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Evaluating the adoption of Augmented Reality in field service networks

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Abstract

This research pertains to the literature streams on service management and on technology-driven innovation. The reference context is a company that provides services to support manufactured products and industrial equipment along their working lives (i.e., industrial services) especially in B2B industries, irrespective of this company is directly the manufacturer through a service division or a service firm. In particular usually the service provision is regulated by contracts in which the provider needs to be compliant with strict service level agreements, e.g. related to product availability, time to recovery, etc. However, as far as installed bases of the equipment become more complex to be served and scattered over a vast territory, the field force can seldom be conveniently kept trained to be skilled to cope with any situations that might arise. For this reason, service organisations are used to deploy the field force with the intent to centralize the most skilled and experienced personnel. Therefore, since field technicians are not always adequately trained and/or skilled, to do their job at their best they need to receive support, to access information, data and documents in several circumstances. From these considerations it follows that the sharing of knowledge among dispersed technicians is crucial. To this concern, recent advances of Information and Communication Technologies (ICT) are expected to play a crucial role in favouring information and knowledge management in service networks, and, among the others, the adoption of Augmented Reality (AR) is expected to have a great impact on field force productivity. Since AR is an emerging technology, the literature is still lacking of studies that address the impacts of its introduction to support field service networks. Therefore, this the-

sis aims at filling this gap. In particular, this overall goal is decomposed in three sub-objectives as follows. Firstly the selection of the adequate AR system to be adopted to satisfy specific service needs is clarified. In particular, based on a thorough literature review on both AR systems and the classifications of industrial services, a typology that categorizes the different AR systems according to three dimensions is presented and three kinds of AR applications that can be leveraged to support industrial services (i.e. three patterns) are identified and discussed.

Secondly, the impact of AR on the delivery of industrial field services is addressed. For this purpose the studies focused on Pattern 1, i.e. on a particular kind of AR, named Mobile Collaborative Augmented Reality (MCAR) that resulted particularly suited to support remote communication between product specialists and field technicians when unforeseen problems arise. Within this context, three explorative case studies were performed involving both a company that is not using MCAR and two companies that, instead, have introduced MCAR to support their field service networks. From these cases several insights into the expected benefits and efforts, the stages of adoption and the feedbacks were achieved and two areas of improvements for companies that are willing to adopt MCAR are identified and discussed.

Finally, if the previous part was purposed to identify the managerial implications related to MCAR adoption, this last one is focused on understanding the end users' perceptions of usefulness and ease of use of MCAR and their intention to use it. Even in this case the study is focused on Pattern 1. Based on Technology Acceptance Model literature, a novel model named ARTAM (i.e. Augmented Reality Technology Acceptance Model) has been developed and validated against the survey of three companies whose field force were selected as test benches.

The results of this thesis represents a valuable contribution both for scientific and industrial world since provide new theoretical models such as AR typology and ARTAM as well as managerial implications of AR adoption, useful for managers interested in adopting this emerging technology

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Contents

List of Figures

List of Tables

Chapter 1

Introduction

This chapter introduces the research problem describing several background phenomena that have inspired this study. Then, the scope and the research questions are formulated, followed by a discussion on the relevance of this study. Finally, the research strategy adopted and the structure of the dissertation is described.

1.1 Research background and objectives

"The service revolution and the information revolution are two sides of the same coin"
(Rust, 2004)

This study stems from two main research streams: the servitization phenomenon in which manufacturing companies are integrating their product-based offering with more and more services and the impact of information and communication technologies (ICT) on organizations and in particular on service delivery systems. The rest of this section, thus, aims at introducing these broad concepts in order to better understand the rationale and the relevance of this study.

1.1.1 *The servitization paradigm - the relevance of services in OEM's offering*

Within a globalized market, original equipment manufacturers (OEMs) need constantly to face off global competition, socio-economic progress and shortening of product innovation cycles. In addition, in order to respond to competitors from developing countries that can provide product at lower cost, OEMs need to differentiate their offerings increasing the value for their customers. For this purpose OEMs, and in particular those producing complex products that require life-long support (Voss, 2005), are shifting from their traditional business based on the sale of industrial product to the provision of an offering composed of products and services (Wise and Baumgartner, 1999, Grönroos, 2008, Schmenner, 2009, Meier et al., 2010, Tan et al., 2010). This shifting is depicted in the extant literature through various terms such as “servitization” (Vandermerwe and Rada, 1988, Baines et al., 2009), “transition from products to services”(Oliva and Kallenberg, 2003), “product-service system (PSS)”(Tukker, 2004), “moving towards high-value solutions, integrated solutions and system integration” (Davies, 2004, Windahl and Lakemond, 2010), “manufacturing/service integration” (Schmenner, 2009), “service business orientation” (Homburg et al., 2002, Antioco et al., 2008).

This strategy is proven to increase the firm’s competitive advantage (Slack et al., 2004) as well as revenues and profits (Cohen and Whang, 1997). Integrated offerings, in fact, aim to create more value in use to the customer than if the product or the services were delivered separately (Shankar et al., 2009) and to establish a long-term relationship with the customer even in the equipment use-phase.

However, to accomplish this goal, the integrated service has to be effectively designed and provided in conjunction with the product, according to customers’ expectation in term of quality, value, performance, etc. (Rapaccini et al., 2012) and requires a relevant transformation of the business model that involves organizational principles, structures and processes (Neely, 2008, Visintin, 2012). In addition, since PSS offering that includes both product-oriented, user-oriented and result-oriented PSS (Baines et al., 2007), values asset performance or utilization rather than ownership, this new business model involves a transfer of risk, from a customer to a service provider, and OEMs are looking for ways to mitigate those risks.

Despite OEMs are proven to possess solid knowledge about product engineering and production processes, they seem rather weak in providing services, i.e. in designing and operating service systems (Neu and Brown, 2005). In addition, usually OEMs provide these services in compliance with “full service contract” based on service level agreements (SLAs) that specify for instance time to response, time to repair and percentage of overall availability of the product. Therefore, the design of an efficient and effective service delivery system is more complex and challenging. In this scenario where several actors (e.g. service providers, spare parts supplier, industrial customers, etc.) are generally involved, besides the OEM, in the delivery of services, information management across these networks is proven to be a critical success factor (Johnson and Mena, 2008) and, therefore, ICT that enable information exchange are essential for the servitization journey (Alonso-Rasgado et al., 2004, Neely, 2008). ICT, in fact, as stated by Kowalkowski et al. (2013), are a catalyst for service business orientation, and OEMs can use those technologies to pursue a differentiation strategy through services, both SSP (i.e. services that support the OEM's product such as maintenance and repair) and SSC (i.e. services that support the customer's action in relation to the OEM's product such as training or consulting services).

In particular, on one side, technologies such as telemetry, condition monitoring, diagnostic and prognostic systems and others that entail to the wider paradigms of e-maintenance (Levrat et al., 2008) and of the Internet of Things (IoT) (Atzori et al., 2010), are more and more used to catch real-time data from the installed base (IB) (Ala-Risku, 2009); on the other side CRM systems, help desks/hotlines, etc. enable OEMs to achieve information from customers. Therefore, in both cases, this information can be leveraged for triggering business opportunities and initiating different processes, such as ordering spares, delivering field-intervention, planning routine maintenance, reporting performance analytics, forecasting service demand, scheduling resources, etc.

Even if the servitization paradigm emphasized the relevance of ICT in solving the information need of OEMs, the importance of technologies within organizations is a well-known topic in literature. Before deeply examining the role of ICT in service delivery, thus, the main perspectives related to the role of technologies within organizations are briefly introduced in the next sub-section.

1.1.2 *The relevance of ICT in companies*

Nowadays, the scientific community agrees that ICT have a primary role in the value creation. However the ways through which value is created can be different. In particular, three main theories can be identified: value-based view, resource-based view and business transformation view. According to the *value-based view*, ICT are a source of competitive advantage. The competitive advantage can be realized through the determination of a cost differential or through the differentiation of company's offering from competitors' one. Hence, several authors (Porter, 1980, Porter and MIllar, 1985, Porter, 2001, Andal-Ancion et al., 2003) claim that ICT are a source of competitive advantage and can affect several processes: at functional area level, ICT shift the traditional manufacturing, sales and procurement function to e-manufacturing, e-commerce and e-procurement; at level of internal or external relations, ICT favour the exchange of information and coordination between different actors such as suppliers, customers and partners; and, at level of supply chain structure, ICT can influence make-or-buy decisions or if insourcing or outsourcing some processes.

Conversely, according to the *resource-based view,* ICT represent the key technologies through which it is possible to determine a cost differential or a unique offering but they not represent directly a source of competitive advantage (Dierickx and Cool, 1990, Hamel and Prahalad, 1994). According to this theory, in fact, the competitive advantage ensues from the set of unique resources/competences that the company has developed through a complex learning process. Therefore, ICT enable the creation, development and dissemination of this knowledge. In fact, the data became knowledge through ICT: firstly the data is gathered and analysed (data-mining) and becomes information; then, this information is made available for *knowledge workers* that, using it for their purposes, produce knowledge. Several authors highlight this strategic role of ICT: according to Bharadwaj (2000) and Sengupta and Masini (2008) ICT are key resource/skill, McAfee (2004), instead, states that ICT are the technologies that contribute to the creation of key resource/skill and, Womack et al. (1990) and Muzyka et al. (1995), finally, consider ICT as the technology that support the learning process of organizations.

Finally, the *business transformation view* states that ICT enable organizational change, continuous improvement and innovation cycle (Lillrank and Kanō, 1989, Garvin, 1993, Goldman et al., 1995, Ghoshal and Bartlett, 1996, Dove, 1999). Usually managers combine organizational/cultural change projects with new technologies introduction projects. The introduction of ICT, in fact, requires a business transformation and, in particular, since ICT empower people in the organization, processes, roles and ownerships need to be carefully redesigned.

Irrespective of the *view* adopted, ICT can be used to support all the activities within an organization such as production, purchasing, service provision, administration, finance, sales, etc. In addition ICT can have different roles depending on if they support i) process execution, ii) process monitoring, iii) process analysis and redesign, and iv) change project management. Thanks to the rapid evolution of ICT, several technologies are adopted by companies so that the study of their impact on processes and people interactions is critical. This study pertains to this broad research stream and, to narrow the scope, it aims at understanding how Augmented Reality can be used to support the information retrieval needed for the provision of industrial services on field (i.e. industrial field services).

Therefore, in the next sub-section the research stream that addresses the role of ICT in service provision is discussed, while in section 1.2 the research problem will be presented in more detail.

1.1.3 *The role of ICT in services*

Service can be defined as the application of competences for the benefit of another (Vargo and Lusch, 2004). More broadly speaking, service can be viewed as value co-creation. Therefore, the *service encounter* concept that represents the different contact points at which customers and providers meet and interact in a service system (Roth and Menor, 2003), is crucial. These contact points, in fact, are also known as "moments of truth" (Chase et al., 1998), since customers experience and evaluate the received services and develop their personal judgments about the value they create (or co-create). As well known, these judgments influence customer satisfaction, retention and loyalty as well. Since interaction in service systems are central to the phenomenon of value creation, service systems should be always considered as the unit of analysis of research that focuses on understanding how value is created and why some options are deemed to create more value than others under some circumstances (Maglio et al., 2009). In service systems, resources as different as people, information, money and technologies are procured and shared by different providers, thus value is created by accessing to these resources (Spohrer and Maglio, 2010). To determine the value created in the service system, both the customer (who actually receives the service) and the provider (who actually provides the service) compare the achieve benefits to the costs sustained for the service delivery. The more benefits exceed costs, the more value is perceived in the service system. In addition, if value is perceived to be higher than expected, entities are mutually satisfied.

Within this framework, the advancements of ICT are altering the ways customers interface with service providers and, therefore, may influence the customer's perceptions of the service experience (Roth, 2000, Heim and Sinha, 2001, Boyer et al., 2002, Oliveira et al., 2002). According to Froehle and Roth (2004) five different modes of customer contact exist in relation to technology (see Figure 1). Firstly they distinguish among "face-to-face" and "face-to-screen" customer contact depending on whether customer and provider are co-located during service provision or not. Then, within the first group, the contact can be: i) "technology-free" (Figure 1A), if technology per se does not play a direct role in providing the service (e.g. psychiatrist's in-office consultation with a patient); ii) "technology-assisted" (Figure 1B) if the provider employs technology as an aid to improve the face-to-face contact, but the customer does not have access to the technology (e.g. airline check-in); and, iii) “technology-facilitated” (Figure 1C) if both customer and provider have access to the same technology to enhance their communication (e.g. a financial consultant that uses a Power-Point in a meeting with a client). If customer and provider are not co-located, instead, to enable communication some form of technology must be employed. If the service is provided through a phone or online instant messaging (e.g. a call centre), Froehle and Roth (2004) refer to “technology-mediated” customer contact (Figure 1D), while if the provider is entirely replaced by technology (e.g. ATMs or automated car washes) the mode of customer contact is called “technology-generated”.

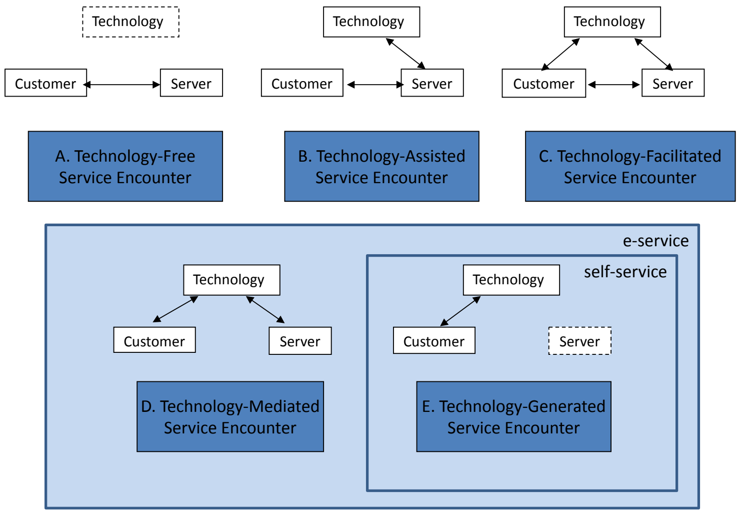

Figure 1 Different modes of customer contact in relation to technology (Froehle and Roth, 2004)

Analysing how ICT change the way services are delivered, a shift in the boundary among customers and providers can be noted (Campbell et al., 2011). More precisely, some technologies are favouring the advent of *super-service* (i.e. the provider performs autonomously, in isolation from the customer, tasks previously done by/with the customer), whilst others, instead, are pushing forward the provision of *self-service* (i.e. the customer performs on her/his own tasks previously done by/with the provider) (see Figure 2). In particular, *relieving technologies* favour the provision of super-services while *enabling technology* of self-services (Sampson, 2012).Of course, this shift aims always at increasing the value created in the service system and/or at reducing the cost related to service provision for both parties.

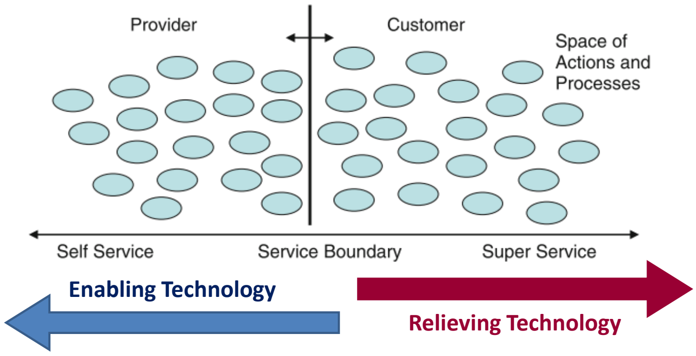

Figure 2 Effect of technology on service boundary (adapted from Campbell et al. (2011))

However, before adopting new technologies for services, their impacts on the value creation from both sides should be carefully addressed. To this aim, according to Campbell et al. (2011), firstly value expectations of customers have to be clearly identified, then the value creation process must be modelled, finally boundary's shifts due to the adoption of technology and their impacts on the service system must be investigated.

1.2 Research problem

From the research streams presented in section 1.1 it can be noticed that two phenomena are more and more relevant for European manufacturers that are inevitably intertwined: on one side the relevance of services that can be provided by service firms or by OEMs that extend the offering range integrating the selling of their manufactured product with the provision of additional services; on the other side, the rapid advancement of ICT that makes available for companies technologies and tools to support their operations, thus increasing internal processes efficiency as well as service delivery performance. However, as already said in sub-section 1.1.3, the adoption of technology to support service provision needs to be carefully studied in order to reach the expected increase in value perceived by customers and providers.

This study pertains to this research area and deals with how ICT can be adopted to support service provision and how they alter its delivery process. In order to narrow the scope of the study we identified a specific service context and an emerging technology. In particular, our frame context refers to service firms that provide long-life support to capital goods such as industrial plants, machine tools, engines, pumps, airplane, etc. and/or OEMs that provide those capital goods and that have reshaped their offerings in the form of integrated solutions, full service contracts, pay-per-use formulas, contractual service agreements, etc. (Schmenner, 2009, Meier et al., 2010, Tan et al., 2010, Shankar et al., 2009). Generally, these goods are exchanged in B2B markets, are characterized by long-life cycles (up to several years) and constitute, to different extents, critical assets in the customer's business. Given the high capital expenditures to purchase these goods and the risk associated to their failures, deterioration, improper use, etc., a whole set of services are offered to the customer, in bundle or not with the product. Among the different kind of services that can be offered (further details are presented in Chapter 2), we focused on the provision of industrial services on field, i.e. industrial field services (IFS). Industrial services include the entire set of services that can be provided in relation to manufacturing products (Gebauer et al., 2008b). Examples are installation, maintenance, repair, condition monitoring, diagnosis etc. that are commonly provided along the working life of an industrial asset (Mathieu, 2001a). The more products are installed and operated in customer facilities that are globally distribute, the more an efficient service network of different resources as field-technicians, spare parts, tools, vehicles, etc., is demanded. Irrespective of who plays the role of the service provider, relevant knowledge about product technology is requested in order to deliver the demandable service (help desk support, troubleshoot problems, perform diagnostic tests, suggest remedies to faults, define action plans, etc.).

To this aim, OEMs, for instance, are introducing smart technologies (Ala-Risku, 2009, Allmendinger and Lombreglia, 2005) to connect their remote centres to installed bases of equipment, to collect real-time data and to provide health condition monitoring (Grubic et al., 2011) and more efficient customer support services (Mathieu, 2001a, Meyer et al., 2009). Field data, if properly stored and analysed, can be helpful for several purposes, such as determining how operating conditions affect equipment reliability (Ulaga and Reinartz, 2011), investigating the causes of equipment malfunction and identifying the most effective remedies and restoration procedures. Usually product specialists are responsible for creating and sharing this knowledge across the whole organization. However, this has proven to be difficult (Corso et al., 2006). In fact, especially in case of dispersed field forces, technicians may not be properly skilled or prepared to accomplish any kind of diagnostic or repair interventions. In situations like this, they would usually resort to using their mobile phones to call the product specialists who reside in R&D or engineering departments. Then they would give an explanation about the issues they are facing and try to get the advice required to successfully complete their work (Dutta, 2012). This communication through mobile phones, however, has some limitations: i) misunderstandings may occur since the parties are not equally exposed to the situation (e.g. the product specialist cannot see what the technician can see); and, ii) since technicians do not generally use their mobile phones hands-free, their movements are restricted whilst they are receiving remote support (Bottecchia et al., 2009).

These limitations could be overcome by the recent advances of ICT, such as Augmented Reality (AR)—a technology that is widely considered to be the most cutting-edge development for the next few years (Fenn and LeHong, 2011). Basically, an AR system supplements real world vision with real-time computer-generated objects (Azuma et al., 2001). Despite the fact that AR systems are still at a pioneering stage, several applications and technological options are discussed in the extant literature (van Krevelen and Poelman, 2010). In addition, since AR allows real-time visualization of the right information in the right position, without additional efforts, the use of this technology would result in fewer misunderstandings and errors and, therefore, in better service delivery performance (e.g. more first-time fixes and quicker restoration).

However, since AR is considered a cutting edge technology for the next years, up to now only few prototype systems have matured enough to become production systems (Regenbrecht, 2006) actually adopted by companies. For this reason there is a paucity of studies that address the issues related to the adoption process of AR. In particular, most of the literature on AR approaches the problem using AR developers' perspective considering mainly issues related to technological choices such as data integration system (Espíndola et al., 2013, Siltanen et al., 2009), tracking system (Behzadan and Kamat, 2009, De Crescenzio et al., 2011, Ishii et al., 2007, Paz et al., 2012, Wang et al., 2008) or output device (Stutzman et al., 2009), and usability issues (Bowman et al., 2002, Swan and Gabbard, 2005). Therefore, their applicability in practice can only be deducted by vague examples or hypotheses, with a poor understanding or description of the contextual factors that could prevent or harness their actual implementation.

Therefore, the overall purpose of this study is to fill this gap, investigating the issues related to AR adoption in field service networks following the user company's perspective.

To address this research problem, several research questions have to be answered. Firstly companies have to assess the AR features in order to understand if AR is suitable for fulfilling field service needs. With this respect, firstly companies need to understand:

RQ1: Which AR system better fits with the specific requirements of different industrial field services?

Matching the state-of-the-art of AR applications for industrial maintenance and the features of industrial services, and using a Task-Technology Fit perspective (Goodhue and Thompson, 1995), a classification of the AR systems and several patterns of fitting with industrial services will be identified.

Secondly, the user company needs to understand the effects of AR adoption on the service delivery system. This corresponds to answer the following research question:

RQ2: *How AR adoption will influence the delivery of industrial field services?*

Based on an explorative approach, several case studies will be performed. Firstly a demonstration of usage of AR in the provision of IFS will be carried out involving a company that is not using AR in order to identify potential benefits, efforts, and process redesign requirements. Then, two case studies will be carried out with pioneering companies that have already adopted AR to support field service provision. The purpose is twofold: i) to validate the results of previous analyses and ii) to understand the adoption journey of AR through retrospective descriptions of the reasons why they decided to adopt AR to support IFS delivery, the steps followed to introduce it, and the experienced benefits and problems. The evidences of these case studies will lead to the identification of some areas of improvements for companies that are willing to adopt AR for IFS delivery.

Finally, since AR is new and for the most part unfamiliar to end users, their perceptions and willingness to use AR need to be carefully evaluated prior to decide to adopt it. This way, any resistance towards its introduction could eventually be reduced. For this purpose the third research question is:

RQ3: *What is the level of acceptance and the willingness to use AR of the field force?*

Based on the literature concerning Technology Acceptance Model (TAM, Davis (1989)) and Task-Technology Fit (Goodhue and Thompson, 1995), a novel model for the assessment of AR will be developed and validated against the surveys of field technicians.

1.3 Research justification

The decision of introducing a new technology within an organization is not nearly a risk free decision. In literature, several studies can be found for instance related to risk management or focused on understanding success and failure factors of ERP introduction (Aloini et al., 2007). For this reason, despite developers of AR applications state that this technology could be adopted to support IFS provision, studies that guide its selection and introduction facilitating thus its adoption, are relevant but still missing.

With this respect, the studies presented in this thesis aim at understanding the overall adoption process from the AR selection to the impacts at managerial (in terms of how the service delivery system is influenced by AR) and individual (in terms of end users' perception of usefulness, ease of use and their intention to use it) level. In this way, a lot of useful information is gathered and frameworks that can guide the AR assessment and adoption are developed such as the typology to select the configuration of AR that better fits with specific context requirements (see Chapter 2) and ARTAM (see Chapter 5) to assess end users' perception in a pre-implementation stage of adoption in order to be able to manage possible resistances of users prior to adopting AR.

1.4 Research strategy

The main objective of this study is to assess the possibility to adopt AR to support the provision of industrial field services. Since research on this topic is still in its infancy, the underlying concepts need to be still explored and clarified. Thus, this is an empirical study that pertains to theory-building research (Meredith, 1993). In particular a hybrid approach will be implemented since different research methodologies are requested to answer the research questions identified in section 1.2 as depicted in Figure 3.

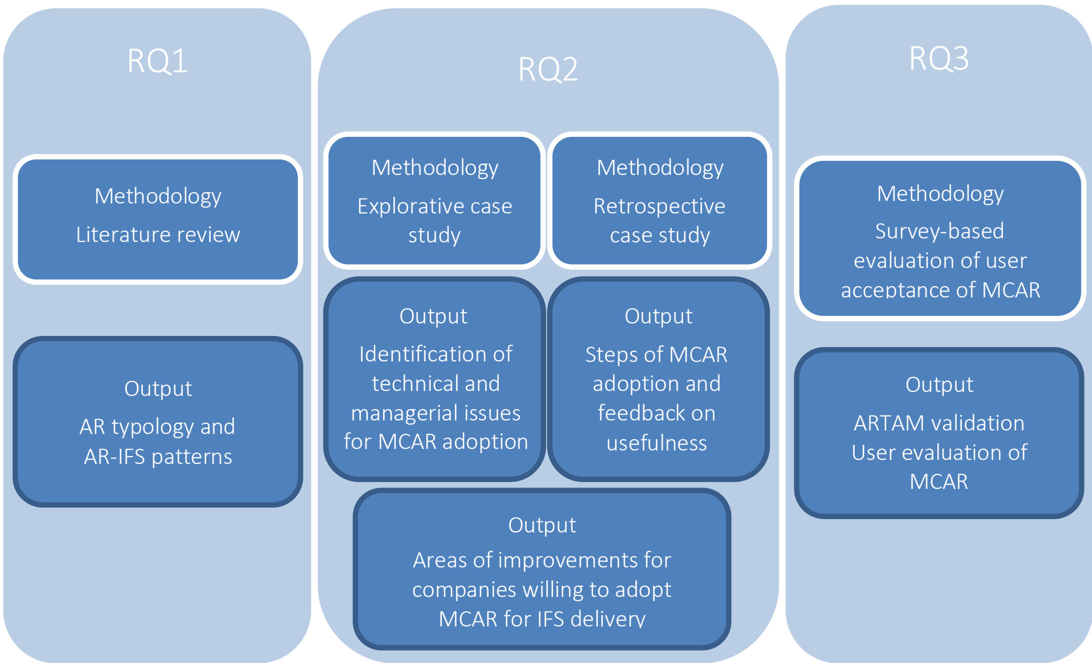

Figure 3 Research strategy.

In the first phase, in order to answer to RQ1, relevant literature addressing industrial field services and AR will be explored and reviewed. Thus, the most important concepts will be combined, resulting in the definition of a typology that classifies the different technical configurations of AR and several patterns that clarify the more suitable AR system to adopt to support a specific IFS. Then, in order to assess the impact of AR on service delivery process

(RQ2), we will carry out an explorative case-study focusing on one pattern (i.e. Pattern 1, see Chapter 2). In particular, both semi-structured interviews and a physical demonstration of usage of a particular kind of AR (i.e. Mobile Collaborative Augmented Reality, MCAR (Billinghurst and Thomas, 2011)) will be planned and executed. In addition, in order to validate these preliminary findings and to complete the investigation with information and activities related to the implementation and post-implementation phase of adoption, two retrospective case studies will be performed (Voss et al., 2002). Therefore, the case findings will be discussed and combined in order to identify some areas of improvement for companies willing to adopt MCAR to support IFS provision. At this point, the perspective of the study shifts from the managerial to the individual level. Since the user acceptance of a new technology is essential for the success of its introduction, prior to deciding to adopt a new technology it is interesting to understand their perceptions in order to manage properly the possible resistances (RQ3). Therefore, this third phase of the study applies a survey-based approach to evaluate end users perception and intention to use MCAR following the TAM and TTF theories. At the end of these three steps, several insights into which AR should be adopted for IFS provision, what managerial issues need to be overcome, how AR will impact the service delivery system and how AR will be accepted by end users will be achieved.

1.5 Thesis Outline

This dissertation is structured in six chapters. Chapter 2 aims to answer RQ1 presenting the results of a thorough literature review on the relevant topics. The first step is the review of the several classifications of services and of the available AR applications for industrial maintenance. This latter is focused on the identification of the main technical features at the basis of AR systems; in fact, according to this, a typology that classifies AR system with respect of those characteristics is developed. Finally, recurring to specific patterns, the AR systems that should be adopted to support different kind of IFS are presented and discussed. Chapter 3, Chapter 4 and Chapter 5 instead, consider the user company perspective and address the evaluation of AR from two different points of view. In Chapter 3 and Chapter 4 the managerial perspective is used to answer RQ2. In particular, Chapter 3 describes the results of the explorative case study in which a usage demonstration of MCAR to support IFS provision has been planned and executed involving service managers, field technicians and product specialists in order to highlight expected benefits, costs and process redesign requirements. Chapter 4, instead, describes the findings of the retrospective case studies performed, and presents the conceptualization, in terms of area of improvements, of how the AR adoption will impact at a managerial level. Finally, Chapter 5 deals with the individual perspective and aims to understand the end users' perceptions and intention to use MCAR. In particular, a novel model is developed based on the extant literature concerning technology acceptance, hypotheses are formulated and then validated against the surveys of three companies whose field force has been selected as test benches. Then, the analyses of the questionnaires, performed using Structural Equation Modelling (SEM) (Byrne, 2009) are presented and discussed. The dissertation ends with Chapter 6 that includes a brief summary, the final conclusions and presents possible future directions of research.

1.6 List of publications

The studies in this dissertation have been previously presented in parts in the following publications:

Porcelli, I., Rapaccini, M., Espíndola D.B., Pereira C.E (2013) Innovating product-service systems through Augmented Reality: a selection model. In: *The Philosopher's Stone for Sustainability*; Shimomura, Y. Kimita, K. eds. Springer Berlin Heidelberg, pp.137-142.

Porcelli, I., Rapaccini, M., Espindola, D.B., Pereira C.E (2013) Technical and Organizational Issues about the Introduction of Augmented Reality in Maintenance and Technical Assistance Services. In *Intelligent Manufacturing Systems*, Vol. 11, No. 1, pp. 257-262.

Rapaccini, M., Porcelli, I. (2013) How Advances of ICT will Impact on Service Systems and on the Delivering of Product-Related Services. *Advances in Production Management Systems. Sustainable Production and Service Supply Chains*. Springer Berlin Heidelberg, pp.57-64.

Rapaccini M., Porcelli I. (2012) Come la tecnologia cambierà il mondo dei servizi. *Logistica e Management*, Dicembre 2012, pp.1-6.

Rapaccini, M., Porcelli, I., Espíndola, D.B., Pereira, C.E. Clarifying how Augmented Reality can support the provision of industrial services: a typology. Under review for International Journal of Advanced Manufacturing Technology.

Porcelli, I., Rapaccini, M. Evaluating the acceptance of Augmented Reality within field service networks. Under review for Information and Management.

Rapaccini, M., Porcelli, I., Espíndola, D.B., Pereira, C.E. Evaluating the use of Mobile Collaborative Augmented Reality within field service networks. The case of Océ Italia – Canon Group. Under review for the special issue "IFAC Workshop on Intelligent Manufacturing Systems" of Production and Manufacturing Research.

Chapter 2

AR typology

This chapter presents the studies carried out to answer RQ1 stated in section 1.2. To this aim, firstly, the different kinds of industrial services that are the frame context of this study are described and classified. Then, a review of the several kinds of AR system developed for different purposes is presented. Based on this systematic analysis of the extant literature, several applications of AR to support industrial service provision have been reviewed and a typology that aims at classifying each system according to the technological features chosen is proposed. Finally using a Task-Technology Fit perspective, the linkages among the technological configurations of AR and the types of outcome to be provided with the service are established, and three patterns that unveil specific contexts of AR application are identified and discussed.

2.1 Types of industrial services

Different kinds of services can be offered in integration with a manufactured product. Saccani et al. (2013), based on eight classifications of the services offered by servitized OEMs, combined them and identified four main service categories. The first one, named "product support services" (Saccani et al., 2013) as well as "product lifecycle" (Ulaga and Reinartz, 2011), "service supporting the product" (Mathieu, 2001a), "product services" (Mathieu, 2001b) and, "product-related services" (Gebauer et al., 2008a), includes services that aim at ensuring product functionality over time. The second category, instead, encompasses services that aim at training a product's end user and/or facilitating their interaction with the product. Sometimes this category could be included in other ones (Oliva and Kallenberg, 2003, Gebauer, 2008). Then, the further two categories focus on customer processes including, thus, i) services that aim at supporting customers to (re)design, manage and optimize the process enabled by a product as considered by (Oliva and Kallenberg, 2003, Gebauer, 2008) and ii) services where the provider takes over the responsibility for operating a product and/or a business process on behalf of the customer.

According to the above-mentioned classification, this study is focused on the first category. In particular with the term "industrial services" (Johansson and Olhager, 2006) we refer to product-related services delivered on capital assets by means of service contracts. In addition, we can refer to the taxonomy proposed by Smith et al. (2012) to further divide the industrial services in sub-categories. Basically Smith et al. (2012) state that the aims of industrial services are manifold but can be grouped according to three value propositions: i) ensure a minimum disruption when product fails; ii) ensure maximum availability of installed/operated product; iii) ensure the capabilities requested to achieve the best/expected outcomes by use of the product (see Table 1).

Table 1 - Types of industrial services (adapted from Smith et al. (2012)).

Value proposition	Ensure prompt recovery	Ensure maximum availability	Ensure maximum outcome
Value comes from the capabilities of the service provider to:	Ensure timely and efficient set up and recovery of the product operable/desired status, altered as a consequence of real or predicted/expected faults, malfunctioning, deterioration, end-of-lives	Ensure, over time, that customers can access to a functional (i.e., functioning and utilitarian) product, if and when potentially needed	Ensure that customers can use the product at its best, empower its knowledge and practical skills, increase its capabilities and expertise as product users
PRS examples	Installation, preventive and corrective (e.g., fix & repair) maintenance, provision of spares and consumables, updates and upgrades (e.g., refurbishing, revamping, etc.).	Inspection, control & troubleshooting (by remote or on field), evaluation of residual lives, planning consumables and spares refurbishment, planning maintenance interventions, etc.	Provide user manuals, guides and help desk, train users, give advice and consultancy about proper product use
Customer input primarily needed	Product and its parts or modules	Information (e.g., product status, process objec-	Product user's mind

for service delivery		tives, functioning parameters, etc)	
Transformation acts mainly on	Tangible objects (products, spares, consumables, etc.)	Intangible objects (data, documents and information)	Intangible objects (knowledge and skills)

Referring to this classification, in general, quite different inputs (i.e., physical objects, data, information, knowledge) can be required during the service delivery and thus, purposes and recipients of industrial services differ to a large extent. In fact, referring to the first group, transformations mostly occur on the product itself and/or its components; therefore some physical interactions with objects from the field are requested. Conversely, information for taking decisions about future actions (e.g., define the so called “action plan”) are the primary input of the second category of industrial services. This required information may specify how to configure the product for a given customer/mission, to forecast the demand for supplying consumables, or to upgrade the product, for instance, as a consequence of a change in product operating conditions. Last but not least, in the latter case (i.e., the third type of industrial services) transformation mostly acts on the knowledge of customers and product users, since they get empowered while receiving support, training, advices, etc. From the above considerations it can be concluded that, depending on the type of industrial services, different information may be needed from, or exchanged among, the different actors that are involved in the execution of the service tasks. These actors may include remote specialists, field-technicians, product users, etc.

This study is focused only on the first two types of industrial services (i.e., recovery and availability value propositions) that in general are those delivered on field and named “industrial field-services” (IFS). The third type (i.e., outcome value proposition), in fact, has been excluded, since we are interested on understanding how AR can support the execution of field-services. Conversely, the third type of industrial service aims at empowering customers and product users through the provision of professional services and training. With respect to this situation, many kinds of mixed reality systems, both virtual and augmented, can be used (Haritos and Macchiarella, 2005, Wang and Dunston, 2007, Schwald and de Laval, 2003, Boud et al., 1999) but a detailed discussion on them is out of the scope of this work.

Since the possibility of knowing or not, in advance, the information that can be requested from the field, is crucial for understanding what kind of technology can be leveraged, it is possible to depict some scenarios. In the first one, the service aims at ensuring product recovery according to a clear and predefined action plan, such in the case of routine installation, maintenance, or problem fixing with known causes. In this case, the information needed can be previously identified and the required actions can be documented and made available through procedures and manuals. For instance, maintenance documents are used to describe the sequence of tasks that should be followed for product repair, the list of parts to be changed, the required tools, etc. A second scenario, instead, refers to a situation where the action plan is not known, ready or associated, in advance, to the problem that technicians or customers face, and so the support of a product specialist, who possesses implicit knowledge about the possible solutions, is proven to be useful. Finally, a third scenario refers to the need of collecting, from remote locations or from the field, information about the operating conditions of the asset, irrespective of interventions that imply tangible operations have then to be executed or not. This latter can be the case of services such as remote monitoring, field-inspection, etc.

