending the products offering to other potential users, who are interested in accomplishing unsatisfied needs. According to this evidence, the performed analysis of the results leads to the conclusion that the product profile obtained through the new value proposition guidelines, presents several characteristics of a Blue Ocean strategy. At first, the new product profile brings to the segmentation of the current marketplace, according to circumstances that haven't been yet investigated in terms of differentiation and reorientation strategies. The same investigation should be, therefore, performed also in other industrial fields, characterized by the employ of hot air jets in order to verify whether the proposed hair drying system is viable to gain the interest of other potential users, so extending the original market boundaries.

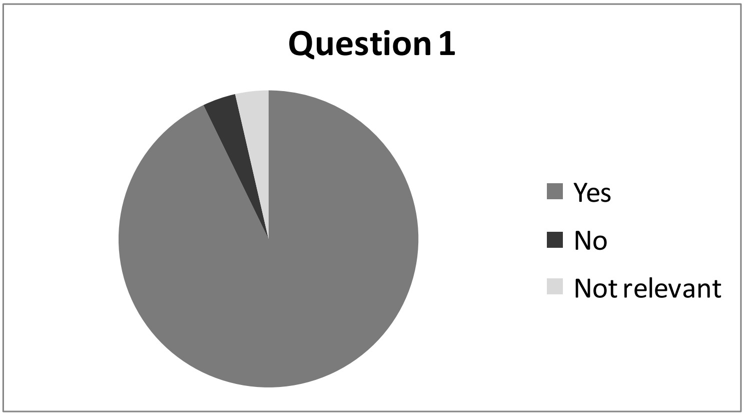


Figure 4.16: Responses to the question: Do you think that the increased lightness and easy handling of the hair dryer, the elimination of the front wire connection and an improved limitation of the noise, may be perceived as improved benefits by the hairdresser?

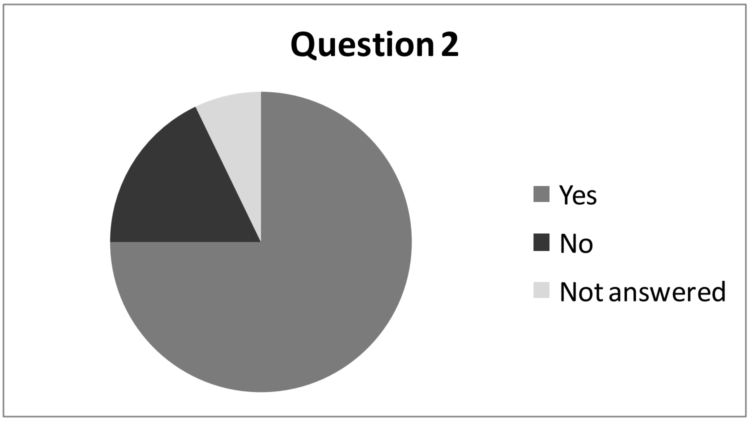


Figure 4.17: Responses to the question: Do you think that the insertion of one or more parts of the hairdryer within the salon facilities such as the chair or other accessories could allow an integrated and harmonious design of the saloon?

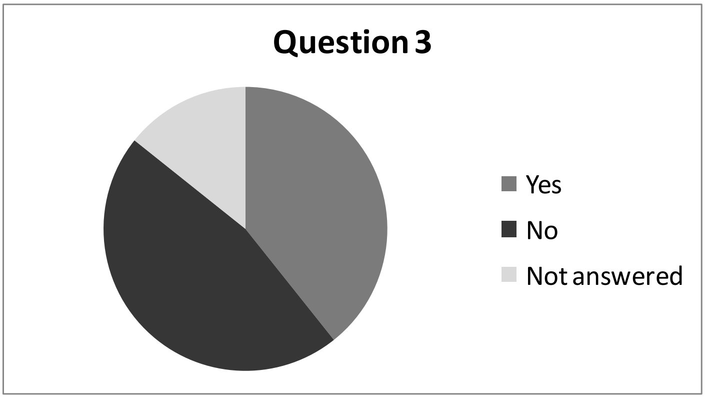


Figure 4.18: Responses to the question: Do you think that the elimination and/or the strong reduction of some traditional performances, such as the drying power, can be accepted by the hairdresser?

5. Verification of the method robustness and repeatability

The encouraging results described in Chapter 4, are useful to demonstrate the effectiveness of the proposed approach for solving the problems introduced in Chapter 1. However, they don't provide further indications about the overall validity of the method.

The performed case studies have demonstrated the great importance of the "Process to Problem" and "Problem to Ideal Solution" phases in solving problems related to the process value bottlenecks. In fact, the analytical activities involved in such tasks allow to point-out the bottlenecks, rank them, identify and prioritize the required actions for their removal. Thus, an experimentation aimed at obtaining useful indication about the robustness and repeatability of the above mentioned key steps, has been performed. This activity was dedicated to ascertain the validity of the method for process problems related to value bottlenecks only. The test has been implemented as summarized in the following:

1. identification of a case study concerning a successful business process reengineering initiative, whose achieved results and boundary conditions are acknowledged by the sector experts;
2. application of the roadmap to the individuated case study, performed in collaboration with the sector experts and verification of the results reliability ;
3. creation of a users group that have learnt the tools, the techniques and the roadmap, without a specific knowledge of the industrial sector at which the case study pertains;
4. test of the methodology with the individuated case study, performed by the users group;
5. comparison between the results arisen from the activity 4 and those obtained by the activity 2.

Here in the following, the above experimentation procedure is widely presented. Section 5.1 describes the users group, provides a brief overview of the case study considered for the experimentation and presents the evaluation parameters against which the benchmark activity has been performed. Section 5.2 presents the results arisen from the application of the roadmap in collaboration with the sector experts. In Section 5.3, the results obtained through the experimentation performed by the users group are described. Eventually, in Section 5.4 the discussion of the benchmark is presented.

5.1. Experimentation setup

A users group composed by 8 students coming from the Academic Course of "Methods and Tools for Process and Product Innovation" (second year of the Master Degree in Mechanical Engineer at the Politecnico di Milano, Prof. Gaetano Cascini), has been considered as the sample for the experimentation. All the students have received the same training regarding the tools used in the roadmap and the roadmap itself.

The considered case study belongs to the pharmaceutical field. It concerns the wet granulation process for the manufacturing of tablets. The wet granulation is commonly employed in order to:

- provide the right level of fluency to the powder constituting the tablet, thus allowing its pressing;
- guarantee the correct distribution of the active pharmaceutical ingredients and consequently the right homogeneity of its dosage within the tablet;
- obtain the correct rate between mass and volume, thus the right level of the porosity of the tablet;
- improve the aesthetic quality of the tablet by guaranteeing an uniform colour distribution;
- strongly decrease the diffusion of the volatile substances during the process, thus preserving the health of the workers.

The most established manufacturing process is the so-called wet granulation at high speed. The process consists in the following phases:

- mixing of the active pharmaceutical principle with water and other ingredients. Such activity is aimed at producing a doughy mixture.
- Extrusion of the dough that is shaped in filamentary structures.
- Drying.

- Crushing of the dried filaments in order to produce the grains.
- Sieving of the grains in order to obtain an output of the process sufficiently homogeneous. During sieving, only the grains having the fluency that allows the subsequent operations involved in the overall tablet manufacturing process, are selected.

The process should produce grains having the following characteristics:

1. a moisture content almost similar to that owned by the ingredients in order to guarantee the required shelf-life of the tablets;
2. the right size and dimensions in order to allow the other phases of the tablet production process;
3. good mechanical properties;
4. low roughness in order to obtain the required aesthetic properties of the tablets;
5. suitable hardness.

The reader can find a more detailed description of the wet granulation process in the Appendix (A2) where the case study is presented in the same way it has been submitted to the users group (for this reason it is reported in Italian).

The comparison between the results obtained by the users group and those arisen by the application of the roadmap in collaboration with the experts of the pharmaceutical sector, has been performed taking into consideration the following main parameters:

- affinity between the models of the process in terms of number of phases and involved flows;
- affinity between the set of CRs in terms of number and type;
- identification of the phase having the highest Overall Value;
- identification of the phase having the lowest Overall Value;
- positioning of the phases according to the Phase Overall Satisfaction and the Resources consumption indexes.

5.2. Application of the roadmap in collaboration with the sector experts

Here in the following the results arisen by the application of the roadmap in collaboration with the sector experts, are presented. The individuated process phases are reported in Table 5.1 (p. 115). Table 5.2 (p. 115) summarizes the identified CRs, classified according to the Kano categories, and their relevance in determining the customer perceived value. The coefficients expressing the contribution of each phase in delivering each CR, are depicted in Table 5.3 (p. 115). Eventually, the Table 5.4 (p. 115) reports the value indexes of each phase of the process, used for the benchmark, i.e. RES (Resource Consumption), POS (Phase Overall Satisfaction) and OV (Overall Value).

According to the value indexes shown in Table 5.4, the dewatering phase owns the highest OV, instead the sieving presents the lowest value. In Figure 5.1 (p. 116) the phases have been reported in a 2D map, according to the POS and RES indexes. The analysis of the graph leads to the following considerations:

- *Mixing*: High performance, this phase presents a high resources consumption, it is the second phase in determining the satisfaction of the customer;
- *Extrusion*: low performance, this phase has a very low contribution in generating the customer satisfaction but it presents also a low resources consumption;
- *Dewatering*: high performance, such phase determines massively the customer satisfaction, however it is also characterized by a not negligible resources consumption;
- *Crushing*: low performance, phase having a low contribution in determining the customer satisfaction and a very high resources consumption;
- *Sieving*: low performance, this phase has similar features of the crushing activity.

The evolution of the wet granulation observed in the pharmaceutical sector has brought to the implementation of two new alternative processes: the wet granulation with fluidized bed and the spray drying. According to the experts' vision, the indication arisen by the analysis of the obtained value indexes, comply with the evolution followed by the process, since:

- the dewatering phase has been improved by lowering the resources consumption and by strongly increasing its performances;
- the resources consumption of the mixing phase has been lowered;
- in the spry drying the crushing and extrusion phases have been integrated.
- in the wet granulation with fluidized bed, they have been trimmed from the process.

Since such results have been confirmed by the sector experts, they can be considered a robust benchmark for this experimentation. Furthermore, the compliance between the obtained outputs and the evolution path of the wet granulation process, demonstrates, once again, the effectiveness of the proposed approach. In Table 5.5 (p. 116), the above described results have been briefly summarized.

Table 5.1: Phases of the wet granulation process as identified by the experts.

Phase	Name
1	Mixing
2	Extrusion
3	Dewatering
4	Crushing
5	Sieving

Table 5.2: Customer Requirements, their classification according to the Kano model and their relevance in determining the customer satisfaction/dissatisfaction.

CR	Attribute	Kano class	Relevance
1	Homogeneous dosage	Must Be	5
2	Porosity	Must Be	4
3	Fluency	Must Be	4
4	Size and dimensions	Must Be	3
5	Moisture content	One dimensional	5
6	Low volatility	One dimensional	1
7	Mechanical characteristics	One dimensional	2
8	Hardness	One dimensional	3
9	Aesthetic quality	Attractive	2
10	Homogeneous colour	Attractive	2

Table 5.3: Coefficients kij expressing the contribution that each phase give in delivering each CR.

Phase	CR1	CR2	CR3	CR3	CR5	CR6	CR7	CR8	CR9	CR10
1	1.00	0.20	0.00	0.00	0.00	1.00	0.00	0.00	0.05	1.00
2	0.00	0.00	0.15	0.60	0.00	0.00	0.00	0.00	0.15	0.00
3	0.00	0.80	0.00	0.00	1.00	0.00	0.40	0.80	0.15	0.00
4	0.00	0.00	0.35	0.40	0.00	0.00	0.20	0.20	0.20	0.00
5	0.00	0.00	0.50	0.00	0.00	0.00	0.40	0.00	0.25	0.00

Table 5.4: Value indexes of the phases, scaled with respect to their maximum.