Hence, since different types of information, inputs and outputs, have to be handled, AR systems should be designed, selected and introduced with respect to the depicted scenario. Prior to understanding which is the more suitable AR system for each scenario, since AR is a novel technology that could join the set of technologies already adopted to support IFS provision, in the next section a brief review of those existing technologies is presented.

2.2 Existing technologies supporting the delivery of industrial services

As the pillars of Product Life Cycle Management (PLM) (Ranasinghe et al., 2011) and of Installed Based Information Management (IBIM) (Auramo and Ala-risku, 2005) suggest, a relevant field of application of ICT is devoted to the collection of field-data from installed/operated products. In fact, the information achieved from the field can be leveraged for purposes as different as catalysing the innovation cycles (i.e., be proactive), taking timely decisions to solve customers' problems (i.e., be reactive), deploying and mobilizing field-resources (i.e., be efficient in service operations) (Allmendinger and Lombreglia, 2005, Cohen et al., 2006, Ulaga and Reinartz, 2011).

If the focus is on solving customer problems that originate from product faults, health, diagnostic and prognostic systems through smart technologies such as sensors, intelligent products, etc. (Meyer et al., 2009), are usually adopted. Irrespective of the implemented logics (e.g., simple rules, neural or Bayesian network for diagnosis), applications that support troubleshooting can greatly assist technicians to promptly understand the causes of faults/malfunctioning, determine the most effective remedy and, therefore, mitigate the implications of unreliable products. Despite it is proven that this kind of technologies can help the development of service-oriented business models (Allmendinger and Lombreglia, 2005, Ulaga and Reinartz, 2011), up to now it seems that the adoption of these tools is still limited. For instance, Grubic et al. (2011), investigating mainstream manufacturers in the UK, found that typical adopters operate in a capital-intensive industry sector, hold a position in its value chain that is close to the eventual user, deal with high-value and complex products, and have a history of early technology adoption.

If the focus is, instead, on making the service operations more efficient, other information technologies such as workforce management systems are usually implemented. In particular, when providing field-services, the right personnel, tools and equipment need to be assigned to the customer demand according to their capabilities and, then, routed from their initial positions (e.g., a facility, a spare parts warehouse) to the customer premise within acceptable time and cost. This is a cumbersome task, that generally presents rooms for improvement (Agnihothri et al., 2002). For this aim, the adoption of mobile applications and devices such as smart phones, PDAs, tablets, etc. can lead to increased productivity and improved performance such as response time, recovery time, and first-time fix. Moreover, decreasing the reliance on paperwork, the distribution of digital documents from remote centres to the field (and vice versa) leads to lower errors and reworks (Dutta and Pinder, 2012).

Actually, the most challenging situation pertains to the case of complex products whose field-services have to be provided on vast territories. In addition, complexity in servicing can stem from the variety of embedded technologies, as complex products include mechanical and electronic parts, control software, sensors, actuators, etc. In this situation, to perform diagnostic tests, identify problems and restore products from faults, on one side unique capabilities are requested but, on the other side, it is highly inconvenient to deploy the few experienced technicians round any corner, ready to intervene and face with relatively short response time any problem that might occur. Generally, technicians are deployed on field according to their skills and experiences with the intent to centralize the most skilled personnel in a central facility with respect to the served district. Remote specialists can then provide 2nd and 3rd help desk, and give remote assistance to field-technicians. In these cases, the adoption of technologies that, besides information retrieval, can provide support to people interactions and technical communications becomes critical as well.

Based on the positive experiences from early adopters of mobile technologies for field-service delivery (Aberdeen Group, 2005, Aberdeen Group, 2007), several organisations are introducing mobile technology and information systems in field-services, with the intent to save resources and increase profitability (Blumberg, 1994, Kearney, 2004). As a consequence, there is an interesting debate around what tools best support, on one hand, the service execution and, on the other, the retrieval of useful information, since they enable specific communication channels. To this concern, PCs and mobile phones are the most used tools. As Dutta (2012) states, on average 73% of field workers are equipped with at least one mobile device. Moreover, of those who are carrying devices, 70% are carrying more than one (59% use a mobile phone for communication, 29% have a laptop to support task execution). However, these devices have strong limits in term of usability since information retrieval is usually neither easy nor fast, and hands-free operations are not supported, etc. In addition, in mobile phones the type, the amount and the presentation formats of the exchanged data are quite limited.

From the above considerations it can be concluded that product specialists and technicians could benefit from a general purpose technology (GPT) that is able to jointly support the execution of diagnostics check or field-operations (e.g. maintenance, product fixing, etc.) irrespective of these tasks are performed in collaboration (interactively) or in isolation, from remote centres or from the field, with hands-free and in perfect mobility.

Within this context, Augmented Reality is appointed as a promising technology for the provision of IFS, since it seems to overcome most of the above mentioned limitations. In the next section, an overview of the main features and functional parts of AR systems as well as of the main fields of application is given.

2.3 Augmented Reality

Augmented Reality (AR) is a novel concept that intertwines various technologies and depending on the context can be viewed as the future of computing, a medium and an interface to digital information and a platform for creating novel services and business. Augmented Reality is a part of a broader concept of Mixed Reality (MR). In general, MR refers to the integration and merging of the real and virtual worlds where physical and virtual objects complement and interact with each other (Milgram and Kishino, 1994). The different ways in which the "virtual" and "real" aspects of MR environments can be realized are depicted in the *virtuality continuum* shown in Figure 4. At the ends of the virtuality continuum the Real Environment (RE) and the Virtual Environment (VE) are positioned. In particular RE includes environments consisting solely of real objects whereas VE is defined as a computer generated, interactive, and three-dimensional environment in which a person is immersed (Rheingold, 1991). Going from RE to VE, then, the virtual component becomes predominant with respect to the real one. In particular, *Augmented Reality* is focused on augmenting the real world with digital information whereas *Augmented Virtuality* brings real-world information in virtual scenarios.

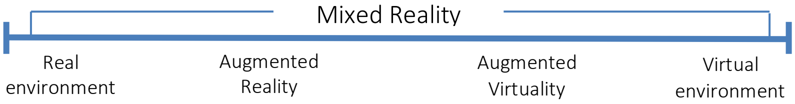

Figure 4 Virtuality Continuum (adapted from (Milgram and Kishino, 1994))

In the widely accepted definition of AR (Azuma, 1997), three requirements are emphasized:

1. the combination of real and virtual objects in a real environment;
2. interactivity and being real time;
3. the registration/alignment of real and virtual objects with each other.

As a result, enhancing the scene superimposing virtual elements, AR technology is used to build more intuitive, efficient and effective Human Machine Interfaces (HMIs), in order to access remote data and visualize information.

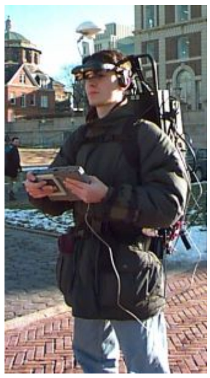

Figure 5 The touring machine (Feiner et al., 1997)

The first officially recognized AR system dates back 1992. The system, proposed by Rosenberg (1992) aimed at enhancing operator performance in telemanipulation tasks through the overlaying of virtual fixtures (i.e. the displaying of assistive cues). Then, in 1997, AR became mobile; the Touring Machine proposed by.Feiner et al. (1997), in fact, is the first example of AR in which a PC mounted on a backpack and the usage of head-mounted display (HMD) as output devices were used to give information about the monuments around the AR user (see Figure 5). From that moment, thanks to the rapid advancement of mobile devices, smartphones and tablets, equipped with integrated cameras, sensor technologies like GPS and orientation sensors, high-resolution full colour displays, high-speed networking, high computing power, dedicated 3D graphics chips etc., became a dexterous platform for building AR applications and services (Wagner and Schmalstieg, 2009). However mobile AR is not only the selection of mobile or handheld devices as hardware; it is, instead, about being enabled for mobile and ubiquitous contexts and activities (Höllerer and Feiner, 2004). The frame context, in fact, is constantly changing; in fact, as the user's physical or social environment, activities or mental state change, even user's needs for interaction and task execution change accordingly. With this respect, mobile AR has recently gained huge public interest. John Jackson, a research analyst for the research firm IDC said, "There is a gold rush mentality around the space now and it is hardly clear who is going to emerge. We have to think about this [i.e. AR] as a platform that makes use of lots of different technologies and mashes them up to give you a new way of interacting with the world around you". Finally, looking at some statistics, the total revenue generated from AR at the end of 2013 is expected to be around $300 million and for 2014 around 30 percent mobile subscribers will use AR at least once in a week and more than 864 million smartphones will have AR technology enabled in them. Then, it is expected that by 2017 more than 2.5 billion mobile AR apps are going to be downloaded (Jackson, 2013).

This study is focused on mobile AR; in the rest of the dissertation we will use the term "Augmented Reality" meaning "mobile Augmented Reality" unless otherwise specified.

2.3.1 *Building blocks of Augmented Reality*

An AR system is generally the combination of: i) tracking and registration systems, that are used to track the position and movements of users and objects and to link the virtual augmentation with a specific position in the scene; ii) an output device such as a display, that is used to see the augmented scene; iii) a sensing system, such as a digital camera, that is used to capture the real scene and usually is embedded in the output device; iv) a data acquisition system, such as gloves, physical or virtual keyboards, haptic systems, etc., that is used to interact with the software application and give commands; v) a software application and the computer system where it runs. The most common platforms and libraries that can be used to develop AR software applications and integrate these applications with commercial hardware devices are ARToolkit[1], ALVAR[2], StudierStube[3], D'Fusion[4] and Layar[5].

The following paragraphs describe and discuss the above-mentioned aspects. However, since we adopt the AR users' perspective, a complete review of the state-of-art of technologies for AR is out of the scope of this study. Therefore, interested readers can refer to Zhou et al. (2008), van Krevelen and Poelman (2010), Nee et al. (2012) Papagiannakis et al. (2008).

2.3.1.1 Tracking and registration

Tracking solutions are essential for an AR system as it is necessary to "sense" the real environment, i.e., the user's field of view, and track the viewer's (relative) movement, preferably with several degrees of freedom (i.e., 3 for position plus 3 for orientation) in order to: i) recognize the exact position in which the virtual object will appear and ii) accurately register and align the virtual object to the real scene (van Krevelen and Poelman, 2010). Several kinds of tracking systems have been developed and can be classified in three main groups.

[1] http://artoolkit.sourceforge.net/
[2] http://virtual.vtt.fi/virtual/proj2/multimedia/alvar/index.html
[3] http://studierstube.icg.tugraz.at/main.php
[4] http://www.t-immersion.com/
[5] http://layar.com/

Marker-based tracking is the first group and employs the recognition of particular landmarks, such as concentric circles placed in known positions (Papagiannakis et al., 2008). The most popular system based on the recognition of markers is ARToolkit (ARToolkit 2.52, Kato and Billinghurst, 1999) that implements particular 2D printed markers to track the scene; however, other kinds of marker, already placed on products for ID purpose, such as 2D barcode (Naimark and Foxlin, 2002) and QR code (Kan et al., 2009) could be used.

The second group of tracking system is called sensor-based and is the oldest system developed (Sutherland, 1968). In this case, the transmission of signals is used to track the user position. Originally based on magnetic, acoustic, inertial, optical and/or mechanical sensors (Zhou et al., 2008), nowadays the most common sensors implemented in AR applications are gyroscopes and accelerometers (inertial sensors) to track the user's movements, while to track the user's field of view RFID tags (Schwieren and Vossen, 2010), infrared sensors or LEDs (Wang et al., 2008) and GPS, in case of outdoor applications (Behzadan and Kamat, 2009, Schall et al., 2009), are used. Usually, in order to increase the tracking robustness, these two kinds of tracking systems are implemented together resulting in a hybrid tracking. In particular, the usage of inertial tracking combined with marker-based tracking, for instance, is used to improve the motion prediction when rapid changes occur.

Finally, the third group includes systems that track the real scene without the need to place markers or sensors in advance, thanks to the recognition of particular features such as lines, textures, edges or changes in lighting (Ferrari et al., 2001, Chia et al., 2002, Comport et al., 2003). These features can be used to directly trace the users' position and orientation with respect to their environment or, more recently, to develop 3D virtual models that can be leveraged to compute these parameters (Reitmayr and Drummond, 2006, Zhou et al., 2008). In particular, the camera pose is estimated starting from known visual features through methods such as SIFT (Scale-Invariant Feature Transform (Lowe, 2004)) and SURF (Speeded-Up Robust Features (Bay et al., 2008)). Up to now, these systems allow tracking in unknown environments but require high computing power and present some problems with changing in lighting and shadows (Carmignani and Furht, 2011).

Once the scene has been tracked, registration, i.e. the final alignment of real and virtual information that is presented to the user (Olsson, 2012) is needed in order to achieve a realistic interface and preserve the illusion of real and virtual coexisting in the same domain. The motions or changes made by the user, in fact, need to result in the appropriate changes in the perceived virtual elements (Azuma, 1993) and thus registration must be made with pixel accuracy at high frame rates. For this purpose, state-of-the-art in registration includes signal processing solutions for face detection, identifying moving objects in videos and continuous detection of specific visual patterns that have been identified in advance (e.g. patterns on packaging, products, clothing, artwork) (Mullen, 2011).

2.3.1.2 Output device

The output device consists in a display through which it is possible to experience the augmentation of reality. The variety of displays that can be used for AR includes screen based display such as head-mounted displays (HMDs), handheld devices such as tablet PCs, smartphones, PDAs (Möhring et al., 2004, Henrysson et al., 2005), as well as more AR oriented handheld displays (Stutzman et al., 2009) and projection based displays such as spatial displays (Olwal and Henrysson, 2007).

Up to 2005, HMDs were the kind of display more used for AR applications (Bimber and Raskar, 2006) but with the rapid development of smartphones functionalities, currently the selection of handheld solutions is growing. Both HMDs and handhelds allow mobile AR and are characterized by being user dependent since HMDs need to be worn even if they leave the hands free and handhelds need to be hold with at least one hand. Conversely, projector based displays are integrated into the environment limiting thus the mobility of the AR application. Recently, some kinds of handheld and HMD projectors have been developed to merge the two options.

HMDs can be monocular or binocular and with respect to the way of merging real and virtual worlds, can adopt *optical see-through (OST)* or *video see-through (VST)* approaches. The first one consists in a partially transparent display that allows the superimposition of the digital graphics on the optical layer itself, while, using the latter, the field of view is recorded with one or two cameras and then this video stream is supplemented with augmentation and showed to the user (see Figure 6).

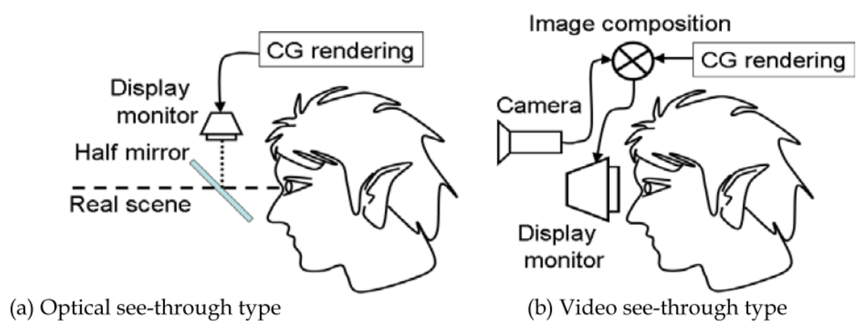

Figure 6 Ways of merging real and virtual worlds (Asai, 2010)

Handhelds include a screen and a digital camera. Therefore the digital camera captures the real scene and using a *video see-through* approach, the augmentations of reality are seen through the screen in real time (Bimber and Raskar, 2006). The field of view is limited and depends on the monitor size (bigger for tablet PCs than for smartphones and PDAs), spatial alignment and distance relative to the observer. However, the CPU, gyroscopes, accelerometers, GPS sensors embedded in more advanced tablet PCs and smartphones make them one of the promising platforms for AR application whenever the need to hold the device with hands it is not perceived as a constraint.

Finally, projection based displays, through video-projectors, optical elements and holograms technologies are based on both *optical* and *video see-through* approaches as well as on direct augmentation. This latter case consists in the usage of the real world surfaces to project visual augmentations on them. For this reason, the AR experience can be perceived by several people simultaneously, enabling multiple-users collaboration resulting, thus an interesting platform for education and entertainment applications (Wang, 2009). The pro and cons of each kind of display are depicted in Table 2.

Table 2 Advantages and disadvantaged of output devices for AR applications (adapted from Carmignani and Furht (2011)).

Display		Advantages	Disadvantages
HMD	Video see-through	Sync with real and virtual images Control over levels of brightness and colour	Time lag for the image composition Non-natural perception of the real scene It can affect the user safety (the user is blind)
	Optical see-through	Natural perception of the real environment No resolution problem in the vision of the real scene No time lag for image composition	Jittering of virtual images Eyes' user stress to focus images on different planes It does not work in highly bright environments
Handheld (video see-through)	Smartphone	Portable Medium CPU power Embedded camera, GPS sensor gyroscope and accelerometer	Small screen Need to be hold with at least one hand
	Tablet PC	High CPU power Embedded camera, GPS sensor gyroscope and accelerometer Big screen	Need to be hold with at least one hand More expensive and heavy
Project based	Video see-through	Need only a standard PC with off-the-shelf hardware Low cost	Time lag for the image composition Non-natural perception of the real scene Mobile device are under de-

			velopment
	Optical see-through	More natural perception of the real scene than VST No resolution problem in the vision of the real scene No time lag for image composition	Mobile device are under development It does not work in highly bright environments
	Direct Augmentation	The augmentations are directly superimposed on the surface of the right object Enable multi-users collaboration	Problems with highly bright environments Usually it is not mobile

2.3.1.3 Input device

Several data acquisition systems can be chosen to interact with the AR application and give commands. Their selection depends on the specific requirements of the context of application. For example, if the user needs the hands free to execute some activities, an intangible data acquisition system should be chosen such as the vocal commands used by Platonov et al. (2006). Otherwise, depending on the output device selected, the input device can be the same or not. Both tablet PCs and smartphones, in fact, are equipped with keyboards of touch screen through which it is possible to interact with AR application (Didier et al., 2005, Chang et al., 2012, Benbelkacem et al., 2013). Using HMDs or projectors, instead, an additional device, specific for AR-user interaction, is requested. In literature several devices are used as input device such as trackballs (Asai, 2010), small keyboards (Benbelkacem et al., 2010), laser pointer (Besbes et al., 2012), wrist-worn controllers (Henderson and Feiner, 2011) and gloves (Reitmayr and Schmalstieg, 2003)

Aleksy and Stieger (2009) compare three AR input devices for industrial field service applications: devices based on keyboard, on handwriting input capabilities, and on voice-operated input capabilities. From the analysis emerges that devices based on handwriting input capabilities usually require long time to insert a lot of information and an efficient handwriting recognition system is needed. Keyboard-based devices, instead, are faster and can include both one-handed keyboard and wrist-mounted keyboard in addition to the classical one. Finally, voice-operated input systems seem to be the more natural way of interaction but present usage problem within noisy environment and require a high CPU power to run the speech recognition algorithm (with consequent higher power consumption).

2.3.2 *Field of applications of Augmented Reality*

Augmented Reality has been appointed as a promising technology for both business and private life applications such as learning, education, leisure and entertainment (Olsson and Salo, 2011), and already applied in several contexts, such as military industry, health care, gaming, and manufacturing. For exemplification, the following table roughly categorizes the application areas and cites a few exemplary publications and systems for each one.

Table 3 Examples of AR applications.

Industry	Area	Activities and references
Military	Soldiers training	To train soldiers in combat scenarios, simulate real-time enemy action (Livingston et al., 2011)
		To display battlefield scene, augmented with annotations (Urban, 1995)
Health care	Surgeons remote support	Remote control of surgical interventions (Lee et al., 2010b); to visualize images (such as CT scan images (Navab et al., 2007) or 3D model of an organ[6]) superimposed on the patient
	Train surgeons	To visualize forceps delivery (Sielhorst et al., 2004)
	Surgeons on-field support	To assist selection and manipulation of surgical tools (Fuchs et al., 1998, Sielhorst et al., 2008)
Gaming	Enable new players experiences	To enable interactive role-players (e.g., Human Pacman) (Cheok et al., 2004)
	Development of smartphones games	AR Basketball, ARDefender, SkySiege, SpaceInvadAR, Rock'em Sock'em robots[7].
Education and entertainment	Support teachers and students activities	To test innovative methods for teaching and learning (Lindinger et al., 2006); to visualize 3D images of geometric shape to support the teaching of geometry (Kaufmann and Schmalstieg, 2003)
	Museum guidance	To provide virtual information about objects in a museum and to route visitors inside the museum (Miyashita et al., 2008)
	Touristic information	To provide virtual information about buildings and points of interest of the surrounding environment (Feiner et al., 1997, El Choubassi et al., 2010)
Advertisement	3D product visualization	3D product visualization using a marker printed on a magazine (e.g. MINI[8])
	Virtual changing room	Magic Mirror to try on virtual shoes (Sacco et al.)
Manufacturing	Support production and assembling activities	To superimpose to the real view instructions on assembling procedures (Webel et al., 2011)
	Support product design	To compare virtual model with real prototype (Schoenfelder and Schmalstieg, 2008); virtual prototype of digital handheld products using AR-based tangible interaction (Park et al., 2009)
	Train maintenance operators	To visualize maintenance procedures on industrial equipment (Schwald and de Laval, 2003)
	Train workers	To visualize assembling procedures (Boud et al., 1999) or training instructions for maintenance in nuclear power plant (Yim and Seong, 2010)
	Factory layout planning	To construct a mixed reality-based digital manufacturing environment (Lee et al., 2011)

[6] http://www.odysseus-project.com
[7] http://augmentedpixels.com/project/ar-basketball/; http://www.ardefender.com/; http://madfirm.com/?page_id=2; http://www.zenitum.com/en/apps/space-invadar/; http://www.qualcomm.com/research/projects/augmented-reality
[8] http://www.metaio.com/customers/case-studies/mini-always-open/

	Picking activities	To support the order picking process of logistics applications (Regenbrecht, 2006, Schwerdtfeger, 2010)
Building	Design	Usage of Spatial AR to support interior design process (Chen and Chang, 2006)
	Architecture	To support design and project impacts on the environment (Tran, 2011)

2.4 Developing a typology for AR

2.4.1 *Literature search strategy*

In order answer the first research question an so to clarify which are the AR systems that better fit with a specific IFS scenario, a thorough review of the literature concerning studies on AR applications in which the provision of IFS was been chosen as the context for inquiring was conducted. Scientific papers have been searched through Scopus. The review includes not only the main journals, but also proceedings of the main conferences that have been organized, in the last years, around Augmented Reality, e.g., the International Symposium on Mixed and Augmented Reality (ISMAR), the International Conference on Virtual Reality Continuum and its Applications in Industry (VRCAI), the International Conference on Computer Vision Theory and Applications (VISAPP), etc. The search criteria are the followings:

- Key-words: “Augmented Reality” plus “industrial”, “maintenance”, “remote maintenance”, “field-service” and “product installation”;
- Year of publication: mainly contributions published between 2008 and 2013 were considered, due to the rapid evolution of technology that affects the main features of AR systems. Exceptions are seminal contributions such as Azuma et al. (2001), Sutherland (1968), etc. as well as research projects such as KARMA (Feiner et al., 1993) ARVIKA (Friedrich et al., 2002), STARMATE (Schwald and de Laval, 2003), ARMAR (Henderson and Feiner, 2007), etc.

Once removed duplicated entries, the number of contributions collected and the percentage of papers pertinent to each combination of keywords resulted as in Table 4.

Table 4 Search results of AR systems in IFS context.

Keywords	Total number of contributions	% pertinent contributions
“Augmented Reality” “Industrial”	155	23%
“Augmented Reality” “Maintenance”	96	36%
“Augmented Reality” “Remote Maintenance”	15	53%
“Augmented Reality” “Field-service”	0	0
“Augmented Reality” “Product installation”	0	0

Papers have been considered as not pertinent if one of the following rules were satisfied: i) their major focus was not on Augmented Reality; ii) keywords used to search the contributions are cited rarely in the body of the paper (e.g., a paper that indicates maintenance as a possible application field for AR, but then mainly describes the development of a new device/tracking system/algorithm irrespective of the application context); iii) the paper is focused on AR in industrial context but the focus is on supporting production operations, assembly tasks, robot path planning, etc.; iv) papers state the AR system is developed to support the provision of IFS, but then the description of the real application or, at least, of the testing phase, is minimal. In addition, since the last two combinations of keywords gave no results in Scopus, another search was conducted with Google Scholar. In this case, using keywords “AR” and “field service”, some additional contributions were found as well as studies about “AR” in industrial, maintenance and remote maintenance context.

At the end, approximately 80 papers that satisfy the aforementioned criteria have been retrieved. In case more than one contribution was from the same authors and dealt with the same research, only the most complete ones were considered, collecting, thus, 35 papers. Then, each paper has been assigned to one of the researchers involved in the study and carefully studied in order to: 1) identify the main feature of the AR system proposed; 2) extract the most relevant constructs; 2) derive a 3-dimension typology that can describe any possible AR solutions; 3) classify the papers with respect to the proposed typology.

2.4.2 *Findings*

All the collected contributions presented an AR system designed to support a specific IFS. The kind of information superimposed on the end user’s field of view is the same among them and consists in 3D models, text, arrows, pictures, technical drawings and video/audio instructions. Conversely, several differences emerged with respect to the selection of input/output devices, tracking systems, number of users involved and the IFS scenario considered. The latter, in particular, distinguishes between a physical (i.e. tangible) interaction between the user and the product to be served and an intangible interaction such as an inspection, where, thus, any physical contact with the product is not requested to accomplish the task. The main features selected in each proposed AR system are reported in Table 5. In particular, “+” means that the corresponding feature is selected, “-” means that the corresponding feature is considered as an alternative option, while “n.s.” means that the characteristics is not specified in the text. In addition, we specified for each paper the AR application context and sometimes even the main purpose (in brackets). Some papers, in fact, even if presenting a complete AR application, are mainly focused on a specific aspect such as data integration (Siltanen et al., 2009, Espíndola et al., 2013), tracking system (Ishii et al., 2007, Wang et al., 2008, Behzadan and Kamat, 2009, De Crescenzio et al., 2011, Bhatia and Vijuyakumar, 2012, Paz et al., 2012) or the development of a specific output device (Stutzman et al., 2009). Therefore, they do not provide an overview of the entire solution. In addition, some architectural and technical choices appeared to be driven mostly by the intent of testing the proposed solution, nor by verifying its applicability to real contexts. Then, in the corresponding papers we considered only those features that were strictly linked to the declared purpose. Nonetheless these limitations, from the review of the mentioned literature appeared that two kinds of applications, basically, seem suitable to support the provision of industrial services. A first kind, hereinafter termed Automatic Augmented Reality (AAR), employs a software agent that is able to superimpose additional information on the scene, once this is captured and recognized by cameras and tracking systems (Friedrich et al., 2002, Schwald and de Laval, 2003, Henderson and Feiner, 2007, Behzadan and Kamat, 2009, De Crescenzio et al., 2011, Martín-Gutierrez and Santos Pérez, 2011, Espíndola et al., 2013). For instance, this technology is proposed for the maintenance of complex products and machines, in particular in safety critical applications (Benbelkacem et al., 2010, De Crescenzio et al., 2011, Henderson and Feiner, 2011, Lee and Akin, 2011), both for indoor (Kang et al., 2006, Wang et al., 2008, Hamid et al., 2011), and outdoor applications (Behzadan and Kamat, 2009, Chang et al., 2012, Ababsa et al., 2012, Schall et al., 2009). In addition AAR can be used to support field engineers in navigating complex industrial plants such as nuclear power plants (Ishii et al., 2007) and paper milling plants (Luukkainen, 2009), in reaching the interested component and in conducting field inspections viewing real-time information on the operating status superimposed on the component itself. A second kind, termed Mobile Collaborative Augmented Reality (MCAR) (Billinghurst and Thomas, 2011, Alem and Huang, 2011), employs groupware applications in order to enable remote collaboration among geographically distributed users that therefore can share an AR experience using their mobile devices. In particular, Bottecchia et al. (2010a) developed T.A.C. (Collaborative Tele Assistance) to enable two communication principles fundamental for any collaboration: designation (i.e., the need to point an object when speaking about it) and sharing the visual space in order to correctly understand the work status. In the same way, Azpiazu et al. (2011) and, Alem et al. (2011a) and Alem et al. (2011b) developed MCAR to enhance maintenance support over critical component being repaired respectively in the railway and mineral extraction sectors.

Table 5 Comprehensive overview of the features selected for the AR system proposed in literature.

Reference	Context (main purpose)	AR environment		Man-machine interaction		Level of collaboration		Output Device		Input Device		Tracking System		
		Indoor	Outdoor	Tangible	Intangible	Single user	Multi-user	HMD	Handheld	Physical device	Intangible system	Signal-based	Image based	Natural feature based
Ababsa et al. (2012)	environmental science		+		+	+			+	+		-	-	+
Alem et al. (2011a)	mineral extraction; mining		+	+			+	+			+			+
Asai (2010)	transportable earth station (usability of HMD)	+		+		+		+		+			+	
Azpiazu et al. (2011)	railway sector		+	+			+	+			+		+	-
Behzadan and Kamat (2009)	urban construction; excavation operation (tracking)		+		+	+		+		+		+		-
Benbelkacem et al. (2013)	solar system; photovoltaic pump system (ARIMA platform)	+		+		+		-	+	+			+	
Berning et al. (2012)	onsite plant monitoring (concept proposal)	+			+	+			+			+	+	
Besbes et al. (2012)	industrial maintenance training	+		+		+		+		+				+
Bhatia and Vijuyakumar (2012)	domestic maintenance (tracking)	+		+		+		-	+	+				+
Bottecchia et al. (2009)	printers and PC	n.s.	n.s.	+			+	+			+			+
Chang et al.	road maintenance		+		+	+			+	+		+		

Reference	Context (main purpose)	AR environment		Man-machine interaction		Level of collabora-tion		Output Device		Input Device		Tracking System		
		Indoor	Outdoor	Tangible	Intangible	Single user	Multi-user	HMD	Handheld	Physical device	Intangible system	Signal-based	Image based	Natural feature based
(2012)														
De Crescenzio et al. (2011)	aircraft mainte-nance (tracking)	+		+		+		+		n.s.	n.s.			+
Didier et al. (2005)	industrial plant maintenance (tracking and mul-timedia content generation)	+		+		+			+	+			+	-
Efthymiou et al. (2012)	production system control	+			+	+			+			n.s.	n.s.	n.s.
Espíndola et al. (2013)	industrial mainte-nance (data inte-gration)	n.s.	n.s.	+		+		+	+	+	-		+	
Friedrich et al. (2002)	industrial mainte-nance (ARVIKA project overview)	+			+	+		n.s.	n.s.	n.s.	n.s.	-	+	
		+		+			+	+			+	-	+	
Hamid et al. (2011)	basic home net-work management	+		+		+			+	+			+	
Henderson and Feiner (2011)	maintenance in an armored vehicle turret	+		+		+		+		+		+		
Henderson and Feiner (2007)	turboprop engine	+		+		+		+			+	+	+	
Ishii et al. (2007)	Nuclear power plant (NPP) maintenance (tracking)	+			+	+			+	+			+	
Kang et al. (2006)	computer mainte-nance	+		+		+		+		+		+	+	

Reference	Context (main purpose)	AR environment		Man-machine interaction		Level of collaboration		Output Device		Input Device		Tracking System		
		Indoor	Outdoor	Tangible	Intangible	Single user	Multi-user	HMD	Handheld	Physical device	Intangible system	Signal-based	Image based	Natural feature based
Kleiber and Alexander (2011)	unexpected events, need of expert support (communication system with limited bandwidth)	n.s.	n.s.	+			+		+		+		+	
Lee and Akin (2011)	Operation and maintenance (O&M) for HVAC system	+		+		+		+		n.s.	n.s.		+	
Luukkainen (2009)	industrial plant maintenance	+			+	+			+	+			+	
Martín-Gutierrez and Santos Pérez (2011)	domestic maintenance	n.s.	n.s.	+		+		-	+	+			+	
Paz et al. (2012)	unprepared environments (tracking)	+	+	+		+			+	+				+
Platonov et al. (2006)	automotive industry	+		+		+		+			+			+
Schwald and de Laval (2003)	general maintenance task	+		+		+		+			+	+		
Schall et al. (2009)	underground infrastructure		+		+	+			+	+		+		
Siltanen et al. (2009)	industrial plant maintenance task (data integration)	n.s.	n.s.	+		+			+	+			+	
Stutzman et al. (2009)	onsite plant monitoring (AR device development)	+			+	+			+	+			+	-

Reference	Context (main purpose)	AR environment		Man-machine interaction		Level of collaboration		Output Device		Input Device		Tracking System		
		Indoor	Outdoor	Tangible	Intangible	Single user	Multi-user	HMD	Handheld	Physical device	Intangible system	Signal-based	Image based	Natural feature based
Tumler et al. (2008)	picking task in warehouse (usability)	+		+		+		+		+			+	
Wang et al. (2008)	milling machine maintenance (infrared marker)	+		+		+			+	+		+		
Wang et al. (2011)	aircraft component (co-located multi user)	+		+		+	+	+			+	+	+	
Zhu et al. (2012)	PM and CM on CNC milling machine (Authorable context-aware AR)	n.s.	n.s.	+		+		+		+			+	

2.4.3 *Identification and description of the typology dimensions*

Starting from the comparison of features of the different applications, we developed a typology that is helpful to identify the most adequate configurations of AR devices, on the basis of the kind of services to be provided. This typology is built around three dimensions, as explained in the following.

The first dimension reflects the way scenes and users movements are recognised and tracked. In some applications, sensors, markers or other devices have to be placed in advance on the location where the service must be delivered. Conversely, other applications use natural-feature algorithms that do not require markers. We call *intrusiveness* the extent to which, prior to adopting and using AR, the service provider is obliged to prepare and modify, in advance, the customer's environment.

The second dimension of the typology addresses the way users are requested to interact with I/O devices. We call *portability* the extent to which user's motions and movements could be prevented or not, as a consequence of specific I/O devices such as handhelds rather than HMDs (van Krevelen and Poelman, 2010). In addition, portability reflects also the fact that technicians need to be agile and move frequently along the day, since they may have to provide several services in different locations (Aleksy and Rissanen, 2012).

Finally, the latest dimension concerns the possibility of having real time augmentations generated by remote users (such as in MCAR applications), instead of software agents (such as in AAR applications). We call *independence* this dimension, as it addresses the extent to which a technician, while doing her/his mission, likely resorts to external assistance as a consequence of the gap between the mastered skills and those needed to perform the demanded task.

For each of the above defined dimensions two levels have been considered, as depicted in Figure 7. In the following paragraphs, the meaning of each level is described in more details.

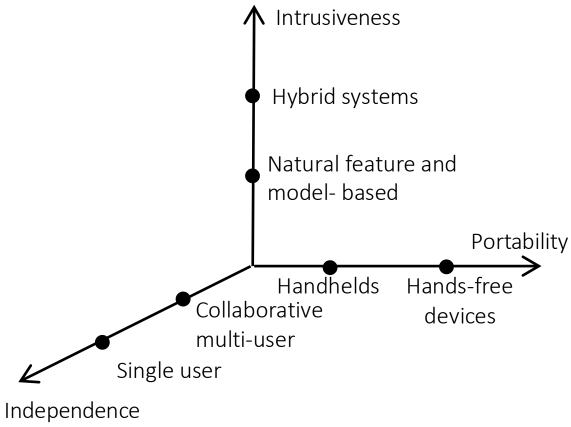

Figure 7 A typology of AR applications to support industrial services.

2.4.3.1 Intrusiveness

As mentioned above, intrusiveness is linked to tracking devices. Notwithstanding several very different tracking devices exist as presented in sub-section 2.3.1.1, these can be grouped with respect to an increasing level of intrusiveness as follows:

1. Natural feature-based and model-based systems

These systems are characterized by a low level of intrusiveness, since, as previously described, no markers or sensors need to be placed in advance in the environment. Therefore, they are suited to be used in contexts where the service provider has to serve a dispersed installed base and the arrangement of the environment is not feasible, e.g., the customer does not allow the service provider to place sensors and markers in its facilities.

2. Hybrid systems

This level corresponds to tracking systems made up of sensor-based and marker-based tracking. In general, the adoption of this kind of solutions requires a high level of intrusiveness due to the need to prepare the environment in advance, placing sensors and markers. However, this kind of systems can be used at least in two situations: i) whenever the product needs anyway to be identified through a barcode, a tag RFID or a NFC device, e.g., to be adequately managed within the enterprise IT systems; ii) whenever the relationship between the service provider and the customer is so strong that the service provider can modify the customer's environment, and place markers and/or sensors over it.

2.4.3.2 Portability

Depending on the portability of the AR devices, a technician can execute freely his/her tasks, i.e., without any impositions related to technologies, or he/she needs to handle a display and/or hold a device with his/her own hands, etc. thereby limiting his/her movements. Therefore, portability takes into account both input and output devices. Two different levels are identified:

1. Handhelds

AR system portability is low when I/O devices constraint the technician's ability to operate, i.e., hands are not totally free to move. For instance, this is the case of devices that require at least one hand to be held such as joysticks or trackballs (to be used as input devices) or smartphones and tablets (to be used as displays or to interact with the software application). In these situations, in fact, the technician has to stop any task, e.g., put down any work tool, in order to handle such devices and use AR.

2. Hands-free devices

AR system portability is high when I/O devices are totally hands-free. For examples, head-mounted displays to visualize the augmentations and vocal commands or opportunistic control (Henderson and Feiner, 2010) to interact with the software application, are proven to be a solution in this case.

According to the kind of input and output devices, four combinations can occur: i) both input and output devices are handheld (e.g. a tablet) limiting then the user's movements and so AR system has low portability; ii) both input and output devices are hands-free (e.g. HMD and vocal commands) so the user does not have constraints in movements and the AR system is highly portable; iii) if the output device is hands-free while the input is handheld, the AR system has high portability since we consider the ability to perform freely the field task viewing the useful information superimposed on the scene more important than the physical interaction to skip to the next augmentation; iv) finally, the last case (i.e. hands-free input and handheld output) is unlikely since usually output devices such as smartphones and tablets allow both displaying of augmentations and interactions with AR application, thus additional hands-free input are not necessary.

2.4.3.3 Independence

The independence of the AR user is linked to the complexity of the task to be performed. According to Perrow (1967), complexity in working procedure stems from uncertainty: when a task is characterized by several exceptions (i.e., high task variety) and frequent new issues (i.e., low task analysability), it is less stable and predictable in terms of outcomes, and thus more complex to perform (Perrow, 1967, Rapaccini and Visintin, 2008). Therefore we can assume that, in these situations, there will be a greater need of obtaining external assistance. Accordingly, in these cases collaborative multi-user systems are almost mandatory. Hence, we can group AR applications with respect to their level of independence, as follows:

1. Collaborative multi-user systems

If task complexity is high, the type of information to be provided for the operator is remarkable hard to be codified, structured and algorithmically treated (Bottecchia et al., 2010b). If tasks require heuristic solutions due to the fact that unforeseen situations may arise frequently, remote product specialists who have been already confronted with this situation could helpfully support the less experienced field technicians. For this reason, AR users are dependent from their colleagues and supervisors in performing their task. In this scenario, MCAR systems allow easier distribution of tacit knowledge among field-technicians and remotely located experts, whose presence on-field is not either possible or convenient.

2. Single-user systems

If task complexity is low (e.g., task is expected to be analysed and coded easily), AR users are independent in performing their task from colleagues or supervisors since they need information easy to store, retrieve and transfer through manuals, procedures etc. (Bottecchia et al., 2010b). This information, in fact, can be efficiently translated into operational instructions that, as in the case of AAR systems, a software agent can superimpose on a display and automatically/immediately associate to the real object, based on context-specific situations.

In the next section, several configurations of AR systems that differ on the basis of the adopted technologies will be discussed at the light of the proposed classification.

2.5 The fit between AR system and IFS scenario

Three patterns that seem particularly suited to group the reviewed applications of AR, in relation to the features of the proposed typology have been identified. Following this line of reasoning, each pattern represents a technological solution for the different scenarios and issues that may arise in the provision of IFS. The main features of each pattern are summarized in Table 6 and discussed in detail in the following paragraphs.

Table 6 Summary of the characteristics of three patterns identified.

	Pattern 1	Pattern 2	Pattern 3
Context of application	Product recovery from unexpected event; action plan not defined; inexperienced technicians	Procedural task on complex systems; action plan defined; not frequent intervention	Plant inspection; monitoring of the industrial product's status to ensure its availability
Objectives of the AR systems	To allow remotely located experts/specialists to support field-technicians in performing a task	To guide step by step the user in performing a procedural technical intervention	To allow access of data from any facility locations
Users of the AR systems	Technicians and product specialists	Field technicians	Maintenance engineers; inspectors
Examples of existing AR systems	MCAR systems: TAC (Bottecchia et al., 2010b), ReMoTe (Alem et al., 2011b), R.E.A.L., etc.	AAR systems: ARIMA(Benbelkacem et al., 2010), ACARS (Zhu et al., 2012), etc.	AAR systems: Simantic Mobile (Luukkainen, 2009), MARTI (Stutzman et al., 2009), etc.
Independence	Collaborative multi-user	Single user	Single user
Intrusiveness	Natural-feature and model-based systems)	Both levels (Context-dependent)	Hybrid systems
Portability	Hands-free devices	Hands-free devices	Handhelds
I/O device	HMD with camera + wearable PC; remote PC + AR application	HMD	Handhelds: MARTI, UMPCs, tablets, smartphones

2.5.1 *Pattern 1: product recovery without a clear action plan*

Pattern 1 refers to the so-called MCAR systems. As shown in Figure 8, a distinctive feature is that MCAR applications allow remotely located users to collaborate in performing a specific task. Correspondingly, this pattern relates to the scenario described in section 2.1 where technicians have to ensure timely and efficient recovery of product operating status, altered as a consequence of uncommon/unknown problems. Hence, they need support because either they cannot easily retrieve information on their own, or even the desired information could not have been previously coded and documented. In this case, the support provided by a product specialist from a remote workplace can be helpful to firstly identify, even heuristically, the searched solution and then to guide the technician towards its application.

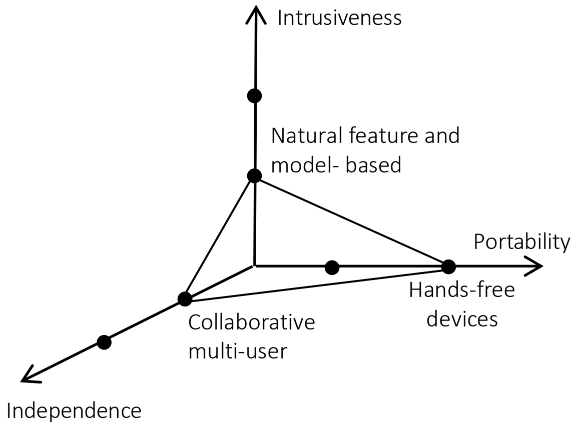

Figure 8 Pattern 1 - AR system features to support product recovery without a clear action plan.

More specifically, two distinct cases can be highlighted. The first case concerns the occurrence of some unexpected events, like failures, for which underneath causes must be firstly investigated in order to identify the action plan to follow. Actually, troubleshooting of complex systems is mostly unstructured. Notwithstanding checklists can be used, practical experiences and intuition of product specialists, still play a major role. Then, if the problem cannot be solved in isolation, it is generally assigned to a more skilled technician that is called for providing remote help-desk. The second case, instead, may concern the deployment of very inexperienced/young technicians. Complexity, in fact, is relative and depends on the gap between the skills requested and those already mastered, on average, by the workforce. Hence, even routine activities (e.g., planned maintenance on new products) in some cases may take advantage of external support (e.g., receive guidance on disassembling steps and procedures). The only difference with respect to the first case is that the task contents or the way these contents can be accessed are not unknown, since they are usually described in technical documents.

As already mentioned, mobile phones are the most used tools to communicate from the field with remote product specialists. However, these devices do not ensure information exchange symmetry, since product specialists could find difficulties in getting a clear picture of the situation that field technicians have to face, and in communicating the actions to be undertaken.

This type of AR application allows thus, collaboration among multi-users (i.e. low independence). In addition, as unexpected events may arise anytime, it is not possible to prepare in advance the working environment with markers or other signs. Hence, the intrusiveness is low and tracking solutions are based on natural features rather than on algorithmic models, that are proven to be effective in keeping a correct position between real and virtual objects, irrespective of changes of user visuals. Lastly, in this pattern, portability is high. In fact, technicians need hands free since they may have to perform physically some tasks. Therefore, AR for this kind of applications should be made up of at least two different user interfaces, one for field technicians and another one for remote product specialists. The first can be implemented through a HMD, with camera, headset, microphone and a wearable computer. Remote workspace, instead, can be equipped with a PC where the application software runs, microphone and headphones (see Figure 9). The camera allows real time sharing of the viewed scene; then, the remote product specialist can augment this scene by adding objects such as forms, arrows, 3D models, in addition to support technicians with voice communication.

Figure 9 Example of MCAR system (Alem et al., 2011a): left product specialist in front of the AR tool; right: technician equipped with MCAR during a field intervention.

2.5.2 *Pattern 2: routine maintenance or product recovery with a clear action plan*

This pattern is used to group AAR systems that do not exploit a remote user to determine the type of augmentation of reality (i.e. high independence) (see Figure 10). Therefore, these systems have been usually proposed as single user applications, in which software agents guide step by step the user in performing its task. Hence, visual aids such as texts, images, videos, graphs, arrows, etc. have to be previously prepared and uploaded into the system's repository, according to the chosen software standards and environments. Since this information has to be known in advance, these systems are suitable for tasks as procedural as disassembling, preventive maintenance, product recovery, i.e. where an action plan can be developed and then coded in advance, through visual instructions. Moreover, these tasks require technicians to perform physical interventions on products, so they need their hands free; to this concern, most of the reviewed applications adopt HMDs as output devices (i.e. high portability).

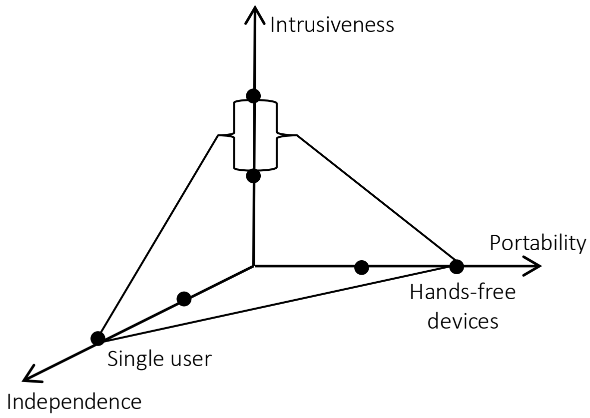

Figure 10 Pattern 2 - AR system features to support product recovery with a clear action plan.

Since procedural tasks are less complex than troubleshooting activities, experienced technicians do not usually need to be assisted by visual aids. Anyway, two situations may arise in which AAR systems could be adopted. The first refers to the case in which a technician has to perform an intervention for the first time, and then a guide could favour its execution. This could be the case of i) inexperienced/young technicians (AAR could support also training on the field), ii) the release of upgrades, modification or totally new versions of the product, and iii) service interventions with very low frequency. The second situation, instead, refers to particular cases in which wrong procedures could affect people safety and/or cause damage to high-value components. In this case, the use of AAR systems could help facing the contextual criticality and complexity. For instance, maintenance sequence for assets as complex as those found in industrial (Platonov et al., 2006, Reinhart and Eursch, 2008, Benbelkacem et al., 2010, Lee and Akin, 2011), military (Henderson and Feiner, 2009) and aerospace domains (Asai, 2010, De Crescenzio et al., 2011) span typically dozens of tasks and involve potentially unfamiliar objects randomly distributed across a given area. Moreover, movements in and around these systems can be complicated by structural characteristics that restrict a technician's view and freedom of movements. This is the situation, for example of maintenance in aircraft (De Crescenzio et al., 2011) or in an armoured carrier turret (Henderson and Feiner, 2009).

It is worth to notice that, according to the literature contributions that concern this kind of applications, both hybrid and natural feature-based tracking systems are proposed to implement the AAR systems. Hence, the selection of the tracking system seems to depend on the context. In particular, if the environment can be prepared in advance, because the customer allows the placing of fiducials and/or the use of existing RFID tags, barcodes, etc. as markers, then hybrid tracking such as inertial and marker-based seems to be the best solution. Conversely, in case fiducials cannot be installed in the service facility, (e.g. fiducials are too bulky or the service provider has not the required permission to place them) natural feature-based and model-based tracking systems have to be adopted. For instance, in case of outdoor applications (environment too large to be covered) GPS technology is used to track the user's movement, while natural feature-based or marker-based systems track the scene (Behzadan and Kamat, 2009).

2.5.3 *Pattern 3: monitoring the equipment/product's functioning*

This pattern (see Figure 11) refers to applications located in a large area. For instance, this could be the case of maintenance crew and engineers that need to carry on some field-inspections (such in the case of risk-based inspection (RBI) maintenance). In a situation like this, AR systems could be helpful to support technicians in reaching the workplace and finding the asset to be inspected and/or maintained among the multiple installations/plants. As the area to be covered by the AR application increases, a larger amount of information needs to be uploaded in advance on the system, and more efforts are required to prepare the environment. Since traditional sensors and marker-based systems can track positions over limited zones, for this kind of applications researchers and engineers are evaluating the use of particular signs (e.g. circular and linear markers) to reduce the number of markers needed to capture larger environments and, at the same time, recognize easily the worker's position and orientation, even from a long distance (Ishii et al., 2007). It is worth to notice that, in the next years, these issues could be definitively overcome with natural feature-based tracking, since an improvement in existing algorithms to compensate changes in brightness and shadows can be expected, and more computing power will be made available.

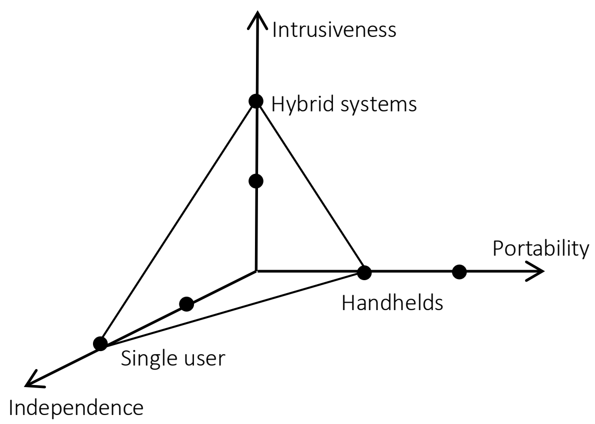

Figure 11 Pattern 3 - AR system features to support the monitoring of the equipment/product's functioning.

Anyway, several situations where these systems are proven to be useful can be pointed out. For example, if a maintenance engineer in order to guarantee the availability of an industrial plant/product needs to carry on a field inspection, he/she needs to access operating information while standing in front of the equipment. In a situation like this, the AR system can provide the right information to the plant floor at the right moment. In fact, through the system interface some simplified information can be superimposed on the real scene and displayed, thus facilitating the interpretation of the running conditions. In particular, the information that can be achieved by the AR system, together with data coming from process control and factory automation systems (Berning et al., 2012), can include also visual aids to safely and efficiently route the workers to their work place and/or help them in identifying the parts to be maintained. This can be very helpful in facilities such as nuclear power plants (Ishii et al., 2007) and paper milling plants (Luukkainen, 2009).

In order to satisfy these needs, the AR systems available in literature present common features. The first one is the need for collecting the field information to display through AR devices. With this respect, Espíndola et al. (2013) developed a solution to integrate information coming from CBM (Condition Based Maintenance) using Watchdog Agent system (i.e. intelligent maintenance system) and CAD models to be displayed through mixed reality devices. In addition Efthymiou et al. (2012) proposed a predictive maintenance platform that integrates data gathered from sensors, fault diagnostics and past knowledge of failures. AR is used in their platform to display in an easy way the results of maintenance activities through handheld devices.

Another common feature of these systems is the selection of handhelds as input/output devices (i.e. low portability). In these scenarios, in fact, the purpose of the task to be performed is to monitor/inspect the condition of a machine or a plant. It is then not necessary to implement HMDs because the user (technician or maintenance engineer) does not need his/her hands free. The selection of handhelds is thus convenient as the screen is wider, and the computer intelligence is embedded avoiding wearing a PC. In addition the touch screen of tablets, the keyboard and trackball embedded on UMPCs or smartphones, and the camera embedded on all the handhelds make them the only device required for both input and output. With this respect, Stutzman et al. (2009) developed MARTI (Mobile Augmented Reality Tool for Industry), a UMPC that incorporates the needed hardware including camera and inertial measurements unit in order to be able to run the most robust visual tracking algorithms.

Finally, to allow the AR application to run in a large area, usually hybrid tracking systems are implemented (i.e. high intrusiveness). If the components are identified with a barcode, a RFID tag (Berning et al., 2012) or using USN (ubiquitous sensor network) (Lee et al., 2010a), the AR application has to be able to read them in order to identify the object and to display the correspondent information. Considering that usually plant components are serialized, in this case the implementation of marker-based tracking system is feasible and do not require the service provider to place additional fiducials at customer's premise.

2.6 Conclusions

Notwithstanding several industrial applications of AR have been already proposed, since this technology is still emerging, indications about which technical solutions should be adopted to support the provision of IFS are not clear. To fill this gap, this chapter introduces a typology that classifies these systems with respect to three dimensions: intrusiveness, portability and independence. Then, three patterns emerged in which different configurations of AR systems are suggested to be adopted to provide IFS that differ in terms of their value proposition and application context. In particular, if the aim is to recover the product functionality, two different types of system could be introduced: i) single-user AAR and, ii) MCAR. The first could be introduced when the action plans can be easily translated into code and algorithms, thus AR technology can help technicians to get the right information in the right place and at the right time. As a result, workforce productivity can be improved. The second, instead, could be adopted in case of complex/divergent problems. In these situations, prior to deciding what actions have to be done, collaboration and support from remote help-desk can favour problems troubleshooting. Therefore, MCAR systems can assure symmetry in bidirectional communications without introducing idle times. However, in case the main goal is an improvement in the asset availability, the focus of service task shifts from tangible to intangible objects. In this case, in fact, information about product status, customer environment, process mission and functional parameters needs to be achieved in order to carry on some inspections or to define, eventually, some action plans. Hence, AR system embedded in handhelds can support this task improving the visualization of information, standing in front of industrial product.

The typology developed in this study reflects the state-of-the-art of technology, prototypes, commercial devices, etc. currently available. However, taking into account the rapid evolution of these kind of systems, we believe that as soon as current limitations related to technical issues will be overcome, different configurations will converge in one-size fits all solutions. Accordingly, the levels of our typology could collapse. In particular:

a) **Intrusiveness.** In a world more and more interconnected, dominated by global telecommunication network with continuously growing bandwidth, AR applications will evolve towards minimum level of intrusiveness. In this way, the augmentation of reality will be experienced independently from the location, since movement tracking will be made possible through gyroscopes, accelerometers and GPS receivers, and markerless algorithms will enable the recognition of any natural features of the environment.

b) **Portability.** In order to provide the users with an AR experience as natural as possible, AR devices need to be less invasive. For this reason we expect an increasing spread of HMDs (probably thanks to the famous Google^{TM} glass project) at the expenses of handheld devices. For example, if the field of view of current HMDs will increase, one of the main advantages of tablets and smartphones, i.e. the wider screen, will be nullify.

c) **Independence.** This dimension identifies two different configurations (single user or remote multi-user) that reflect scenarios as diverse as procedural tasks and troubleshooting of unexpected events. However, sometimes the outputs of a troubleshooting activity include the identification of procedural task to be performed in order to solve the problem. For this purpose, it is expected that AR systems will allow firstly the communication with a product specialist to find a solution and then, being automatically guided in the execution of the procedure.

Concluding, in this chapter the results of the first step of our theory building process are reported. In particular, based on the review and consequent conceptualization of the literature concerning AR applications for service provision, the possible IFS scenarios in which AR systems can be adopted are identified and discussed. Given the theoretical foundation of the typology and related patterns proposed, some empirical studies will be presented and discussed in the next chapters in order to verify our framework. In particular the rest of this dissertation will focus on deepen Pattern 1, i.e. the usage of MCAR to improve the communication and interaction between technicians and remote experts during troubleshooting activities. Firstly, some case studies are carried out in order to understand the impacts of MCAR on the service delivery system i) involving a company that is not using MCAR through a usage demonstration (Chapter 3) and ii) interviewing some companies that have already adopted MCAR on their introduction process and MCAR experience (Chapter 4). Then, Chapter 5 deals with the evaluation of MCAR adopting the end users' perspective. In particular their perceptions of usefulness and ease of use and, their intention to use MCAR in their activities will be investigated.

Chapter 3

How AR impacts on service delivery system: the case of Océ Italia-Canon Group

The analysis of the literature carried out in the previous chapter highlighted that there is a paucity of studies that investigate in depth the impacts of AR in real contexts. Most of this literature, in fact, is focused on discussing advances of technology and on developing state-of-the-art prototypes (Zhou et al., 2008). The few works that address the impact of AR technology on end users usually focus on devices' usability issues, since they are purposed to improve the design of human-computer interfaces (Bowman et al., 2002, Swan and Gabbard, 2005). However, even understanding how the interactions of end users in performing IFS change and how the service delivery system should be modified to include the usage of Augmented Reality is critical for the success of its adoption but, to the authors' best knowledge, still unexplored. In particular, we focused on Pattern 1, i.e. the usage of MCAR to support product recovery without a defined action plan. Since research upon those issues is still in its infancy, the underlying concepts need to be still explored and clarified. Thus, we adopted a qualitative case-based research that has proven to be particularly adequate in the early stage of theory-building (Meredith, 1993, Voss et al., 2002). In particular, from October 2011 to May 2012 we carried out an in-depth single case study in Océ Italia – Canon Group, a company that provides contractual services such as routine maintenance and fix & repair, to the installed base of equipment and that is not using MCAR for service provision. To evaluate the opinion of service managers, product specialist and technicians towards MCAR, we planned and executed a demonstration of its usage in a real setting, thus involving some potential users. In this way, interviewing the participants after the demonstration, technical and managerial issues that can prevent the adoption of this kind of technology were identified and discussed.

In the following, firstly the company and the MCAR selected for the case study are described. Then, in sections 3.3 and 3.4 the methodology is presented whereas section 3.5 summarizes the main findings emerged.

3.1 Case study selection

We focus our analysis on the Italian subsidiary of Océ (i.e. Océ Italia – Canon Group). This company was selected since: i) it provided contractual services such as routine maintenance, spare parts, consumables, repairs and upgrades, to the owners/operators of its professional products (i.e. installed base); ii) a substantial part of revenues (around 30%) streamed from service contracts; iii) services were delivered by a direct work force, according to specific service level agreements; iv) the service network was sufficiently large to consider field technicians as dispersed workers (Corso et al., 2006); v) the service director was interested in investigating how collaboration among field technicians and remote experts could improve by means of Augmented Reality and mobile technologies; and vi) the authors were allowed to access the company's data as well as to interview several technicians.

3.1.1 *Océ – Canon Group*

In 2010, Océ joined the Canon group of companies with headquarter in Tokyo but only during 2012 Canon was the majority stakeholder of Océ shares, so that Océ is now part of the Canon group. However, at the time of the study, it was one of the world's leading providers of document management and printing for professionals. Océ counted more than 20,000 employees and was active in over 100 countries, in which 27 with its own direct sales and service organizations. The company had research and manufacturing facilities in Europe, the United States, Canada and Singapore. Total revenues in 2011 were € 2,597million and the operating income excluding one-off items was €22 million, showing a negative trend compared to the previous year (i.e. in 2010: total revenues amounted to €2,674 million and operating income was €74 million). The financial results of Océ mainly depended on the external disruptions of their ordinary business and deterioration of some of their markets (e.g. the market of wide format printers usually used in building industry) (Océ N.V., 2011). With this respect, its acquisition by Canon was seen as an opportunity to extend their product portfolio mainly focused on production and wide format printers, including Canon products that cover the market segment of office printers where Océ had a lower market share (De Silva et al., 2010, De Silva and McNee, 2011). In addition the shared purpose of Canon and Océ was to become in this way the world leader in the printing industry, covering all market segments, developing together innovative technologies for printing and thicken the distribution and support network on field.

Océ is present in Italy since 1969 with the subsidiaries named Océ Italia – Canon Group. Its headquarters is in Milan but it is present in all the national territory with more than 400 people. The total revenues of Océ Italia – Canon Group in 2011 amounted to €83 million confirming the negative trend showed at global level, if compared to the previous year (i.e. in 2010: total revenues amounted to €90 million).

In the rest of the section, the offering and the organization of the field service network are presented with respect to Océ Italia – Canon Group.

3.1.2 *The offering*

Océ Italia –Canon Group is divided in three business units: Digital Document Systems that includes Document Printing and Production Printing, Wide Format Printing Systems and Business Services. The first two business units correspond to products lines manufactured whereas the latter is transversal to the organization.

Document printing focused on document flow and printing management solutions for small format - maximum A3 format. Main products are multi-functions, laser printers, fax and, since 2010, those products are mainly Canon office printers sold through Océ own distribution channels. In addition printers can be equipped with software programs for device management, scanning and distribution management, cost and access management, security management and print management.

Production printing, instead, includes printers for transaction, graphic arts, corporate environments and for publishing. Products in this category include production printers and digital presses both cut sheets and continuous feed and colour or black and white. This equipment can reach a speed higher than 1000 duplex A4 printed pages per minute, and they are the core of the production process of TransPromo and Direct Mailing business. To manage this huge printing data flow, besides mechanical and electrical parts, these machines are equipped with sophisticated controllers and dedicated software (such as software for creation, job submission, production management, pre-press and make ready, order processing and archiving of print jobs).

Figure 12 Continuous feed production printer.

Wide format printing systems, then, include large format printers, plotters, copiers, finishing equipment and software (such as for display graphics and CAD/GIS workflow management, print shop management and distribution management) for the production of wide format documents for technical and graphic arts solutions.

Finally, with respect to business services, these are divided in managed print services and professional services. The first one consists in managing the installed base of printers of the customer during their working life taking charge of maintenance activities, refurbishment of spare parts and consumables, help-desk services etc. Usually the provision of those services is regulated by service contracts. The latter, instead, are consulting services in which Océ Italia – Canon Group offers support from first advice to life-long support, including the optimization of the document workflow of the customer.

With respect to the case study carried out, we focused on production printing since this kind of printers were pointed out as the most complex and critical products to be serviced. In particular, we decided to focus on the latest model of continuous feed production printer, in order to address the potential applications of MCAR in those cases in which the effective provision of field services can be largely critical for the continuity of the customer's business. In the next sub-section the service delivery process of Océ Italia – Canon Group is described.

3.1.3 *The organization of field service network*

Given the high complexity of production printers, their maintenance and restoration require specific capabilities and tools. For this reason, usually these printers are sold in bundle with different types of multiyear service contracts. In the most common situation, services such as installation, preventive maintenance, replacement of defective/broken spares, remote support, and firmware upgrade, etc. are provided by the OEM service network against a fixed-rate fee.

However, the service performance to match is dictated by Service Level Agreements (SLAs) that may concern response or recovery times, as well as the yearly availability of equipment to be assured. In case the expected performances are not respected, some penalties may be issued. Hence, to make more profits and achieve customers' satisfaction, the service network is in charge of delivering effective and efficient field services, in the shortest time. This is not straightforward, for the following reasons. Firstly, as innovation cycles become more frequent, new printers as well as hardware, firmware and software updates, are continuously released to the market. Hence, field force needs to be systematically trained and this is expensive and complicated, since technicians are dispersed over several districts (e.g. at the time of the study Océ Italia – Canon Group, counted more than 30 service centres, mostly located near customers' premises). Secondly, unexpected events and/or unknown situations frequently occur in the field. Hence, field force needs to receive constantly support from remote experts. Irrespective the ultimate goal is to either train technicians from remote centres or support remotely the field intervention, in many occasions the field force is requested to communicate with remote experts—such as the product specialist—that are residing in customer support centres. To this regard, field technicians are commonly equipped with mobile phones and laptop PCs. These latter can be used to connect to the printer, run diagnostic checks, retrieve operating status and fault history, as well as to access technical documentation including user manuals and procedures. In case a field issue cannot be solved by the field technician in isolation, she/he recurs to the remote support. The first attempt is, thus, to use the mobile phone, call the product specialist and ask for suggestions. In case, again, the problem cannot be solved, the product specialist establishes a remote connection to the machine, and runs some troubleshooting procedures. If a solution is not found, he/she is definitively entitled to visit the customer site in the next days.

From the above considerations follows that the Océ network is adopting the typical multi-skills structure, where issues are escalated from inferior to superior levels in case of need, to engage more skilled resources. Given the intense collaboration among the network levels, the Océ Italia – Canon Group service director appeared enthusiastic of evaluating a technology that, even if at a pioneering stage, could improve the exchange of information. This is clearly pointed out by this passage from the interview:

"*We have to face different degrees of criticality and complexity of field interventions, thus we designed our service network with different levels of competence in order to adequately support the field force. The introduction of ICT that could improve the way we deliver services is thus an interesting opportunity*".

3.2 Selection of MCAR system

To organize the demonstration, we needed to select an MCAR system according to the following criteria: i) it should allow video/audio communication between remote users; ii) technicians should use it with hands free; iii) it should not require to place markers in the customer's facility; iv) it should be set up easily and quickly, in different contexts; lastly, v) a testable system should be made available, at low cost, for the purpose of this study. Following these criteria, we selected a system, named REAL, that is produced by VRmedia, a start-up company of Scuola Superiore Sant'Anna of Pisa.

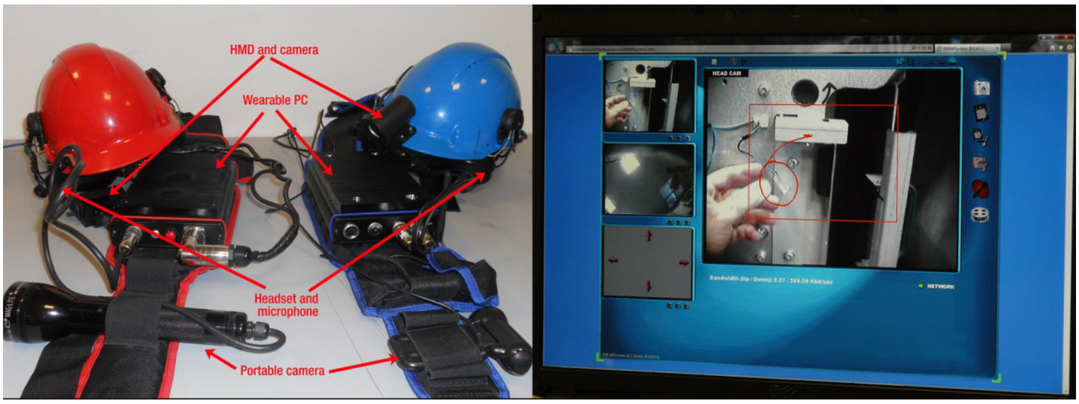

Figure 13 MCAR system used in this study for the field force (left side) and the product specialist (right side).

The chosen system is composed of several separate devices (see Figure 13). The technician is equipped with a mini PC and a portable camera, which is tied at his/her waist. In addition, he/she wears a near-eye display that can be either optical or video see-through, and a camera as well as a headset, both mounted on his/her helmet (thus, matching the second criterion). The product specialist can be remotely connected via any desktop/laptop computer running the AR application. Hence, he/she receives the video stream from the cameras and is able to communicate with the field technician through audio and visual instructions, such as text, arrows, circles, 3D images, etc. (first criterion). Visual aids and voice commands would thus make field troubleshooting faster, as more specialized skills can be exploited to investigate the cause of any failure, as well as to guide field interventions, maintenance and recovery activities. The AR application uses a natural feature recognition algorithm as markerless tracking system (third criterion). In this way it automatically determines the technician's position in the scene in order to superimpose the virtual information at points of the screen that follow the technician's movement. Moreover, communication can be supported by networks as different as Wi-Fi, LAN, cellular or satellite. Finally, since it is the duty of the product specialist to retrieve and upload information such as documents, drawings, procedures, etc. to be sent to field technicians, there is no need to upload these contents in advance on the mobile device (fourth criterion).

3.3 Research protocol

In this case study we used a qualitative approach. In particular, to evaluate different experiences of usage of MCAR technology, we needed to detect and observe any factor that could undermine the delivery of technology-assisted services. Thus, we arranged a demonstration in a real setting. Firstly, we asked the service director for selecting one of their customers to host the demonstration stage at its factory, making available some printers to simulate the servicing activities. A company that prints massive volumes of transaction-related documents, such as statements, invoices, or bills, using the latest models of production printers manufactured and serviced by Océ Italia – Canon Group was chosen. After having explained the purposes of our study, the manager agreed to stop for a few hours one of its machines to allow our demonstration to take place. The only restriction was that the demonstration should not occur at the end of a quarter, when millions of bank statements have to be printed and sent to the account holders. Secondly, a non-disclosure agreement of reserved and confidential information was prepared and signed by the involved parties, i.e. our laboratory, Océ Italia – Canon Group, the selected customer and the MCAR provider. Then, we defined the demonstration program in accordance with the service director of Océ Italia – Canon Group. In particular, a couple of technicians and a product specialist that were appointed to be representative of the field force were selected to take part in the demonstration. After being equipped with the technology, they were asked to respectively execute and remotely support certain service activities. Lastly, they were interviewed recurring to a semi-structured questionnaire that was previously prepared by the researchers. In addition, the authors interviewed the service director—who assisted to the event without interfering—in order to obtain data triangulation as well as internal consistency (Yin, 1994, p.46). This allowed us to achieve new insights into the opinions of the interested people, from multiple points of view. A short video of this experience was produced to explain how MCAR could support the execution of field services in the Océ Italia – Canon Group assistance network[9].

[9] http://www.youtube.com/watch?v=5-5EHkA-6qY

3.4 Demonstration and interviews settings

The purpose of the demonstration is to achieve information about the use experience of the people involved that, therefore, act as informants. Their roles and company positions are pointed out in Table 7. In order to let both the technicians and the remote specialist experiment the MCAR system and get aware of its main features, the real conditions of different service scenarios were simulated.

Table 7 People from Océ Italia – Canon Group involved in the case study.

Informant	Company position	Role played in the demonstration
A	Service director	Responsible of managing and coordinating the team of people involved, as well as to handle the relationships with the customer that hosted the demonstration
B	Product specialist	Remote expert, responsible to guide the field technicians in executing the intervention, by means of the MCAR system
C and D	Field technicians	Workforce, responsible to directly execute the field intervention supported by the remote expert through MCAR

Then, in order to evaluate the learnability and ease of use of the MCAR system from a broader perspective, only the technician identified as *Informant C* received a 2 hour training session. In particular, we give detailed instructions about how to wear the personal devices, how to use the see-through display and visualize the contents superimposed to the real environment, etc. Lastly, two scenarios related to the use of MCAR to support the execution of field service activities were planned and executed. These consisted, firstly, in running a troubleshooting procedure to discover the causes of a simulated malfunctioning. Then, the field operator had to identify, among several components, the one that caused the fault (e.g. a disconnected switch) and, lastly, to execute the maintenance activity. Demonstration was repeated twice, with Informant C and D, both being remotely supported by Informant B. Actually, he was located in a room next to the job shop in order to let the researchers observe his behaviour at the same time. To make them comfortable, the people involved were previously assured that the observers were not evaluating their individual performance. At the end of the experiment, all participants were requested to take part to a face-to-face interview. In particular, they were asked to report their overall impression of the MCAR use, the difficulties they had, the positive aspects, what they would change and, lastly, the issues they believe could prevent the adoption of MCAR technologies to support their field operations. Each interview lasted around one hour, were tape-recorded, then transcribed and sent to the Informants for validation.

3.5 Findings

Technicians involved in the demonstration gave us a very positive evaluation of the MCAR system. As *Informant B, C* and *D* stated, the device was found to be "*easy to use, simple and user-friendly*". The system was suggested to be particularly effective in supporting field interventions, when a high level of uncertainty must be faced. This is remarked by the following passage from *Informant C*'s interview: "*When there is a strong need for collaboration, as for servicing new products, these devices are certainly useful*". Moreover, a substantial improvement of the communication between the remote expert and the field technician was recognized, as the bidirectional exchange of visual information was proven to lower misunderstandings. "*I cannot deny my enthusiasm for the system that, if properly implemented can give good results, greatly improving also my daily activities*" stated *Informant B*. As *Informant B* stated, in case field technicians would use MCAR, the amount of field interventions by product specialists— 3rd-level support—could be greatly reduced.

Figure 15 Field technician.

Figure 14 Product specialist.

On the other hand, interviewees pointed out some criticalities, pertaining to both technical and organizational issues that, in their opinions, should be overcome before MCAR could be adopted for field services. In the following the mentioned problems are further discussed.

3.5.1 *Technical issues*

Firstly, some issues related to a not adequate ergonomics of the devices are identified. For instance, both *Informants B* and *C* complained that the size and the weight of the HMD should be reduced to avoid stress for its users in case of prolonged use. As also confirmed by some authors (Zhou et al., 2008, van Krevelen and Poelman, 2010), these kinds of improvements are crucial for state-of-the-art devices, prior to introducing them in industries. Despite technicians found that "*using HMD was intuitive and easy*", they actually suggested that some additional resting time could be required as a consequence of the eye's strain due to the continuous change of focus of the see-through display. In addition, the way the different equipment is worn should match any health and safety requirements. For instance, to hold up the camera, the display and the headset, wearing a helmet is adequate in case workers are anyway obliged to wear helmets due to safety requirements. Some other limitations identified in the experiment, can be easily overcome with technology advancements. For instance, the cable that connects the display with the mini PC and that restricts the mobility of the user could be replaced by a wireless connection. Finally, the portable camera was extremely useful to access tight areas and send pictures and video streams of hidden objects. Nevertheless, some additional lights would allow a clearer view of the most shaded objects. In addition, this video stream could be enhanced as well, through the superimposition of virtual objects by the remote expert.