Phase	RESj	POSj	OVj
Mixing	1.00	0.54	0.41
Extrusion	0.41	0.17	0.31
Dewatering	0.76	1.00	1.00
Crushing	0.78	0.28	0.27
Sieving	0.80	0,23	0.21

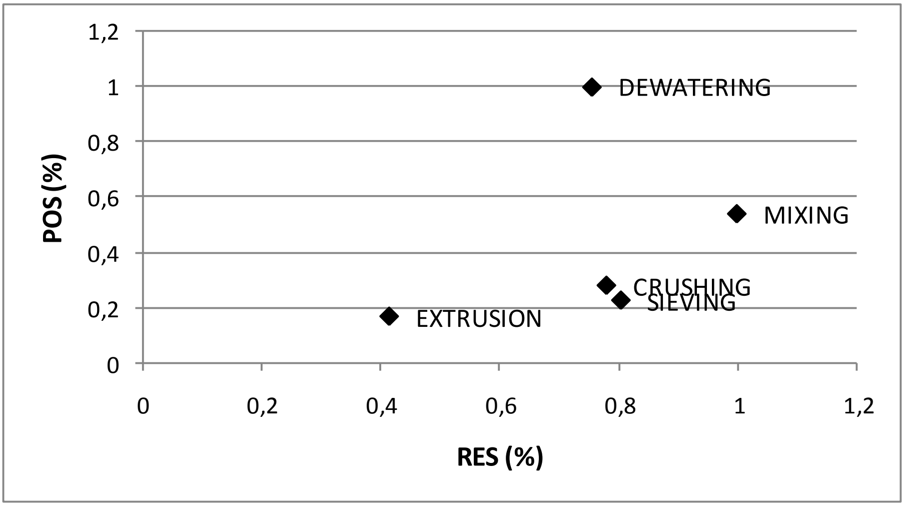


Figure 5.1: Map of the relative positions of the process phases according to the POS (Ordinate) and RES (Abscissa) indexes.

Table 5.5: Summary of the achieved results (the value indexes are scaled with respect their maximum values).

Phase	RESj	POSj	OVj	Performance
Dewatering	0,76	1	1	HIGH high generated value, not negligible resources consumption
Mixing	1	0,54	0,41	HIGH not negligible contribution to the generated value, high resources consumption
Extrusion	0,41	0,17	0,31	LOW low contribution to the generated value, low resources consumption
Crushing	0,78	0,28	0,27	LOW low contribution to the generated value, high resources consumption
Sieving	0,8	0,23	0,21	LOW low contribution to the generated value, high resources consumption

5.3. Results of the experiment

The experimentation campaign performed through the users group, has brought to the following results:

1. 8 out of 8 students have identified all the process phases and flows of the involved resources;
2. 4 out of 8 students have identified all the customer requirements related to the tablet, in accordance with those defined in collaboration with the sector experts.
3. 8 out of 8 students have completed the application of the steps 1 and 2 of the roadmap, thus reaching the stage, in which the relevant process value indexes are estimated.

Only the 4 tests with the set of CRs complying with those individuated by the sector experts, have been considered to perform a meaningful comparison.

The Figure 5.2 (p. 119) depicts the average values of the relevance indexes assigned by the students to each customer requirement; their distribution is plotted so to compare it with the one performed by the experts. The relevance indexes represent the relative contribution of the requirements in determining the customer benefits; according to this consideration such coefficients are presented in the graph in terms of the percentage of the total assigned values. As shown, the weight of the requirement 5 has been widely under estimated with respect the value considered by the experts (-30%). Consistent deviations of the mean values from the expected ones are observed also for CR4, CR6 and CR7.

Table 5.6 (p. 119) reports the classification of the requirements according to the Kano model performed by the students and the one operated by the expert. None of the students has identified a classification in accordance with that elaborated by the experts. 3 out of 4 students considered the CR2 as a “One dimensional” thus acknowledging for this attribute a contribution in generating also customer satisfaction; an akin incoherence can be observed for the student 4 in classifying the CR3. 2 out of 4 students classified the CR6 and 7 as pertaining to the “Must be” category, thus assigning them only a contribution in avoiding the customer dissatisfaction. Eventually, 2 out of 4 students classified the CR9 as “One dimensional” instead of “Attractive”, hence this requirement has been considered impacting also the customer dissatisfaction.

The Figure 5.3 (p. 120) reports the average customer satisfaction (CS) indexes evaluated for each requirement by the students and those determined in collaboration with the experts. The CS coefficients express the contribution of each requirement to the determination of the customer satisfaction; as well known, they depend on the assigned Kano categories and on the attributed relevance indexes. The graph highlights how the classification as “One dimensional” for the CR2 performed by almost all the students, heavily affects the CS index for such requirement. The same evidence can be observed also for the CR3. Another observed singularity is represented by the extent of the CR5 in determining the customer satisfaction, even if the Kano classification of this requirement is coherent with that of the experts. In this specific case the under estimation of its relevance (see Figure 5.2) has led to a reduced evaluation of the attribute contribution in fulfilling the customer satisfaction. The CR7 has been considered as “Must be” instead of “One dimensional” by 2 out of 4 students, thus leading to a decreased value of its contribution to CS with respect to the experts’ estimation. A similar consideration can be made also for the CR8.

With reference to the customer dissatisfaction index (CD), Figure 5.4 (p. 120) shows both the distribution of the average extents gained through the students experiment and the set of values provided by the experts. The CD coefficient gives a measure of the contribution of each CR in avoiding the customer dissatisfaction. Therefore, similarly to the CS index, the extent of CD depends on the Kano classification and the attributed relevance for each feature. The only remarkable singularities are represented by the over estimation of the contributions to the customer dissatisfaction of CRs 9 and 10, since they have been widely considered as “One dimensional” instead of “Attractive”.

The Figure 5.5 (p. 121), shows the observed distribution of the average coefficients kij that determine the contribution of each phase of the process to the achievement of the customer satisfaction. They are plotted together with the values assigned in collaboration with the experts. The assignment of such coefficients carried out by the students is very similar to that performed by the sector experts. However, the contribution of the crushing phase seems over evaluated while that of the sieving results under estimated.

In Table 5.7 (p. 121) the POS indexes are summarized. All the students have indentified the dewatering and mixing phases as those having the major contribution in determining the overall satisfaction and the sieving and extrusion phases as those providing the lowest benefits. It is worth nothing that the student 1 has identified a POS distribution resulting completely compliant with the experts’ experiment.

The RES indexes are depicted in Table 5.8 (p. 121). In accordance with the experts, all the students have identified the mixing and sieving as the most expensive phases, while the extrusion results the cheapest manufacturing stage. Table 5.9 (p. 122), depicting the OV indexes, shows that 2 out of 4 students, indentified the dewatering phase has the one having the best score whereas the other 2 students keep it in the second position. All the students recognized the sieving as the most critical phase. In order to facilitate the comparison between the experiments and the experts, 2D maps reporting the positioning of the phases in terms of POS and RES indexes for each student, are presented in the Figures 5.6-5.9 (pp 122-124).

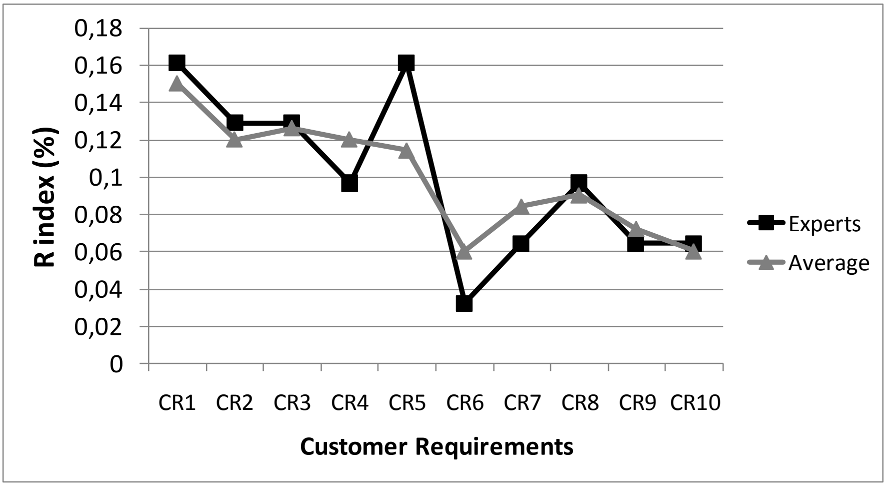


Figure 5.2: Average observed distribution of the contribution to the perceived value assigned by the students, compared with that assigned by the sector experts. The values are expressed as percentages of the ratio between the assigned relevance indexes and their sum, for the observed average and experts' estimations.

Table 5.6: Classification of the CRs according to the Kano model performed by the students and by the sector experts. The classifications meeting the expected ones are highlighted in grey colour.

CR	Attribute	Experts	Student 1	Student 2	Student 3	Student 4
1	Homogeneous dosage	Must Be	Must Be	Must Be	Must Be	Must Be
2	Porosity	Must Be	One dim	Must Be	One dim	One dim
3	Fluency	Must Be	Must Be	Must Be	Must Be	One dim
4	Size and dimensions	Must Be	Must Be	Must Be	Must Be	Must Be
5	Moisture content	One dim	One dim	One dim	One dim	One dim
6	Low volatility	One dim	Must Be	Must Be	One dim	One dim
7	Mechanical characteristics	One dim	Must Be	Must Be	One dim	One dim
8	Hardness	One dim	One dim	One dim	One dim	Must Be
9	Aesthetic quality	Attractive	One dim	Attractive	One dim	Attractive
10	Homogeneous colour	Attractive	Attractive	One dim	Attractive	Attractive
	TOT	100%	60%	70%	80%	70%

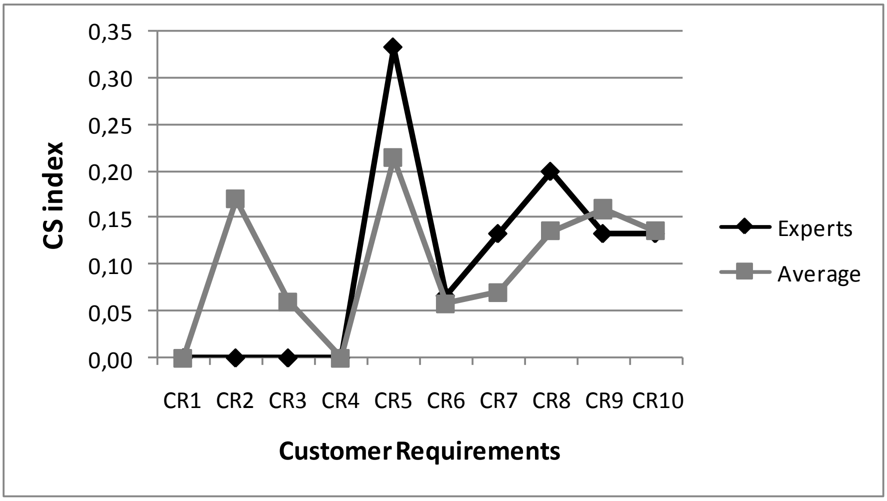


Figure 5.3: Distribution of the average observed Customer Satisfaction indexes for each customer requirement compared with the akin distribution performed by the sector experts. The values have been normalized with respect to the sums of the CS coefficients for the observed average and experts' estimations.

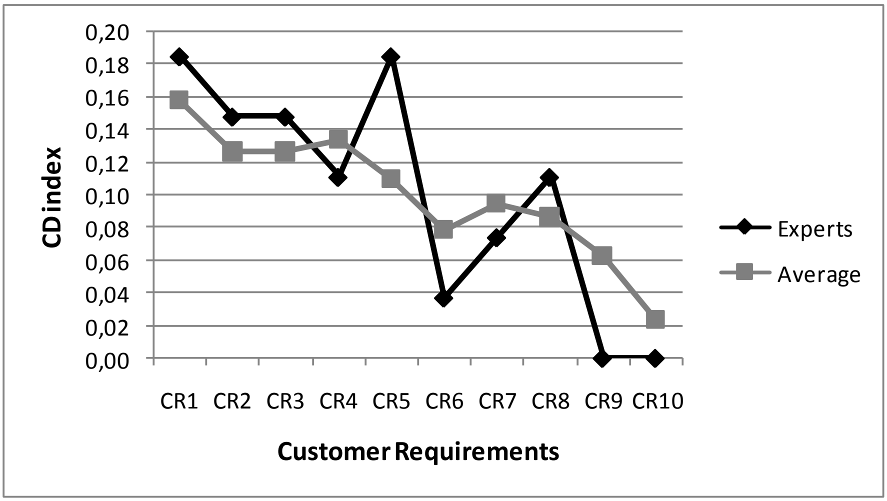


Figure 5.4: Distribution of the average observed Customer Dissatisfaction indexes for each customer requirement compared with the distribution performed by the sector expert. The values have been normalized with respect the sums of the CD coefficients for the observed average and experts' estimations.