Then, the issue related to the efficiency and security in transferring data and communication between remote users was pointed out. With respect to the first aspect, *Informant B* believed that "*good connection and transfer rates are the basis of a successful AR experience*". Hence, the choice of the telecommunication infrastructure—Wi-Fi, cellular or satellite— plays a crucial role. Moreover, the transfer of data has to be protected by means of secure protocols, since customers would never allow unencrypted data to be accessed and transmitted outside their facilities. This latter issue was remarked also by *Informant B* that, in a passage of his interview, highlighted the "*problem to connect the machine with the external world*".

3.5.2 *Managerial issues*

Interviewing *Informant A,* some preconditions for favouring the introduction of AR in industrial companies as well as some considerations related to how MCAR will change the service delivery system were pointed. With respect to the first aspect, firstly, this adoption must be evaluated at the light of a detailed cost/benefit analysis that should consider if the organization needs this kind of technology, how service delivery process is impacted, how resource are saved and so on. In other words, the introduction of AR should be feasible from both a technical and economic point of view. With respect to Océ Italia – Canon Group, for instance, MCAR systems have been considered as a way to simplify maintenance tasks, improving the efficiency and effectiveness of the intervention. In addition this technology has been pointed out as a great opportunity to reduce the highly costs related to the deployment of skilled technicians. Secondly, the mind-set of people and, therefore, the innovation pace of the organization should be considered, since it could greatly favour or, conversely, impede the adoption of this technology. In fact, the openness or not to innovation and new technologies is a crucial factor for the acceptance of new methods in providing the same outputs in a better way. *Informant A* actually, perceived that the mentioned managerial issues could prevent, if not properly managed, the rapid spread of this technology in maintenance and in services, more than the technical issues described in the previous sub-section. In fact, he believes that these will be overcome in the next years. Similarly, the amount of investments that up to now is not negligible is believed to decrease as a wider utilization will lead to the down pricing of displays, microprocessors, etc.

With respect to the process redesign, we believe that MCAR is directed, within a few years, to become a standard equipment of service network and maintenance departments. Therefore, managers should be aware of this, and prepared to work for their adoption as soon as few technical restrictions will be overcome. For this reason, different stakeholders (technicians, remote experts, R&D department, customers, etc.) should be involved in demos, simulations, prototypes testing activities etc. for two reasons: on one side managers can assess and control the resistances towards the wide spread innovation of the service network, and on the other, this could be an occasion to rethink the ways field services are delivered. With respect to this latter possibility, we can draw out some considerations concerning the redesign of the service delivery system, as also suggested by several passages of the interview with *Informant A*. Given the above-mentioned expected benefits mentioned by *Informant A*, in fact, he stated that MCAR adoption will "*change significantly when and how to train field force and so the kind of skills distributed on the field and in the back office*". Therefore, by means of MCAR, the delivery network could be redesigned through the introduction of a highly skilled central help desk to support field workers. Hence, field force could be mostly productive even with a simplified training program. However, prior to deciding to reduce the efforts for training field technicians, labour unions relationships should be carefully managed, especially in large service networks.

Finally, *Informant A* highlighted the possibility to use these systems also to support maintenance tasks on low complex products, where the AR user could be the final user i.e., the product operator.

3.6 Conclusions

This chapter deals with a first assessment of the perception of potential users of MCAR technology in supporting IFS provision. In particular, using data from a single case study (i.e. Océ Italia – Canon Group) we performed a demonstration in a real setting, to show how MCAR can support field service delivery. Through the qualitative observation of a couple of technicians and a product specialist while testing the devices and collaborating to solve a simulated fault on a printing machine, and through interviews, several issues that could prevent MCAR adoption were identified. As confirmed by our study, even if some features of the MCAR system were pointed out as suggested improvements prior to introducing this technology as a working tool (e.g. the size and weight of the wearable equipment, the security of data transfer outside the customer's local network), the technicians involved in the demonstration declared they would be willing to use MCAR in their daily work. In addition, even from a managerial perspective the possibility to achieve benefits in terms of cost and time savings adopting MCAR emerged as well as some ideas related to the redesign of the service delivery system.

Notwithstanding its relevance, this study has got some limitations as well. Firstly, since we used a single case study involving a company that is not currently adopting MCAR, this research will be repeated in other contexts/companies. In particular, in the next chapter two retrospective case studies will be carried out involving companies that are adopting or have already adopted MCAR in their field network in order to evaluate how they faced or are facing the related challenges. Secondly, this study involved only few technicians. Therefore, the generalizability of our findings needs to be accurately addressed. For this purpose, in Chapter 5 the users' perception of usefulness and ease-of-use of MCAR will be quantitatively investigated administering a survey based on TAM (Davis, 1989) and TTF (Goodhue and Thompson, 1995) to the field force of several companies.

Chapter 4

How AR impacts on service delivery system: two retrospective case studies

This chapter aims at refining the preliminary findings gained through the explorative case study presented in the previous chapter in order to confirm or not the technical and managerial issues identified. With this respect this chapter presents the findings from two retrospective case studies conducted during the first three months of 2013 in SIDEL and IMA Servizi, both pioneering companies that have adopted MCAR technology to support their field service network. In addition to confirming the preliminary results, then, purpose of these case studies is to get insights into the introduction process of MCAR. In particular, we highlight and discuss the issues related to the pre-implementation stage of adoption such as the reasons why they decided to introduce this kind of technology to support field service delivery and to the implementation and post-implementation stages such as the steps followed to introduce MCAR and the benefits and problems experienced.

In the following, firstly the research protocol used and the profiles of the case studies selected are described. Then, in sections 4.2 the main findings are summarized while section

4.3 concludes the chapter merging the findings gained from both the explorative and retrospective case studies, and identifying two main areas of improvements for companies that decide to adopt MCAR technology.

4.1 Research protocol

In this study we adopted the same methodology of the previous chapter, i.e. an exploratory case-based research, since it is proven to be effective for dealing with "how" type questions that are typical in descriptive/exploratory research (Meredith, 1993, Yin, 1994, p.46). To reduce the risk of misjudgement (Flynn et al., 1990, Voss et al., 2002), and to allow achieving a higher external validity focusing on similarities and differences across cases (Meredith, 1998, Voss et al., 2002), two polar case studies were identified. Since we needed to explore the rationales behind the scouting, the experimentation and the introduction process of MCAR in industrial field service delivery (our unit of analysis), sampling was a critical process. Hence, we adopted a purposive sampling strategy, in order to be confident that the selected companies had certain characteristics that were pertinent to our research. To investigate the impacts of MCAR adoption on the service delivery system, we asked the provider of MCAR system presented in section 3.2 (i.e. VRmedia) to select among their customers, some companies that were available to be interviewed with respect to their experience with MCAR adoption. Since theory development in early stages requires lesser cases (Stuart et al., 2002), we identified two companies among the ones proposed, that together constitute a polar case study in order to increase the generalizability and external validity of results. As showed in Table 8, in fact, the two companies differ with respect to the main business (i.e. SIDEL is an OEM that integrates its offering with services whereas IMA Servizi is a service firm), the industry, the dimensions in terms of annual revenue and number of employees and the extension of the area served (i.e. SIDEL is a multinational company that operates worldwide whereas IMA Servizi is an Italian firm that operates in the north-east region of Italy). A short description of the companies' profile and the organization of their service delivery systems are provided in the next sub-sections.

Table 8 Case-studies characteristics.

Company	SIDEL	IMA Servizi
Type of company	Servitized OEM	Service firm
Industry	Liquid packaging	Oil&Gas
Core business	Design, installation and long life support services on bottling lines	Construction and maintenance services on petrol stations and fuel pumps
Revenues (M€ -2011 - IT)	571	10
Number of employees (2011 - IT)	1144	80
Extension of area served	Global	Regional
Dimension of IB	10000 ÷ 50000	500 ÷ 1000
Number and type of informants	1 service manager	1 product specialist 2 service manager

4.1.1 *SIDEL*

SIDEL is member of the TetraLaval group (together with Tetrapack and DeLaval) and is a multinational company leader in the supply of solutions for liquid packaging. With headquarters in Zurich, Switzerland, SIDEL operates in more than 190 countries, it employs more than 5,000 people worldwide (around 1,000 in Italy) and counts 1,350 million euro of net sales in 2011 (around 570 M€ in Italy). The core business of SIDEL consists in offering integrated solutions to its customers, from preliminary design to the drafting plans of the line layout, from fabrication, commissioning and handover of the bottling line to life-long on-site maintenance. In particular, besides the line design phase, even installation and services provision are challenging in this business. On one side, in fact, each bottling line manufactured is tailored to the specific customer requirements (e.g. kind of products, filling speeds, bottle dimensions, level of automation etc.). On the other side, the sales of industrial services that include spare parts provision, field inspections and remote monitoring, preventive maintenance and repairs, accounts for 40% of total revenues. Therefore, a highly skilled and flexible field force is deployed across a vast network. In particular, the field network of SIDEL adopts the typical multi-skill structure, where issues are escalated from inferior to superior levels in case of need, to en-

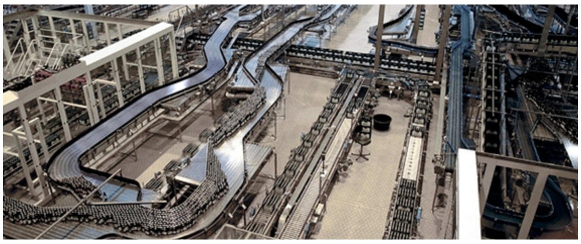
Figure 16 SIDEL bottling line.

gage more skilled resources. Therefore, technicians are assigned to a specific zone and can ask the product specialist located in central help-desk for support. In addition currently more than 1,300 out of 15,000 machines are remotely connected and can be accessed by product specialists. In this way they can solve around 80% of the electronic problems remotely. Conversely, with respect to mechanical faults or if problems arise during critical operations, such as the installation of new bottling lines, technicians could require remote support and MCAR has been adopted in order to improve the efficiency of technical support.

4.1.2 *IMA Servizi*

IMA Servizi, instead, is a local firm of northern Italy, providing construction, inspection and maintenance services to petrol stations and fuel pumps. It counts more than 10 million euro of net sales in 2011 and 80 employees throughout northern Italy. These services are provided through a direct service network that includes people specialized in servicing mechanical or electrical components, rather than in construction services. In particular, with respect to the workflow of the technical support service delivery, IMA Servizi handles around 30-35,000 service requests per year. Each request is firstly coded by an operator of the call centre that creates a service ticket in which the description of the problem noticed and all the information related to the name of customer, its location, etc. are stored and then forwarded to the ticket scheduler. Therefore, the ticket scheduler, filtering the open tickets with respect to the skills requested (i.e. mechanical, electrical or building skills), assigns the ticket to a specific technician considering also his proximity to the customer's premise. Finally, the field technician performed the service task and can be supported by a product specialist if some unexpected problems occur.

Figure 17 Petrol station

In addition to service requests, IMA Servizi is in charge of executing some renovation works of the petrol station involving thus mainly technicians with construction skills. For this kind of task usually inspectors are sent to check onsite the progress and the correctness of the construction work on site, since this kind of work in the oil and gas industry is strictly ruled and requires many inspections for certification purposes.

Since the core business of IMA Servizi is focused on service provision and due to the general economic crisis that affects especially small and medium-sized enterprises, IMA Servizi is constantly looking for ways (such as adopting new ICTs) to increase the efficiency of its field force and reducing internal costs being in this way more profitable.

4.1.3 *Data collection and analysis*

In order to increase the research reliability (Yin, 1994, p.46), a formal research protocol was adopted for collecting data. Data were collected through in-depth interviews. To achieve triangulation (Yin, 2003), other information was achieved from secondary sources such as service contracts, work procedures, organizational charts, web sites and balance sheets. Each interview was carried out through the use of a semi-structured questionnaire, by two or three researchers, to increase the confidence in our findings (Eisenhardt, 1989). Interviews lasted from one to two hours. To comply with the suggested profiles (Voss et al., 2002), informants were selected among managers of the company's service division, responsible for innovation projects as well as for operations. Overall, 4 respondents were contacted to capture all the relevant aspects of our research (e.g. the manners in which providers and customers interact; the difficulties in being efficient and/or effective in creating value for the customers, the contextual and structural characteristics of the studied firms, etc.). Each interview was recorded and verbatim transcribed, and each respondent received a copy for verification. Feedbacks received were considered to increase the accuracy and the validity of the results (Yin, 2009). Data from interviews were coded and the findings were analysed according to the life cycle stages of a new technology introduction. In particular we referred to the framework proposed by Aloini et al. (2007) with respect to ERP adoption that includes three stages: i)concept or pre-implementation, i.e. the activities from strategic planning of requirements to technology selection; ii) implementation, i.e. the activities from technology deployment or installation to parameterization, integration, testing, and stabilization; and iii) post-implementation, i.e. maintenance activities such as upgrading and new-release management (see Figure 18). The analyses and the discussion of the main findings are presented in the next section.

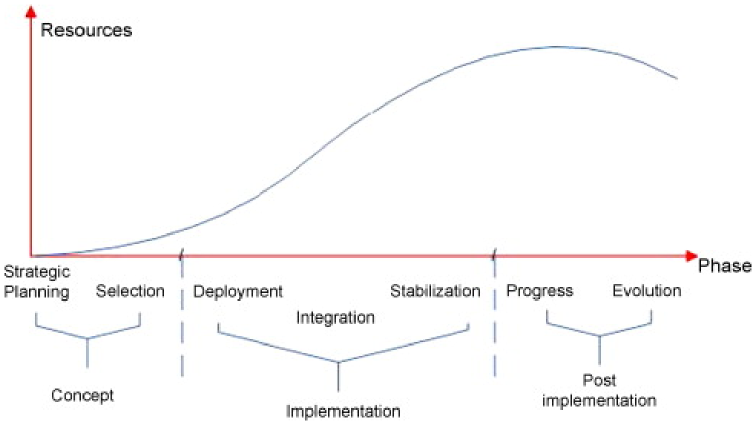

Figure 18 ERP life cycle (Aloini et al., 2007).

4.2 Findings

From the interviews emerged that both companies introduced MCAR to support their field force. However, since both of them bought only three devices, they can be considered still in an implementation stage of adoption. In fact, both companies implemented a first version of MCAR but the final release is still in progress. Nevertheless, several feedbacks pertaining to a post-implementation stage of adoption such as ergonomics and functional issues as well as hypotheses for future modes of employ MCAR can already be collected. For these reasons, we analysed and grouped the information gathered during the interviews only in two stages, i.e. i) pre-implementation and ii) implementation and post-implementation, as shown in Table 9. In the following sub-section each activity is briefly discussed.

Table 9 Findings of the two retrospective case studies.

Stage of introduction		SIDEL	IMA Servizi
Pre-implementation	Trigger	Reduce internal costs Improve service performance Need of audio-video communication system	Reduce time for staff training Increase the productivity and profits Need of training on the job system
	Selection process	Top-down decision Research project with VRmedia for MCAR development	Top-down decision Purchase of MCAR system designed by VRmedia
Implementation and post-implementation	Number of devices	3	3
	Training	One device is available at the learning centre for all the technicians	One device is available at the learning centre A specific training is

	No specific training are planned	planned only for new/young technicians
Customization	Several releases have been designed during the research project Data input not requested	No customization requested
Mode of employ of MCAR	Stored in central site and available to support technicians during critical installation	Stored in central site and assigned to technicians if a clear action plan cannot be defined
Resistance management	Communication	Communication
Feedback on MCAR	Several releases to solve ergonomics issues. They are working on MCAR with expert's hands gesture recognition Network: customer Wi-Fi (no security data transfer issues)	Need to improve the image quality for viewing details, and image contrast for lighted environments. High acoustic isolation with current headset. Network: cellular, UMTS
Ancillary benefits	Increase company's image	Increase company's image
Future development and mode of employ	Service corner. Expand the installed base to equip more technicians with MCAR. Provide the operator of the plant with MCAR.	Develop an augmented reality system that integrates the function of AAR and MCAR.

4.2.1 *Pre-implementation stage*

In both cases, the process of MCAR introduction started as a consequence of the need to be more efficient, reducing, thus, internal costs. Then, the specific trigger that led them to adopt MCAR was different. For instance, SIDEL, due to the long distance between customers' sites and R&D centres, was looking for a system that allows an efficient audio-video communication between on field technicians and remote specialists whereas IMA Servizi was looking for a way to shorten the time of technical training of new technicians in laboratories in order to send young and/or inexperienced resources sooner on field.

Once aware of the need, the selection process of the technology (i.e. the identification of MCAR system as the solution) was quite different for the two companies even if both of them adopted a top-down decision approach involving the top management but not the end users. For instance, SIDEL funded a research project with the purpose of developing a tool that fitted its requirements. In particular the project with VRmedia started in 2006 with the development of systems for the stereoscopic visualization of groups, then, with the introduction of 3D visualization, VRmedia developed REAL, the MCAR system described in section 3.2. From that moment on, several releases have been produced in order to give an answer to user feedbacks concerning ergonomics and technical issues such as the weight of the portable PC, the lifelong of batteries, the kind of communication network, etc. IMA Servizi, instead, introduced the MCAR system in August 2012, choosing the already developed REAL system.

4.2.2 *Implementation and post-implementation stages*

The MCAR system selected is plug and play and does not require to upload any kind of data in advance or to integrate itself with other information systems. For this reason, if we refer to the final output of the research project between SIDEL and VRmedia (i.e. the same device adopted by IMA Servizi), no customization activity was requested.

Conversely, during the implementation several activities to train both technicians and product specialists in using the system as well as activities focused on handling possible resistances were performed. In particular, both companies made available one device in their learning centres but SIDEL did not plan any specific training for technicians whereas IMA Servizi included a MCAR demonstration in the training program of young/inexperienced technicians. Both service managers highlighted that some resistances emerged in using MCAR. In particular from the field technician's perspective, the feeling of being under control was remarked whereas from the product specialist's point of view, the feeling of losing their skills in sharing their knowledge with technicians was highlighted especially in IMA Servizi. Both companies handled those resistances through communication programs. To handle the first, they let the technician understand that MCAR is a tool that improves the communication with product specialist if compared with mobile phones but it is not used to control their work whereas to handle the latter, the communication was targeted to empower the product specialist and let him understand that with MCAR adoption, his/her role is more and more important since it is essential for the successful execution of the field tasks.

Despite both companies introduced MCAR, some differences with respect to the mode of employ can be noted. For instance, the service manager of SIDEL highlighted that the installation phase of new bottling lines was the most critical situation to be faced on field. As already stated, in fact, each line has its distinctive features. Moreover, usually the customer site is far away from the R&D centre where the line is designed. For these reasons, SIDEL decided to procure and keep at the headquarters three MCAR devices, in order to send them to the installation site in case a critical situation occurs. This way, the crew that is deployed on field to provide the installation can have assistance by a remote specialist that, in case, suggests the usage of the MCAR device to get a clear picture of the faced situation. Conversely, as already said, IMA Servizi introduced MCAR to reduce the time of technical training of new technicians. In a normal situation, in fact, when a service request arrives, according with the skills required to perform it, a specific kind of technician is sent to the petrol station to execute the intervention. However sometimes happens that the technician is asked to perform extra-activities for whose he/she could not be adequately prepared. Hence, the most inexperienced technicians are equipped via MCAR to favour their training on the job and, at the same time, deliver field intervention with adequate quality, as they are assisted by a remote specialist. The service manager told us that, due to the adoption of MCAR, the amount of second visits at the customer's premise was greatly reduced, since the technician that is in front of an unknown situation can contact the product specialist and, following his/her instructions, can complete successfully the task at first visit. Even IMA Servizi decided to procure and keep at the headquarters three MCAR devices and then the ticket planner is responsible for deciding which technician will take MCAR on field with respect to the criticality expected by the intervention. Moreover, the service manager of IMA Servizi identifies a new way of employing MCAR such as to check the quality of construction work. Having MCAR on site, it is possible to perform an inspection by remote, thus guiding the maintenance technician (that is not skilled to do inspections) on the base of inspection procedures that are defined by the construction site engineers.

Definitively, these findings confirmed the situation mentioned in the first pattern of the typology discussed in section 2.5.1. In fact, in these cases MCAR technology is used to face unexpected situations, to favour troubleshooting and collaborative resolution of complex problems.

In addition, the informants pointed out that, as a consequence of introducing AR in their service network, a better company's image in the customers' eyes was obtained. In fact, the availability of an advanced technology such as AR was seen by the customers as the proof of the efforts sustained by the service provider towards the achievement of a higher quality in the service provision.

Finally, with respect to future development or mode of employ of MCAR, several directions emerged. With respect to SIDEL, they are planning to introduce a service corner, i.e. creating an area within the customer's site under the responsibility of SIDEL and in which SIDEL stores spare parts, has benches to execute maintenance tasks and can communicate remotely with product specialists through MCAR. In this way even the operators of the bottling line have direct access to SIDEL help-desk if needed. In addition, when current limits, such as the high cost of each device and the inadequate support network for MCAR will be solved, SIDEL is evaluating the possibility to include in the service contract the possibility for the customer to have a MCAR device through which contact the SIDEL product specialist in order to be remotely guided during the execution of some field interventions. Finally, since the high cost of the device is one of the main limits for a spread adoption of MCAR, up to now, the described cases are good examples of how MCAR can be adopted and used even if not all technicians are equipped with it. The usage of MCAR is infrequent, since MCAR fulfils the need for external support in unexpected and/or critical situations; therefore, few devices could be enough if properly managed. The main issue, in fact, becomes how identify the expected most critical intervention in order to assign MCAR to the technician that more likely will need it to perform his/her intervention. However, SIDEL is looking for ways to achieve economies of scale (e.g. involving other companies of TetraLaval group in this project) in order to increase its installed base.

With respect to IMA Servizi, instead, the service manager suggests VRmedia to develop a new AR system that integrates MCAR and AAR, in order to provide a multi-level help desk: first level assistance is provided by AAR, on the base of codified procedures that are initiated when technician is in front of the fuel pump. If the situation to be faced cannot be solved autonomously, the technician asks for second level support by a remote expert, thus activating MCAR.

4.3 Conclusions

This chapter was focused on understanding the introduction process of MCAR in real contexts. In particular, through two retrospective case studies, the issues related to each stage of adoption as well as the current mode of employ MCAR was discussed, integrating thus the preliminary results achieved in the previous chapter. Notwithstanding we carried out only two polar case studies, useful insights have been achieved. Firstly, both cases are related to companies that have only partially introduced MCAR to support their field force. This finding confirms that MCAR is still an emerging technology that only recently has matured so much that few prototypes are ready to enter the market. Both companies, in fact, although pioneers in adopting MCAR, are still in the implementation phase, looking for new releases that better fits their needs prior to letting MCAR be a standard equipment for each technician. Then, from the interviews emerged that Pattern 1 proposed in our typology was confirmed since the service managers of both companies state to use MCAR in critical situations in which a clear action plan is not defined; then, the specific situation selected can differ from the installation of new bottling lines to the assistance of petrol stations if the customer is vague in the description of the problem noticed.

Notwithstanding the relevance of our results, this study has got some limitations as well. Firstly, even if in early stages of theory development few cases can be acceptable (Stuart et al., 2002) using only two case studies, the generalizability of our results need to be accurately addressed. Therefore, this research should be repeated, for instance involving other technology providers, since the involved companies are currently adopting the same MCAR device, or looking for companies that have massively adopted MCAR to support their field force. Then, these studies are mainly focused on the managerial implications of MCAR adoption. Interviewing the service managers, then, a low involvement of the end users of MCAR in the pre-implementation stage of adoption emerged, and, as a consequence, several communication efforts were requested during the implementation stage to handle the resistances. For this purpose, in the next chapter, a study to assess in a pre-implementation stage perceptions of usefulness and ease-of-use of MCAR from the end user perspective is presented.

Despite the limitations identified above, the explorative and retrospective case studies carried out gave useful insights into how MCAR adoption can influence the delivery of industrial field services (i.e. RQ2). In particular we identified two main areas of improvement on which companies have to work to be ready to adopt MCAR once current issues such as its cost or an inadequate support network will be overcome.

Firstly in our opinion companies need to increase the investments to enhance the competence centres such as control room, R&D department, help-desk from which technical product knowledge is distributed towards these new technologies across the world. In fact, the product knowledge is more and more important and at the same time in continuous evolution so that keeping the dispersed field force updated time after time could be highly inconvenient. Therefore, with the increasing availability of technologies similar to MCAR we expect that the need of having highly skilled people distributed on field will decrease on behalf of the centralization of knowledge in few centres. However this change has important implications. For instance, the traditional cascade training between the R&D centres and direct and indirect service networks will become less important. In addition, even the kind of training attended by technicians will change: besides a basic technical training, in fact, more and more important will be the ability of technicians to interact with product specialists in foreign languages in order to be trained on field on demand. In order to allow a 24/7 support all around the world, in fact, the traditional escalation process that involved two levels of support, i.e. a first level in which local product specialist support the field force and if needed the problem is forwarded to the second level usually made up of international specialists residing in R&D centres, became unfeasible. Conversely, the development of few knowledge centres able to handle the field requests world-wide (e.g. with a follow-the-sun organization) could be a solution. For this reason we expect that companies will spend time, money and efforts to develop a knowledge distribution system that effectively and efficiently supports the field force, and to accurately define how many centres are needed, where locate them, etc.

Secondly, once the support network essential for the usage of MCAR is developed, i.e. companies are able to remotely support somebody on field worldwide and 24/7 through MCAR, we expect that companies will include the MCAR-based support system in their offering. In fact, the next step of the service delivery evolution could be the replacement of direct service network with customer's personnel such as the machine/industrial plant's operators. Therefore, in addition to the traditional service contract, companies can offer an alternative option that includes the selling of the MCAR device through which the customer can contact 24/7 the technical help-desk of the company improving thus performances such as the availability of the machine and the recovery time since no time for waiting the technician is needed. Obviously, this could be an alternative option to the traditional service contract; then the decision will be up to the customer.

Chapter 5

The Augmented Reality Technology Acceptance Model

This chapter examines the perceptions of field technicians about the introduction of Mobile Collaborative Augmented Reality (MCAR) in field service networks. In the previous chapters, a first evaluation of users' perception towards MCAR, the steps of its introduction and how MCAR adoption can influence the delivery of industrial field services are pointed out. In addition, it emerges that the use of this technology would result in fewer misunderstandings and errors and, therefore, in better service delivery performance (e.g. more first-time fixes and quicker restoration) (Porcelli et al., 2013a). However, since the case studies described in Chapter 3 and Chapter 4 involved only few informants and especially for managerial considerations, a deeper assessment of the level of acceptance and the willingness to use this technology of a larger amount of technicians is requested. Therefore, the purpose of this study is twofold: i) to understand what factors effect field technicians' opinions about and intentions to use MCAR technology; and, ii) to evaluate the suitability of using this kind of system for field service tasks. With respect to the first objective, we follow the well-known

Technology Acceptance Model (TAM) (Davis et al., 1989) and the Unified Theory of Acceptance and Usage of Technology (UTAUT) (Venkatesh et al., 2003). For the latter, we refer to Task-Technology Fit theories (TTF) (Goodhue and Thompson, 1995). Based on these theoretical contributions, in this chapter we propose an original model named ARTAM, i.e. Augmented Reality Technology Acceptance Model, and show how ARTAM was validated against the surveys of three companies whose field force were selected as test benches.

The remainder of the chapter is organized as follows: Section 5.1 describes the theoretical background, highlights the underpinning theories and discusses the literature that argues against the development of technology acceptance models for AR. Section 5.2 shows how ARTAM was developed; then Section 5.3 presents the companies' profile of our sample and the research method. The results of the measurement model and structural model testing are presented in Section 5.4 as well as the technicians' evaluation of MCAR while in Section 5.5 the main conclusions are pointed out.

5.1 Review of Acceptance model

Scientific research studying the effects of technology on individual performance mostly pertains to the stream of utilization or behavioural-related models (Davis, 1989, Venkatesh et al., 2003) rather than to Task-Technology Fit theories (Goodhue and Thompson, 1995). Both of these streams are presented below.

5.1.1 *Utilization-related models*

Utilization-related models posit that the intention to use a technology is influenced by the user's beliefs about and affect towards it. In particular, the seminal Technology Acceptance Model (TAM) proposed by Davis et al. (1989) (see Figure 19), argues that two beliefs, respectively perceived usefulness (PU) and perceived ease of use (PEOU), affect the attitude (A) of individuals towards a technology, their intention to use it (BI) and, the resulting actual use. Perceived usefulness is defined as "the degree to which a person believes that using a specific system will enhance his/her job performance" within an organizational context, whereas perceived ease of use refers to "the degree to which the user expects the target system to be free of effort" (Davis (1989), p.320). In addition, TAM posits that perceived usefulness is influenced by perceived ease of use.

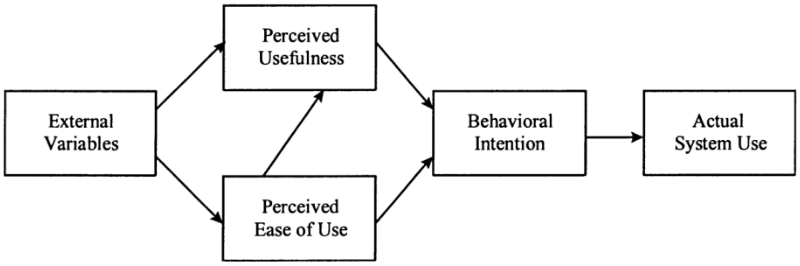

Figure 19 The conceptual model behind TAM (Davis et al., 1989)

In its original version, TAM has proven to explain about 40% of the utilization variance (Venkatesh and Davis, 2000). Therefore, in order to improve its predictive power, some authors considered the intention to use as directly influenced by PU and PEOU (Venkatesh and Davis, 1996, Szajna, 1996, Agarwal and Prasad, 1998, Gefen and Keil, 1998, Venkatesh and Morris, 2000, Wu et al., 2011), whereas some other researchers introduced new constructs and moderators, such as the perceived enjoyment (Davis et al., 1989), the subjective norms (Venkatesh and Davis, 2000), the perceived risk (Al-Gahtani, 2011) and other external variables (Burton-Jones and Hubona, 2006) to adjust the model. As already mentioned, in MIS literature, other utilization-related models exist, such as the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975), the motivational model (Davis et al., 1992), the theory of planned behaviour (TPB) (Ajzen, 1991), the innovation diffusion theory (IDT) (Rogers, 1995), the social cognitive theory (SCT) (Bandura, 1986) and, the integrated model of technology acceptance and planned behaviour (Taylor and Todd, 1995). To include most of the findings of the extant literature, Venkatesh et al. (2003) propose a Unified Theory of Acceptance and Usage of Technology (UTAUT) that integrates any aspects that should be taken into account to evaluate the acceptance of a given technology (see Figure 20).

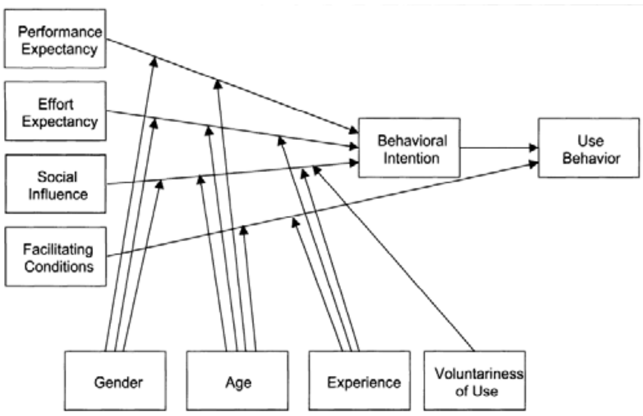

Figure 20 The conceptual model behind UTAUT (Venkatesh et al., 2003)

UTAUT posits that “use behaviour” is influenced by facilitating conditions (FC) and “behavioural intention.” This latter, in its turn, depends on three factors: performance expectancy (PEE), effort expectancy (EE) and, social influence (SI). “Performance expectancy” is the degree to which an individual believes that the usage of a technology can improve his/her job performance, and reflects the PU concept of TAM. “Effort expectancy” measures the effort expected, and so it is the mirror measure of PEOU. “Social influence” refers to the subjective norms such as those proposed by TRA. Therefore, this construct measures the degree to which an individual perceives that other “important” people believe he/she should use the new system. Lastly, “facilitating conditions” measures the degree to which an individual believes that an organizational and technical infrastructure exists to support the system use. In addition to these four constructs, four moderators are included in the model: gender, age, experience and voluntariness of use. These moderators affect the strength of the relationship between a specific factor and the intention to use the technology.

UTAUT has been recently used to explore the acceptance of consumer technologies, such as mobile phones (Carlsson et al., 2006, Park et al., 2007, Min et al., 2008). However, it does not consider any linkages between the technology features and the task characteristics that individuals have to perform in business contexts. These aspects, instead, are the core concern of Task-Technology Fit models (TTF), and they are presented in the next sub-section.

5.1.2 *Task-Technology Fit models*

TTF models (Goodhue and Thompson, 1995) posit that a technology positively affects the performance of individuals if it is well utilized, and that the adoption of a technology in a working environment depends in part on how well it fits the working tasks. These tasks are broadly defined as the actions carried out by individuals to turn inputs into outputs, while technologies are viewed as the tools used by people to carry out their tasks. Hence, TTF models are based on the following constructs (see Figure 21): “task characteristics” and “technology characteristics,” which jointly affect the TTF that, in its turn, influences the outcomes “performance impacts” and “utilization.”

As in the case of TAM, later studies have extended the original TTF model to improve its predictive power. For instance, Gebauer et al. (2004) added the construct “intention to use,” distinguishing it from the “real use.” Yan and Lihua (2008), instead, included “individual characteristics” as a determinant to the fit between task and technology. Lastly, some authors adapted the model to specific contexts (Gebauer and Ginsburg, 2006, Gebauer and Tang, 2007).

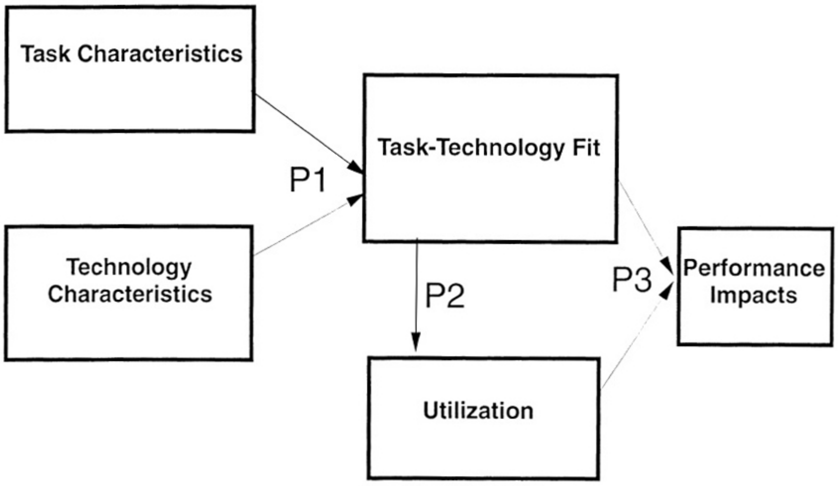

Figure 21 TTF Model (Goodhue and Thompson, 1995)

Since the TTF and TAM/UTAUT models by themselves have some limitations, an interesting avenue of research development concerns their integration. On one side, TTF follows a rational approach, assuming that, in a work environment, people intend to adopt a technology as far as the task they perform is supported by its functionalities. Following this line of reasoning, however, individual attitudes towards technology are not considered, even if it has been proven that they strongly favour technology adoption. On the other side, TAM and UTAUT are based on attitude/behavioural models, thus they ignore that, in some cases, the reasons behind the adoption of technologies are not dictated by positive attitudes, but by a willingness to improve work performance. A possible link between these models lies in the assumption that the fit between task and technology can influence the user's perception about the ease of use and the usefulness of technology (Dishaw and Strong, 1999). Based on this thinking, several authors have proposed specific applications of integrated models to evaluate the adoption of technologies in the fields of high speed data service (Pagani, 2006), mobile commerce (Yen et al., 2010), e-tourism (Usoro et al., 2010), PDA and wireless networks (Shih and Chen, 2013), online shopping (Klopping and McKinney, 2004) and, mobile banking (Zhou et al., 2010). However, to the authors' best knowledge, the aforementioned models have never been integrated and applied to study the adoption of AR systems. In the next sub-section, a brief review of studies related to the adoption of AR is reported.

5.1.3 *TAM applied to Augmented Reality*

The scholars' interest in the evaluation of user/social acceptance of AR systems is rather recent and there are paucity of studies that address the evaluation of end users' perceptions toward and intention to use AR systems (Azuma et al., 2001). Firstly, by searching the literature with keywords such as "acceptance model," "augmented reality" and similar, only few papers were retrieved from the most common scientific databases (e.g. EBSCO, Science Direct, Google Scholar). Despite the potential applications of AR covering almost all sectors of life, such as work and business, learning and education or, leisure and entertainment (Olsson and Salo, 2011), up to now its acceptance has been addressed mostly in the field of learning and entertainment applications. The reasons for this are twofold: i) handheld devices, such as smartphones and tablets, are now widespread, and these devices greatly favour the adoption of AR in consumer contexts—such as tourism and learning—for which users do not need hands-free; and, ii) at this stage, studying technology acceptance in the case of consumer applications is simpler, since researchers can easily select the sample to test the technology (e.g. interviewing people in the street (Haugstvedt and Krogstie, 2012) or university students (Balog and Pribeanu, 2010, Arvanitis et al., 2011)). Secondly, as these papers mostly focus on usability issues, they investigate qualitatively the point of view of potential users (Nilsson and Johansson, 2007, Rasimah et al., 2011). Thirdly, the few quantitative analyses made have been based on TAM, but no TTF, UTAUT nor integrated models have been used, since the applications are not for business contexts. Hence, the fit between task and technology turns out to be less relevant. Conversely, the construct "perceived enjoyment" is always included (Balog and Pribeanu, 2010, Rasimah et al., 2011, Pribeanu, 2011, Haugstvedt and Krogstie, 2012). Lastly, since most of the studies refer to pre-implementation stages, the end users studied are completely unfamiliar with AR. Usually, they are given the possibility to either test the technology through a prototype (Balog and Pribeanu, 2010, Arvanitis et al., 2011) or watch a video explaining its main features (Haugstvedt and Krogstie, 2012), prior their perceptions being surveyed. For this reason, the construct "actual use" is not included in the model, as the "intention to use" the technology is the only dependent variable.

In summation, from this brief review of the literature about acceptance models of AR, we can conclude that: i) the user acceptance of MCAR to support IFS interventions is a totally unexplored research area and, ii) up to now, constructs from UTAUT and TTF have not been combined for this purpose. This study aims to fill these gaps.

5.2 ARTAM and hypothesis development

The model proposed in this study is adapted from the model found in Zhou et al. (2010), that integrates TTF with UTAUT (see Figure 22). However, several changes have been made.

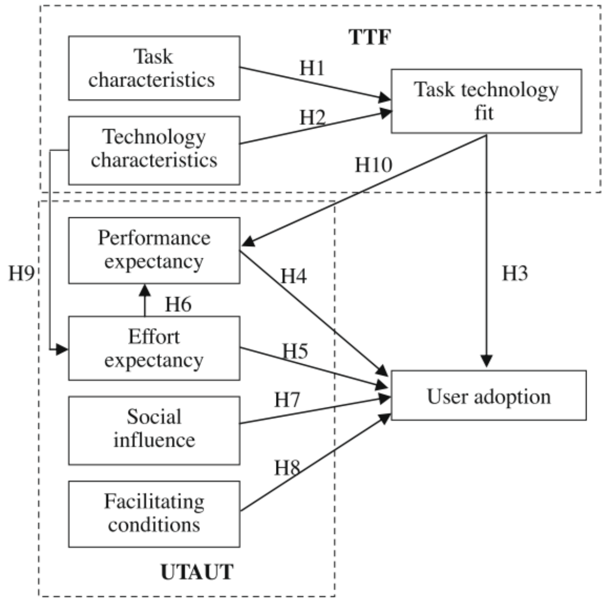

Figure 22 The model proposed by Zhou et al. (2010).

First, the final construct evaluated by Zhou et al. (2010) is "user adoption." Like the studies cited in sub-section 5.1.3, this paper relates to pre-implementation stages. In fact, the field technicians studied neither know nor use MCAR in their daily work. For this reason we prefer to focus on "behavioural intention"/"intention to use", rather than on "actual use". Second, according to Venkatesh et al. (2003), "effort expectancy" can be used to measure the TAM construct "perceived ease of use", as they are quite opposite. However, in order to formulate hypotheses with positive correlations only, we preferred the latter construct that is supposed to be correlated positively with the "intention to use". Third, Zhou et al. (2010) propose the following connections between constructs from TTF and UTAUT: i) "task-technology fit" with "user adoption"; ii) "task-technology fit" with "performance expectancy"; and iii) "technology characteristics" with "effort expectancy". The first linkage is not considered in ARTAM because user adoption is not taken into account. Moreover, in accordance with Dishaw and Strong (1999), we assume that "task-technology fit" influences "intention to use" through "performance expectancy" (i.e. "perceived usefulness"). ARTAM also includes second and third connections, and proposes a fourth one between "task-technology fit" and "effort expectancy" (i.e. "perceived ease of use"). In fact, if MCAR fits with the work task, users should believe that this technology is also easy to use (TTF→PEOU), therefore its adoption should lead to a higher performance (TTF→PEE). Fourth, the construct "social influence" is omitted since the user's opinion could not have been influenced by friends, relatives and, supervisors—they became aware of MCAR only a few minutes prior being asked to answer the survey. Finally, contrary to Zhou et al. (2010), we assume that "facilitating conditions", such as help-desk and user training, can directly influence "behavioural intention" rather than the "actual use", as this latter concept cannot be assessed since MCAR is still at a pioneering stage. Therefore, we assume that experiences related to how the companies had previously supported the introduction of new technologies, could affect the intention to use MCAR.

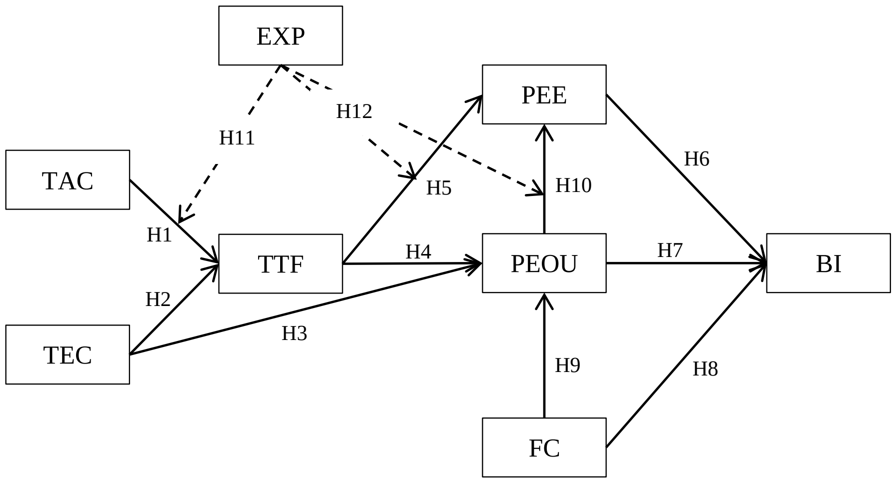

Figure 23 The ARTAM model.

As shown in Figure 23, ARTAM is based on eight constructs. The dependent variable "behavioural intention" (BI), as it measures the individual intention to use MCAR when available, is a proxy of technology acceptance. Moreover, "task characteristics" (TAC) reflects the contents and properties of field activities that could favour the use of MCAR. In more detail, ARTAM focuses firstly on complexity and the "non-routineness" of tasks, as suggested by the well-known work of Perrow (1967). Secondly, we consider context-specific issues, such as the need to receive remote support to either be faster or to make more timely decisions in case unexpected events may occur. These latter capabilities are proven to be crucial, especially in those contexts where customer support is given according to specific service level agreements (Grönroos, 2008, Schmenner, 2009). "Technology characteristics" (TEC), instead, takes into account the technical features of the proposed system and, in particular, the following functions: i) sending video images remotely to the expert; ii) receiving virtual images that can be superimposed on the real scene; and, iii) enabling effective and efficient communication and information exchange among product specialists and the field force. The construct "task-technology fit" is used to measure the fit between MCAR and the industrial field service tasks. According to Dishaw and Strong (1999), the task-technology fit can be evaluated through a mechanical approach, i.e. starting from the values of TAC and TEC, rather than using users' perceptions (Goodhue and Thompson, 1995). Since the latter is preferred in case of new technologies and prototypes (Gebauer et al., 2004), it was also followed in the present study. "Performance expectancy" (PEE) reflects the degree to which individuals believe that the use of MCAR would improve their performance on the job. "Perceived ease of use" (PEOU) is introduced to assess how much technicians expect that MCAR could be used without additional effort. "Facilitating conditions" (FC) reflects the individual beliefs that some kind of infrastructure (organizational and technical) will be provided by the company to support the early adoption and use of MCAR. Lastly, "workforce experience" (EXP) is considered a moderator in ARTAM, since experienced technicians could have different perceptions when compared with inexperienced ones. It is worth noticing that this construct differs from the construct "tool experience", considered by Dishaw and Strong (1999), that focuses on past events and interactions among users and technology. This latter factor, indeed, has been neglected since we are exploring contexts that are not currently using MCAR for field services.

With these considerations in mind, we can posit some hypotheses. The first argues that MCAR is a proper tool to help with the execution of complex activities (TAC), as it allows technicians to exchange images, symbols and data as well as to communicate quickly and easily with a remote product specialist. Thus:

H1: Field service characteristics significantly affect the task-technology fit (TAC → TTF)

H2: MCAR characteristics significantly affect the task-technology fit (TEC → TTF)

Then, as suggested by Dishaw and Strong (1999), MCAR functionalities (TEC) determine the perceived ease of use (PEOU) of the system. In addition, as mentioned before, a good fit between task and technology determines perception of ease of use (PEOU) and expectation of performance improvement (PEE). Thus:

H3: MCAR characteristics positively affect technicians' perceived ease of use (TEC→ PEOU)

H4: The fit between field service task and MCAR positively affects technicians' perceived ease of use (TTF→ PEOU)

H5: The fit between field service task and MCAR positively affects technicians' performance expectancy (TTF→ PEE)

According to the original UTAUT and to later studies (Carlsson et al., 2006, Park et al., 2007), the effects of performance expectancy (PEE) and of perceived ease of use (PEOU) on users' behavioural intention can be formulated as follows:

H6: Performance expectancy positively affects behavioural intention to use MCAR (PEE → BI)

H7: Perceived ease of use positively affects behavioural intention to use MCAR (PEOU → BI)

Lastly, facilitating conditions (FC) are assumed to directly influence the behavioural intention (BI) and, in addition, to favour the usage of MCAR since they also alter perception about technology friendliness (PEOU). Thus:

H8: Facilitating conditions positively affect behavioural intention to use MCAR (FC → BI)

H9: Facilitating conditions positively affect perceived ease of use of MCAR (FC → PEOU)

If MCAR is perceived as easy to use (PEOU), the performance expectancy (PEE) should be positively impacted too. In fact, as already validated in the seminal work of Davis et al. (1989), if a technology is actually easy to use, it will be exploited at its best and thus the overall performance of the task will substantially improve. Hence, we can posit:

H10: Perceived ease of use positively affects performance expectancy (PEOU → PEE)

Finally, workforce experience (EXP) in performing their job is assumed to be negatively correlated with the need to receive remote support from a product specialist as well as with performance expectancy. In fact, a more experienced technician will most likely perform his/her tasks without asking for help and in a more efficient and effective way, in comparison to a less experienced and skilled technician. Thus:

H11: A technician's experience in performing his/her tasks moderates the relationship between task characteristics and task-technology fit.

H12: A technician's experience in performing his/her tasks moderates both the relationship between perceived ease of use and performance expectancy and between task-technology fit and performance expectancy.

5.3 Research methodology

5.3.1 *Sample and MCAR selection*

In order to test ARTAM, we selected a sample of companies that provide industrial field services to the installed bases of their customers. The companies were chosen according to the following criteria: i) they were OEMs offering life-long customer support and contractual services such as routine maintenance, diagnostic checks, repairs and update/upgrade; ii) they were not rivals in the same industry or competing with similar products; and, iii) they contractually offered services in accordance to strict service level agreements; iv) their field force and service network were sufficiently large and globally scattered, at least at country level; v) their field force was remotely supported with specific tools and resources; and, vi) they allowed us to interview their field technicians and access their data and information, since they were interested in scouting AR technologies as a potential work tool for their service networks. Three companies that matched these criteria were chosen as the case studies. In particular, we included in our study Océ Italia - Canon Group, broadly presented in Chapter 3, IBM Italia and Tecnomatic, briefly described in the following sub-sections. With respect to the MCAR selection, this study focuses on the same MCAR system presented in Section 3.2.

5.3.1.1 IBM Italia

The history of IBM is quite long. It was born in 1911 as Computing- Tabulating-Recording (CTR), and since 1924, it was renamed as International Business Machines Corporation (IBM). Currently, IBM is an American multinational technology and consulting corporation, with headquarters in Armonk, New York, United States. IBM manufactures and sells computer hardware and software, and offers infrastructure, hosting and consulting services in areas ranging from mainframe computers to nanotechnology. IBM has a significant global presence, operating in over 170 countries and employing 435,000 people, with an increasingly broad-based geographic distribution of revenue. In 2012 IBM's total revenue and net profit were US$ 104.5 billion and US$ 17.6 billion respectively. IBM operates in Italy since 1927 and its headquarter is in Segrate (Milano). IBM Italia counts 14 subsidiaries spread along the national territory and around 15,000 employees. Its total revenue in 2011 was €3,595 million and the net profit €158 million.

IBM is organized in geographical areas (i.e. North America, Europe, Japan and Growth Markets) and in 4 business units:

- Sales & Distribution;
- Global Services that aims at helping companies managing their IT operations and resources. In particular it includes Global Technology Services (GTS) and Global Business Services (GBS). GTS offers infrastructure services such as outsourcing services, business continuity and resilience, integrated technology services, and maintenance. It accounts for around 40% of IBM's total revenue, the highest revenue among the segments of IBM. GBS, instead, provides professional services such as management consulting, system integration and application management services.
- Software Group is divided in middleware and solutions groups. The first one develops applications for text analytics, content management, lifecycle management, and system management whereas the second one for collaboration, business analytics and industry solutions.
- System & Technology Group is the "hardware" division of IBM and it is responsible for the manufacturing of each electronic device from consumer electronics to the fastest supercomputers. The main product families of IBM are mainframes and servers (i.e. System Z, System X, and Power System), Storage System (such as disk, tape, NAS and Flash storage products) and Networking solutions that include the set of switches and software necessary to connect server and storage.


Figure 24 IBM servers

The majority of IBM's revenue, excluding the company's OEM technology business, occurs in industries that are broadly grouped into six sectors:

- Financial services: banking, financial markets, insurance
- Public: education, government, healthcare, life sciences
- Industrial: aerospace/defence, automotive, chemical and petroleum, electronics
- Distribution: consumer products, retail, travel and transportation
- Communications: telecommunications, media and entertainment, energy/utilities
- Small and Medium Business: mainly companies with less than 1,000 employees

IBM is one of the best examples of servitized companies. It was born as a hardware manufacturer and now is a solution provider in the IT sector. Currently the IBM hardware is sold to the customer as a part of a solution that includes technical support services regulated by contracts. Therefore, for the aim of this study, how IBM technical support services (TSS) are designed and delivered is briefly described in the following.

"Help – when and where you need it" is the IBM slogan for TSS. IBM has a support presence in 209 countries/nations and a remote technical support as well as a local, on-site service infrastructure able to make sure to have what it is needed, when it is needed, for the fastest possible service - service ranges from qualified call backs within two hours to having a service representative on site with parts within three or four hours to the next business day. In particular, the worldwide network of remote technical support centres and technical experts is made up of three levels:

- Call entry and "Level 1" remote technical support centres with technical specialists who speak the local language;
- "Level 2" remote technical support centres with higher-level skills and deeper product knowledge. Product specialists of this level are part of the Virtual Front End team that groups the second level product specialists of all Europe;
- Third and last-level support centres, including global research laboratories and hardware and software development laboratories that help in solving even the most challenging problems and in answering tough questions.

In Italy the field network is made up of around 300 technicians on field, to support 53,000 customers and 500,000 machines. On average IBM Italia manages 3,000,000 calls per years (Service Desk included) and dispatches 350,000 tasks on field per year. The workflow of the delivery of technical support services is depicted in Figure 25.

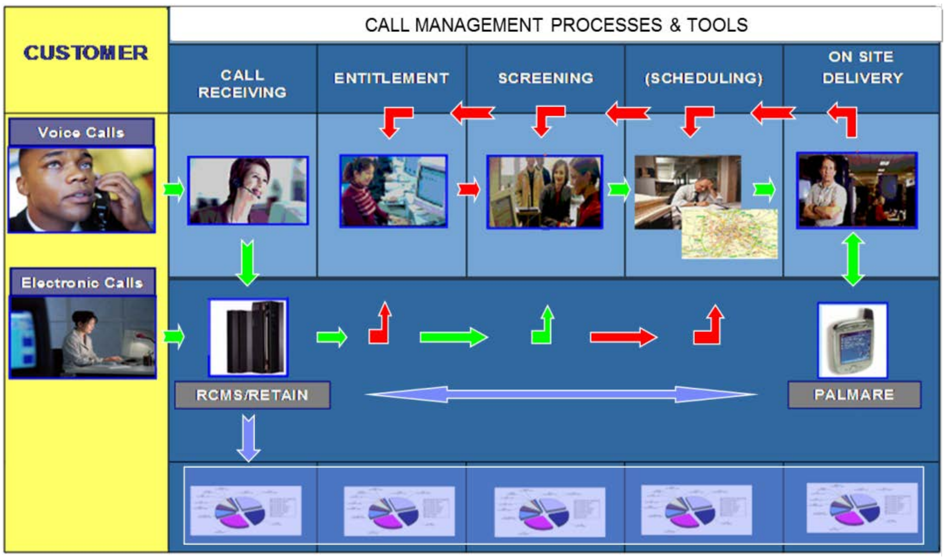

Figure 25 Workflow of TSS delivery

The service request can arrive through phone or via Web. The call is received by a Request Taker that gathers information from the customer about the kind of product that requires support and the problem noticed. This information is stored in IBM databases such as RCMS (i.e. Reliable and Consistent Message Streaming used for SW problems) and RETAIL (i.e. Remote Technical Assistance Information Networks, a database system, which provides service support to IBM field personnel and customers) and thus forwarded to the Front Office for the next task. The Front Office, in fact, verifies the entitlement and the status of the service contract. If some problems are identified, the Entitlement Exception Handler handles the situations according to urgency/severity of the problem. Then, the first level support determines the problem and defines the action plan that includes the sequence of tasks to be performed and the spare parts needed. If the problem can be solved remotely (e.g. for the most complex IBM products such as System Z and Power System servers, the remote control of the machine is included in the service contract so that IBM can access the machines without asking the customer permission in order to solve his problem as soon as possible), he solves the problem and then closes the service requests otherwise he sends the action plan to the Remote Management Call (RMC) centre. In Italy, the national territory is divided in three areas: northeast, northwest, centre south. Each area is coordinated by a RCM that is a resource scheduler since it verifies the resource and spares availability, it assigns RCMS resources according to the skills required, and it coordinates the action plan execution and handles possible exceptions. Finally, the action plan is performed by the field technician that can be supported by the product specialists if some unexpected problems occur.

Figure 26 Service provision on IBM products

The field technicians are deployed on the national territory according to the density of the business. For this reason, in regions where there are a lot of technicians, usually they are more specialized on a specific kind of product while in regions where only few technicians are deployed, usually they have to face a higher variability in the service demand and so multi-skilled technicians are required. Therefore, the adoption of MCAR technology is expected to be more effective in this latter situation.

5.3.1.2 Tecnomatic

Tecnomatic is an Italian small company (total revenue: €1.8 million, net profit: €13,105 and 42 employees in 2012) that is specialized in the installation, maintenance and repair of the machines produced and owned by DEDEM (total revenue: €33 million, net profit: €612,855 and 48 employees in 2012 - www.dedem.it). These machines can be grouped in three categories: ID and fun booths, Minilab and Kiddie Rides. The first ones are the more complex machines manufactured in terms of numbers of parts and kind of technology embedded. The second ones are printers sold to optical shops in order to print mosaics, calendars, postcards, ID photos, personalized print, etc. and represent only a minor part of the product served by Tecnomatic. The last ones, finally, are coin-operated amusement rides for small children usually placed in public building such as in amusement parks, arcades, malls, hotel game rooms and outside supermarkets and discount department stores. When activated by a coin, a kiddie ride entertains the rider with motions actuated by electromechanical and hydraulic mechanisms.

Figure 27 ID Booth.

DEDEM is the leading Italian company in the market of this kind of products and counts more than 5,000 machines spread along the national territory that are serviced by Tecnomatic. In general Tecnomatic business is focused mainly on ID booths since this category is the most numerous and more prone to failures as they are placed outdoors and thus more exposed to weather and vandalism. The field workforce of Tecnomatic is made up of 72 multi-skilled technicians assigned to a specific area whose extension depends on the number of machines installed. Technicians are asked to perform some tasks on each machine periodically such as withdrawing the money gained, replacing consumables, updating advertisement, updating the software and repairing the machine if necessary. In addition the technician has to count the money and deposit it in a bank.


Figure 28 Kiddie Ride.

The customers of DEDEM and Tecnomatic are the final users of their products. With respect to ID Booths and Kiddie Rides, in fact, these are owned by DEDEM and located on the public land thanks to the permission of the municipality or in a building such as a mall after the payment of a monthly fee to the owner. Since the machines are owned by DEDEM, service level agreements are not specified with the final customer but it is in the interest of the company to guarantee the maximum availability of the machines in order to improve their profits. For this reason, in fact, Tecnomatic field network allows 24/7 service provision with the shortest time to repair thanks to an efficient resource management directed towards the saturation of a technician in terms of numbers of machines serviced and incentive polices such as production bonuses linked to the revenues of the machines under his responsibility.

Usually in case of a fault, the customer calls the call centre that collects the information related to the customer (in order to pay back the customer for the lost coin) the location of the machine and the problem noticed. The service request is then forwarded to the field technician responsible for the area where the machine is located. During the intervention the technician is equipped with a PDA through which he enters the information about the intervention. If he needs help in solving the problem, he can ask his supervisor via phone. Tecnomatic has 12 supervisors that are responsible for the work of technicians and in addition to supporting him during the field intervention, have to check the quality of the work, substitute the technician on vacation and help him during installation of machines. Supervisors, thus, represent the linkage between the field force and the company.

Finally the overall complexity of the machines serviced by Tecnomatic is low, since components are not many and usually standardized, the span of complexity of the intervention is quite low and the main source of variability is the vandalism damage. Conversely to the case of Océ Italia – Canon Group and IBM Italia, this case has been selected in order to evaluate if some differences emerge depending on the level of complexity of the product served.

Summing up, the main figures of each case study are shown in Table 10.

Table 10 Companies' characteristics.

Company	Océ Italia – Canon Group	IBM Italia	Tecnomatic
Company type	Italian subsidiary of a multinational company	Italian subsidiary of a multinational company	Small-sized local company
Industry/Products	Printing/production printers, office printers	IT/IT systems (e.g., NAS, servers, mainframes)	Printing/booths for ID photos and for printing from digital files, photo kiddie rides, minilab
Served territory	Nation-wide	Nation-wide	Nation-wide
Size of IB [equipment nr.]	100,000	500,000	5000 ÷ 6000
Number of technicians	90	235	70
Span of products	Medium	High	Very Low
Remote support	Field technicians resort to communication via mobile phones to contact product specialists and get remote support. In addition, product specialists have direct access to the equipment from remote centres, in order to check their operating status and run diagnostic tests.		Field technicians get remote support from product specialists only through mobile phone communication.

5.3.2 *Questionnaire design*

With direction from the vast literature on this subject, a 23-item questionnaire was developed to test ARTAM within the selected sample. Table 11 shows the items that the literature commonly uses to investigate the constructs (i.e. PEE, PEOU, FC, TTF and BI) of acceptance models, whereas Table 12 reports the ones selected for this study. Each item was measured with a five-point Likert scale (i.e. 1-strongly disagree; 2-moderately disagree; 3-agree; 4-moderately agree; 5-strongly agree). The questionnaire was originally developed in English and then translated into Italian by an Italian-English translator. Following this, another translator performed a back-translation to ensure that the original one was accurate. After the draft had been designed, a pre-test was carried out. To this purpose, we submitted and then discussed the questionnaire vis-à-vis with the people of Océ Italia – Canon Group involved in the usage demonstration (i.e. two technicians, a product specialist and the service director presented in Chapter 3). Based on the respondents' feedback, the questionnaire was adjusted to remove any ambiguous expressions, improve readability and ensure accuracy and appropriateness. The final version was checked again by both researchers and the service directors of the selected companies, who then granted their permission to submit the questionnaire to their field forces.

Table 11 Question items found in literature.

Construct	Items	Reference
PEE	1. I feel mobile banking is useful 2. Using the system in my job would enable me to accomplish tasks more quickly 3. Using the system improves my performance in my job 4. Using the system in my job increases my productivity 5. Using the system enhances my effectiveness in my job 6. Using the system would make it easier to do my job 7. I would find the system useful in my job	(Davis et al., 1989) (Davis, 1989) (Dishaw and Strong, 1999) (Venkatesh and Davis, 2000) (Venkatesh and Bala, 2008) (Li et al., 2008) (Fang et al., 2008) (Kuo and Yen, 2009) (Zhou et al., 2010) (Wu et al., 2011) (Al-Gahtani, 2011)
PEOU	1. My interaction with the system is clear and understandable 2. Interacting with the system does not require a lot of my mental effort 3. I find it easy to get the system to do what I want it to do 4. Learning to operate the system would be easy for me 5. I would find the system flexible to interact with 6. It would be easy for me to become skilful at using the system 7. I would find the system easy to use	(Davis et al., 1989) (Davis, 1989) (Dishaw and Strong, 1999) (Venkatesh and Davis, 2000) (Venkatesh and Bala, 2008) (Li et al., 2008) (Fang et al., 2008) (Kuo and Yen, 2009) (Zhou et al., 2010) (Wu et al., 2011) (Al-Gahtani,

		2011)
TTF	1. The data that I use or would like to use is accurate enough for my purpose 2. The computer systems that give me access to the data are convenient and easy to use 3. The functionalities of the system were very adequate 4. The functionalities of the system were very appropriate 5. The functionalities of the system were very useful 6. The functionalities of the system were very compatible with the task 7. The functionalities of the system were very helpful 8. The functionalities of the system were very sufficient 9. In general, the functionalities of the system fit the task well	(Lin and Huang, 2008) (Yen et al., 2010)
FC	1. I have control over using the system 2. I have the resources necessary to use the system 3. I have the knowledge necessary to use the system 4. When I need help to learn to use the system, the system's help support is there to teach me 5. Specialized instructions concerning the system are available to me 6. A specific person (or group) is available for assistance with system difficulties 7. I think that using the system fits well with the way I like to work	(Venkatesh et al., 2003) (Venkatesh and Bala, 2008) (Zhou et al., 2010) (Terzis and Economides, 2011)
BI	1. I intend to use the system in the next n months 2. I predict I would use the system in the next n months 3. I plan to use the system in the next n months 4. Assuming that I had access to the system, I predict that I intend to use it 5. Given that I had access to the system, I predict that I would use it 6. Assuming the technology would be available on my job, I predict that I will use it on a regular basis in the future 7. I intend to use the system if I have problems 8. I would use and recommend the system to my colleagues 9. If possible, I will try to use the system 10. I will try to use the services if necessary in life or work 11. Given the chance, I intend to use the system 12. It is likely that I will use the system in the near future	(Dishaw and Strong, 1999) (Venkatesh et al., 2003) (Venkatesh and Bala, 2008) (Kuo and Yen, 2009) (Tjahjono, 2009) (Yen et al., 2010) (Wu et al., 2011) (Al-Gahtani, 2011) (Terzis and Economides, 2011)

When comparing Table 12 to Table 11, some differences arise. For instance, the constructs TEC and TAC are measured according to items that were added on purpose, to consider specifically the context of this study (i.e. industrial field services, MCAR). In particular, we decided to investigate the characteristics of the technology by means of three items that address: i) the relevance of sharing real-time information; ii) the extent to which product specialists can directly troubleshoot, from a remote location, any sort of issues coming from the field; and, iii) the effectiveness of the information sent by the product specialist to the field technicians, in providing them remote support. Instead, to measure the task characteristics with respect to their different dimensions (e.g. task complexity, task variance, etc.), we resorted to several questions. In detail, technicians were asked to declare the occurrences, during their daily job, of these events: i) following well-defined procedures; ii) unexpected situations that require handling; iii) the checking of user manuals and work documents; iv) asking for external support; and, v) making immediate decisions in the field as a consequence of particular emergencies. To keep the questionnaire reasonably short, we decided to use only one item per each of the abovementioned aspects, since they all appeared to be pertinent during pretesting (see Table 12). It is worth noticing that the items related to the construct TEC follow the same 5-point Likert scale as above, whereas the ones related to TAC are measured with a different scale that ranges from 1 (Never) to 5 (Always).

Table 12 Question items used in questionnaire.

Construct	Item code	Question
PEE	PEE_1	I think that the usage of the MCAR system would improve my job performance, enabling better communication with the product specialist in order to analyse and solve the problem
	PEE_2	Using the MCAR system would enable me to accomplish tasks more quickly
	PEE_3	Using the MCAR system would enhance my effectiveness in my field service tasks
	PEE_4	I think that the MCAR system would simplify my job
	PEE_5	Overall, I think that the MCAR system would be useful in my job
PEOU	PEOU_1	Learning how to use the MCAR system would be easy and fast for me
	PEOU_2	I think that using the MCAR system in real settings would be easy for me
	PEOU_3	I think that using the MCAR system in my job would require a lot of mental effort
TTF	TTF_1	To support my field service tasks, the functions of the MCAR system are enough
	TTF_2	In general, the functions of the MCAR system fully meet my support needs
FC	FC_1	In the past, when new technologies were introduced to support my job, my organization provided all the necessary resources and knowledge to use them at their best
	FC_2	The MCAR system is not compatible with other systems needed to perform my activities
	FC_3	If I needed help with using the MCAR system, I am confident that my organization would arrange the resources (people and systems) to help me
BI	BI_1	Assuming that the MCAR system would be available in my job, I predict that I would use it every time I needed to ask for support
	BI_2	I would like the MCAR system would be available in my job
TAC	TAC_1	My job requires precise procedures to be followed
	TAC_2	In my job I need to handle unexpected events
	TAC_3	In order to complete my activities, I need to check manuals and procedures
	TAC_4	In order to complete my activities, I need technical support from a colleague or a

		product specialist
	TAC_5	My job requires me to make quick decisions and work promptly
TEC	TEC_1	The MCAR system allows information exchange in real-time
	TEC_2	Exchanging images in real-time, to help the product specialist understand the problem, will solve issues easily and quickly
	TEC_3	Thanks to the ability to see my instructions superimposed onto the real scene, it is easy to understand the advice of the product specialist

In conclusion, the questionnaire that was used for surveying the field service networks in the selected cases was structured into three sections. The first captured the general information about the respondent, such as age, gender, years of work experience, etc. The second focused on investigating the characteristics of the different field service tasks. As most of the technicians were unaware of MCAR technology, they were asked to read a brief written presentation and to watch the video recorded during the usage demonstration presented in the previous chapter, prior to answering the questionnaire (the questionnaire and the presentation of MCAR features are showed in Appendix A). Therefore, this section was also intended to verify whether the respondent had fully understood the features of MCAR technology prior to providing the requested answers. Finally, the third section evaluated the respondent's perception about the technology. The survey was administered via e-mail, and data were collected through a public web service (Google Drive). We prepared a cover letter and an e-mail containing the link to access the web service. Then, to achieve higher response rate, we asked each of the service directors to forward our message to their field technicians, requesting them to fill in the survey. In the following section, we present and discuss the most relevant findings that came out from data analysis.

5.4 Data analysis, results and discussion

5.4.1 *Sample characteristics*

In total, 396 questionnaires were distributed, and 352 were collected from respondents. The exclusion of the questionnaires with missing, invalid or blank answers left a total of 312 valid records, leading to a final response rate of 78.8%. The general profiles of the respondents are shown in Table 13. It is worth noticing that very few females were included in our sample, as the field service networks were mostly made up of men. In addition, 99% and 96% of the technicians that work in, respectively, Océ Italia – Canon Group and IBM Italia, are more than 35 years old, whereas, on average, the personnel from Tecnomatic is younger (76% less than 45 years old). It follows that, on average, the experience of the workers will differ too. Océ Italia – Canon Group and IBM Italia employ, generally, more experienced technicians (47% and 51%, respectively, have more than 25 years of experience) than Tecnomatic (only 8% have more than 25 years of experience). Finally, none of the technicians were actually familiar with MCAR or AR technologies, either in their personal lives or in a business context.

Table 13 General profiles of respondents.

	Options	Océ Italia – Canon Group	IBM Italia	Tecnomatic
		Nr. (%)		
Questionnaires	Sent Valid Response rate	90 80 88.9%	235 172 73.2%	71 60 84.5%
Gender	Male Female	80 (100%) -	170 (98.3%) 2 (1.7%)	59 (98.3%) 1 (1.7%)
Age (years old)	< 25 25-34 35-44 45-54 ≥ 55	- 1 (1%) 27 (34%) 48 (60%) 4 (5%)	- 7 (4%) 39 (23%) 64(37%) 62 (36%)	2 (3%) 12 (20%) 32 (53%) 14 (23%) -
Experience in field services (years spent doing this or similar work)	< 10 10-19 20-24 25-29 ≥ 30	8 (10%) 13 (16%) 22 (28%) 26 (33%) 11 (14%)	7 (4%) 44 (26%) 33 (19%) 21 (12%) 67 (39%)	24 (40%) 19 (32%) 12 (20%) 5 (8%) -

5.4.2 *Results and discussion*

The questionnaires were analysed in several ways. Firstly the descriptive statistics of the items are measured in order to assess the perception of users towards MCAR (see sub-section 5.4.2.1). Secondly, the results of reliability and validity testing of the measurement model are presented (sub-section 5.4.2.2). Thirdly, multi-group analysis was performed using AMOS 20 (Arbuckle, 2011) and SPSS 19 for Windows as the analysis tools in order to understand if the results of each company significantly differ with respect to the confirmation of the relationships among constructs hypothesized in Section 5.2. Finally, since non-invariance of the constructs among the three groups (i.e. the companies) was achieved, all the data were grouped together and the statistical significance of the hypotheses (the validation of the structural model) was evaluated through a structural equation model (SEM) using maximum likelihood method for parameters estimation (a brief introduction on SEM is given in Appendix B).

5.4.2.1 Evaluation of MCAR technology

In order to assess the perception of end users towards MCAR and to understand if those perceptions differ depending on the specific context of the companies interviewed, we evaluated the descriptive statistics of each item (see Table 14) and tested if a statistically significant difference existed between the answers of each item of the questionnaire depending on the company. In particular we performed a non-parametric test (we could not assume that the data were normally distributed) which null hypothesis states that the groups have the same median (i.e. the Kruskal-Wallis test). The results of the test (i.e. *p-value*) are showed in Table 14 (significant differences are in bold): since the null hypothesis states the invariance of the median among the groups, if *p-value*<0.05*,* a significant difference exists; otherwise, if *p-value*>0.05, the company does not have influence on the answers.

Table 14 Descriptive statistics of the questionnaire items for each company and p-value of Kruskal-Wallis test.