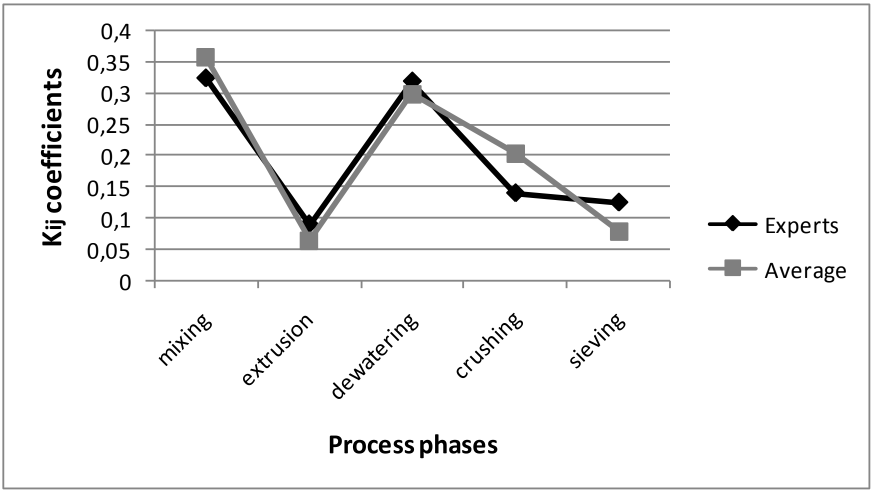


Figure 5.5: Average observed distribution of the coefficients Kij expressing the contribution of each phase in determining the customer perceived value, plotted along with the akin coefficients assigned by the sector experts. The values are normalized with respect their sums.

Table 5.7: Distribution of the Phase Overall Satisfaction (POS) indexes. The values are scaled with respect their maximum value; the white colour has been assigned to the best evaluated phase for each experiment, while the heavy grey pertains to the worst evaluated phase.

Phase	Experts	Student 1	Student 2	Student 3	Student 4
Dewatering	1.00	1.00	0.73	0.88	0.82
Mixing	0.54	0.79	1.00	1.00	1.00
Crushing	0.28	0.64	0.41	0.59	0.43
Sieving	0.23	0.32	0.12	0.11	0.18
Extrusion	0.17	0.18	0.21	0.04	0.52

Table 5.8: Distribution of the Resources consumption (RES) indexes. The values are scaled with respect their maximum value; the white colour has been assigned to the best evaluated phase for each experiment, while the heavy grey pertains to the worst evaluated phase.

Phase	Experts	Student 1	Student 2	Student 3	Student 4
Mixing	1.00	1.00	1.00	1.00	1.00
sieving	0.80	1.00	0.70	0.73	0.65
Crushing	0.78	0.79	0.30	0.57	0.43
Dewatering	0.76	0.79	0.70	0.73	0.60
Extrusion	0.41	0.57	0.30	0.40	0.33

Table 5.9: Distribution of the Overall Value (OV) indexes. The values are scaled with respect their maximum value; the white colour has been assigned to the best evaluated phase for each experiment, while the heavy grey pertains to the worst evaluated phase.

Phase	Experts	Student 1	Student 2	Student 3	Student 4
Dewatering	1.00	1.00	0.77	1.00	0.85
Mixing	0.41	0.62	0.74	0.83	0.62
Extrusion	0.31	0.25	0.51	0.08	1.00
Crushing	0.27	0.64	1.00	0.86	0.63
sieving	0.21	0.25	0.13	0.12	0.17

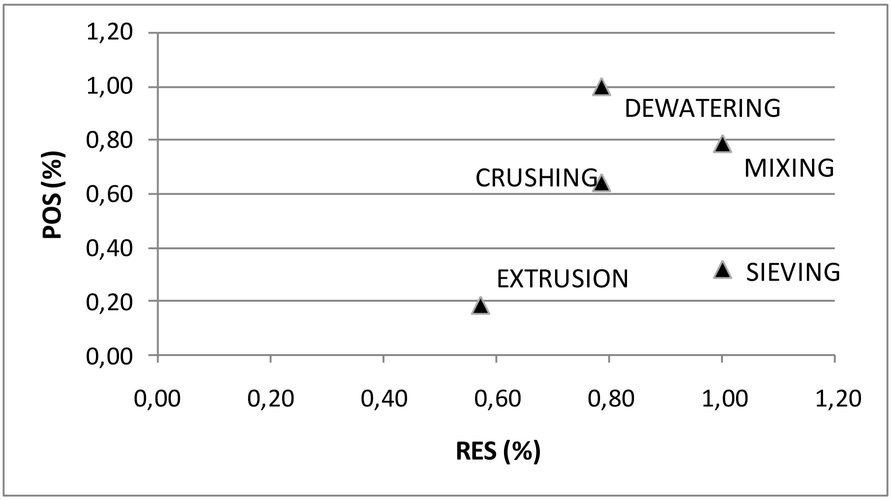


Figure 5.6: Phases distribution in terms of POS (ordinate) and RES (abscissa) indexes for the student 1.

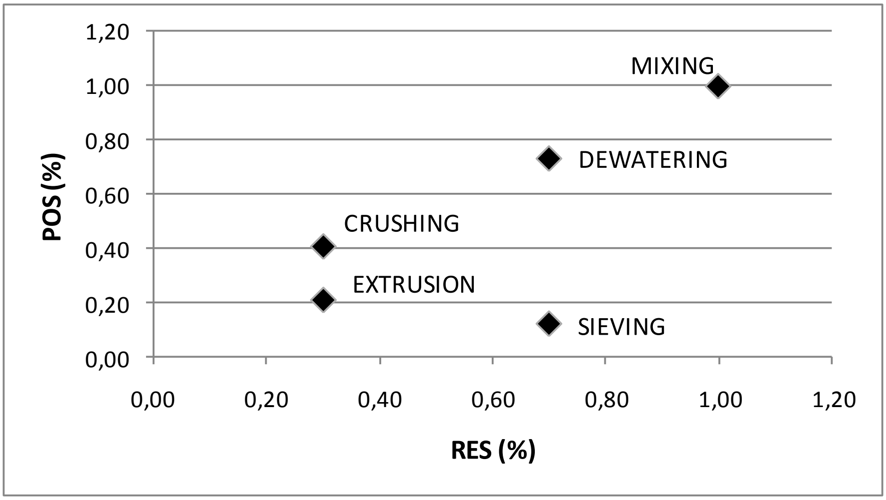


Figure 5.7: Phases distribution in terms of POS (ordinate) and RES (abscissa) indexes for the student 2.

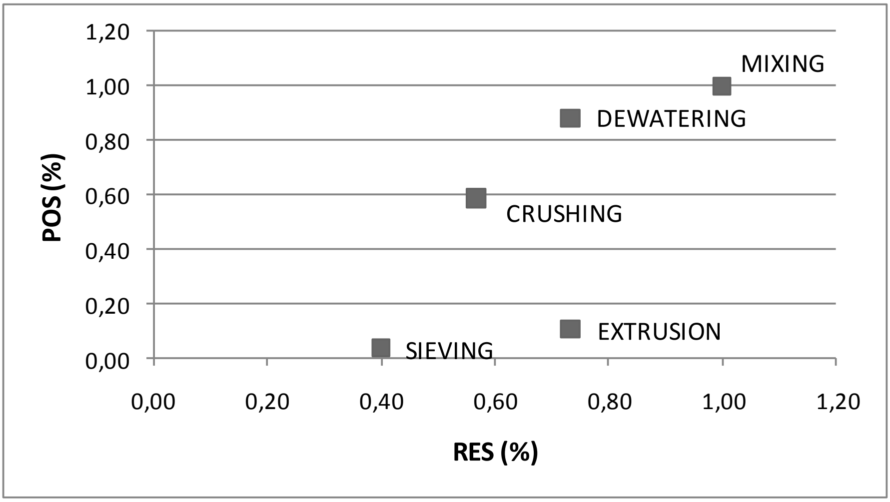


Figure 5.8: Phases distribution in terms of POS (ordinate) and RES (abscissa) indexes for the student 3.

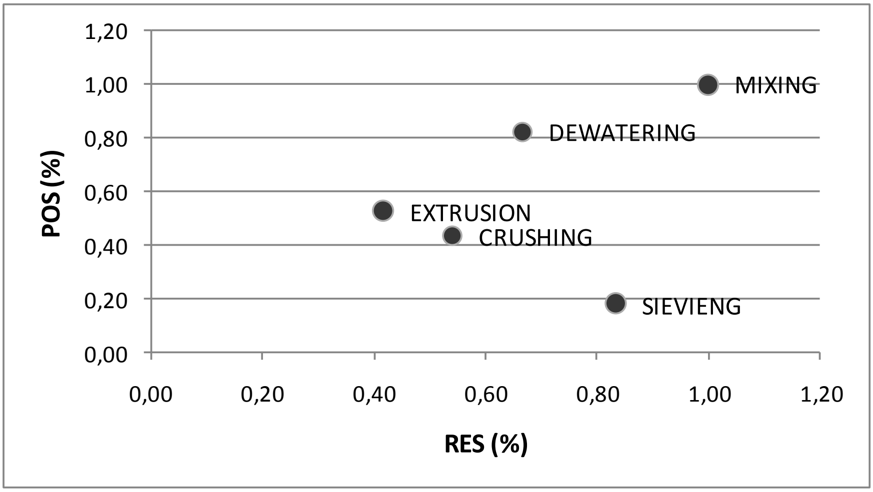


Figure 5.9: Phases distribution in terms of POS (ordinate) and RES (abscissa) indexes for the student 4.

5.4. Discussions of the results

The experimentation activity was aimed at verifying the robustness and repeatability of "Process to Problem" and "Problem to Ideal Solution" phases for problems related to process under capacities. They have been recognized as key steps for the successful solution of problems involving process value bottlenecks. The case study that has been considered as benchmark, pertains to the pharmaceutical field. It has been analyzed in collaboration with the sector experts in order to obtain robust results against which compare the outcomes provided by the users group.

The obtained results, are unfortunately not sufficient to perform a full validation of the method, due to the limited number of the available testers. However, some interesting evidences can be observed, providing useful indications about robustness, repeatability and usability of the tools for process value analysis.

The modelling of the process has been performed in a correct way by all the students. The number and the kind of process phases have been identified in compliance with the experts, as well as the analysis of the flows of the involved resources.

With reference to the value assessment, two interesting evidences are represented by the strongly different distributions of the relevance indexes assigned by the students to the customer requirements, as well as their divergent Kano classification. This led to a very different estimation of the perceived customer value with respect to that estimated by the sector experts. As a consequence the distribution of the customer perceived benefits in terms of CS and CD coefficients presents not negligible divergences with respect to the expected values. Although the coefficients measuring the phase contribution to the customer satisfaction and dissatisfaction have been evaluated similarly with respect to those estimated by the sector experts, the high variability of the CS and CD indexes has considerably impacted the variability of the POS values. The sensitivity of the overall value assessment to the inputs should be carefully further investigated. The experiment underlines the need to strengthen the tasks related to the relevance indexes definition and to the Kano classification of the requirements. Such measures could result particularly advantageous from the perspective of enhancing the robustness of the methodology.

Notwithstanding the variability of the inputs, the ranking of the process phases in terms of POS, RES and OV indexes achieved by the students shows a substantial compliance with respect to the experts' estimations. Indeed, by taking into account the overall value of the phases, the sieving operation results as the most critical phase, while the dewatering and mixing are classified as high performance phases. Moreover, looking to the 2D maps reported in the Figures 5.6-5.9 and comparing them with the map achieved by the experts and depicted in Figure 5.1 (p. 116), the following considerations can be drawn:

- 4 out of 4 students have identified the mixing and dewatering as high performance phases, with the mixing showing a resources consumption greater than the dewatering, while the POS of the mixing results slightly greater than the POS of the dewatering;
- 4 out of 4 students have evaluated the sieving as a low performance phase;
- 3 out of 4 students have identified the extrusion as a low performance phase;
- 2 out of 4 students have identified the crushing as a low performance phase.

According to this analysis, it can be assessed that the performed experimentation has highlighted a good level of robustness and repeatability of the method. Nevertheless, its usability could be improved by strengthening the assignment of the relevance indexes to the customer requirements, as well as their classification according to Kano model.

6. Overall discussion

In this Chapter an overall discussion about the results achieved during the research activities, is presented. The Section 6.1 summarizes the results of the performed tests keeping the focus of the discussion on the evaluated performances of the method in terms of effectiveness, robustness and repeatability. In Section 6.2, the discussion is focused on the methodological objectives presented in Chapter 1. More in particular, the aim of such section is to provide an overview of what has been done until now and what could be done as future research activities, to further develop the proposed roadmap.

6.1. Effectiveness, robustness and repeatability of the method

Several combinations of the proposed tools have been applied to some case studies. The considered tests were referred to the different business process problem described in Chapter 1.

The method has been applied in the footwear sector bringing to the definition of suitable directions for re-engineering initiatives aimed at improving the time to market of accessible fashion shoes. All the strategic actions identified through the application of the method are compliant with those successfully implemented in the sector and arisen from research Projects having national and international relevance.

The logic and the tools for process analysis have been proposed also for BPR activities in the field of the solid bio-fuel production process. Starting from the analysis of the market opportunities and process needs, the application of the method has brought to design an innovative dewatering and grinding technology for woody biomass capable to improve the efficiency of the whole manufacturing process. Also in this sector, the arisen indications aimed at improving the process, have been widely verified through the well established and acknowledged scientific literature.

The guidelines for new value proposition have been applied in the field of the professional hair dryers with the aim of verifying their effectiveness. Such tool supported the definition of the new relevant product features, starting from the analysis of the customer needs and the survey of the devices currently in the marketplace. The effectiveness of the arisen indications has been verified by asking the Voice Of the Customer. The results have shown that the suggested new value profile meets the thorough consensus of a not negligible segment of users (about 50%). They have claimed their interest in the new product features, although established performances could be jeopardized. The extent of the new market opportunities based on the generated product profile, presents characteristics that could be referred to a Blue Ocean strategy. All such encouraging indication provide positive feedbacks about the validity of the developed guidelines.

Eventually, an experimentation activity involving 8 students of the Politecnico di Milano, has been performed to verify the robustness and the repeatability of some key steps of the method. A case study related to the pharmaceutical field has been considered for the experimentation. Unfortunately, the dimension of the testers group, was not sufficient to perform a fully acceptable validation. However some interesting evidences have arisen. With respect to the robustness and the repeatability, the test revealed an overall coherence with the value estimations performed by the experts. Nevertheless a more detailed survey of the results has showed that the successful application of the method depends on the knowledge of the user about the business process.

The manifold applications of the method in very different contexts have demonstrated its effectiveness in identifying process value bottlenecks and subsequently suitable actions for overcoming the main hurdles. Moreover, the performed experimentation activity has verified a good repeatability of the results as well as a good robustness.

6.2. Achieved methodological objectives and further research opportunities

Here in the following a discussion is performed in reference to the level of attainment of the objectives that were presented in Chapter 1. What has been done is briefly summarized together with the proposition of other research initiatives devoted to further develop the roadmap.

A multi domain process model has been implemented, allowing the collecting and structuring of all the information and data related to the business process, in both technical and economical domains. The model is based on the integration of different techniques such as: IDEF0 to represent the process activities according to scheduled times, involved know-how, employed technologies, process constraints; EMS, to account for the flows of energy, materials and information involved in the business process; Throughput Analysis belonging to the TOC, to represent all the monetary flows related to each phase of the business process according to T, I and OE classes. Such a hybrid model guarantees a high level of customization and it can be easily tailored to the specific nature of the business process problem that has to be faced. A not negligible open research issue that requires further investigation, is represented by the identification of the right level of detail at which to deepen the modelling activity. Indeed, an enhanced formalism should account for all the needed data and information, which allow a sufficiently supported analysis activity, representing a key step for the identification of the process value bottlenecks.

Proper metrics have been developed, based on the rate between the contribution of each phase in generating the perceived customer satisfaction and the resources required by the process phases to deliver such benefits. Such metrics allow the evaluation of the process according to different and well defined value indexes. These coefficients permit to rank the process phases according to their criticalness in generating the customer satisfaction. Furthermore, suitable guidelines have been defined to support new value proposition tasks for products and services, focused on the Blue Ocean strategy. Such guidelines have been extrapolated thanks to a deep analysis of the attributes undergoing the Eliminate, Reduce, Raise and Create actions in more than thirty success stories, which have been used to motivate the logic of BOS.

Further research activities should be aimed at improving the developed tools along the paths described in the following.

The value indexes are viable to provide a meaningful contribution in determining the process value bottlenecks. Nevertheless the evaluation of the process criticalness performed through these metrics still doesn’t take into account the impact of the phase performances in determining the offering level of the product attributes. This evaluation could strengthen the identification of process criticalness also by considering the extent of the phases performance. Thus, the integration of the defined metrics with models allowing the assessment of the impact of the phase performances, is strongly recommended.

According to the evidences arisen during the experimentation activity, some tasks should be enhanced in order to improve the overall robustness. With a particular emphasis the definition of the customer requirements, their relevance in determining the customer perceived value and their classification according to the Kano model, are still not sufficiently supported. These activities are completely committed to the knowledge of the sector experts. Thus, a more systematic support should be provided to perform these tasks in order to reduce the impact of the expertise level within the field of investigation.

Even if the case study related to the professional hair dryer has led to positive feedbacks about the effectiveness of the new value proposition guidelines, a full and extensive validation activity is required in order to verify their robustness, repeatability and usability. Moreover, the following research activity are suggested in order to improve the potential of this tool:

- making the functional classification of the product/service attribute more formalized;
- performing a verification activity aimed at providing more information about the validity of the guidelines by studying their suitability with successful and unsuccessful new value proposition experiences;
- defining more prescriptive rules for the identification of the product or service attributes that should be submitted to the value move when the number of identified attributes is greater than the number of guidelines;
- defining a selection criterion viable to suggest what attribute should be subjected to the value move when there are several attributes pertaining to the same functional class.

Furthermore, the integration of new value proposition and process value analysis tasks is still not sufficiently formalized. This is a crucial issue to be addressed in order to obtain a fully integrated product and process re-engineering approach. Such an objective can be achieved by defining a common value metric for the considered tasks. In this way will be easy to assess the impact of the new product or service profile on the process, in terms of the required reorganization actions.

Eventually, a more precise criterion viable to guide the designer in selecting the appropriate tool according to the nature of the technical problem to be solved, could make more efficient the tasks related to the "Ideal Solution to Physical Solution" phase.

By summarizing the above performed discussions, it is straightforward that the original contribution of the research is widely referred to the steps 1 and 2 of the developed roadmap, that are those related to the modelling and the analysis of the business processes. According to the above performed discussions, it can be concluded that the methodological objectives have been globally attained. However some developed tools and some application steps require further investigation in order to enhance the effectiveness and the systematic level of the proposed roadmap.

7. Conclusions

In this Thesis a methodology aimed at supporting business process re-engineering activities on the basis of customer satisfaction requirements has been presented. The proposed road-map is useful to identify guidelines allowing the definition of both process/product/service evolution strategies and resource reorganization activities to preserve or gain market competitiveness. The procedure is based on the original integration of well known complementary methods and tools in order to perform technical-economic analysis according to the multidisciplinary nature of the task. The main aspects of the proposed integration have been investigated and described.

The proposed approach is based on the evaluation of the benefits generated by each phase of the process in terms of its own contribution to the customer perceived value. This task is accomplished by means of a comparison among the process phases, performed through suitable value indexes. They have been properly defined by parameters related to customer satisfaction and needed resources. As a result the comparison leads to the identification of the main guidelines by which it is possible to define evolution strategies for the business process. Moreover, within the framework of re-engineering initiatives related to product and process, also proper new value proposition guidelines have been defined aimed at systematizing new value proposition tasks. A functional classification of the attributes has been identified, allowing to link the main aspects of value to the functions of the product or service evaluated from the customer perspective. Such classification is performed taking into account if the product attributes are related to useful functions delivered to the customer, mitigation of the effects due to harmful functions, impacting directly or indirectly the customer, limitation of resources consumption accounted to the customer for the system working.

Once the process/product/service value bottlenecks have been highlighted, the consequent activity is a “typical” engineering inventive task aimed at identifying suitable technical solutions for overcoming these limits.

The road-map has been already applied in four different case studies, the first related to the footwear industry, the second to the production of solid bio-fuel, the third to a new value proposition task in the field of professional hair dryer and the fourth to the granulation process in the pharmaceutical sector.

In the footwear sector, the results show that the proposed approach is able to support the identification of the critical process phases giving effective improvement guidelines for preserving market competitiveness. The effectiveness of the methodology has been assessed through a benchmark of results obtained by other approaches in the field of shoes manufacturing and distribution process.

The application of the method in the bio-fuel sector has tested its effectiveness also for an under development production process with poor performances, which consequently don’t allow the complete exploitation of both the available resources and the market demand. Such evidence provides a positive feedback for the applicability of the proposed roadmap for re-engineering activities of manufacturing processes experiencing under capacities in satisfying the market demand.

The application of the new value proposition guidelines for a new value proposition in the field of the professional hair dryer has demonstrated the effectiveness of the tool in suggesting the actions to be performed in order to radically improve the value of the product according to the logic of the 4 Actions Framework model. The achieved results have been verified by asking to the users their opinion about the new product profile. Such an activity shown that a high percentage of users claimed their interest in some new features of the hair dryer that don’t belong to the current industrial standard.

The application of the method to the case study related to the pharmaceutical field has led to a further confirmation of its effectiveness. This case study has been also used to perform an experimentation activity aimed at verifying the robustness and repeatability of some key steps, using a sample of 8 students from Politecnico di Milano. Even if the size of the sample wasn’t sufficient to perform a full validation, the results reveal a good level of agreement among the indications arisen from the students’ experiment and the paths of evolution indicated by the experts within the granulation process.

Finally, the main improvements of the developed approach should concern:

- the identification of a criterion by which establish the sufficient level of detail of the process multi domain model;

- the definition of a more systematic approach aimed at supporting the identification of the customer requirements, their relevance in determining the customer perceived value and their classification according to the Kano model.
- an extensive validation activity aimed at verifying the robustness, repeatability and usability of the new value proposition guidelines.
- the definition of more prescriptive rules for the identification of the product or service attributes that should be submitted to the value move.
- the integration of new value proposition and process value analysis tasks by defining a common value metric.