	Océ Italia – Canon Group		IBM Italia		Tecnomatic		Kruskal-Wallis Test
	Average	St.dev.	Average	St.dev.	Average	St.dev.	p-value
TAC_1	4,35	0,68	4,37	0,65	4,17	0,87	0.395
TAC_2	3,43	0,67	**2,60**	0,63	3,42	0,81	**0.000**
TAC_3	4,08	0,61	3,70	0,79	**2,48**	0,70	**0.000**
TAC_4	**2,60**	0,56	2,88	0,58	2,87	0,60	**0.001**
TAC_5	3,85	0,73	3,56	0,91	**3,07**	0,94	**0.000**
TEC_1	3,31	0,84	4,34	0,78	4,13	0,87	**0.013**
TEC_2	3,15	1,02	3,99	0,98	3,97	0,82	0.574
TEC_3	3,26	0,98	4,09	0,88	3,87	0,81	**0.043**
TTF_1	3,15	0,99	3,30	1,12	3,15	0,92	0.366
TTF_2	3,46	1,01	3,26	1,15	2,98	0,91	0.175
PEE_1	4,03	1,06	3,41	1,08	3,15	1,04	0.303
PEE_2	3,85	1,08	3,14	1,20	2,9	1,07	0.405
PEE_3	3,83	0,92	3,34	1,20	3,02	1,03	0.116
PEE_4	3,14	1,04	3,27	1,18	2,88	1,15	0.099
PEE_5	3,15	0,98	3,44	1,14	3,15	1,12	0.153
PEOU_1	3,61	0,97	3,81	0,94	**3,33**	0,82	**0.004**
PEOU_2	**3,26**	1,00	3,71	1,03	**3,22**	0,87	**0.001**
PEOU_3 (reverse scale)	2,13	0,85	2,14	0,87	1,93	0,74	0.820
FC_1	3,49	0,84	3,69	0,87	**3,23**	1,08	**0.005**
FC_2 (reverse scale)	2,13	0,88	2,15	0,90	2,22	1,01	0.883
FC_3	**3,24**	0,85	3,87	0,99	**3,42**	0,91	**0.000**
BI_1	3,50	1,03	3,30	1,23	3,23	1,16	0.341
BI_2	3,51	1,09	3,37	1,21	3,35	1,10	0.660

Analysing the descriptive statistics several consideration can be highlighted. With respect to task characteristics (i.e. items from TAC_1 to TAC_5) significant differences among companies resulted for all the items except for TAC_1. The need to follow specific procedure, in fact, is often/always perceived by technicians as part of their job (TAC_1 > 4) in each case study. Conversely, the need to handle unexpected event is less frequent than TAC_1, and Océ Italia – Canon Group and Tecnomatic (TAC_2 ≈ 3.4) significantly differ from IBM Italia (TAC_2 ≈ 2.6). This result was expected since IBM Italia is the case study in which the activities performed to define the action plan are more structured so that the occurrence of situations that differ from the action plan identified by the first level of support is rare. With respect to the need to consult user manuals, instead, a significant difference resulted among all the companies: technicians of Océ Italia – Canon Group state to consult manual often (i.e. TAC_4 > 4), technicians of IBM Italia sometimes and the ones of Tecnomatic only rarely. Finally, all the respondents state that on average the need to be supported by a product specialist is rare and the need to make quick decisions and work promptly is less frequent in Tecnomatic than in the other two case studies. Probably this result is related to the absence of a service contract in Tecnomatic if compared Océ Italia – Canon group and IBM Italia that, instead have to be compliant with strict service level agreements.

With respect to the items that measure the Task-Technology Fit and Performance Expectancy, on average all the respondents agree that there is a fit between the characteristics of the MCAR system and the feature of their service task (TTF_1 and TTF_2 > 3) and, thus that MCAR system could be useful for their activities. In particular the usefulness is recognized especially in terms of performance improvements, speed and effectiveness of the intervention. The Kruskal-Wallis tests for these items resulted in not-rejection of the null hypothesis and so any statistical difference was not noticed among the companies. However, looking at the average scores for TTF and PEE, lower scores resulted for Tecnomatic but these differences are not significant due to the high standard deviations. This finding suggests that maybe MCAR is more suitable in contexts characterized by a high level of product complexity and uncertainty in the kind of field intervention but further analyses are needed prior to confirming this hint.

MCAR is perceived to be easy to learn and to use (PEOU_1 and PEOU_2 > 3, PEOU_3 ≈ 2 with a reverse scale) and respondents from all the companies on average agree that their organization will provide the resources and infrastructures to support them in using MCAR (FC_1 and FC_3 > 3, FC_2 ≈ 2 with a reverse scale). Even in this case from the Kruskal-Wallis test results a significant difference was noticed for Tecnomatic with respect to the other companies and in particular lower scores were achieved in terms of both easiness to learn and use and facilitating conditions.

Finally all the respondents on average are willing to use MCAR when needed (BI_1 and BI_2 > 3). Even in this case there is a slightly difference in score depending on the company not confirmed by the Kruskal-Wallis test. Océ Italia – Canon Group seems to be the most prone to use MCAR (BI_1=3.5) whereas Tecnomatic got the lowest score (BI_1=3.23) but due to the high standard deviation further analyses are needed to confirm this hint.

From this analysis seems that the span of products and their complexity in terms of how often the technician has to face unknown situations could impact MCAR evaluation. Tecnomatic, in fact, has simpler products than IBM Italia and Océ Italia – Canon Group. In addition, Océ's printers have more mechanical parts than IBM Italia's products so, while IBM Italia often can solve problems through a remote connection to the machine, Océ Italia – Canon Group needs to perform physical intervention and it is more likely that a technician needs external support. Concluding, MCAR system seems to be particularly suitable to support industrial field services on products characterized by several mechanical and electrical components and whenever the disassembling of the product and substitution of parts can be critical.

5.4.2.2 Assessment of the measurement model

The measurement model (i.e. the questionnaire) was assessed with respect to each single construct, except for the items pertaining to the task characteristics. As already mentioned, since they measure different aspects of the work content, we did not merge them into a single construct but considered each of them as directly influencing the TTF. Then, with regard to the other constructs (i.e. PEE, PEOU, TEC, TTF, FC and BI), we examined the internal consistency (i.e. if the items that propose to measure the same general construct produce similar scores) of each individual scale by subjecting it to Cronbach's alpha test. As shown in Table 15, Cronbach's alpha values greater than the standard threshold value of 0.70 (Nunnally, 1978) were obtained except for PEOU and FC. These latter cases, in fact, were affected by PEOU_3 and FC_2 respectively. These items were both measured according to a scale that is reverse, in comparison to the one used for other items of the same constructs. It is probable that the questionnaire was not clear enough when specifying that the respondent had to follow a reverse scale to answer those specific questions. In fact, if these items are removed, the values of Cronbach's alpha raise up to 0.871 (PEOU) and 0.671 (FC). Despite these latter values do not match the Nunnally's criterion (Nunnally, 1978), we accepted the consistency of the measurement tool, since even lower values have been regarded as satisfactory in previous research (McKinley et al., 1997, Bosma et al., 1997). After making the suggested changes, we obtained a final 21-item questionnaire that was tested as reliable.

Table 15 Reliability, correlations, convergent validity and discriminant validity.

	Cronbach's Alpha	CR	AVE	PEE	TTF	BI	TEC	FC	PEOU
PEE	0.944	0.947	0.782	**0.894**					
TTF	0.911	0.911	0.836	0.884	**0.915**				
BI	0.957	0.957	0.918	0.636	0.617	**0.958**			
TEC	0.886	0.889	0.728	0.706	0.736	0.505	**0.853**		
FC	0.671	0.756	0.631	0.349	0.362	0.360	0.413	**0.794**	
PEOU	0.871	0.876	0.780	0.572	0.529	0.477	0.656	0.502	**0.883**

Next, we carried out a confirmatory factor analysis (CFA) to test the overall fit of the model as well as its convergent validity (i.e. if two measures of items that are supposed to be related, are in fact related) and discriminant validity (i.e. if two measures of items that are supposed to be unrelated, are in fact unrelated). Four common measures were used for model fitting, namely chi-square/degree of freedom (χ^2/dof), the goodness-of-fit index (GFI), root mean square error of approximation (RMSEA) and, the comparative fit index (CFI). As shown in Table 16, in all cases, the model-fit indices exceeded the respective levels of acceptance, as suggested in prior literature (Hair et al., 1998, Byrne, 2009). Therefore, we concluded that the measurement model was a good fit with the data collected.

Table 16 Fit indices for measurement model.

Fit Indices	Recommended Value	Result
χ^2/dof	< 2	1.761
GFI	> 0.9	0.943
RMSEA	< 0.08	0.050
CFI	> 0.95	0.984

Convergent validity was assessed by examining the item reliability, the loadings and their statistical significance through composite reliability and average variance extracted (AVE) (see Table 15). The composite reliability (CR) of each construct is above the minimum recommended level of 0.60, as it ranges from 0.756 to 0.957. Hence, all measures reveal a good reliability (Bagozzi and Yi, 1988, Hair et al., 1998). Finally, the completely standardized factor loadings reached values higher than 0.7 for their corresponding construct (see Table 17), and all the constructs had a CR above 0.6. In Table 15, off-diagonal values are pairwise squared correlations between couples of constructs, whereas the diagonal bold values represent the AVE measures of each construct. The first were found to be smaller than the average variance extracted measures of the related constructs, so each construct appeared to be more closely related to its own measures than to those of other constructs. As a result, discriminant validity was also supported. In addition, the AVE measures always exceeded 0.50, as recommended by Fornell and Larcker (1981). Therefore, as good model fit, reliability, convergent validity and discriminant validity were achieved, we assumed that the measurement model was appropriate for testing the structural model at subsequent stages.

Table 17 Descriptive statistics and factor analysis for the measurement model.

	Average	Std.dev.	PEE	TEC	BI	PEOU	TTF	FC
PEE_1	3.34	1.060	0.895					
PEE_2	3.09	1.144	0.881					
PEE_3	3.25	1.106	0.899					
PEE_4	3.17	1.142	0.904					
PEE_5	3.40	1.093	0.897					
TEC_1	4.22	0.821		0.870				
TEC_2	3.95	0.961		0.916				
TEC_3	3.97	0.898		0.907				
TTF_1	3.23	1.044					0.826	
TTF_2	3.19	1.067					0.894	
PEOU_1	3.68	0.929				0.953		
PEOU_2	3.52	1.006				0.922		
FC_1	3.55	0.917						0.971
FC_3	3.62	0.979						0.947
BI_1	3.33	1.166			0.976			
BI_2	3.40	1.157			0.976			

$p<0.01$

5.4.2.3 Multi-group analysis

Even if some differences in the descriptive statistics emerged among the companies that form our sample, in order to verify if a significant difference exists in the hypothesized relationships among constructs in the structural model depending on the company selected, a multi-group analysis was performed. The dataset corresponding to the answers collected from each company forms a group and the purpose of the multi-group analysis is to assess the replicability of the structural model across groups. This analysis was performed using AMOS 20. Firstly, a baseline model (named configural model) that fits with the datasets of all the three companies was defined. In particular, the configural model is depicted in Figure 29 and the parameters are estimated for all the groups simultaneously. The set of indices used to evaluate the fitting were χ^2/dof, GFI, RMSEA and, CFI. As we can see from Table 18, even if only χ^2/dof and RMSEA values respect the corresponding threshold, according to Byrne (2009) it is possible to conclude that a satisfying fit exists between the proposed model and the three datasets tested and so it can be used as a baseline for the multi-group analysis.

Table 18 Fit indices for structural model for each company.

Fit Indices	Recommended Value	Result
χ^2/dof	< 2	1.603
GFI	> 0.9	0.815
RMSEA	< 0.08	0.044
CFI	> 0.95	0.927

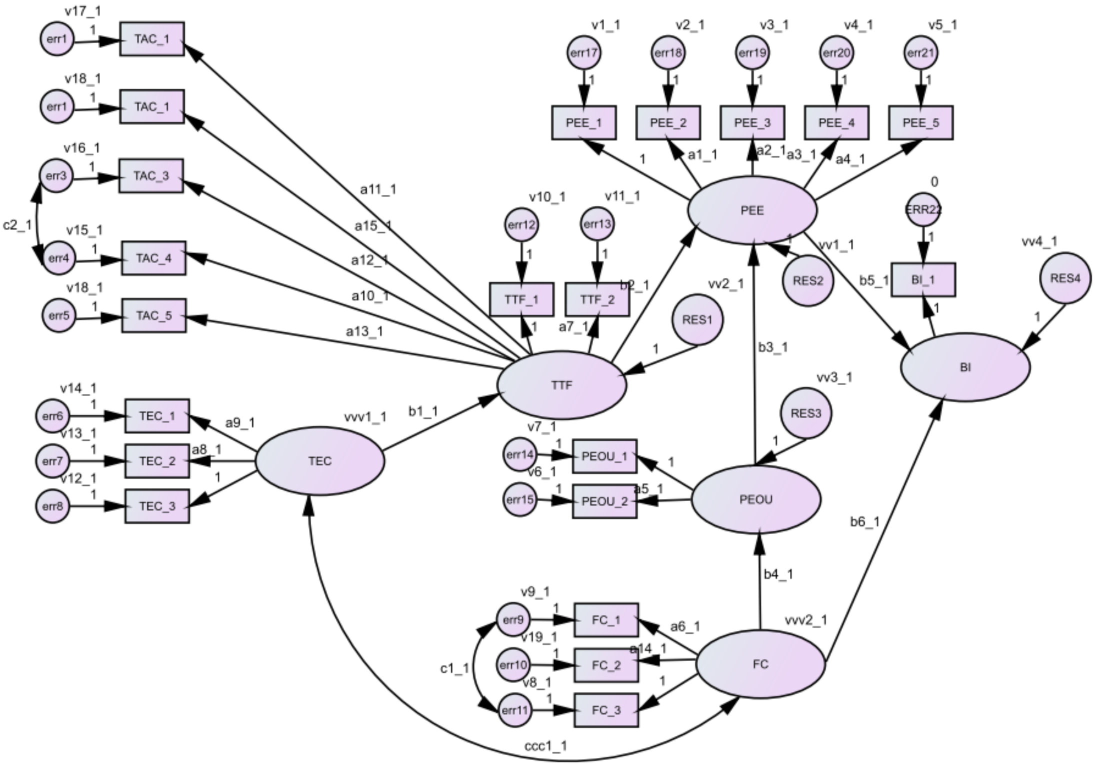

Figure 29 Baseline model for multi-group analysis.

According to Arbuckle (2011), multi group analysis compares a model with equality constraints to a model that allows parameters to vary (e.g. the baseline model defined above). As suggested by Byrne (2009) and Jöreskog (1971), testing equivalence requires executing a global test of the equality of covariance structures across the groups of interest. Hence, the null hypothesis tests the equivalence of the population variance-covariance matrix. In case this is rejected—the groups are supposed to be non-equivalent—so further investigations are necessary to identify the sources of heterogeneity. Conversely, if the null hypothesis cannot be rejected, the groups have equivalent covariance structures. Therefore, in this latter case, the difference among the companies turns out to be not significant. In our study, two methods were applied to verify the effects of the application context on MCAR evaluation: a traditional approach based on assessing the χ^2 difference ($\Delta\chi^2$) and an approach that focuses on CFI differences (ΔCFI). Firstly, the non-invariance of the measurement weights was assessed comparing the configural model with Model 1, i.e. a model where all the parameters (named "a" in Figure 29) that weight the relation between a construct and an observed variable (a questionnaire item) are constrained equal across groups. Table 19 reports the χ^2 and CFI values for the configural model and Model 1, as well as their differences (i.e $\Delta\chi^2$ and ΔCFI). $\Delta\chi^2$, that is distributed as a χ^2 with degrees of freedom equal to the difference of the degrees of freedom of the compared models (i.e. dof=28), turned out to be not significant. In addition, since the value of ΔCFI was lower than 0.01 (Cheong and Rensvold, 2002) the presence of invariance in the measurement weights was confirmed.

Table 19 Results of multi group analysis: fit indices of configural model, comparison models, and differences with configural model.

	Fit Indices					
	χ^2	CFI	$\Delta\chi^2$	Significant? (α=0.05)	ΔCFI	Significant? (ΔCFI>0.01)
Configural model	779.074	0.927	-	-	-	-
Model 1	815.155	0.925	36.081	No	0.002	No
Model 2	840.761	0.922	61.687	Yes	0.005	No
M2 – TEC→TTF	823.974	0.923	44.9	No	0.002	No
M2 – TTF→PEE	817.205	0.927	38.131	No	0.002	No
M2 – PEOU→PEE	815.288	0.926	36.214	No	0.001	No
M2 – FC→PEOU	817.417	0.925	38.343	No	0.002	No
M2– PEE→BI	824.314	0.923	45.24	Yes	0.004	No
M2– FC→BI	820.800	0.924	41.726	No	0.003	No

Secondly, the non-invariance of the structural weights was assessed comparing the configural model with Model 2, i.e. a model where in addition to the parameters constrained in Model 1, all the parameters (named "b" in Figure 29) that weight the relation between two constructs are constrained equal across group. In Table 19 the χ^2 and CFI values for Model 2 as well as their differences, are reported too. In this case, $\Delta\chi^2$ with dof=40 turned out to be significant at α=0.025 while ΔCFI was lower than 0.01. Based on the results of $\Delta\chi^2$ we conclude that one or more of the structural weights are not operating equivalently across groups. Therefore, the next step is to determine which structural weight is contributing to these non-invariant findings constraining one structural weight at a time to be equal across groups. The results of this step are presented in Table 19; the name of the model includes the path constrained equal across groups. The path responsible for the non-invariance of the structural weights across groups is the one that links Performance Expectancy and Behavioural Intention (i.e. M2– PEE→BI). However, analysing this result it is possible to observe that $\Delta\chi^2$ value is significant with α=0.05 but became not significant if α=0.025. Therefore, from the multi-group analysis we can state that the structural equation model is invariant with respect to the three datasets collected from the case studies. For this reason, in the following section, the hypothesis testing to assess the structural model is performed against a unique dataset that gathers the answers from the three companies.

5.4.2.4 Assessment of the structural model and discussion

As shown in Table 20, the fitness of the structural model was tested with respect to the same indices used for the measurement model—χ^2/dof, GFI, RMSEA and, CFI. Comparing the values of each index with their corresponding recommended values, we can conclude that ARTAM has a good fit with the data. Given the fit of the structural model, we estimated the path coefficients to assess the strength of the relationships between dependent and independent variables. In Figure 30, the values for the standardized path coefficients and for the coefficients of determination (R^2) of the latent variables are reported.

Table 20 Fit indices for structural model.

Fit Indices	Recommended Value	Result
χ^2/dof	< 2	1.862
GFI	> 0.9	0.913
RMSEA	< 0.08	0.053
CFI	> 0.95	0.965

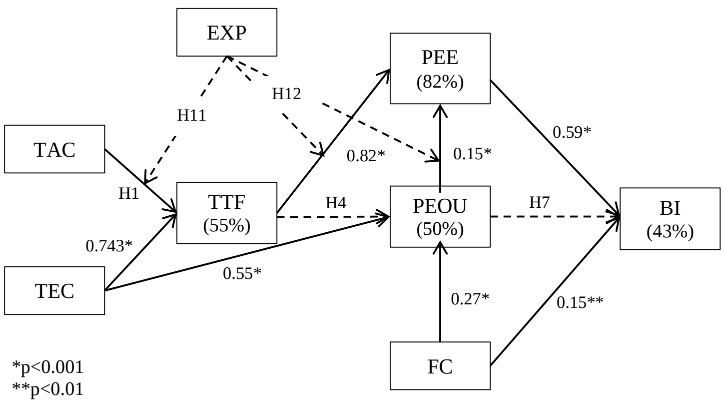

Figure 30 Path coefficients and coefficients of determination of ARTAM.

In summary, our assumptions appeared to be strongly supported, except for hypotheses H4 (β=0.06, p=0.451) and H7 (β=0.11, p=0.084) that, conversely, were not supported. In addition, H1 was only partially supported. In detail, the characteristics we chose to describe MCAR were found to be relevant with respect to the evaluation of the fit between task and technology, as H2 was confirmed (β=0.743, p<0.001). In addition, this value is consistent with previous findings (Lin and Huang, 2008, Zhou et al., 2010, Yen et al., 2010, Shih and Chen, 2013). Regarding the effect of TAC on TTF, we tested the direct influence of each item (i.e. TAC_1, TAC_2, TAC_3, TAC_4 and TAC_5), thus splitting H1 into five sub-hypotheses (i.e. H1_1, H1_2, H1_3, H1_4 and H1_5). While H1_3 (β=0.19, p=0.001) and H1_4 (β=0.26, p<0.001) were strongly supported, H1_5 was only moderately supported (β=0.11, p=0.06). H1_1 (β=0.09, p=0.105) and H1_2 (β=-0.04, p=0.449) were not supported. Therefore, we can state that MCAR technology seems to fit the needs of field services the more technicians need to: i) receive remote support (TAC_4); ii) frequently consult manuals and written procedures (TAC_3); and, iii) make quick decisions in the field (TAC_5). Therefore, we can infer that technicians perceived both the retrieval of information and the promptness of interactions with remote specialists as relevant features of MCAR. Conversely, no significant relationship emerged between the features of MCAR and the complexity and divergence of the service tasks, since TAC_1 and TAC_2 respectively focused on evaluating the amount of time that is spent doing routine work (e.g. a recurrent/cyclical maintenance duty that follows a rigid and well-codified procedure) and on handling unexpected events (e.g. planning actions to restore equipment from sudden/not conceivable faults).

Another relevant issue to be discussed concerns the linkages between TTF and UTAUT. In this case, we have to refer to H3, H4 and H5. H3 (β=0.55, p<0.001) and H5 (β=0.82, p<0.001) were strongly supported, whereas H4 turned out to be not significant. Therefore, we can conclude that the perceived ease of use is determined directly by the technical features of MCAR, since it is not influenced by the fit between TAC and TEC. This is also in line with findings from previous studies (Zhou et al., 2010, Yen et al., 2010). Conversely, the performance expectancy was significantly influenced by TTF, confirming that if a technology is perceived adequate to support a task, the perception of usefulness is positively impacted. Again, similar results have been found in other research (Zhou et al., 2010, Shih and Chen, 2013).

As mentioned in Section 5.2, the hypotheses from H6 to H10 arose from the UTAUT constructs of ARTAM. It turned out that BI was mainly determined by PEE (H6: β=0.59, p<0.001) and only moderately influenced by FC (H8: β=0.15, p<0.01). In addition, PEOU did not have a direct influence on BI (H7 was not supported), but it turned out that it affected it indirectly, through PEE. In fact, their relationship was significant (H10: β=0.15, p<0.001). Regarding the fact that H7 was not supported, this is indeed an expected result. In line with some other studies (Keil et al., 1995, Shen and Eder, 2009), Davis himself suggests that "ease of use operates through usefulness" (Davis (1989), p.332). However, a direct relation between PEOU and BI can be supposed, especially in case the task is integral to technology (Gefen and Straub, 2000). In our study, instead, MCAR is intended to be not a mandatory "prosthesis" of technicians (Hollnagel and Woods, 2005), but only a tool to enhance, eventually, their ability.

Thus, in a situation like this, usefulness is prevalent compared to perceived ease of use in determining behavioural intention to use a technology.

Finally, the results show that FC influences more PEOU (H9: β=0.27, p<0.001) than BI. In fact, facilitating conditions may positively impact upon perceived ease of use and, as a result, on behavioural intention to use. This finding is also confirmed by other studies on UTAUT (Venkatesh et al., 2003, Zhou et al., 2010, McKenna et al., 2013) that suggest that facilitating conditions affect the use, not the intentions. Therefore, in order to evaluate the users' perceptions towards future adoption of MCAR to support industrial field services, the relationship between FC and BI is only moderately confirmed. The summary of testing results is depicted in Table 21.

Table 21 Summary of testing results.

Hypothesis	Path	Result of hypothesis testing
H1	TAC→TTF	Partially supported
H2	TEC→TTF	Supported
H3	TEC→PEOU	Supported
H4	TTF→PEOU	Not supported
H5	TTF→PEE	Supported
H6	PEE→BI	Supported
H7	PEOU→BI	Not supported
H8	FC→BI	Supported
H9	FC→PEOU	Supported
H10	PEOU→PEE	Supported
H11	EXP moderates TAC→TTF	Not supported
H12	EXP moderates TTF→PEE and PEOU→PEE	Not supported

With respect to the causal relationships among variables, it is important to notice that the ARTAM explained the substantial variance in PEOU (R^2=0.50), PEE (R^2=0.82), TTF (R^2=0.55) and BI (R^2=0.43). Moreover, TEC explained 55% of the variance contained in TTF, whereas TEC and FC had a significantly positive effect on PEOU, by explaining 50% of its variance. Together, PEOU and TTF explained 82% of the variance in PEE. However, TTF contributed more than PEOU in determining PEE. Finally, PEE and FC jointly explained 43% of the variance in BI, with a more dominant contribution of PEE in comparison to FC.

The last analysis concerns the assessment of the moderating effect of the technicians' experience on the relationships between firstly, task characteristics and task-technology fit, secondly, task-technology fit and performance expectancy and, thirdly perceived ease of use and performance expectancy (H11 and H12). First of all, the questionnaires were grouped with respect to the technicians' experience. We considered "expert" technicians as those who had accumulated more than 10 years of experience doing the same or quite similar jobs. This led to having 258 “expert” respondents and 54 “non-expert” respondents. Against the different datasets, we tested the ARTAM model with a multi group analysis, using the same approach as presented in sub-section 5.4.2.3. In this case we compare a model with equality constraints (e.g. non-expert) to a model that allows some parameters to vary (e.g. expert). Then the global test of the equality of covariance structures across the groups of interest were performed in order to evaluate if the moderating effect of the technician’s experience is not significant (null hypothesis cannot be rejected). Even in this case the methods of χ^2 difference ($\Delta\chi^2$) and CFI differences (ΔCFI) were used and two models were created to measure the non-invariance of the measurement weights (i.e. model 1) as well as of the structural weights (i.e. model 2) with respect to the moderating variable “experience.” Table 22 reports the χ^2 and CFI values for the configural model and the comparison models, as well as their differences.

Table 22 Multi group analysis: fit indices of configural model, model 1 and model 2, and differences with configural model.

Fit Indices	Configural model	Model 1	Model 2
χ^2	589.236	604.415	612.561
CFI	0.950	0.950	0.949
$\Delta\chi^2$	-	15.179	23.325
ΔCFI	-	0.000	0.001

$\Delta\chi^2$, that is distributed as a χ^2 with degrees of freedom equal to the difference of the degrees of freedom of the compared models (i.e. dof=15 for model 1 and dof=22 for model 2), turned out to be not significant in both cases. In addition, since the values of ΔCFI were always lower than 0.01 the presence of invariance was confirmed. Therefore, since H11 and H12 are not supported we can state that the technicians’ experience has no moderating effect on the ARTAM structure.

5.5 Conclusions, limitations and future research

This chapter presents an extended technology acceptance model (ARTAM) that aims to understand how field technicians perceive and would, potentially, adopt MCAR technology in their jobs. From a theoretical perspective, this research is unique for at least three reasons: i) it takes into account an emerging technology (Augmented Reality) that is expected, over the next few years, to be widely adopted in service networks (Fenn and LeHong, 2011, Porcelli et al., 2013b); ii) to the best of the authors’ knowledge, it represents the first attempt to determine the acceptance of MCAR in the context of interest—through a quantitative investigation of the perceptions of field-technicians; and, iii) it is the first attempt to consider technology acceptance (TAM and UTAUT) in conjunction with a task-technology fit (TTF) model for assessing AR usage. Another relevant result is the validation of the proposed model, ARTAM. The measurement model confirmed an adequate convergent validity and discriminant validity, and the structural one explained more than 40% of the "intention to use" variance. In particular, "intention to use" was mostly influenced by "performance expectancy" rather than "perceived ease of use" and "facilitating conditions," whereas TTF strongly affected "performance expectancy" with respect to "perceived ease of use."

With respect to the end-users valuation of MCAR, from this study we achieved interesting insights (see Table 14 and Table 17). In brief, the overall acceptance of this technology appeared quite good—it was considered by technicians sufficiently adequate to support their daily jobs and useful in improving their work performance. In addition the cross-sectional analysis suggests that slightly differences exist with respect to the context. However, since those differences are not statistically significant, more focused research are needed in order to assess the dependence of perceptions towards MCAR from the complexity of the context under investigation in terms of products and kind of field intervention. Beyond these specific results, however, the proposed model must be considered a valuable tool to evaluate the perceptions of end users towards the adoption of this kind of technology. Managers, in fact, could exploit this framework at the early stage of technology introduction, i.e. in pre-implementation stages, to evaluate in greater detail the barriers and resistances, prior to further development and full acquisition of the technology.

Finally, the study's findings also provide some helpful hints to engineers who are engaged in developing MCAR systems. On one side, the relevance of user-centred design is highlighted, since ease of use affects usefulness that, in its turn, determines the intention to use. In fact, if technicians think that the use of MCAR would not be free of effort, their perceptions about the achievable improvements of job performances could be reduced. On another side, it is important to design and develop systems that fulfil specific needs. In fact, as our study revealed, MCAR is mostly viewed as adequate in providing remote support (TAC_4), helping to retrieve and consult written procedures (TAC_3) and, lastly, in helping to make faster decisions in the field (TAC_5). Thus, system developers should focus on making the exchange of audio/video streams more efficient, as well as on integrating MCAR into enterprise content management applications for easier document access, retrieval and distribution.

Despite the relevance of this study, several limitations must be also acknowledged. Firstly, as mentioned in Section 5.3.2, the characteristics of the job are measured through the

TAC construct. In order to keep the questionnaire short, it detects only one item for each relevant aspect. However, including more items would improve internal consistency. Hence, this could be one avenue of future research. Secondly, since MCAR had not yet been adopted within the studied companies, only cross-sectional data was collected. Since users' behaviour is dynamic and constantly changing, a longitudinal research study involving technicians who already use these systems at work, would provide more insights into how user adoption behaviour changes over time. Thirdly, despite the explained variance (43%) being consistent with the extant literature (Venkatesh and Davis, 2000, Kuo and Yen, 2009, McKenna et al., 2013), some factors that are not considered in the ARTAM model could also affect the user's intentions. For instance, the few papers that address the acceptance of Augmented Reality in education and tourism considered the "perceived enjoyment" construct (Balog and Pribeanu, 2010, Rasimah et al., 2011, Pribeanu, 2011, Haugstvedt and Krogstie, 2012). Hence, future research could also include this construct to assess if it can improve the scope of ARTAM.

Another limitation may refer to the sample—technicians from companies that provide products and services in the IT and printing industries. The selected companies are very different with respect to the type and complexity of their products, their size and, the extension of their service business. Therefore, generalizability of the study's findings should not be questioned. However, as these companies are, to a certain extent, all competing in the vast arena of digital equipment, it is reasonable that the interviewed technicians could have a higher propensity to adopt and use ICTs than individuals who are employed in very different industries. Another limitation concerns our unit of analysis. We investigated the perceptions of field technicians only, without taking into account the points of view of remote specialists, as they are very limited in number. However, their intentions can be relevant for the companies as well. Hence, future research should carefully consider this aspect. Lastly, our sample of respondents included a majority of "experienced" technicians (82.6%). In order to confirm the non-significant moderating effect of experience, a greater concentration of less experienced/skilled technicians should also be included in the sample and interviewed.

Chapter 6

Conclusions and direction for future research

6.1 Conclusions

This thesis examined the issues related to the adoption of Augmented Reality technologies to support the provision of industrial field services. The relevance of this topic is confirmed by the increasing number of OEMs that, in addition to service firms, are integrating the selling of their products with the provision of services so that the part of their revenues coming from service delivery is more and more strategic. For this reason, be effective and efficient in the delivery of services on field is a necessary goal to pursue. However, several sources of complexity in servicing the installed bases can be identified such as the shorter and shorter innovation cycles as well as frequent upgrades that continuously inject the latest technologies into the installed bases, the increasing complexity of equipment that require a large plethora of skills to be configured and maintained and the need to deploy on field technicians able to perform different tasks such as making a diagnosis, finding a solution to an unknown problem, following complicated maintenance procedures, etc. Moreover, according to AR developers, the situation depicted above, and in particular the issue related to the knowledge distribution to the field force, could be improved with the adoption of AR technologies. However, since AR is an emerging technology, up to now only few pilots project for its introduction in the industrial context can be found; for this reason, using the perspective of the service provider, irrespective of servitized OEMs or service firms, we conducted several explorative studies in order to get insights into its potential use, the expected benefits and efforts related to its adoption and, the acceptance of AR by the field force.

In section 1.2 this overall goal has been broken down in three research questions. It is now possible to give an answer to each one.

RQ1: Which AR system better fits with the specific requirements of different industrial field services?

In order to answer this question, a thorough literature review on both AR systems and industrial services has been conducted in order to firstly derive a 3-dimension typology that classify the main feature of the AR proposed and then identify the AR system that better fits with the specific requirement of each kind of IFS identified.

From this study emerged that to specify an AR system, the level of each of the following three dimensions need to be selected: i) the intrusiveness, i.e. the extent to which, prior to adopting and using AR, the service provider is obliged to prepare and modify, in advance, the customer's environment; ii) the portability, i.e. the extent to which user's motions and movements could be prevented or not, as a consequence of specific I/O devices; iii) the independence, i.e. the extent to which a technician, while doing her/his mission, likely resorts to external assistance as a consequence of the gap between the mastered skills and those needed to perform the demanded task. In particular, the first dimension distinguishes between hybrid tracking systems instead of natural feature-based ones, the second one between the I/O devices such as handhelds rather than HMDs, while the latter one between AAR and MCAR systems.

Merging this typology with the IFS classification, three patterns emerged:

Pattern 1. If the aim is to recover the product functionality and complex/divergent problems arise so that troubleshooting is needed to decide what actions have to be done, MCAR can favour collaboration and support from remote help-desk, assuring symmetry in bidirectional communications without introducing idle times.

Pattern 2. If the aim is to recover the product functionality and action plans can be easily translated into code and algorithms, single-user AAR can help technicians to get the right information in the right place and at the right time. As a result, workforce productivity can be improved.

Pattern 3. If the main goal is an improvement in the asset availability, information about product status, customer environment, process mission and functional parameters needs to be achieved in order to carry on some inspections or to define, eventually, some action plans. In this case, AR system embedded in handhelds can support this task improving the visualization of information, standing in front of industrial product.

This first result can be of some interest for both scholars and practitioners. On one side, in fact, since this study represents a first attempt to organize the huge amount of existing information, ideas, conceptual assumptions, the typology can guide CIOs and service managers in understanding how AR could be a solution for their businesses and what kind of technologies fit better their technical and functional needs. On the other hand, this study gives useful insights even for developers of AR devices into both considering IFS-related issues during the design phase and the requirements definition.

RQ2: How AR adoption will influence the delivery of industrial field services?

To answer this question, we focused the study on Pattern 1 and we carried out several explorative case studies in order to get insights directly from the field. In particular, potential benefits, efforts, and process redesign requirements were identified through the case study with Océ Italia - Canon Group, whereas the steps of MCAR adoption including the reason why it was decided to adopt MCAR to support IFS delivery and the experienced benefits and problems resulted from the two retrospective case studies (i.e. SIDEL and IMA Servizi).

Summing up all the information achieved we identified two main areas in IFS delivery that companies need to work on in order to be ready to introduce MCAR as soon as the current issues will be overcome. Firstly, the need for increasing the investments to enhance the competence centres that become essential for the technical product knowledge distribution towards these new technologies across the world. In this way, in fact, if specialists residing in remote centres can adequately support the field force through MCAR, even poorly skilled technicians could be sent to the customer for the IFS provision. Then, once the support network essential for the usage of MCAR is developed, i.e. companies are able to remotely support somebody on field worldwide and 24/7 through MCAR, we expect that companies will include the MCAR-based support system in their offering, replacing, thus, the direct service network with the customer's personnel such as the machine/industrial plant's operators.

The main contribution of the findings of these explorative studies is that relevant hints are identified for CIOs and service managers. We believe these technologies are directed, within a few years, to become a standard equipment of service and maintenance department. However, several changes are requested to the traditional service delivery system in order to gather the maximum benefits. Therefore, in order to be ready as soon as the current issues will be overcome, it is necessary to rethink to the entire field organization involving all the interested workers and stakeholders (such as managers, technicians, product specialists, labor unions, etc.).

RQ3: What is the level of acceptance and the willingness to use AR of the field force?

This research question has been quantitatively addressed using a survey-based approach. In particular, even in this case we referred to Pattern 1 and to the adoption of MCAR technology. Based on TAM (Davis, 1989) and TTF (Goodhue and Thompson, 1995) literature, we developed a novel model named ARTAM (i.e. Augmented Reality Acceptance Model) that identifies the factors that affect the intention to use MCAR of the field force. Then, the model was validated against the surveys of three companies (i.e. Océ Italia – Canon Group, IBM Italia and Tecnomatic) whose field force were selected as test benches. Analysing the questionnaires collected using SEM (Byrne, 2009), the main findings with respect to RQ3 are twofold. Firstly, regarding the relationship among constructs, the intention to use MCAR resulted mainly determined by Performance Expectancy (PEE) and to a lesser extent by facilitating conditions (FC). In its turn, PEE is mainly determined by Task-Technology Fit (TTF) and to a lesser extent by Perceived Ease of Use (PEOU). Finally, Technology Characteristic influences PEOU whereas, together with Task Characteristics, affects TTF. Secondly, regarding the quantitative evaluation of MCAR and the resulting intention to use, the overall acceptance of this technology appeared quite good—it was considered by technicians sufficiently adequate to support their daily jobs and useful in improving their work performance. In addition MCAR was recognized as an adequate tool when remote support is needed, written procedure needs to be retrieved and consulted and, lastly when faster decisions in the field need to be made.

Concluding, this study is relevant for scientific research as well as for its managerial implications. From a theoretical perspective, this research is the first example of an integrated model (TAM and TTF) for assessing MCAR usage—through a quantitative investigation of the perceptions of field-technicians. In addition, ARTAM has been validated since the measurement model confirmed an adequate convergent validity and discriminant validity, and the structural one explained more than 40% of the "intention to use" variance.