List of Acronyms

ABC:	Activity Based Costing
ANCI:	Italian National Shoe Factories Association
BOS:	Blue Ocean Strategy
BPR:	Business Process Re-engineering
BSC:	Balanced Score Card
CD:	Customer Dissatisfaction
Cj:	Costs resources spent during the j-th phase
COS:	Direct costs
CR(s):	Customer Requirement(s)
CS:	Customer Satisfaction
CTRL:	Controllability
DFD(s):	Data Flow Diagram(s)
EM:	Enterprise Modelling
EMS:	Energy Material and Signal
ENE:	Energy
ENV:	Element Name Value
ERRC:	Eliminate Raise Reduce Create
ERs:	Engineering Requirements
ETO:	Engineering to Order
FOS:	Function-Oriented Search
HF:	Harmful Function
I:	Inventory
IDEF:	Integrated Definition for Function Modelling
INF:	Information
JIT:	Just in Time
JITS:	Just In Time for Shoes
LCE:	Life Cycle Engineering
LHV:	Lower Heating Value
MAT:	Material

NPD:	New Product Development
OBJ:	The object of the main function of the system
OE:	Operating Expenses
OO:	Object Orientated
OV:	Overall Value
OVj:	Overall Value of the j-th Phase
PCD:	Phase Customer Dissatisfaction
PCS:	Phase Customer Satisfaction
PDC:	Product Development Cycle
pij:	Offered performance of the attributes i of the product j
POS:	Phase Overall Satisfaction
POSj:	Phase Overall Satisfaction of j-th phase
PSSs:	Product Service Systems
QFD:	Quality Function Deployment
QRM:	Quick Response Manufacturing
RAD(s):	Role Activity Diagram(s)
RES:	Resources consumption
Ri:	Relevance Index of the attributes i
RID(s):	Role Interaction Diagram(s)
ROB:	Robustness
ROI:	Return Of Investment
SPA:	Space
SPE:	Service Product Engineering
SUP:	The external environment or some element of the super-system that is due to be safeguarded
SYS:	The system under investigation itself
T:	Throughput
THR:	Threshold achievement
Tj:	Time resources spent during the j-th phase
TOC:	Theory of Constraint
TQM:	Total Quality Management
UF:	Useful Function
UML:	Unified Modelling Language
Vj:	Delivered value of the product j
VE:	Value Engineering
VA:	Value Analysis
VAC:	Value Assessment Chart
VOC:	Voice of the Customer
VEj:	Value for Exciting requirements
VER:	Versatility
VNj:	Value for Needed requirements

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Appendix

A1. Systematizing new value proposition through a TRIZ-based classification of functional features[1]

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Abstract

In recent years, several TRIZ practitioners have focused their attention on the application of TRIZ concepts for new business strategy definition. Among the others, the Blue Ocean Strategy has attracted the largest consensus. Nevertheless, this methodological approach proves to be very elegant to describe past business innovation successes, while it provides just general directions if a new profile of "values" is requested for a given product or service. The present paper analyzes with a TRIZ perspective 32 case studies from the BOS literature and shows that more prescriptive guidelines can be identified from these experiences.
Keywords: New value proposition, functional features, TRIZ ideality, System Operator

1 INTRODUCTION

One of the main assumptions of TRIZ concerns the concept that repeatable patterns characterize the evolution of technical systems regardless the field of application. The Laws of Engineering Systems Evolution (LESE) [1-2] and the Inventive Standards [3] allow thus to envisage the viable evolutionary scenarios

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regarding any technical system; as a consequence TRIZ has represented the theoretical background for technological forecasting activities [4-5]. In the same context the authors have proposed a tool named Network of Evolutionary Trends (NET) [6-7], aimed at mapping the evolution of product platforms and the related employment of resources. The network illustrates the development followed by products in the marketplace and patented inventions, suggesting unprecedented evolution paths that cope with the LESE. Within business innovation the alternatives suggested by the NET have to be subsequently evaluated in terms of the expected appeal on the market. The last step can be supported by an estimation of the customer perceived value of the options depicted by each evolutionary branch.

On the other hand business experts are aware of social and economical macro-trends, that shape the core of knowledge for the decision making process, but codified and systematic tools for technological forecasting are not widespread. TRIZ has represented the first attempt to build a homogeneous set of trends viable to anticipate the development of technical systems. Thus, from this point of view, TRIZ tools can provide the missing link for systematic business innovation activities dealing with the development of successful products to enter the marketplace.

Within business innovation policies, a particular attention is given nowadays to the identification of systematic means to propose products and services characterized by a new value profile, rather than competing within the current features and performance levels of the reference industry, as formalized by Kim and Mauborgne with the Blue Ocean Strategy (BOS) [8-9]. The existing "new value proposition" strategies, and BOS is not an exception, lack of systematic paths to envisage innovative products and services, since they are very elegant to describe past successes, but they are not really prescriptive, i.e. they provide just fuzzy directions about the space where to look for new market opportunities.

Dealing with these deficiencies and with the general purpose of building a systematic approach for the development of successful products and services, the paper aims at supporting the identification of the attributes that determine customer perceived satisfaction. Further on, the measures to be attained in order to propose new valuable product platforms are suggested through a preliminary set of guidelines, arising through the analysis of the case studies described by BOS authors. The outcomes of such comprehensive task are viable to orientate the choice of the alternatives suggested by the NET.

The following Section provides an overview about new product development techniques, focusing on those employing the concept of value and performs a critical review of BOS. Section 3 explains the methodology used to gain the preliminary guidelines by the characterization of products and services attributes in terms of useful functions, harmful effects and resources consumption, hereafter indicated as functional features. Section 4 highlights the outcomes of the performed survey of BOS' cases by listing the preliminary guidelines. Section 5 provides an overview of coherences and mismatches between the indications emerged and the evidences provided by different models and researches about the performed modifications of the functional features. Subsequently, Section 6 reports the conclusions and the proposed further research issues in order to strengthen the guidelines and the process for systematizing the development of successful products.

2 STATE OF THE ART OF NEW VALUE PROPOSITION METHODOLOGIES

The product conceptualization phase plays a fundamental role in the New Product Development (NPD) cycle since, in order to develop a successful product in competitive and globalised markets, customer requirements need to be carefully investigated during the front-end design and the product platform planning [10]. The companies have pursued product lifecycle re-engineering strategies, by taking into account a wide range of features, such as price, delivery lead-time, delivery conformance, performance, quality and reliability, sources of risk, environmental factors and life-cycle costs. Consequently different approaches have been developed, characterized by the priorities, concerning one or more of the previously listed features, assigned to perform the product development [11,12].

However it is well acknowledged in literature, that successful NPD initiatives strongly depend on the business opportunity identification stage. The objective of this task is to search for new areas of opportunities which typically swivel on the unsatisfied and unspoken needs of the customers. In the following paragraphs a literature review of tools and methods developed during the last years to assist the definition of product re-engineering strategy based on the new value proposition is presented in order to introduce the specific objectives of the present research. Section 2.1 illustrates a general overview of the methods developed with the aim of assisting the product planning task, focusing on the tools for the investigation of customer needs and the identification of the most impacting product attributes for the customers. Section 2.2 is specifically dedicated to the description of the tools suggested by the Blue Ocean Strategy (BOS) for the identification of business opportunities with superior customer value. In Section 2.3 the research objectives are summarized according to the literature review.

2.1 General overview of methods for the definition of new products having superior value

Several methods have been developed in the consumer research field, with the aim to capture the so called "Voice of Customer" (VOC); in [13] an extensive survey is presented. Many approaches such as those based on Free Elicitation, Laddering, Conjoint Analysis, etc., try to extrapolate the product attributes having major interests for the user by interviewing techniques in which the customers are asked to identify the attributes they consider relevant in the perception of a product. Other methodologies (i.e., Empathic Design, Information Acceleration, etc.) are based on observing the consumer behaviour during the day life. The assumption behind these approaches is that designers can easily identify opportunities for products in response to perceived needs, by examining the consumer behaviour.

According to Ulwick [14], even if all these methods help in gaining knowledge of consumers and their behaviour, they cannot support the systematic identification of new product attributes, since asking the customers helps just to reveal the needs they are clearly aware, without shedding light on potentially novel valuable attributes.

Quality Function Deployment (QFD) has been applied to several domains such as robust design and business process re-engineering [10,15,16]. It allows to focus the design tasks on the customer requirements along the whole product development process from conceptual design to manufacturing. A market-driven design system to integrate QFD technique with marketing analysis was proposed in [17]. The suggested approach is focused on concentrating the design efforts on particular product features, which generate maximum benefits for customer satisfaction. More recently, Ulrich and Eppinger [18] provided a methodological approach for identifying customer needs and for establishing their relative importance, but they didn't provide any guidelines for ranking and selecting needs based on their perceived value.

In the above mentioned approach and several others available in literature, QFD is used as a method to relate the customer demands to the engineering requirements in the early stage of NPD, but it cannot provide any useful support in identifying the product attributes having superior value. Thus QFD is used, very often, together with the above cited methods for customer research in order to investigate the end-user needs and to translate them in product attributes.

By summarizing the above performed literature review, the following drawbacks and lacks of the considered methods arise:

- the identification of the product features creating superior value for the user is demanded to the VOC, but it cannot support the systematic identification of new product attributes since the consumers don't know exactly what they want;
- some of the described methods are useful to identify the impact that each product attribute has on the customer satisfaction, but they don't provide any useful indication on the measures to be undertaken in order to shift towards more valuable product platforms.

2.2 Overview of Blue Ocean Strategy

From the business point of view, most of the well-established strategies mainly focus on the ways to achieve competitive leadership and advantage, with a crucial role played by the relationship between the performance and the prices of the manufactured products or the delivered services. On the contrary, the strategy fine-tuned by Kim and Mauborgne aims at looking for new business opportunities, through the definition of an innovative set of features for a company's industry, allowing to create new market space due to a novel value proposition. In this way BOS intends to break the quality/cost trade-off through value innovation, thus "killing" the competition with industry rivals and creating a new business model through the investigation of communalities of different groups of costumers and non-customers. The so built uncontested marketplace is symbolized by a blue ocean in contrast with severe competition, the red ocean infested by bloody sharks.

The reasons of BOS' success, witnessed by acknowledgements [19], awards [20], quick adoption by the companies looking for innovation tools [21], are to be traced, beyond the suggestive picture of the blue ocean [19,22], in the attempt to develop and systemize ideas and theories regarding a dynamic market characterized by breakthroughs opposed to incremental improvements [23] and pushed by the interplay among needs (functional, emotional, aesthetical, etc.), consumers and firms [24]. The advantages of pursuing a blue ocean are pointed out by Kim and Mauborgne through the evidences arising from numerous breakthrough case studies belonging to manifold sectors [20]. The widespread applicability of the strategy in the business context has pushed its diffusion. In the literature the case studies regarding the fruitful application of BOS' framework, guidelines and tools, as well strong recommendations for their implementation, range from big companies to SMEs, from the tertiary sector to institutions; the involved industrial fields encompass manufacturing, apparel and footwear, energy and sustainability, pharmaceutics and biotechnology, education, communications, logistics, transportation, insurance, financial activities, healthcare, entertainment, tourism, agriculture, husbandry, constructions, real estate.

The application of the strategy has been carried out with the direct implementation of BOS fundamentals, as well as employing the suggested tools described in the book [9]. Among them, the strategy canvas represents the conceptual framework aimed at summarizing the ideas to perform a successful strategic "move". In the strategy canvas the value curves stand for the graphical representation of the relative performances of products or services, across the relevant factors of competition for the companies and their value propositions in their pertinent business industry.

BOS issues in terms of selecting the relevant attributes and applying the Four Actions Framework

In the BOS a new curve is built by proper modifications of the current product/service attribute performances and by the introduction of previously ignored properties. The innovative bundle of attributes and performances is obtained by the Four Actions Framework and summarized by the Eliminate Reduce Raise Create (ERRC) Grid. While it is relatively simple to investigate the current relevant product features to be properly removed, worsened or enhanced, by benchmarking the competition, the proposition of new valuable product attributes represents a severe challenge [25]. Within BOS such task can be eased by the Six Path Framework, which represents a set of indications that help in finding new ideas that are viable to break the established market boundaries.

Nevertheless, it has been argued that the strategy canvas represents just a useful visual tool to represent the ideas underpinning the BOS “move”, whilst it misses proper guidelines in order to select successful value propositions among multiple alternatives [26]. As a consequence, assessing a strategy canvas results in a difficult matter [22,27]. Several scholars [28-30] have attempted to make the process of building the strategy canvas more robust, taking into account the extent of importance levels attributed to competition factors in terms of customer perceived value. However, these measures can be adopted just after the relevant business features have been identified and defined, so when the range of possible choices has already been consistently reduced and the actions to be applied have just to be prioritized.

A relevant matter consists in the proper actions to be applied to the various product attributes. From Kim and Mauborgne’s description of Four Actions Framework it emerges that the attributes to be investigated are those related to buyer’s perceived value:

- the eliminate action concerns factors the pertinent industry has long competed on and that don’t represent anymore a source of competitive advantage in terms of customer value;
- the reduce action is related to product/service attributes that are overdesigned and that could be provided at much lower performance without affecting perceived value;
- the raise action consists in increasing the performance of certain attributes well above the current industry standard, breaking the compromise with other features of the value curve;
- the create action aims at introducing brand new sources of value for customers.

Thus, the company's strategy should be reoriented acting on those features that directly affect the buyer's perception, whereas a performance increase for a certain attribute represents a growth in customer's value. However, already Ziesak [30] has highlighted how Kim and Mauborgne themselves use price in their value curves and how a high score of this attribute results in a low value for customers. Thus the employment of attributes generating dissatisfaction may result misleading especially with reduce and raise actions. The non-prescriptive formulation of the rules has resulted in several applications performed by BOS practitioners that show an incorrect use of the Four Actions Framework. These include the use of features that are not valued by customers [31,32] and mainly inherent to internal business processes, as well as attributes that have a reverse impact on buyers' perception and satisfaction [33].

Another issue related to BOS tools concerns the need to apply all the four actions in order to create a blue ocean, as recalled by Kim and Mauborgne in the Chapter that introduces the ERRC Grid. However, it is arguable to assess such statement as a constraint, since even in classical BOS application cases, it is not straightforward to clearly individuate factors submitted to all the four actions: examples can be drawn by Siegemund [34], who examined Southwest Airlines, and Formule 1's value curve without any newly created attribute, as represented by Kim and Mauborgne [35] and subsequently by Narasimhalu [29].

BOS' reliability

Kim and Mauborgne have illustrated a set of case studies from a wide range of industrial sectors, in order to show the strength and the positive outcomes of their strategy. However it has been argued that is not possible to determine whether the examples have contributed to the formulation of the theory or if they have been chosen because they fit the strategy. As well as it is also unclear how exactly the method was developed [36], issues arise in terms of BOS' reliability and applicability.

The need for an enhanced formalism

As a consequence of the whole bundle of observations, the BOS' tools result to be pretty descriptive, useful to motivate the success of product and processes ex post, but don't provide systematic paths to identify the new product/service profile. The authors describe in this paper the preliminary results of a research encompassing multifaceted aspects of product development and lifecycle carried out in order to provide BOS' tools and value proposition strategies an enhanced formalism in the correct identification of the attributes and subsequently in the actions to be performed.

2.3 Objectives of the research

The aim of the paper is therefore to provide a first contribution in order to systematize the individuation and the classification of the attributes subjected to the application of the Four Actions Framework. The guidelines emerging from the present research originate from the statistical analysis of the features, that are switched in the successful examples exposed in literature by Kim and Mauborgne.

3 METHODOLOGICAL APPROACH OF THE RESEARCH

3.1 Investigating preliminary guidelines aimed at systematizing a new value proposition

The guidelines aimed at supporting the definition of value profiles for products and services thus lean upon the investigation of acknowledged successes in the market, carried out in order to verify the existence of any regularity arisen in the reconfiguration of the product attributes. The performed research encompasses various phases, starting from the individuation of the pertinent case studies for the investigation, to a statistical analysis about the functional features of the product/service attributes, whose modifications have led to new value propositions. The following paragraphs will describe more in detail these steps, summarized in Table 1.

Table 1: steps followed to extrapolate the guidelines.

Step	Objective	Task	Tools	Outputs
1	To create a set of case studies to be investigated in order to extrapolate further guidelines	Individuating and selecting the case studies	Scientific and technical literature	A set of case studies acknowledged in the literature as successful New Value Proposition applications
2	To identify and characterize the shifts occurred to the value curves of successful products or services with respect to well-established standards	Comparing the value curves and classifying the actions applied to the attributes according to the Four Action Framework	Strategy canvas, value curve, Four Action Framework	Classification scheme of the product attributes in terms of the Eliminate Reduce Raise Create (ERRC) actions
3	To provide an insight about the retrieved attributes in terms by considering the elements that enable customer value at a functional level	Classifying the attributes in terms of the functional features	TRIZ functional analysis and Ideality; classification employed to rank Evaluation Parameters	Classification scheme of the attributes in terms of the Functional Features of the system
4	To characterize the evolution of the product profiles by the occurred modifications of the customer perceived value	Correlating the Four Actions and the functional features	Statistical analysis	Guidelines to perform an enriched value proposition strategy, based on Four Action Framework and TRIZ Ideality terms

Individuating and selecting the case studies

The aim of this step is to select a representative group of acknowledged products or services that, as documented by literature, have gained uncontested success in the marketplace, due to breakthroughs in the value profiles with reference to their industries of expertise. Such cases are then identified as successful implementations of a new value proposition strategy.

The case studies described by Kim and Mauborgne in the works that have led to the formulation of the BOS [9, 35,37], have been thus collected and examined in order to create the set of examples. The described products and services have been further investigated through scientific and technical literature, thus allowing to select those responding to the criteria of acknowledged success and characterization, through features both significantly enhanced and dropped to a lower level. This investigation has led to the identification of 32 case studies, that represent a wide set of product and services. The detailed list, as well as the references that don't pertain Kim and Mauborgne's literature will be provided in an extended version of the paper,

Comparing the value curves and classifying the actions applied to the attributes according to the ERCC model

The transformations, occurred from the traditional to the novel value curves for each case study, are substantiated by the attributes subjected by the actions foreseen within the ERRC framework. Thus, the task of this step is the individuation of product/service attributes that have been firstly introduced, eliminated by the set of competing factors, subjected to a drastic modification of their performance level. Such attributes are therefore classified according to the Eliminate, Raise, Reduce and Create actions.

In some cases, the literature about the BOS already individuates and explains the actions applied to the various product/service features. The authors have therefore defined all the attributes in terms of desired outputs, whose increase implies a growth in the customer perceived satisfaction. This leads to avoid misleading identifications of the actions applied. At the same time a particular attention has been paid in order to list attributes without mutual interrelations and dependences, as well as communalities in the contribution to more general valuable aspects for the customers. Thus, the sets of competing factors include just decoupled evaluation parameters that play an independent role in the generation of customer perceived value.

In order to systematically classify the actions of the ERRC framework, further ambiguities have been solved resorting to the Elements-Name of the feature-Value (ENV) model [38]. The properties which first characterize the value curves are the novel Elements of the strategy canvas and are distinguished by the action Create. The features which are not proposed in the strategy canvas, or don't represent anymore a factor of competition, are assumed as removed Elements and thus subjected to the action Eliminate. In the cases in which the modification of the attributes is outlined as a shift in the Value of the feature of a certain Element, the classification deals with the actions Raise or Reduce, depending on the enhanced or reduced perceived satisfaction for the customer.

Classifying the attributes in terms of the functional features

The guidelines that the paper aims to extrapolate are based on the classification of the attributes into three main categories (functional features), representing the terms that characterize the ideality (in TRIZ terms) from the viewpoint of the end user of the system under investigation. Thus, the scope of this step is to distinguish the attributes among outcomes of the useful functions (UF), measures to attenuate or avoid the inconvenience due to harmful effects (HF) and efforts aimed at mitigating the impact of resources' consumption (RES). Due to such definition of the functional features' classes, the increase of each attribute results in a growth of customer perceived value.

The classification and subsequent categorization (through clusters that will be indicated as sub-functional features) comply with a previously proposed classification for the Evaluation Parameters of a technical system [39]. As well as the Evaluation Parameters represent the requirements to be satisfied by a technical system, the attributes related to a strategy canvas represent the core of the requirements to be fulfilled in order to foreshadow a successful value proposition. However, while the features of technical systems are considered at a functional level, the attributes have to be classified by the user point of view in order to cope with an approach swivelling on customer value. Consequently the classification has been slightly customized in order to be employed within the application field. The authors have thus categorized the useful functions into threshold achievement (THR), versatility and adaptability under changing conditions (VER), robustness and repeatability of the outputs (ROB), controllability (CTRL); the harmful functions are classified according to the item subjected to the negative effect (system itself, SYS; super system, SUP; object of the Main Useful Function, OBJ); the resources are subdivided in space (SPA), time (TIME), materials (MAT), information (INF), energy (ENE), direct costs (COS). Table 2 provides an example of classification of the attributes in terms of both functional and sub-functional features, as well as the indication of the actions to which they are subjected.

Table 2: exemplary classification of the attributes subjected to the actions in a successful new value proposition

Case	Action	Attribute	Functional feature	Sub-functional feature
NetJets	CREATE	Time saving for aircraft administration	RES	TIME
	CREATE	Ease of aircraft management	RES	INF
	CREATE	Savings on deadhead costs	RES	COS
	RAISE	Purchase cheapness	RES	COS
	REDUCE	Travel flexibility	UF	VER
	REDUCE	Flight speed	RES	TIME

Correlating the Four Actions and the functional features

The goal of this step is to delineate the proper guidelines by assessing the results of a statistical analysis. Once the attributes are classified according to the above defined criteria and the proper actions are identified, their mutual correlations are counted. By observing the statistical outcomes of the most occurring and the rarest crossover correspondences among attributes' classes and actions, the extrapolated guidelines provide indications about the most viable measures for building successful new value curves and about what to avoid at the greatest extent in order to prevent from failing propositions.

Another TRIZ model, the System Operator, has been adopted to strengthen the systematic procedure for the creation of new value curves.

Often referred as Multi-screen Schema in classical TRIZ literature, the System Operator is a key model of the TRIZ body of knowledge. It constitutes an effective means for avoiding psychological inertia in several steps of the problem solving process, and the essence of reasoning of a creative person [40].

Given its flexibility of use, the System Operator can be thus employed for mapping a wide range of situations, circumstances and working conditions otherwise neglected, consequently allowing to scout for enhancement opportunities. The application of the System Operator proposed in the paper is aimed at individuating unprecedented sources of value for the end user of manufactured products or delivered services. In order to customize the tool and so to highlight the valuable aspects considered by customers, temporal dimensions can be suitably articulated following a lifecycle perspective. It is hereby proposed to adopt a standard subdivision into the followings: purchasing and access activities; operations and conditions preceding the employment of the system; the utilization time; the period elapsing before further exploitations; the phases related to the definitive termination of the functions, the disposal, the dismantling.

4 OUTCOMES OF THE RESEARCH

This Section describes the outcomes of the survey performed about the classification of the attributes subjected to modifications within BOS' cases.

4.1 Overview of the research and of the employed tools

The analysis of the previously listed 32 case studies has led to the identification of 288 product attributes that underwent the Four Actions of BOS.

The classification of these attributes has been carried out by more research fellows, in order to evaluate the robustness and the repeatability of the clustering criteria defined in Section 3.1. The number of attributes, whose classification has been considered disputable, resulted appreciably low. At the first level of classification, thus considering the functional features only, 273 attributes were classified in the same way by all the fellows, resulting in an overlap equal to 94.5%. As mentioned in Chapter 3.1, the classified attributes have been further clustered at a more detailed (sub-functional) level. The number of attributes that resulted with a convergent sub-functional classification from all the fellows is 232, equal to:

- a 80.6% overlap taking into account the total number of attributes;
- a 85,0% overlap with reference to the set of attributes having a concordant classification for the functional features.

The controversial clustered attributes haven't been considered for the preliminary investigation of the guidelines. In other terms, at both the functional and sub-functional level, only the attributes having convergent and undisputed classification, have been employed as the overlay of the subsequent statistical analysis.

The distribution of the applied Four Actions can oppositely be referred to the grand total of the attributes:

- Create: 82 (28.5%);
- Raise: 107 (37.2%);
- Reduce: 58 (20.1%);
- Eliminate: 41 (14.2%).

Therefore the first conclusion which can be drawn by this study is that the actions aimed at increasing the user's perceived value (Create and Raise) represent about two thirds of the total. They are thus strongly predominant if compared with the number of measures that entail a drop in the customer satisfaction (Reduce and Eliminate).

4.2 Statistical evidences according to the first level of classification

According to the level of classification related to the functional features, the attributes are distributed as summarized in Table 3:

Table 3: Distribution of the attributes according to the functional features.