From a managerial perspective, besides the interesting results on how technicians perceive MCAR, since ARTAM was validated, it should be considered a valuable tool to evaluate the perceptions of end users towards the adoption of this kind of technology during pre-implementation stages of introduction in order to evaluate in greater detail the barriers and resistances, prior to adopting the technology. Finally, this study confirms the relevance of the user-centred design in developing MCAR systems, since ease of use affects usefulness that, in its turn, determines the intention to use.

6.2 Direction for future research

Each chapter of this dissertation concludes identifying the limitations of each study and discussing directions for further research. However, analysing the study as a whole, the main research opportunities that have been identified for future developments of the investigations reported in the present dissertation consist in the following research directions:

- Investigation in contexts that massively adopted AR on how the interactions in the service provision between field technicians, product specialists and the product will change as a consequence of AR adoption. One of the main limitations of the explorative case studies carried out, in fact, is that a full understanding of the redesign of the service delivery system was not possible since companies involved either were not using AR or were using only few devices.
- Starting from the preliminary results related to RQ2, move on to the next step and understand through simulation models and benefit-cost analysis how much the centralization of knowledge and its consequent on demand distribution on field is beneficial if compared to the traditional cascade training between the R&D centres and direct and indirect service networks.
- Extension of this kind of study to the other patterns identified in Chapter 2 in order to complete the validation of the typology proposed and to be able to carry on some cross-pattern analysis.
- Validation of ARTAM depending on the sample, such as against product specialists, technicians that use MCAR or users of AAR systems.

Appendix A

ARTAM questionnaire and MCAR presentation

Survey - Research on Augmented Reality

Dear Mr. and Mrs.,

this document includes a survey that investigates the usefulness of Augmented reality-based device to support industrial field service provision.

Please:
- take a look to the short presentation about the main features of Augmented Reality technology and the final video that is attached to the mail you received;
- answer the following questions concerning this technology and your activity as field technician.

The questionnaire is structured into three sections. The first captured the general information about you, such as age, gender, years of work experience, etc. The second focused on the characteristics field service tasks and of Augmented Reality systems. Finally, the third section evaluates your perception about the technology.

It will take about 15 minutes to answer.

Thank you in advance for your valuable cooperation.

Privacy:
Under Law 196/2003 the information that you provide will be used only for statistical purposes and will not be used for advertising or transmitted to third parties.

1.1 Age *
How old are you?

[ ]

1.2 Gender *

- [ ] Male
- [ ] Female

1.3 Esperience *
How long (in years) have you been working in the area of field service delivery?

[ ]

1.4 Products *

Which product are you currently serving? Select one or more of the following options.

- ☐ Sistems and servers - System X
- ☐ Sistems and servers - Power System
- ☐ Sistems and servers - System Z
- ☐ Sistems and servers - Multivendor
- ☐ Storage - disk systems
- ☐ Storage - tape systems
- ☐ Storage - NAS
- ☐ Networking
- ☐ Software
- ☐ Other: ______

1.5 Time spent on products

Provide an estimate of the percentage of time spent on each type of product selected in 1.4.

	less than 10%	10% - 25%	25% - 50%	50% - 75%	75% - 100%
Sistems and servers - System X	○	○	○	○	○
Sistems and servers - Power system	○	○	○	○	○
Sistems and servers - System Z	○	○	○	○	○
Sistems and servers - Multivendor	○	○	○	○	○
Storage - disk systems	○	○	○	○	○
Storage - tape systems	○	○	○	○	○
Storage - NAS	○	○	○	○	○
Networking	○	○	○	○	○
Software	○	○	○	○	○
Other	○	○	○	○	○

1.6 Experience on products *

How long (in years) have you been working in serving HW and SW products that you specified?

______

2 Task Characteristics

Please, if possible, answer always referring to your main activity (i.e. the one that involves the products on which you spent most of the time).

Indicate the frequency of occurrence of the statements in the following sentences.
(1-never; 2-rarely; 3-sometimes; 4-often; 5-always)

2.1 My job requires precise procedures to be followed (i.e. a clear action plan has been defined). *

	1	2	3	4	5	
NEVER	○	○	○	○	○	ALWAYS

2.2 In my job I need to handle unexpected events. *

	1	2	3	4	5	
NEVER	○	○	○	○	○	ALWAYS

2.3 In order to complete my activities, I need to check manuals and procedures. *

	1	2	3	4	5	
NEVER	○	○	○	○	○	ALWAYS

2.4 In order to complete my activities, I need technical support from a colleague or a product specialist. *

	1	2	3	4	5	
NEVER	○	○	○	○	○	ALWAYS

2.5 My job requires me to make quick decisions and work promptly. *

	1	2	3	4	5	
NEVER	○	○	○	○	○	ALWAYS

If you have not already done so, we invite you to view the presentation on Augmented Reality technology that is attached to the email you received.

3. Technology Characteristics

Based on what you understand from the presentation of Augmented Reality technology, select how much do you agree from 1 to 5 with the following sentences.
(1-strongly disagree; 2-moderately disagree; 3-agree; 4-moderately agree; 5-strongly agree)

3.1. The Augmented Reality system allows information exchange in real-time. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

3.2. Exchanging images in real-time, to help the product specialist understand the problem, will solve issues easily and quickly. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

3.3. Thanks to the ability to see my instructions superimposed onto the real scene, it is easy to understand the advice of the product specialist *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

4.1. To support my field service tasks, the functions of the Augmented Reality system are enough. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

4.2 In general, the functions of the Augmented Reality system fully meet my support needs. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

5. Usefulness of Augmented Reality technology

Select how much do you agree from 1 to 5 with the following sentences.
(1-strongly disagree; 2-moderately disagree; 3-agree; 4-moderately agree; 5-strongly agree)

5.1. I think that the usage of the Augmented Reality system would improve my job performance, enabling better communication with the product specialist in order to analyse and solve the problem. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

5.2. Using the Augmented Reality system would enable me to accomplish tasks more quickly. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

5.3. Using the Augmented Reality system would enhance my effectiveness in my field service tasks. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

5.4. I think that the Augmented Reality system would simplify my job. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

5.5. Overall, I think that the Augmented Reality system would be useful in my job. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

5.6 Usefulness *

For which product categories do you think Augmented Reality could be more useful?

- ☐ Sistems and servers - System X
- ☐ Sistems and servers - Power System
- ☐ Sistems and servers - System Z
- ☐ Sistems and servers - Multivendor
- ☐ Storage - Disk systems
- ☐ Storage - Tape systems
- ☐ Storage - NAS
- ☐ Networking
- ☐ Software
- ☐ Other: ____________

6. Ease of use of Augmented Reality

Select how much do you agree from 1 to 5 with the following sentences.
(1-strongly disagree; 2-moderately disagree; 3-agree; 4-moderately agree; 5-strongly agree)

6.1 LEARNING how to use the Augmented Reality system would be easy and fast for me *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

6.2. I think that USING the Augmented Reality system in real settings would be easy for me *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

6.3. I think that using the Augmented Reality system in my job would require a lot of mental effort. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

7. Facilitating Conditions

Indicate the frequency of occurrence of the statements in the following sentence.
(1-never; 2-rarely; 3-sometimes; 4-often; 5-always)

7.1. In the past, when new technologies were introduced to support my job, my organization provided all the necessary resources and knowledge to use them at their best. *

	1	2	3	4	5	
NEVER	○	○	○	○	○	ALWAYS

Select how much do you agree from 1 to 5 with the following sentences.
(1-strongly disagree; 2-moderately disagree; 3-agree; 4-moderately agree; 5-strongly agree)

7.2. The Augmented Reality system is NOT compatible with other systems needed to perform my activities. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

7.3. If I needed help with using the MCAR system, I am confident that my organization would arrange the resources (people and systems) to help me. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

8. Intention to use Augmented Reality

8.1. Assuming that the Augmented Reality system would be available in my job, I predict that I would use it every time I needed to ask for support. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

8.2. I would like the Augmented Reality system would be available in my job. *

	1	2	3	4	5	
STRONGLY DISAGREE	○	○	○	○	○	STRONGLY AGREE

Università degli Studi di Firenze

Ibis

AUGMENTED REALITY

www.vrmedia.it

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What is R.E.A.L?

Ibis

2

- **Augmented Reality** allows to combine the real and the virtual world, generated by a computer, blending these two dimensions into **one single real-time visualization**.
- R.E.A.L. is a **mobile system of remote maintenance** exploiting **Augmented Reality**.

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What is R.E.A.L?

3

- It allows on-site technicians to receive **audio/video support from Remote Experts** consulting the information provided by these on a wearable viewer.
- R.E.A.L. enables real-time assistance in remote training, following step by step users in the different stages: **assistance, maintenance, troubleshooting**.

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User equipment:

4

- Central unit based on mini PC
- Helmet with Near Eye Display and video camera
- Portable video camera
- Two batteries
- Connection cables

The field technician is equipped with a helmet that supports a camera, through which he sends the images he is seing to the remote expert, a display to visualize the virtual instruction superimposed to the real scene and a microphone and headset.

Important: the helmet and the kind of headset can be substituted with more ergonomic devices (for contexts that do not have safety issues)

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Remote equipment:

6

- R.E.A.L. client software used by the remote expert to communicate with the on-site technician

- The remote expert is in front of a PC equipped with an Internet connection and can communicate with the field technician through an ad-hoc SW that allows the creation of symbols, pointers, and the uploading of files useful to perform the field task

Video

7

- And now watch the video:
- http://www.youtube.com/watch?v=5-5EHkA-6qY

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Appendix B

Basics of Structural Equation Modelling

The brief introduction to Structural Equation Modelling (SEM) that follows is extracted from Byrne (2009) and Raykov and Marcoulides (2006). Please refer to these books for further details.

SEM is a statistical methodology that provides researchers with a comprehensive method for the quantification and testing of substantive theories. It takes a confirmatory (i.e. hypothesis-testing) approach to the analysis of a structural theory bearing on some phenomenon. Usually, this theory represents “casual” processes that generate observations on multiple variables (Bentler, 1988). The term structural equation modelling comprises two important concepts related to the procedure: i) the causal processes under study are represented by a series of structural (i.e. regression) equations and ii) these structural relations can be modelled pictorially to enable a clearer conceptualization of the theory under study. The model can be then tested statistically in order to evaluate the fit with the data. If the model is consistent with the data, the hypothesized relations among variables are plausible otherwise they are rejected.

The main advantages of SEM with respect to multivariate procedure are:

- SEM takes a confirmatory rather than exploratory approach to the data analysis. In addition, since SEM demands that the pattern of inter-variable relations be specified a priori, it lends itself well to the analysis for inferential purposes while multivariate analysis are essentially descriptive by nature and so hypothesis testing is difficult.
- SEM provides explicit estimates of measurements errors variance parameters.
- Using SEM procedures both unobserved (i.e. latent) and observed variables can be incorporated.
- SEM allows modelling multivariate relations and estimating point and/or interval indirect effects.

To date, numerous programs are available for conducting SEM analyses such as AMOS (Arbuckle, 2011), EQS (Bentler, 2004), LISREL (Jöreskog and Sörbom, 1993, Jöreskog and Sörbom, 1999), Mplus (Muthén and Muthén, 2004), SAS PROC CALIS (SAS, 1989), SEPATH (Statistica, 1998) and RAMONA (Browne and Mels, 2005). In the following the basics of SEM will be illustrated with respect to AMOS, since this is the program selected for this study.

1. Latent versus observed variables

In behavioural sciences, often the purpose of the research is to study theoretical constructs that cannot be observed directly, i.e. *latent variables* or *factors*.

- *Latent variables or factors*

  It is an abstract phenomenon that cannot be measured directly (i.e. the “performance expectancy” of ARTAM). For this reason it must be defined in terms of behaviour believed to represent it. The assessment of the behaviour (the term behaviour is used in a broader sense to include scores on a particular measuring instrument) constitutes the direct measurement of an observed variable.
- *Observed or manifested variables*

  These are the measurement scores and they serve as indicators of the underlying construct which they are presumed to represent (i.e. the 5 items of the questionnaires formulated to assess the “performance expectancy” construct).

In addition latent variables can be divided in exogenous and endogenous. The first ones are independent variables; they cause fluctuations in the values of other latent variables in the model and they are not explained by it. Their changes are influenced by other factors external to the model (e.g. gender, age, socioeconomic status). The latter, instead, are dependent variables; they are influenced by the exogenous variables in the model, either directly or indirectly. Fluctuations in the values are explained by the model because all latent variables that influence them are included in the model specification.

2. Types of model

- ***Factor analytic model***

Factor analysis is the oldest and best-known statistical procedure to investigate relations between sets of observed and latent variables. In particular, using this approach, the covariation among set of observed variables are examined in order to gather information on their underlying latent constructs (i.e. factors). There are two types of factor analysis:

- o *Exploratory factor analysis (EFA)*

It is used when the links between the observed and latent variables are unknown or uncertain. In this case, the analysis determines how and to what extent the observed variables are linked to their underlying factors (in terms of factor loadings). Usually the purpose is to minimize the number of factors. Since the researcher has no prior knowledge that the items measure the intended factors, this approach is considered exploratory.

- o *Confirmatory factor analysis (CFA)*

It is used when the researcher has some knowledge of the underlying latent variable structure. According to this knowledge, in fact, the researcher postulates relations between the observed measures and the underlying factors a priori and then tests this hypothesized structure statistically, once verified that an adequate goodness-of-fit exists between the model and the sample data.

EFA and CFA focus only on how and the extent to which the observed variables are linked to their underlying latent factors. Their primary interest, in fact, is to measure the strength of the regression paths from the factors to the observed variables (the factor loadings) without considering any regression structure among them. Since CFA model focuses only on the link between factors and their measures variables, it represents the *measurement model* within the framework of SEM.

- ***Full latent variable model***

The full la tent variable model allows for the specification of regression structure among the latent variables. The researcher can hypothesize the impact of one latent construct on another in the modelling of causal direction. This model is termed “full” because comprises both a measurement model (CFA) and a structural model in which the latent variables are linked among themselves. In the following we will refer to a full latent variable model that specifies direction of cause from one direction only (i.e. a recursive model).

3. General purpose and process of statistical modelling

Typically a researcher postulates a statistical model based on his knowledge of the related theory on empirical research in the area of the study, or on some combination of both.

Specified the model, the researcher tests its plausibility based on sample data that comprise all observed variables in the model. With a model-testing procedure, the purpose is to determine the goodness-of-fit between the hypothesized model and the sample data.

$$Data = Model + Residual$$

- Data: score measurement related to the observed variables
- Model: hypothesized structure linking the observed variables to the latent variables (or latent ones with each other)
- Residual: discrepancy between the hypothesized model and the observed data

There are three scenarios of strategic framework for testing structural equation models (Jöreskog, 1993):

1) Strictly confirmatory (SC)

The researcher postulates a single model based on theory, collects the appropriate data, and then tests the fit of the hypothesized model to the sample data. From the results of this test, he rejects or fails to reject the model; no further modifications of the model are made.

2) Alternative models (AM)

The researcher proposes several alternative (competing) models grounded on theory. Following analysis of a single set of empirical data, he selects one model as most appropriate in representing data.

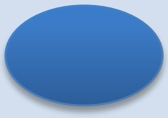
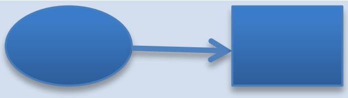
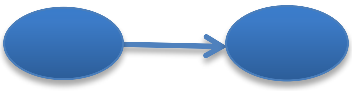
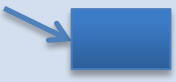
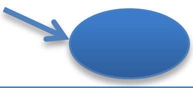
3) Model generating (MG)

After rejecting a theoretically derived model on the basis of its poor fit to the sample data, the researcher proceeds in an exploratory way to modify and estimate again the model. The ultimate purpose is to locate the source of misfit to determine a model both substantively meaningful and statistically well-fitting (i.e. that better describes the sample data).

4. The general structural equation model

Structural equation model are schematically portrayed using particular configuration of four symbols (i.e. circles, squares, single-headed arrows and double-headed arrows). The meaning of each symbol is depicted in Table 23.

Table 23 Commonly used symbols for SEM models in path diagrams.

Symbol	Meaning
	Unobserved latent variable
	Observed variable
	Impact of one variable on another
	Covariance or correlation between pairs of variables
	Path coefficient for regression of an observed variable onto an unobserved latent variable
	Path coefficient for regression of one factor onto another factor
	Measurement error associated with an observed variable
	Residual error in the prediction of an unobserved factor

Schematic representations of models are termed *path diagrams* and are the graphical equivalent of its mathematical representation whereby a set of equations relates dependent variables to their explanatory variables. Figure 31 represents a general structural equation model. In particular:

- err1 → err5: measurement errors. They reflect the adequacy of observed variables in measuring the related underlying factors. They can derive from two sources: random measurement error and error uniqueness, i.e. systematic errors.

- resid1: residual term, i.e. an error in the prediction of endogenous factors from exogenous factors.
- MSC→MATH: one way arrow that represents structural regression coefficients and thus indicates the impact of how much MSC "causes" MATH.
- Factor (e.g. MSC) → observed variables (e.g. SDQMSCM APIMSC, SPPMSC): one way arrows that suggest that these score values are each influenced by their respective underlying factors. These paths represent the magnitude of expected change in the observed variables for every change in the related latent variable.
- Error (e.g. err1) → observed variable (e.g. SDQMSC): one way arrow that measures the impact of the measurement error on observed variables. Resid1 → MATH, instead, is one way arrow that measures the impact of the error in prediction of MATH.
- err1↔err2: covariance between the measurement errors.

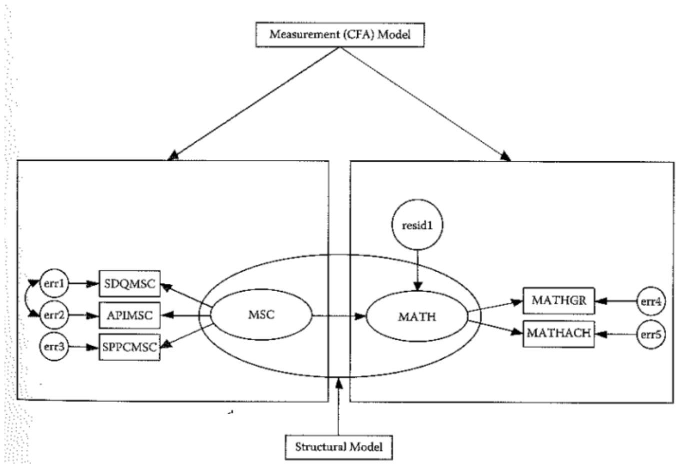


Figure 31 A general structural equation model demarcated into measurement and structural components (Byrne, 2009).

SEM can be also represented by a series of regression equations. In particular to formulate these equations, it is necessary to note each variable that has one or more arrows pointing towards it, and then record the summation of all such influences for each of those dependent variables.

$$MATH = MSC + resid1$$

$$SDQMSC = MSC + err1$$

$$APIMSC = MSC + err2$$

$$SPPMSC = MSC + err3$$

$$MATHGR = MATH + err4$$

$$MATHACH = MATH + err5$$

Neither one of these model representations (graphical or equations) tells the whole story. Firstly, some parameters critical to the estimation of the model are not explicitly shown and thus may not be obvious to the novice structural equation modeler. For example, there is no indication that the variances of the exogenous variables are parameters in the model. With this respect AMOS facilitates the specification process by automatically incorporating the estimation of variances by default for all independent factors. Then, certain parameters in the model are not present. For example the absence of double-headed arrow between err4 and err5 means that there is a lack of covariance between the error terms associated with the observed variables MATHGR and MATHACH. With this respect, AMOS automatically assumes these specifications to be non-existent.

Finally, a SEM can be decomposed in two sub models (see Figure 31):

- Measurement model (CFA model): it defines relations between the observed and unobserved variables, i.e. it provides the link between scores on a measuring instrument and the underlying constructs.
- Structural model: it defines the relations among the unobserved variables, i.e. it specifies the manner by which particular latent variables directly or indirectly influence changes in the values of certain other latent variables in the model.

5. The concept of model identification

Model identification focuses on whether or not there is a unique set of parameters consistent with the data. This bears directly on the transposition of the variance-covariance matrix of observed variables (data) into the structural parameters of the model under study. The model is identified if a unique solution for the values of the structural parameters can be found. A structural model can be:

- JUST-IDENTIFIED: there is a one-to-one correspondence between the data and the structural parameters.

Number of data variance and covariance = number of parameters to be estimated

The number of data variance and covariance is p(p+1)/2 where p is the number of observed variables. The number of parameters to be estimate includes first and second order measurement or structural regression paths, variances (i.e. error variances and factor variances), factor covariance and residual errors.

Since in a just-identified model there is no degree-of-freedom, there is no interest in solving it from a research point of view because the model cannot be rejected.

- OVER IDENTIFIED: in this case the number of parameters is lower than the number of data variance and covariance. Therefore a positive degree of freedom that allows for rejection of the model can be achieved, thereby rendering it of scientific use.

A SEM model needs to meet the over-identified criterion.

- UNDER IDENTIFIED: In this case the number of parameters is higher than the number of data variance and covariance. Therefore, there is not enough information (from the input data) for the purpose of attaining a determinate solution of parameter estimation. An infinite number of solutions are possible.

The specification of an over-identified model is a *necessary* but *not sufficient* condition to solve the identification problem. The imposition of constraints on particular parameters can sometimes be beneficial in helping the researcher to attain an over-identified model.

Linked to the identification issue is the requirement that *every latent variable has its scale determined.* This constraint arises because these variables are unobserved and therefore have not definite metric scale. For this purpose the measurement model is specified in a way that the unmeasured latent variable is mapped onto its related observed indicator variable. This scaling requisite is satisfied by constraining to some non-zero value (typically 1) one factor loading parameter in each congeneric set of loadings (i.e. a set of measures where each measure in the set purports to assess the same construct except for errors of measurement).

6. Examples of models

6.1. First-order CFA model

The model depicted in Figure 32 includes 4 self-concept factors (academic SC, social SC, physical SC, emotional SC). Each factor is measured by three observed variables, the reliability of which is influenced by random measurement errors. Each of these variables is regressed onto its respective factor and the four factors are interconnected.

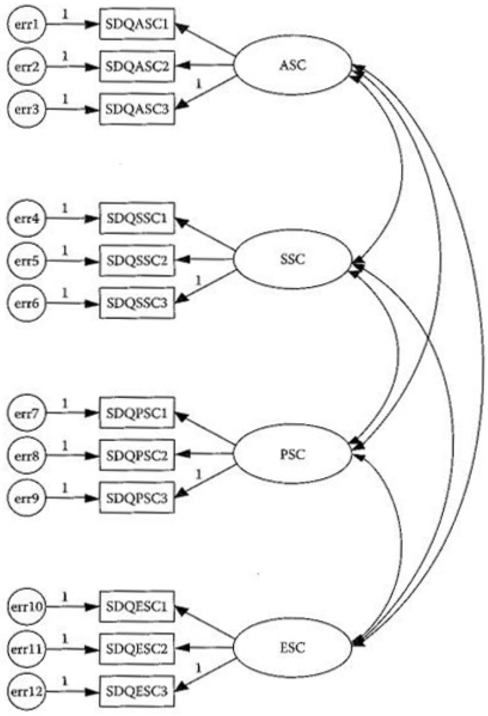


Figure 32 Hypothesized first order CFA model.

6.2. *Second-order CFA model*

In the first example 4 factors were independent variables; however it could happen that theory argues for some higher level factor accountable for the lower order factors. In the example depicted in Figure 33, GSC is the second order factor hypothesized as accounting for all variances and covariances related to the first order factors.

GSC does not have its own set of measurements because it is linked indirectly to those measuring the lower order factors. The single-headed arrows from GSC to factors are freely estimated.

To address the identification problem,

Key parameters to be estimated in a CFA model are:

- Regression coefficients (8 factor loadings)
- Factor and error variances (4 and 12 respectively)
- Factor covariance (6)

Variances associated with these specified variables (latent and observed variables) are freely estimated by default.

Parameters covariance, instead, are ruled by WYSIWYG (what you see is what you get) i.e. if a covariance path is not included in the path diagram, it will not be estimated.

Number of parameters: 30

Numbers of variances and covariances: (p=12 observed variables) 12x13/2=78

The model is over-identified.

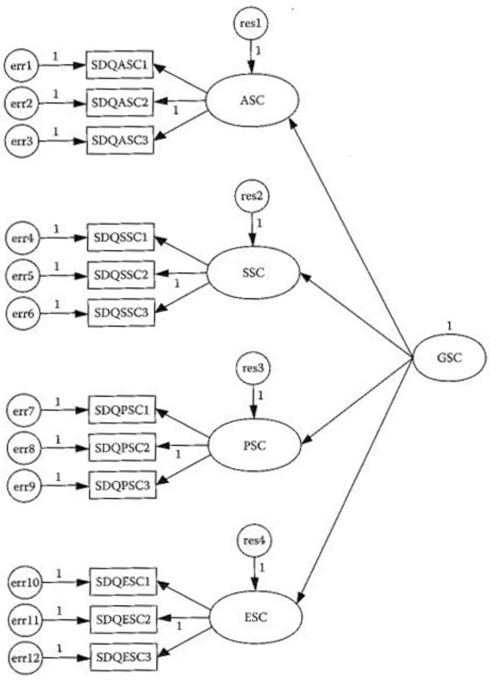


Figure 33 Hypothesized second order CFA model.

there is the need to constraint either one regression path or the variance of an independent factor (in this example the variance of GSC is constraint equal to 1 because the impact of GSC on the other factors is of primary interest).

First order factors function as dependent variables so their variances and covariances are no longer estimable parameters. Such variation is presumed to be accounted for by the higher order. The prediction of each of the first order factors from the second order is presumed to be with error. For this reason a residual error term is associated with each lower level factor.

Number of parameters: 28 (8 first order regression coefficients, 4 second order regression coefficients, 12 measurement error variances, 4 residual error terms)

Numbers of variances and covariances: (p=12 observed variables) 12x13/2=78

The model is over-identified.

6.3. Full SEM model

First order CFA comprises only the measurement component while in the second order CFA the higher level is represented by a reduced form of structural model. The full SEM model, instead, encompasses both measurement and structural models. In particular the model embodies a system of variables whereby latent factors are regressed onto other factors as dictated by theory as well as on the appropriate observed measures.

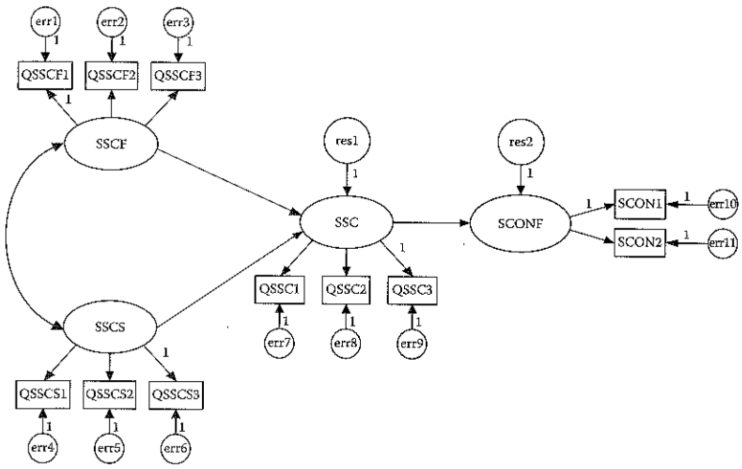


Figure 34 Hypothesized full structural equation model.

In the example depicted in Figure 34, SCONF derives from SSC that in turns is influenced by SSCF and SSCS. Each factor has three indicator measures and SCONF two. Among the four factors, two are independent (i.e. SSCF and SSCS) but correlated and linked to other factors by regression paths whereas the other two (i.e. SSC and SCONF) are dependent since single-headed arrows point towards them and they have residual errors.

For the model identification issue, one path from each of two independent factors to their indicators is constraint to 1 while their variance can be freely estimated. Variances of SSC and SCONF are not parameters in the model. In addition, to establish the scale of each unmeasured factor in the model (and for purpose of statistical identification), one parameter in each set of regression path is fixed to 1.

Each observed measure has an error term, the variance of which is of interest while observed measures act as dependent variables so their variance is not estimated.

Number of parameters: 26 (7 measurement regression coefficients, 3 structural regression coefficients, 2 factor variances, 11 error variances, 2 residual error terms, 1 covariance)

Numbers of variances and covariances: (p=11 observed variables) 11x12/2=66

The model is over-identified.

7. Model fitting process and goodness-of-fit statistics

The model-fitting process determines the goodness-of-fit between the hypothesized model and the sample data.

Let *S* represent the sample covariance matrix (of observed variable scores), $\sum$ represent the population covariance matrix, and θ represent a vector that comprises the model parameters. Thus, $\sum(\theta)$ represents the restricted covariance matrix implied by the model (i.e. the specified structure of the hypothesized model). In SEM:

H_0: $\sum=\sum(\theta)$ i.e. the postulated model holds in the population.

Therefore, the purpose of the researcher is to not reject H_0.

In addition, during the estimation process in SEM the purpose is to yield parameter values such that the discrepancy (i.e. residual) between the sample covariance matrix *S* and the population covariance matrix implied by the model $\sum(\theta)$ is minimal.

$$F[S, \sum(\theta)]: F_{min} = S - \sum(\theta)\ minimum$$

F_{min} serves as a measure of the extent to which *S* differs from $\sum(\theta)$.

7.1. Goodness-of-fit statistics

The output file specifies several statistics to evaluate the goodness-of-fit: chi-square/degree of freedom (χ^2/dof), minimum discrepancy (CMIN), root mean square residual (RMR), goodness-of-fit index (GFI),adjusted goodness-of-fit index (AGFI), parsimony goodness-of-fit index (PGFI), normed fix index (NFI), comparative fit index (CFI), relative fit index (RFI), incremental index of fit (IFI), Tucker-Lewis index (TLI), parsimony NFI (PNFI), parsimony CFI (PCFI), root square mean error of approximation (RMSEA), Akaike's information criterion (AIC), consistent AIC (CAIC), Browne-Cudeck criterion (BCC), Bayes information criterion (BIC), expected cross-validation index (ECVI), Modified ECVI (MECVI) and Hoelter's critical N (CN).

In the following, further details will be provided for the indices used in the study, i.e. chi-square/degree of freedom (χ^2/dof), the goodness-of-fit index (GFI), root mean square error of approximation (RMSEA) and, the comparative fit index (CFI). For the other statistics, please refer to (Byrne, 2009).

The output file of AMOS specifies for each set of statistics:

1. The hypothesized model under test;
2. The saturated model, i.e. is the model in which the number of estimated parameters equals the number of variances and covariances;
3. The independence model, i.e. where no correlation among variables is hypothesized and so all the variables are independent.

These three models represent points on a continuum, with the independence model at one extreme, the saturated model at the other extreme and the hypothesized model somewhere in between.

7.1.1. Chi-square/degree of freedom (χ2/dof)

Chi-square is the statistic that represents the discrepancy between the unrestricted sample covariance matrix *S*, and the restricted covariance matrix $\sum(\theta)$, and in essence, represents the Likelihood Ratio Test statistic. This statistic is equal to $(N\text{-}1)F_{min}$ (sample size minus 1, multiplied by the minimum fit function) and, in large samples, is distributed as a central χ^2 with degrees of freedom equal to $\frac{1}{2}p(p+1)-t$ where p is the number of observed variables, and t is the number of parameters to be estimated.

H_0: $\sum=\sum(\theta)$, i.e. specification of factor loadings, factor variances and covariances, and error variances for the model under study are valid; the χ^2 test simultaneously tests the extent to which this specification is true. Since the probability value associated to χ^2 represents the likelihood of obtaining a χ^2 that exceeds the χ^2 when H_0 is true, the higher the probability associated with χ^2, the closer the fit between the hypothesized model (under H_0) and the specific fit (Bollen, 1989).

However, the Likelihood Ratio Test is sensitive to sample size and usually for large samples it is difficult to obtain precise parameter estimates. Thus, findings of well-fitting hypothesized model, where χ^2 value approximates the degree of freedom, have proven to be unrealistic in most SEM empirical research.

To address the χ^2 limitations, researchers developed several goodness-of-fit indices among which Chi-square/degree of freedom (χ^2/dof) (Wheaton et al., 1977). If χ^2/dof is lower than 2, the model fits the sample data.

7.1.2. Goodness-of-fit index (GFI)

The Goodness-of-fit index (GFI) is a measure of the relative amount of variance and covariance in *S* that is jointly explained by $\sum$. If GFI is higher than 0.9, the model fits the sample data.

7.1.3. Comparative fit index (CFI)

The Comparative Fit Index (CFI) belongs to a group of statistics, classified as incremental or comparative indices of fit (Hu and Bentler, 1995). These indices are based on a comparison of the hypothesized model against some standards.

CFI has been introduced to solve the problem of NFI to underestimate fit in small samples. CFI values ranges from 0 to 1 and are derived from the comparison of a hypothesized model with the independence or null model. CFI, thus, provides a measure of complete covariation in the data. Although value >0.9 was originally considered representative of a well-fitting model, a revised cut-off value close to 0.95 has recently been advised (Hu and Bentler, 1999).

7.1.4. Root mean square error of approximation (RMSEA)

Root mean square error of approximation (RMSEA) is one of the most informative criteria in covariance structure modelling. RMSEA takes into account the error of approximation in the population and asks the question: "How well would the model, with unknown but optimally chosen parameter values, fit the population covariance matrix if it were available?"

This discrepancy is measured by RMSEA and is expressed per degree of freedom, taking into account the number of estimated parameters (i.e. the complexity of the model). In particular:

- Value < 0.05 indicates a good fit;
- Value comprises between 0.05 and 0.08 indicates a reasonable error of approximation in the population;
- Value comprises between 0.05 and 0.08 indicates a mediocre fit;
- Value > 0.1 indicates a poor fit.

The use of RMSEA is recommended for three reasons:

1. It is adequately sensitive to model misspecification;
2. Commonly used interpretative guidelines would appear to yield appropriate conclusions regarding model quality;
3. It is possible to build confidence interval around RMSEA value. AMOS reports 90% confidence interval around RMSEA. If RMSEA is small but confidence interval is wide, the estimate discrepancy is quite imprecise. If, instead, the confidence interval is narrow, RMSEA is precise, so it reflects the model fit in the population. Confidence intervals are influence by sample size: for example with a small sample size, and a large number of parameters, the confidence interval is wide so, a very large sample is required to narrow it. Otherwise if the number of parameters is small, the probability of obtaining a narrow confidence interval is high, even for samples of rather moderate size (MacCallum et al., 1996).

8. Parameter estimation

The evaluation of fit, i.e. the extent to which a hypothesized model fits or adequately describes the sample data, in addition to follow the above presented criteria of the adequacy of the model as a whole (i.e. goodness-of-fit-statistics), can follow the criteria of adequacy of parameters estimates too. In particular three sub criteria can be identified:

1) <u>Feasibility of parameter estimates</u>

Parameter estimates should exhibit the correct sign and size, and be consistent with the underlying theory. Example of parameters exhibiting unreasonable estimates are correlation>1, negative variances, and covariances or correlation matrices that are not positive definite.

2) <u>Appropriateness of standard errors</u>

Standard errors reflect the precision with which a parameter has been estimated, with small value suggesting accurate estimation. Thus, another indicator of poor model fit is the presence of standard errors that are excessively large or small.

3) <u>Statistical significance of parameter estimates</u>

The test statistic here is the critical ratio (CR), which represents the parameter estimate divided by its standard error. The test verifies if the estimates are statistically different from zero. The purpose is to reject the null hypothesis.

Non-significant parameters can be indicative of a sample size that is too small; anyway, usually they are considered unimportant and deleted from the model.

9. Model misspecification

If an inadequate goodness-of-fit is achieved, the next step is to detect the source of misfit. Two types of information can be helpful in detecting the model misspecification: the standard residuals and the modification indices.

9.1. Residuals

If $\sum(\theta) \neq S$, the discrepancy $\sum(\theta)-S$ is captured by the residual covariance matrix. Only their magnitude is of interest in alerting the researcher to possible area of model misfit.

Both standardized and unstandardized residuals are presented in AMOS output but only the standardized ones are usually examined.

$$Std.residuals = \frac{fitted\ residuals}{\begin{array}{c}asimptotically\ std\ errors\\(large\ sample)\end{array}}$$

They represent estimates of the number of standard deviations the observed residuals are from the zero residuals that would exist if model fit were perfect (i.e. $\sum(\theta)-S=0$). Usually values higher than 2,58 are considered to be large (Jöreskog and Sörbom, 1993).

9.2. Modification indices

This information reflects the extent to which the hypothesized model is appropriately described. Evidence of misfit in this regard is captured by the modification indices (MIs), which can be conceptualized as a χ^2 statistic with 1 dof (Jöreskog and Sörbom, 1993).

Associated with MI is an Expected Parameter Change (EPC) value that represents the predicted estimated change, in either a positive or negative direction, for each fixed parameter in the model and it yields important information regarding the sensitivity of the evaluation of fit to any subsequent parameterization of the model.