	OCCURENCES	OVERALL %
USEFUL FUNCTIONS	157	57.5%
HARMFUL FUNCTIONS	29	10.6%
RESOURCES	87	31.9%
TOTAL	273	100.0%

Such distribution shows that a wide majority of attributes pertains outcomes related to useful functions, while the number of those related to the mitigation of negative effects and resources' consumption, is considerably smaller. The data demonstrate that the biggest attention is focused on the desired effects for the user, that are the terms standing on the numerator of TRIZ ideality formula.

The occurrences of the functional features along the Four Actions are summarized in Table 4, while their percentage distribution is summarized in Table 5.

Table 4: Occurrences of the functional features along the Four Actions.

	UF	HF	RES	TOTAL
CREATE	45	7	23	75
RAISE	40	15	47	102
REDUCE	41	5	11	57
ELIMINATE	31	2	6	39
TOTAL	157	29	87	

Table 5: Percentage distribution of the functional features within each action.

	UF	HF	RES	TOTAL
CREATE	60.0%	9.3%	30.7%	100.0%
RAISE	39.2%	14.7%	46.1%	100.0%
REDUCE	71.9%	8.8%	19.3%	100.0%
ELIMINATE	79.5%	5.1%	15.4%	100.0%

In order to obtain useful information for the definition of the preliminary guidelines aimed at supporting the identification of new value curves, analysis criteria have to be defined for evaluating the extent of the impact played by the Four Actions on each class of functional features.

Beyond the previously depicted data, the authors believe that a possible way to evaluate this impact could be the evaluation of the difference between the percentage distribution of the functional features within each action, and that expected, alike in the general framework.

According to this assumption, the differences between the values summarized in each row of the Table 5 and percentages depicted in Table 3 have been calculated. The values reported in Table 6 express the percentage gaps for each functional feature within the actions, dividing the previously calculated differences by the expected distribution of Table 3.

Table 6: Percentage gaps between the real and expected distribution of the attributes within each action according to the functional features.

.	UF gap	HF gap	RES gap
CREATE	4%	-12%	-4%
RAISE	-32%	38%	45%
REDUCE	25%	-17%	-39%
ELIMINATE	38%	-52%	-52%

The analysis of the general distribution of the attributes and of the percentage gaps brings the following relevant indications:

- no particular preference is hereby remarked in the implementation of new attributes, hence the outcomes of Useful functions (UF) and the mitigated inconveniences due to harmful effects (HF) or resources' consumption (RES) follow a distribution within the Create action that is pretty similar to their global distribution;
- within the Raise action it is observed that the meaningful mitigations of the inconveniences due to HF and to the consumption of resources (RES) seem to be recommendable; conversely enhancements, although relevant, of the performances related to attributes classified as Useful Functions, don't show likewise benefits for the end user;
- the main trend related to the Reduce action is the drop of the performances defined as UF; on the other hand, the increase of needed resources is scarcely diffused and it could result as strongly inconvenient;
- the Eliminate action tends to be applied mainly to the UF attributes and meaningfully seldom to the features classified as HF and RES; therefore it

seems to be extremely risky to introduce harmful effects previously absent or to foresee the employment of new kinds of resources; thus, when some outcomes of the system have to be jeopardized, in order to allow a new value proposition, the preliminary observations strongly advise to address the removal of attributes consistent to useful functions.

4.3 Statistical evidences according to the second level of classification

In order to obtain useful indications from the analysis of the second level classification of the attributes, a similar analysis has been performed in analogy with the distribution of UF, HF and RES sub-functional features. For the determination of the percentage gaps the calculation has been carried out with reference to the distribution of the sub-functional features within the related cluster at the first level of classification. Tables 7, 8 and 9 report the percentage gaps of the sub-functional features concerning UF, HF and RES attributes respectively.

Table 7: Percentage gaps between the real and expected distribution of the attributes within each action according to the UF sub-functional features.

	THR	ROB	VER	CTRL
CREATE	1%	-3%	-11%	21%
RAISE	-3%	171%	-33%	8%
REDUCE	19%	-100%	-5%	-34%
ELIMINATE	-17%	-100%	58%	-4%

The analysis of the depicted values brings to the identification of some relevant trends related to UF sub-functional features:

- it is worth to mention the emphasis that seems to be given to the creation of attributes related to the controllability of the system;
- a tendency is observed to consistently raise the capability to provide the same desired outcomes under varying inputs (robustness);
- the Reduce action is preferably addressed to diminish the value of UF attributes that are ranked into Threshold achievement;
- the features that are eliminated or that don’t represent anymore competition issues, deal significantly with the versatility and the adaptability of the system, i.e. blue ocean can be found through specialization.

Table 8: Percentage gaps between the real and expected distribution of the attributes within each action according to the HF sub-functional features.

	OBJ	SYS	SUP
CREATE	-31%	-100%	95%
RAISE	24%	24%	-54%
REDUCE	4%	-100%	30%
ELIMINATE	-100%	333%	62%

Through the outcomes of Table 8, further preliminary guidelines can be drawn out; however the small amount of HF attributes doesn't allow to assess their reliability at all:

- at a first glance, the attributes that are firstly introduced in the new value curve and that pertain undesired effects and drawbacks, are mainly associated to those that play an impact on the external environment (SUP);
- significant enhancements in terms of attenuating undesired effects affecting the object of the system, are quite diffused in building new value curves;
- worsened outcomes in terms of drawbacks against the super-system seem to be the most accepted;
- as a consequence of redefining the sets of values for a product or a service, the introduction of harmful functions that seems to be tolerated at best, is related with the impacts on the system itself; on the contrary, relying on the observations, any bad consequence on the object of the system, not being already present in the reference industry, has to be discouraged.

Table 9: Percentage gaps between the real and expected distribution of the attributes within each action according to the RES sub-functional features.

	SPA	TIME	MAT	ENE	INF	COS
CREATE	-100%	7%	42%	-100%	70%	-41%
RAISE	80%	-2%	-100%	80%	-28%	18%
REDUCE	-100%	23%	-100%	-100%	-26%	27%
ELIMINATE	-100%	-44%	800%	-100%	35%	-53%

According to the values presented in Table 9 the following preliminary indications can be outlined about RES sub-functional features:

- benefits can arise by introducing new features centered on the reduction of employed resources in terms of required information, know how, practice of use, materials; on the contrary, starting to compete on the price and on the need of energy doesn't result to be advantageous at the same extent;
- positive feedbacks come out by attenuating the user needs in terms of energy and space;
- the increase of time requirements and direct costs, on which the competition is already based, seems to be the least impacting;
- the introduction of novel requirements for the system employment, if necessary, should be best based on materials or information; at the current stage of the survey, analogous measures related to other kinds of resources have to be discouraged.

5 DISCUSSION ABOUT THE GUIDELINES AND OTHER EVOLUTION HYPOTESES

This Section is aimed at discussing the most noticeable congruencies and mismatches between the preliminary guidelines, obtained through the statistical analyses described in Section 4, and the indications pertaining different evolution hypotheses in the field of innovation and business. However, it is worth to notice that the parallel drawn is affected by the circumstance that most development theories concern the evolution observed by product platforms, while by means of BOS the competing systems that are compared can be significantly different and pooled only by the common accomplishment of certain user needs.

The main evidence arising from the research is the growing role played, within the renewal of product value profiles, by resources safeguard, and more generally by the measures performed to attenuate undesired aspects of a product/service. Indeed, both RES and HF functional features come out more frequently in the groups of attributes subjected to the actions Create and Raise; on the contrary, the functional features classified as UF constitute the bulk of the attributes having reference to the actions Reduce and Eliminate.

Within the LESE, the Law of Uneven Development of the Parts of a System assesses that the priority assigned to certain performances, and specifically to the Main Useful Function (MUF), lead to the unequal evolution of the elements of the system itself and consequently to the birth of contradictions. If such conflicts are overcome in the last phase of the system development, the system faces the enhancement of the aspects that had been jeopardized by the growth of the main function. It is not possible to directly link the law with the recalled main evidence of the research carried out, since the improvements can concern secondary useful functions, as well as harmful effects and resources requirements. Nevertheless the terms that constitute the denominator of the ideality formula are relevant just during the last steps of the evolution of the technical system. The Law of Increasing the Degree of Ideality foresees two different mechanisms, in agreement with the wave model of resources consumption [2]. The first type of ideality growth involves the enhancement of the MUF with minor increase of the consumed resources; the second half of the S-curve is characterized by a drop of the required resources, still preserving the outcomes related to the MUF.

Within the Wave Model by Salamatov [2] the mechanism of reduction of resources required by the system happens after the maturity stage. With a greater affinity with the indications arisen by the statistical analysis, the obsolescence phase, depicted in the final part of the S-Curve of Evolution, observes a relevant drop in the resources employment and a less consistent decrease of useful functions, in terms of their number or extent. The same model pertaining an akin set of stages characterizing the S-Curve is outlined also by Lapidot [41], that employs the concept of “costs” instead of “resources”, by considering the overall expenditures and undesired outcomes, thus including also the harmful functions.

Still in the context of product innovation, a study about awarded original engineering systems reveals how the determinants for their success lie in the enhancements brought to interaction with the user and the environment [42]. These kinds of improvements, that can be ranked among the attributes related to resources and harmful effects, overbear the benefits generated by additional functions.

Some analogies with the assessed relevance of resources and drawbacks of mature products can be tracked also in the field of business and industrial management. Utterback and Abernathy, already in the 70s [43], depicted a product development model constituted by three different stages, foreseeing:

- a first performance maximization, addressed to fulfil the needs of the user and characterized by high products innovation;
- a massive competition aimed at pushing the sales at the greatest extent, from which a dominant design emerges; such phase shows remarkable process innovation and is stimulated by technological progress;
- the minimization of the costs for highly standardized products, competing thus on the resources requested to the user.

This model constitutes the basis for more recent frameworks within industry lifecycle evolution, assessing the shift of emphasis from products to processes and services. Thus the evolution involves at a greater extent those aspects that are less connected with the main performance of the system and more linked with efforts played by the customers in order to gain certain outcomes. A survey of these models is provided by Cusumano et al. [44].

6 CONCLUSIONS AND FUTURE DEVELOPMENTS OF THE RESEARCH

The paper is a first attempt to systematize the procedure for building a successful new value proposition strategy. The preliminary attempts have been addressed to overcome formal ambiguities related to the successful strategies developed within BOS. After showing some fuzzy aspects of this technique, the authors propose a classification of product and service attributes that have been subjected to consistent modifications in BOS literature examples of new value propositions. The Four Actions Framework and the functional features characterizing the TRIZ ideality formulation from the user's viewpoint, together with proposed subcategories, have been chosen as the taxonomy of the classification. The statistical analysis of the attributes categories has led to the identification of relevant recommendations that represent a first attempt towards the synthesis of more systematic guidelines aimed at supporting new value proposition tasks. Moreover, it has been showed that the System Operator can provide useful suggestions to investigate the viable directions for the definition of product and service value profiles. A step forward in order to implement the guidelines with TRIZ tools is foreseen by linking the outcomes of the present survey with the Network of Evolutionary Trends [6]. Indeed, among the alternatives offered by the evolution trends depicted through the NET, the guidelines should guide the designer in choosing the most promising branch to develop a successful product to enter the marketplace.

According to the discussion performed in Section 4, the statistical analysis has highlighted, in the renewal of product platform, a trend assessing an increasing emphasis on resources and harmful functions and a substantial reduction of the useful outputs that the industry has long competed on. This trend is confirmed also by other indications coming from various scientific domains. Nevertheless, in order to integrate and validate such preliminary guidelines and the other suggestions emerging from the statistical analysis, it is worth to apply the employed classification framework also to other successful examples of new value proposition not belonging to BOS literature. As well, with the objective of substantiating the recommendations about the measures to be avoided, an examination of unsuccessful value proposition examples could provide a better understanding of the motivations that have led to products' and services' failures.

The guidelines emerging from the investigation of the Create action should be the most relevant, being the proposition of pretty new product attributes appreciated in the marketplace the most severe challenge for the strategies based on value. Unfortunately, the statistical analysis of the attributes firstly introduced in the domain industry hasn't brought any unmistakable hint. In order to fill this gap and strengthen the definition of the guidelines, it could be appropriate to provide other taxonomies for classifying the attributes.

Even if the guidelines that were defined by the functional classification of the attributes provide suitable suggestions on what should be done to define a new value curve, criteria giving a prioritization in the selection of the most suitable recommendations are still lacking. Therefore further development of the research should go towards the definition of such additional criteria.

With this purpose, the use of the System Operator itself, suggests to investigate the elements and the product lifecycle phases affected by the novel attributes, thus establishing the mutual relationships with the operative time and space of the MUF of the system. In other terms it is viable to identify whether the new benefits are perceived during, before or after the display of the main performance of the system, as well as to observe the hierarchical level of the product or service involved in order to provide the advantages originated by the attributes under investigation.

Some other research has been carried out in order to link the new valuable attributes to seeded and yet unrevealed needs. Although a theoretical background [45] has been built to relate needs theories (especially Maslow's model and its evolutions) with the attributes created by applying the BOS or the attractive requirements described by the Kano model [46], practical indications to systematize the new value proposition process are still lacking. Working on a similar background, studies have been carried out to deepen the perception of functional and emotional features of products and services, fulfilling users' requirements and nevertheless related to human needs [47]. As well, Cagan and Vogel [48] have advanced proposals to accomplish new value proposition strategies based on the interplay of functional and emotional product features. These hints, beyond representing a critical support for the BOS' path "Look across functional or emotional appeal to buyers", can constitute a further field of research for strengthening the guidelines, by taking into account the human needs that are stimulated by the new attributes and the forms of customer perceived value.

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LIST OF ACRONYMS

BOS: Blue Ocean Strategy
COS: Direct costs attribute
CTRL: Controllability attribute
ENE: Energy attribute
ENV: Elements-Name of the feature-Value

ERRC: Eliminate Reduce Raise Create
HF: Harmful Functions
INF: Information, know-how attribute
LESE: Laws of Engineering Systems Evolution
MAT: Material attribute
MUF: Main Useful Function
NET: Network of Evolutionary Trends
NPD: New Product Development
OBJ: Object attribute
QFD: Quality Function Deployment
RES: Resources
ROB: Robustness attribute
SPA: Space attribute
SUP: Environment (super-system) attribute
SYS: System attribute
THR: Threshold achievement
TIME: Time attribute
TRIZ: Theory for Inventive Problem Solving
UF: Useful Functions
VER: Versatility attribute
VOC: Voice of Customer

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A2. Wet granulation process

Generalità sulle compresse farmaceutiche

Le compresse farmaceutiche rappresentano una elevata porzione dei medicinali utilizzati. L'ingrediente fondamentale è costituito dal principio attivo o API (Active Pharmaceutical Ingredient), ovvero la sostanza chimica che permette l'effetto curativo per il paziente. Le formulazioni farmaceutiche, tuttavia, fanno larghissimo uso, in particolare, anche di eccipienti, sostanze che favoriscono l'accettabilità del farmaco, il rilascio del principio attivo, la produzione delle compresse. Sia i principi attivi che gli eccipienti vengono forniti ai produttori di compresse in forma di polveri.

Le caratteristiche di APIs ed eccipienti non permettono la compressione diretta delle polveri per un larghissimo numero di formulazioni ed è quindi necessario ricorrere ad operazioni intermedie per la realizzazione della compressa. Difatti, nell'industria si fa larghissimo impiego della trasformazione delle polveri in granuli, particelle che risultano più grandi, più resistenti e complessivamente più adatte ad essere sottoposte alla fase di compressione. Pertanto, le aziende che producono compresse farmaceutiche, affidano a terzisti o ad altri rami delle aziende stesse la produzione di granuli, i quali poi verranno conseguentemente sottoposti alla compressione. La granulazione consente di:

- fornire quelle proprietà di scorrevolezza tali da consentire la successiva compattazione, altrimenti impossibile da realizzare; l'eventuale inadeguatezza di tale proprietà può causare infatti numerose problematiche nelle fasi di produzione successive alla granulazione;
- garantire la corretta distribuzione del principio attivo e di conseguenza la necessaria omogeneità di dosaggio del composto, requisito fondamentale per l'efficacia delle compresse farmaceutiche (che altrimenti, evidentemente, non possono essere usate); ciò avviene evitando in particolare i fenomeni di segregazione, ossia la stratificazione dei componenti secondo la densità;
- ottenere il rapporto prestabilito tra volume e massa, garantito da un'adeguata porosità: anche quest'ultima caratteristica influenza fortemente le successive operazioni a cui i granuli sono sottoposti ed un valore non corretto di questa proprietà genera enormi problemi ex post;
- garantire proprietà estetiche migliori per la compressa, in virtù di una loro colorazione più uniforme (per mezzo di una distribuzione più omogenea di eccipienti ed eventualmente coloranti);
- ridurre in maniera più che sufficiente la diffusione di sostanze volatili (che possono costituire un pericolo per gli operatori), anche se, evidentemente,

questo parametro non è particolarmente percepito nelle fasi produttive a valle.

- I granuli devono inoltre essere caratterizzati anche da:
- una umidità relativa assai simile a quella naturale dei prodotti in ingresso, in maniera da garantire un lungo equilibrio della compressa durante la sua conservazione e consentire perciò una buona vita utile del farmaco (shelf-life), persino maggiore di quanto prescritto dalle normative; tanto più l'umidità relativa è corretta per una determinata composizione, maggiore sarà la durata della compressa e la sua efficacia in termini di corretto rilascio dei principi attivi nell'organismo;
- le dimensioni desiderate, che se non ottenute, impediscono le fasi successive di lavorazione;
- buone caratteristiche meccaniche ed elastiche, tali da evitare in maniera soddisfacente i fenomeni di deformazione della compressa quali decalottamento e laminazione (ovvero formazione di fori, spaccature, frastagliature);
- caratteristiche fisiche tali da consentire la liscezza della compressa, qualità che ne enfatizza le proprietà estetiche e conseguentemente stimola l'accettabilità da parte del paziente;
- una durezza del tutto soddisfacente, che a sua volta influenza la medesima caratteristica per le compresse.

Caratteristiche generali della granulazione ad umido

La granulazione ad umido, rispetto alle cui varianti illustreremo in seguito la tecnica più comune e consolidata (ad alta velocità), è largamente utilizzata nell'industria farmaceutica grazie alla sua capacità di trattare tutti gli API a disposizione. Tale largo impiego non è compromesso neanche da alcuni aspetti sconvenienti inerenti la granulazione ad umido, come i costi e la difficoltà di controllo di certe operazioni, data dalla complessità dei fenomeni fisico-chimici in atto, che richiede delicati setup in ogni fase; inoltre, l'utilizzo di solventi determina la presenza di un ambiente potenzialmente reattivo. Purché alcune fasi prevedano tempi di lavoro piuttosto consistenti, la produttività non rappresenta uno dei problemi chiave per questa tecnica. Caratteristica comune di tutte le fasi è invece l'alto consumo di risorse materiali per la realizzazione dei macchinari predisposti per le varie operazioni. La trasformazione più significativa, emersa nell'evoluzione di tale tecnologia, è stata la messa al bando di numerosi solventi chimici, cosicché le soluzioni impiegate attualmente sono pressoché esclusivamente acquose. Questa trasformazione non ha tuttavia inficiato il meccanismo generale di funzionamento della granulazione ad umido. La presenza della soluzione, in particolare con l'attuale utilizzo dell'acqua come solvente, consente oltretutto una drastica riduzione della volatilità delle polveri e della loro potenziale contaminazione.

Descrizione della granulazione ad umido ad alta velocità

Lo schema funzionale più comune è quello della cosiddetta granulazione ad umido al alta velocità. Essa prevede la miscelazione di polveri di principio attivo, eccipienti ed acqua per la produzione di una mistura pastosa; questa fase precede quella di frantumazione (una sorta di estrusione) della pasta stessa in delle strutture filamentose che verranno successivamente essiccate prima di sottoporle ad una nuova frammentazione in grado di ridurne le dimensioni fino a renderle granuli. La fase di setacciatura si rende infine necessaria per ottenere un output di processo sufficientemente omogeneo da garantire le richieste caratteristiche di scorrevolezza, selezionando soltanto i granuli propri per la successiva operazione di compressione, in pratica scartando quelli non conformi derivanti dalla fase precedente, responsabile pertanto di un significativo consumo aggiuntivo di materiali.

Attraverso la granulazione ad umido al alta velocità, attraverso complessi fenomeni fisico-chimici, i granuli realizzati risultano di consone proprietà meccaniche ed elastiche (grazie all'essiccazione, alla vagliatura ed, in misura minore alla seconda frammentazione), tali da impedire i (successivi ed eventuali) fenomeni di deformazione della compressa, ed altresì dotati di una struttura tale da permettere la liscezza della compressa, in base a meccanismi che interessano l'intero processo con un ruolo crescente delle fasi che si susseguono.

La miscelazione delle polveri di principio attivo, eccipienti ed acqua per la produzione di una mistura pastosa, effettuata attraverso l'azione di pale meccaniche le quali permettono la redistribuzione spaziale delle polveri e del solvente, presiede alla realizzazione di una miscela umida omogenea in ogni aspetto, di tipo pastoso. Il necessario utilizzo di acqua per la realizzazione della miscela compromette evidentemente l'umidità relativa dei prodotti in ingresso, la quale verrà ripristinata successivamente. Tramite la miscelazione si contribuisce, pur in maniera non determinante, anche alla porosità dei granuli. Rispetto al consumo di materiali, oltre all'utilizzo significativo di acqua purificata, alla miscelazione va attribuito anche lo scarto (tuttavia in genere non eccessivo) di polveri e materiali non trasformati correttamente. Limitanti sono invece l'elevato consumo energetico, la durata della miscelazione ed una serie di operazioni ausiliarie (sterilizzazione, pulizia dei macchinari, smaltimento delle acque reflue con fanghi attivi), che impattano notevolmente sia in termini di costi che di tempi. Al contrario l'utilizzo di spazio fisico è limitato, pur variabile rispetto alla quantità dei materiali da trattare.

La successiva fase di frammentazione della pasta è realizzata attraverso l'azione combinata di superfici prementi e spigoli taglienti di fori, in cui essa viene incanalata, in maniera da ottenere una forma filamentosa, indicata generalmente col nome di 'spaghetti' umidi. Grazie alla prima frammentazione si dà un contributo iniziale alle caratteristiche di scorrevolezza dei granuli che poi si formeranno e si riduce la materia in dimensioni opportune secondo due dimensioni. Il consumo di risorse più significativo è quello di spazio, che cresce consistentemente con la quantità di materia da trattare. Non particolarmente impattanti risultano il consumo di energia, la durata del processo e la necessità di provvedere a funzioni ausiliarie, che si limitano all'utilizzo di sistemi di abbattimento del rumore.

L'essiccazione (eseguita comunemente in forni ventilati) viene quindi praticata sui prodotti umidi e filamentosi realizzati con la fase di frammentazione. I prodotti di questa fase, quindi, non saranno altro che gli stessi filamenti privi del loro surplus di contenuto acquoso. Una corretta essiccazione contribuisce oltretutto, in maniera preponderante, alla porosità ed alla durezza dei granuli. L'operazione di essicazione necessita di elevate risorse energetiche, spaziali e temporali; meno impattante è l'adozione di sistemi per l'abbattimento del rumore. Il consumo di aria per il funzionamento del forno è ovviamente trascurabile in termini di costi.

La riduzione della materia in granuli consiste nella frammentazione meccanica per mezzo di un moto forzato della massa attraverso una maglia calibrata. Tale fase, oltre a portare a termine la determinazione delle corrette dimensioni dei granuli, influenza in maniera non marginale la loro scorrevolezza ed in misura più ridotta la loro durezza. Risulta critico il consumo di spazio per il funzionamento del processo di riduzione in granuli, soprattutto per elevate produzioni. Di ridotto impatto sono il consumo energetico e la durata della fase, mentre non è trascurabile l'impiego di sistemi di abbattimento del rumore.

Il processo produttivo termina pertanto con la fase di vagliatura dei granuli per mezzo di setacci vibranti. Tale fase presenta diverse criticità dal punto di vista delle risorse, in quanto sono significativi il consumo di energia, lo spazio impiegato, la durata dell'operazione, l'adozione di sistemi di abbattimento del rumore.