If the researcher decides to specify and estimate again the model, analyses become framed within an exploratory rather than a confirmatory mode. Ultimate decision must consider:

1) Whether the estimation of the targeted parameter is substantially meaningful;
2) Whether the existing model exhibits an adequate fit;
3) Whether or not the re-specified model would lead to an over-fitted model. Overfitting model involves the specification of additional parameters in the model after having determined a criterion that reflects a minimally adequate fit.
   For example over-fitted model can result from the inclusion of additional parameters that:
   a. represent weak effects and are not likely replicable;
   b. lead to a significant inflation of standard errors;
   c. influence primary parameters in the model, but their own substantive meaningfulness is somewhat equivocal (Wheaton, 1987).

References

ABABSA, F., ZENDJEBIL, I., DIDIER, J. Y., POUDEROUX, J. & VAIRON, J. 2012. Outdoor Augmented Reality System For Geological Applications *IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM).* Kaohsiung, Taiwan: IEEE.

ABERDEEN GROUP 2005. The mobile field service solution selection report. Aberdeen Group.

ABERDEEN GROUP 2007. Making Money via Mobile field services. Aberdeen Group.

AGARWAL, R. & PRASAD, J. 1998. The antecedents and consequents of user perceptions in information technology adoption. *Decision Support Systems,* 22**,** 15-29.

AGNIHOTHRI, S., SIVASUBRAMANIAM, N. & SIMMONS, D. 2002. Leveraging technology to improve field service. *International Journal of Service Industry Management,* 13**,** 47-68.

AJZEN, I. 1991. The theory of planned behavior. *Organizational behavior and and human decision processes,* 50**,** 179-211.

AL-GAHTANI, S. S. 2011. Modeling the electronic transactions acceptance using an extended technology acceptance model. *Applied computing and informatics,* 9**,** 47-77.

ALA-RISKU, T. 2009. *Installed Base Information: Ensuring Customer Value and Profitability after the Sale.* Doctoral thesis, Helsinki University of Technology.

ALEKSY, M. & RISSANEN, M. J. 2012. Utilizing wearable computing in industrial service applications. *Journal of ambient intelligence and humanized computing***,** 1-12.

ALEKSY, M. & STIEGER, B. 2009. Challenges in the Development of Mobile Applications in Industrial Field Service. 586-591.

ALEM, L. & HUANG, W. 2011. *Recent Trends of Mobile Collaborative Augmented Reality Systems,* New York, Springer.

ALEM, L., TECCHIA, F. & HUANG, W. 2011a. HandsOn Video: Towards a Gesture based Mobile AR System for Remote Collaboration. *In:* HUANG, L. A. A. W. (ed.) *Recent Trends of Mobile Collaborative Augmented Reality Systems.* Springer.

ALEM, L., TECCHIA, F. & HUANG, W. 2011b. Remote Tele-assistance System for Maintenance Operators in Mines. *11th Underground Coal Operators' Conference.* University of Wollongong & the Australasian Institute of Mining and Metallurgy.

ALLMENDINGER, G. & LOMBREGLIA, R. 2005. Four Strategies for the Age of Smart Services. *Harvard Business Review,* 83**,** 131–145.

ALOINI, D., DULMIN, R. & MININNO, V. 2007. Risk management in ERP project introduction: review of the literature. *Information & Management,* 44**,** 547-567.

ALONSO-RASGADO, T., THOMPSON, G. & ELFSTRÖM, B. O. 2004. The design of functional (total care) products. *Journal of Engineering Design,* 15**,** 515-540.

ANDAL-ANCION, A., CARTWRIGHT, P., A. & YIP, G. S. 2003. The digital transformation of traditional businesses. *MIT Sloan Management Review,* 44**,** 34-41.

ANTIOCO, M., MOENAERT, R. K., LINDGREEN, A. & WETZELS, M. G. M. 2008. Organizational antecedents to and consequences of service business orientations in manufacturing companies. *Journal of the Academy of Marketing Science,* 36**,** 337-358.

ARBUCKLE, J. L. 2011. *IBM SPSS Amos 20 user's guide,* Armonk, NY.

ARTOOLKIT 2.52 http://www.hitl.washington.edu/research/shared_space/download/. *(Last accessed 25/09/2012).*

ARVANITIS, T. N., WILLIAMS, D. D., KNIGHT, J. F., BABER, C., GARGALAKOS, M., SOTIRIOU, S. & BOGNER, F. X. 2011. A Human Factors Study of Technology Acceptance of a Prototype Mobile Augmented Reality System for Science Education. *Advanced Science Letters,* 4**,** 1-11.

ASAI, K. 2010. The Role of Head-Up Display in ComputerAssisted Instruction. *Human-Computer Interaction, New Developments.*

ATZORI, L., IERA, A. & MORABITO, G. 2010. The internet of things: A survey. *Computer Networks,* 54**,** 2787-2805.

AURAMO, J. & ALA-RISKU, T. 2005. Challenges for going downstream. *International Journal of Logistics: Research and Applications,* 8**,** 333-345.

AZPIAZU, J., SILTANEN, S., MULTANEN, P., MÄKIRANTA, A., BARRENA, N., DÍEZ, A., AGIRRE, J. & SMITH, T. 2011. Remote Support for Maintenance Tasks by the Use of Augmented Reality: The ManuVAR Project. *IX Congress in Virtual Reality Applications.* Álava, Spain.

AZUMA, R. 1997. A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments,* 6**,** 355-385.

AZUMA, R., BAILLOT, Y., BEHRINGER, R., FEINER, S., JULIER, S. & MACINTYRE, B. 2001. Recent Advances in Augmented Reality. *Computer Graphics And Applications, IEEE,* 21**,** 34-47.

AZUMA, R. T. 1993. Tracking requirements for augmented reality. *Communications of the ACM,* 36**,** 50-51.

BAGOZZI, R. P. & YI, Y. 1988. On the evaluation structural equation models. *Academic of Marketing Science,* 16**,** 74-94.

BAINES, T. S., LIGHTFOOT, H. W., BENEDETTINI, O. & KAY, J. M. 2009. The servitization of manufacturing: A review of literature and reflection on future challenges. *Journal of Manufacturing Technology Management,* 20**,** 547-567.

BAINES, T. S., LIGHTFOOT, H. W., EVANS, S., NEELY, A., GREENOUGH, R., PEPPARD, J., ROY, R., SHEHAB, E., BRAGANZA, A., TIWARI, A., ALCOCK, J., ANGUS, J., BASTL, M., COUSENS, A., IRVING, P., JOHNSON, M., KINGSTON, J., LOCKETT, H., MARTINEZ, V., MICHELI, P., TRANFIELD, D., WALTON, I. & WILSON, H. 2007. State-of-the-art in product service systems. *Journal of Engineering Manufacture,* 221**,** 1543-1552

BALOG, A. & PRIBEANU, C. 2010. The Role of Perceived Enjoyment in the Students' Acceptance of an Augmented Reality Teaching Platform: a Structural Equation Modelling Approach. *Studies in Informatics and Control* 19**,** 319-330.

BANDURA, A. 1986. *Social foundations of thought and action: a social cognitive theory,* Englewood Cliffs, NJ, Prentice Hall.

BAY, H., ESS, A., TUYTELAARS, T. & VAN GOOL, L. 2008. Speeded-Up Robust Features (SURF). *Computer Vision and Image Understanding,* 110**,** 346-359.

BEHZADAN, A. H. & KAMAT, V. R. 2009. Interactive Augmented Reality Visualization for Improved Damage Prevention and Maintenance of Underground Infrastructure. *Construction Research Congress 2009: Building a Sustainable Future.*

BENBELKACEM, S., BELHOCINE, M., BELLARBI, A., ZENATI-HENDA, N. & TADJINE, M. 2013. Augmented reality for photovoltaic pumping systems maintenance tasks. *Renewable Energy,* 55**,** 428-437.

BENBELKACEM, S., ZENATI, N., BELHOCINE, M., BELLARBI, A., TADJINE, M. & MALEK, S. 2010. Augmented Reality Platform for Solar Systems Maintenance Assistance. *Proceeding of the International Symposium on Environment Friendly Energies in Electrical Applications. In: EFEEA.* Ghardaïa, Algeria.

BENTLER, P. M. 1988. Causal modeling via structural equation systems. *In:* NESSELROADE, J. R. & CATTELL, R. B. (eds.) *Handbook for multivariate experimental psychology.* 2nd ed. New York: Plenum.

BENTLER, P. M. 2004. *EQS structural equations program manual,* Encino, CA, Multivariate Software, Inc.

BERNING, M., RIEDEL, T., KARL, D., SCHANDINAT, F., BEIGL, M. & FANTANA, N. 2012. Augmented service in the factory of the future. *Ninth International Conference on Networked Sensing Systems (INSS).*

BESBES, B., COLLETTE, S. N., TAMAAZOUSTI, M., BOURGEOIS, S. & GAY-BELLILE, V. 2012. An Interactive Augmented Reality System: a Prototype for Industrial Maintenance Training Applications. *International Symposium on Mixed and Augmented Reality* Atlanta, Georgia: IEEE

BHARADWAJ, A. S. 2000. A resource-based perspective on information technology capability and firm performance: an empirical investigation. *MIS Quarterly,* 24**,** 169-196.

BHATIA, S. & VIJUYAKUMAR, P. 2012. Augmented Reality Repair Guidance System. *International Journal of Computer Science Issues,* 9**,** 333-343.

BILLINGHURST, M. & THOMAS, B. H. 2011. Mobile Collaborative Augmented Reality. *In:* ALEM, L. & HUANG, W. (eds.) *Recent Trends of Mobile Collaborative Augmented Reality Systems.* New York: Springer.

BIMBER, O. & RASKAR, R. 2006. Modern approaches to augmented reality. *Technical Report.* Mitsubishi Electric Research Laboratories.

BLUMBERG, D. F. 1994. Strategies for improving field service operations productivity and quality. *The Service Industries Journal,* 14**,** 262-277.

BOLLEN, K. A. 1989. *Structural equations with latent variables,* New York, Wiley.

BOSMA, H., MARMOT, M. G., HEMINGWAY, H., NICHOLSON, A. C., BRUNNER, E. & STANSFELD, S. A. 1997. Low Job Control and Risk of Coronary Heart Disease in Whitehall II (Prospective Cohort) Study. *BMJ: British Medical Journal***,** 558-565.

BOTTECCHIA, S., CIEUTAT, J.-M. & JESSEL, J.-P. 2010a. Experimentation of a New TeleAssistance System Using Augmented Reality. *Virtual Reality International Conference.* Laval, France: Richir Simon, Shirai Akihiko

BOTTECCHIA, S., CIEUTAT, J.-M. & JESSEL, J.-P. 2010b. T.A.C: augmented reality system for collaborative tele-assistance in the field of maintenance through internet. *Augmented Human International Conference.* Megève, France: ACM.

BOTTECCHIA, S., CIEUTAT, J.-M., MERLO, C. & JESSEL, J.-P. 2009. A new AR interaction paradigm for collaborative teleassistance system: The POA. *International Journal on Interactive Design and Manufacturing (IJIDeM),* 3, 35-40.

BOUD, A. C., HANIFF, D. J., BABER, C. & STEINER, S. J. 1999. Virtual reality and augmented reality as a training tool for assembly tasks. *Information Visualization, 1999. Proceedings. 1999 IEEE International Conference on. IEEE.* London.

BOWMAN, D., GABBARD, J. & HIX, D. 2002. A survey of usability evaluations in virtual environments: trade classification and comparison of methods. *Presence: Teleoperators and Virtual Environments,* 11, 404-424.

BOYER, K. K., HALLOWELL, R. & ROTH, A. V. 2002. E-services: operating strategy—a case study and a method for analyzing operational benefits. *Journal of Operations Management* 20, 175-188.

BROWNE, M.-W.-. & MELS, G. 2005. Path Analysis (RAMONA). *SYSTAT 11: Statistics III [computer software and manual].* Richmond, CA: SYSTAT Software, Inc.

BURTON-JONES, A. & HUBONA, G. S. 2006. The mediation of external variables in the technology acceptance model. *Information & Management,* 43, 706-717.

BYRNE, B. M. 2009. *Structural equation modeling with AMOS: Basic concepts, applications, and programming,* USA, Routledge Taylor & Francis Group.

CAMPBELL, C. S., MAGLIO, P. P. & DAVIS, M. M. 2011. From self-service to super-service: a resource mapping framework for co-creating value by shifting the boundary between provider and customer. *Information Systems and e-Business Management,* 9, 173-191.

CARLSSON, C., CARLSSON, J., HYVONEN, K., PUHAKAINEN, J. & WALDEN, P. 2006. Adoption of mobile device/service-searching for answers with the UTAUT. *Proceedings of the 39th Hawaii international conference on system sciences.*

CARMIGNANI, J. & FURHT, B. 2011. Augmented Reality: An overview. *In:* FURHT, B. (ed.) *Handbook of Augmented Reality.* Springer.

CHANG, J.-R., HSU, H.-M. & CHAO, S.-J. 2012. Development of a road monitoring and reporting system based on location-based services and augmented-reality technologies. *Journal of Performance of Constructed Facilities,* 26, 812-823.

CHASE, R. B., AQUILAND, N. J. & JACOBS, R. 1998. *Operations Management for Competitive Advantage,* Boston, MA, McGraw-Hill, Irwin.

CHEN, C.-T. & CHANG, T.-W. 2006. Spatially Augmented Reality Design Environment. *In:* (EDS.), J. P. V. L. A. H. J. P. T. (ed.) *Innovations in Design & Decision Support Systems in Architecture and Urban Planning*

CHEOK, A. D., GOH, K. H., LIU, W., FARBIZ, F., FONG, S. W., TEO, S. L., LI, Y. & YANG, X. 2004. Human Pacman: a mobile, wide-area entertainment system based on physical, social, and ubiquitous computing. *Personal and Ubiquitous Computing,* 8, 71-81.

CHEONG, G. W. & RENSVOLD, R. B. 2002. Evaluating goodness-of-fit indexes for testing measurement invariance. *Structural equation modelling: a multidisciplinary journal,* 9, 233-255.
CHIA, K. W., CHEOK, A. D. & PRINCE, S. J. D. 2002. Online 6 DOF augmented reality registration from natural features. *Mixed and Augmented Reality, 2002. ISMAR 2002. Proceedings. International Symposium on.*
COHEN, M. & WHANG, S. 1997. Competing in product and service: A product life-cycle model. *Management Science,* 43, 535-545.
COHEN, M. A., AGRAWAL, N. & AGRAWAL, V. 2006. Winning in the Aftermarket. *Harvard Business Review,* 84, 129–138.
COMPORT, A. I., MARCHAND, É. & CHAUMETTE, F. 2003. A real-time tracker for markerless augmented reality. *Proceedings of the 2nd IEEE/ACM International Symposium on Mixed and Augmented Reality. ISMAR '03*
CORSO, M., MARTINI, A., PELLEGRINI, L., MASSA, S. & TESTA, S. 2006. Managing dispersed workers: the new challenge in Knowledge Management. *Technovation,* 26, 583-594.
DAVIES, A. 2004. Moving base into high-value integrated solutions: A value stream approach. *Industrial and Corporate Change,* 13, 727-756.
DAVIS, F. D. 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly,* 13, 319-340.
DAVIS, F. D., BAGOZZI, R. P. & WARSHAW, P. R. 1989. User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Management Science,* 35, 982-1003.
DAVIS, F. D., BAGOZZI, R. P. & WARSHAW, P. R. 1992. Extrinsic and intrinsic motivation to use computers in the workplace. *Journal of applied social psychology,* 22, 1111-1132.
DE CRESCENZIO, F., FANTINI, M., PERSIANI, F., DI STEFANO, L., AZZARI, P. & SALTI, S. 2011. Augmented Reality for Aircraft Maintenance Training and Operations Support. *IEEE, Computer Graphics and Applications.*
DE SILVA, F. & MCNEE, S. 2011. Printer/MFP Magic Quadrant. Gartner, Inc.
DE SILVA, F., MCNEE, S. & TRIPATHI, V. 2010. Magic Quadrant for MFPs and Printers. Gartner Inc.
DIDIER, J., ROUSSEL, D., MALLEM, M., OTMANE, S., NAUDET, S., PHAM, Q. & BOURGEOIS, S. AMRA: Augmented Reality assistance in train maintenance tasks. Workshop Industrial Augmented Reality, 4th ACM/IEEE International Symposium on Mixed and Augmented Reality, 2005 Vienna, Austria.
DIERICKX, I. & COOL, K. 1990. A resource based perspective on competitive strategy. Mimeo INSEAD.
DISHAW, M. T. & STRONG, D. M. 1999. Extending the technology acceptance model with task-technology fit constructs. *Information & Management,* 36, 9-21.
DOVE, R. 1999. Knowledge management, response ability, and the agile enterprise. *Journal of Knowledge Management,* 3, 18-35.
DUTTA, S. 2012. Field Service 2012: Mobile Tools for the Right Technician. Aberdeen Group.
DUTTA, S. & PINDER, A. J. 2012. Field service 2012: the right technician. Aberdeen Group.
EFTHYMIOU, K., PAPAKOSTAS, N., MOURTZIS, D. & CHRYSSOLOURIS, G. 2012. On a Predictive Maintenance Platform for Production Systems. *Procedia CIRP,* 3, 221-226.

EISENHARDT, K. M. 1989. Building theories from case study research. *The Academy of Management Review,* 14**,** 532-550.

EL CHOUBASSI, M., NESTARES, O., WU, Y., KOZINTSEV, I. & HAUSSECKER, H. 2010. An augmented reality tourist guide on your mobile devices. *In:* BOLL, S., TIAN, Q., ZHANG, L., ZHANG, Z. & CHEN, Y.-P. P. (eds.) *Advances in Multimedia Modeling - 16th International Multimedia Modeling Conference, (MMM 2010).* Chongqing, China: Springer Berlin Heidelberg.

ESPÍNDOLA, D. B., FUMAGALLI, L., GARETTI, M., PEREIRA, C. E., BOTELHO, S. S. C. & VENTURA HENRIQUES, R. 2013. A model-based approach for data integration to improve maintenance management by mixed reality. *Computer in Industry,* http://dx.doi.org/10.1016/j.compind.2013.01.002.

FANG, R.-J., LEE, C.-P., LOU, S.-J., TSAI, H.-L. & YANG, H.-J. 2008. Developing a model of online learning-technology acceptance model (TAM). *American conference of applied mathematics (MATH'08).* Harvard, Massachusetts USA.

FEINER, S., MACINTYRE, B., HÖLLERER, T. & WEBSTER, A. 1997. A touring machine: Prototyping 3D mobile augmented reality systems for exploring the urban environment. *Personal Technologies,* 1**,** 208-217.

FEINER, S., MACINTYRE, B. & SELIGMANN, D. 1993. Knowledge-based augmented reality. *Communications of the ACM,* 36**,** 53-62.

FENN, J. & LEHONG, H. 2011. Hype Cycle for Emerging Technologies, 2011. Gartner.

FERRARI, V., TUYTELAARS, T. & VAN GOOL, L. 2001. Markerless augmented reality with a real-time affine region tracker. *IEEE and ACM International Symposium on Augmented Reality, 2001.* New York, NY.

FISHBEIN, M. & AJZEN, I. 1975. *Belief, Attitude, Intention and Behaviour: An Introduction to Theory and Research*, Addison-Wesley.

FLYNN, B. B., SAKAKIBARA, S., SCHROEDER, R. G., BATES, K. A. & FLYNN, E. J. 1990. Empirical research methods in operations management. *Journal of operations management,* 9**,** 250-284.

FORNELL, C. R. & LARCKER, D. F. 1981. Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research***,** 39-50.

FRIEDRICH, W., JAHN, D. & SCHMIDT, L. 2002. ARVIKA Augmented Reality for development, production, and service. *Proceedings of the IEEE/ACM International Symposium on Mixed and Augmented Reality, ISMAR 2002.*

FROEHLE, C. M. & ROTH, A. V. 2004. New measurement scales for evaluating perceptions of the technology-mediated customer service experience. *Journal of Operations Management,* 22**,** 1-21.

FUCHS, H., LIVINGSTON, M. A., RASKAR, R., COLUCCI, D. N., KELLER, K., STATE, A., CRAWFORD, J. R., RADEMACHER, P., DRAKE, S. H. & MEYER MD, A. A. 1998. Augmented reality visualization for laparoscopic surgery. *In:* WELLS, W. M., COLCHESTER, A. & DELP, S. (eds.) *Medical Image Computing and Computer-Assisted Interventation — MICCAI'98.*

GARVIN, D. A. 1993. Manufacturing strategic planning. *California Management Review,* 35**,** 85-106.

GEBAUER, H. 2008. Identifying service strategies in product manufacturing companies by exploring environment-strategy configurations. *Industrial Marketing Management,* 37, 278-291.

GEBAUER, H., KREMPL, R. & FLEISCH, E. 2008a. Service development in traditional product manufacturing companies. *European Journal of Innovation Management,* 11, 219-240.

GEBAUER, H., KREMPL, R., FLEISCH, E. & FRIEDLI, T. 2008b. Innovation of product-related services. *Managing Service Quality,* 18, 387-404.

GEBAUER, J. & GINSBURG, M. 2006. Exploring the black box of task-technology fit: the case of mobile information systems. *Proceedings of WeB: Workshop on e-Business.*

GEBAUER, J., SHAW, M. & GRIBBINS, M. 2004. Usage and impact of mobile business applications - An assessment based on the concepts of task/technology fit. *Proceedings of AMCIS American conference on information systems.*

GEBAUER, J. & TANG, Y. 2007. Applying the theory of task-technology fit to mobile technology: the role of user mobility. *International Journal of Mobile Communications,* 6, 321-344.

GEFEN, D. & KEIL, M. 1998. The impact of developer responsiveness on perceptions of usefulness and ease of use: an extension of the technology acceptance model. *The DATA BASE for advances in information systems,* 29, 35-49.

GEFEN, D. & STRAUB, D. W. 2000. The Relative Importance of Perceived Ease of Use in IS Adoption: A Study of E-Commerce Adoption. *Journal of the Association for Information Systems,* 1, 1-30.

GHOSHAL, S. & BARTLETT, C. 1996. Release the entrepreneurial hostage from your corporate hierarchy. *Strategy and Leadership,* 24, 36-43.

GOLDMAN, S. L., NAGEL, R. N. & PREISS, K. 1995. *Agile competitors and virtual organizations: strategies for enriching the customer,* New York, Van Nostrand Reinhold.

GOODHUE, D. L. & THOMPSON, R. L. 1995. Task-Technology Fit and Individual Performance. *MIS Quarterly,* 19, 213-236.

GRÖNROOS, C. 2008. Service logic revisited: who creates value? And who co-creates? *European Business Review,* 20, 298-314.

GRUBIC, T., REDDING, L., BAINES, T. & JULIEN, D. 2011. The adoption and use of diagnostic and prognostic technology within UK-based manufacturers. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture,* 225, 1457-1470.

HAIR, J. F., ANDERSON, R. E., TATHAM, R. L. & BLACK, W. C. 1998. *Multivariate data analysis (5th edition),* Englewood Cliffs, NJ, Prentice-Hall.

HAMEL, G. & PRAHALAD, C. K. 1994. *Competingfor the future,* Boston, MA, Harvard Business School Press.

HAMID, A. K. A., ZHU, W., KAWAHARA, Y. & TOHRU, A. Design and Implementation of an AR-Assisted Tool for Basic Home Network Management. IEEE/IPSJ International Symposium on Applications and the Internet, 2011. 208-213.

HARITOS, T. & MACCHIARELLA, N. D. 2005. A mobile application of augmented reality for aerospace maintenance training. *Digital Avionics Systems Conference, 2005. DASC 2005. The 24th. IEEE.*

HAUGSTVEDT, A.-C. & KROGSTIE, J. 2012. Mobile augmented reality for cultural heritage: A technology acceptance study. *IEEE International Symposium on Mixed and Augmented Reality (ISMAR).*

HEIM, G. R. & SINHA, K. K. 2001. A Product-Process Matrix for Electronic B2C Operations Implications for the Delivery of Customer Value. *Journal of Service Research,* 3**,** 286-299.

HENDERSON, S. J. & FEINER, S. 2009. Evaluating the Benefits of Augmented Reality for Task Localization in Maintenance of an Armored Personnel Carrier Turret. *Mixed and Augmented Reality, 2009. ISMAR 2009. 8th IEEE International Symposium on.* IEEE.

HENDERSON, S. J. & FEINER, S. 2010. Opportunistic Tangible User Interfaces for Augmented Reality. *Visualization and Computer Graphics, IEEE Transactions on* 16**,** 4-16.

HENDERSON, S. J. & FEINER, S. 2011. Exploring the benefits of augmented reality documentation for maintenance and repair. *IEEE Transactions on Visualization and Computer Graphics,* 17**,** 1355-1368.

HENDERSON, S. J. & FEINER, S. K. 2007. Augmented Reality for Maintenance and repair (ARMAR). *Columbia University, New York, Dept of Computer Science*.

HENRYSSON, A., BILLINGHURST, M. & OLLILA, M. 2005. Face to face collaborative AR on mobile phones. *Fourth IEEE/ACM International Symposium on Mixed and Augmented Reality (ISMAR 2005).* Vienna, Austria.

HÖLLERER, T. H. & FEINER, S. K. 2004. Mobile Augmented Reality. *In:* H., K. & A., H. (eds.) *Telegeoinformatics: Location-Based Computing and Services.* London, UK: Taylor & Francis Books Ltd.

HOLLNAGEL, E. & WOODS, D. D. 2005. *Joint cognitive systems: Foundations of cognitive systems engineering,* Boca Raton, FL, CRC Press, Taylor & Francis Group.

HOMBURG, C., HOYER, W. D. & FASSNACHT, M. 2002. Service orientation of a retailer's business strategy: dimensions, antecedents and performance outcomes. *Journal of Marketing,* 66**,** 86-101.

HU, L.-T. & BENTLER, P. M. 1995. Evaluating model fit. *In:* HOYLE, R. H. (ed.) *Structural equation modeling: Concept, issues, and applications.* Thousand Oaks, CA: Sage.

HU, L.-T. & BENTLER, P. M. 1999. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural equation modeling,* 6**,** 1-55.

ISHII, H., BIAN, Z., FUJINO, H., SEKIYAMA, T., NAKAI, T., OKAMOTO, A., SHIMODA, H., IZUMI, M., KANEHIRA, Y. & MORISHITA, Y. 2007. Augmented Reality Applications for Nuclear PowerPlant Maintenance work. *International Symposium on Symbiotic Nuclear Power Systems for 21st Century.*

JACKSON, C. 2013. Augmented Reality: How has it Changed in 2013? . *Augmented Reality Trends* [Online]. Available from: http://www.augmentedrealitytrends.com/augmented-reality/augmented-reality-how-has-it-changed-in-2013.html 21 Dec. 2013].

JOHANSSON, P. & OLHAGER, J. 2006. Linking product–process matrices for manufacturing and industrial service operations. *International Journal of Production Economics,* 104**,** 615-624.

JOHNSON, M. & MENA, C. 2008. Supply chain management for servitised products: a multi-industry case study. *International Journal of Production Economics,* 114**,** 27-39.

JÖRESKOG, K. G. 1971. Simultaneous factor analysis in several populations. *Psychometrika,* 36, 409-426.

JÖRESKOG, K. G. 1993. Testing structural equation models. *In:* BOLLEN, K. A. & LONG, J. S. (eds.) *Testing structural equation models.* Newbury Park, CA: Sage.

JÖRESKOG, K. G. & SÖRBOM, D. 1993. *LISREL8: User's reference guide,* Chicago, IL, Scientific Software Inc.

JÖRESKOG, K. G. & SÖRBOM, D. 1999. *LISREL8.30: User's reference guide* Chicago, IL, Scientific Software, Inc.

KAN, T.-W., TENG, C.-H. & WEN-SHOU, C. 2009. Applying QR code in augmented reality applications. *Proceedings of the 8th International Conference on Virtual Reality Continuum and its Applications in Industry.* Tokyo, Japan: ACM.

KANG, B., REN, P. & KE, C. 2006. An Augmented Reality System for Computer Maintenance. *ICAT 2006.*

KATO, H. & BILLINGHURST, M. 1999. Marker tracking and HMD calibration for a video-based Augmented Reality conferencing system. *Augmented Reality, 1999.(IWAR'99) Proceedings. 2nd IEEE and ACM International Workshop on. IEEE.* CA, USA.

KAUFMANN, H. & SCHMALSTIEG, D. 2003. Mathematics and geometry education with collaborative augmented reality. *Computers & Graphics,* 27, 339-345.

KEARNEY, A. 2004. Transforming field-service operations.

KEIL, M., BERANEK, P. M. & KONSYNSKI, B. R. 1995. Usefulness and ease of use: field study evidence regarding task considerations. *Decision Support Systems,* 13, 75-91.

KLEIBER, M. & ALEXANDER, T. 2011. Evaluation of a Mobile AR Tele-Maintenance system. *In:* STEPHANIDIS, C. (ed.) *Universal access in human-computer interaction. Application and services.*: Springer.

KLOPPING, I. M. & MCKINNEY, E. M. 2004. Extending the technology acceptance model and the task-technology fit model to consumer e-commerce. *Information technology learning and performance journal,* 22, 35-48.

KOWALKOWSKI, C., KINDSTRÖM, D. & GEBAUER, H. 2013. ICT as a catalyst for service business orientation. *Journal of Business & Industrial Marketing,* 28, 506-513.

KUO, Y.-F. & YEN, S.-N. 2009. Towards an understanding of the behavioral intention to use 3G mobile value-added services. *Computers in Human Behavior,* 25, 103-110.

LEE, J.-M., LEE, K.-H., KIM, D.-S. & KIM, C.-H. 2010a. Active inspection supporting system based on mixed reality after design and manufacture in an offshore structure. *Journal of Mechanical Science and Technology,* 24, 197-202.

LEE, J., HAN, S. & YANG, J. 2011. Construction of a computer-simulated mixed reality environment for virtual factory layout planning. *Computers in Industry,* 62, 86-98.

LEE, S.-L., HUNTBATCH, A., PRATT, P., M., L. & YANG, G.-Z. 2010b. In vivo and in situ image guidance and modelling in robotic assisted surgery. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science,* 244, 1421-1434.

LEE, S. & AKIN, Ö. 2011. Augmented reality-based computational fieldwork support for equipment operations and maintenance. *Automation in Construction,* 20, 338-352.

LEVRAT, E., IUNG, B. & CRESPO MARQUEZ, A. 2008. E-maintenance: review and conceptual framework. *Production Planning and Control,* 19, 408-429.

LI, Y., QI, J. & SHU, H. 2008. Review of Relationships Among Variables in TAM. *Tsinghua Science & Technology,* 13, 273-278.

LILLRANK, P. M. & KANŌ, N. 1989. *Continuous improvement: Quality control circles in Japanese industry*, Center for Japanese Studies, the University of Michigan.

LIN, T.-C. & HUANG, C.-C. 2008. Understanding knowledge management system usage antecedents: An integration of social cognitive theory and task technology fit. *Information & Management,* 45, 410-417.

LINDINGER, C., HARING, R., HÖRTNER, H., KUKA, D. & KATO, H. 2006. Multi-user mixed reality system 'Gulliver's World': a case study on collaborative edutainment at the intersection of material and virtual worlds. *Virtual Reality,* 10, 109-118.

LIVINGSTON, M. A., ROSENBLUM, L. J., BROWN, D. G., SCHMIDT, G. S., JULIER, S. J., BAILLOT, Y., SWAN II, J. E., AI, Z. & MAASSEL, P. 2011. Military Applications of Augmented Reality. *In:* FURTH, B. (ed.) *Handbook of Augmented Reality.* Springer New York.

LOWE, D. G. 2004. Distinctive Image Features from Scale-Invariant Keypoints. *International Journal of Computer Vision,* 60, 91-110.

LUUKKAINEN, M. 2009. Plant model based services for nomadic users. *In:* VÄHÄ, P. (ed.) *Scientific activities in service science and business.* VTT - Technical Research Center of Finland 2009.

MACCALLUM, R. C., BROWNE, M. W. & SUGAWARA, H. M. 1996. Power analysis and determination of sample size for covariance stucture modeling. *Psychological Methods,* 1, 130-149.

MAGLIO, P. P., VARGO, S. L., CASWELL, N. & SPOHRER, J. 2009. The service system is the basic abstraction of service science. *Information Systems and e-Business Management,* 7, 395-406.

MARTÍN-GUTIERREZ, J. & SANTOS PÉREZ, I. I. 2011. Augmented Reality Approach to Domestic Maintenance Tasks. *In:* STEPHANIDIS, C. (ed.) *Communications in Computer and Information Science, 14th International Conference on Human-Computer Interaction, HCI International 2011.* Orlando, FL.

MATHIEU, V. 2001a. Product services: from a service supporting the product to a service supporting the client. *Journal of Business & Industrial Marketing,* 16, 39-61.

MATHIEU, V. 2001b. Service strategies within the manufacturing sector: benefits costs and partnership. *International Journal of Service Industry Management,* 5, 451-475.

MCAFEE, A. 2004. Do you have too much IT? *MIT Sloan Management Review,* 45, 18-22.

MCKENNA, B., TUUNANEN, T. & GARDNER, L. 2013. Consumers' Adoption of Information Services. *Information & Management,* 50, 248-257.

MCKINLEY, R. K., MANKU-SCOTT, T., HASTINGS, A. M., FRENCH, D. P. & BAKER, R. 1997. Reliability and Validity of a New Measure of Patient Satisfaction with out of Hours Primary Medical Care in the United Kingdom: Development of a Patient Questionnaire. *BMJ: British Medical Journal* 193-198.

MEIER, H., ROY, R. & SELIGER, G. 2010. Industrial Product-Service Systems-IPS2. *CIRP Annals - Manufacturing Technology,* 59, 607-627.

MEREDITH, J. 1993. Theory building through conceptual models. *International Journal of Operations & Production Management,* 13, 3-11.

MEREDITH, J. 1998. Building operations management theory through case and field research. *Journal of Operations Management,* 16, 441-454.

MEYER, G. G., FRÄMLING, K. & HOLMSTRÖM, J. 2009. Intelligent Products: A survey. *Computers in Industry,* 60, 137-148.

MILGRAM, P. & KISHINO, F. 1994. A taxonomy of mixed reality visual displays. *IEICE Transactions on Information Systems,* 77, 1321–1329.

MIN, Q., JI, S. & QU, G. 2008. Mobile commerce user acceptance study in China: a revised UTAUT model. *Tsinghua Science & Technology,* 13, 257-264.

MIYASHITA, T., MEIER, P., TACHIKAWA, T., ORLIC, S., EBLE, T., SCHOLZ, V., GAPEL, A., GERL, O., ARNAUDOV, S. & LIEBERKNECHT, S. An Augmented Reality Museum Guide. 7th IEEE/ACM International Symposium on Mixed and Augmented Reality, 2008. 103-106.

MÖHRING, M., LESSIG, C. & BIMBER, O. 2004. Video see-through AR on consumer cell-phones. *Third IEEE/ACM International Symposium on Mixed and Augmented Reality (ISMAR 2004).* Arlington, VA USA.

MULLEN, T. 2011. *Prototyping augmented reality,* Indianapolis, Indiana, John Wiley & Sons Inc.

MUTHÉN, L. K. & MUTHÉN, B. O. 2004. *Mplus User's guide,* Los Angeles CA, Muthén & Muthén.

MUZYKA, D., DE KONING, A. & CHURCHILL, N. 1995. On transformation and adaptation: building the enterpreneurial corporation. *European Management Journal,* 13, 346-362.

NAIMARK, L. & FOXLIN, E. 2002. Circular Data Matrix Fiducial System and Robust Image Processing for a Wearable Vision-Inertial Self-Tracker. *Proceedings of the 1st International Symposium on Mixed and Augmented Reality. ISMAR '02. IEEE Computer Society.*

NAVAB, N., TRAUB, J., SIELHORST, T., FEUERSTEIN, M. & BICHLMEIER, C. 2007. Action- and Workflow-Driven Augmented Reality for computer aided medical procedure. *Computer Graphics and Applications, IEEE* 27, 10-14.

NEE, A. Y. C., ONG, S. K., CHRYSSOLOURIS, G. & MOURTZIS, D. 2012. Augmented reality applications in design and manufacturing. *CIRP Annals - Manufacturing Technology*.

NEELY, A. 2008. Exploring the financial consequences of the servitization of manufacturing. *Operations Management Research,* 1, 103-118.

NEU, W. A. & BROWN, S. W. 2005. Forming successful business-to-business services in goods-dominant firms. *Journal of Service Research,* 8, 3-17.

NILSSON, S. & JOHANSSON, B. 2007. Fun and usable: augmented reality instructions in a hospital setting. *Proceedings of the 19th Australasian conference on Computer-Human Interaction: Entertaining User Interfaces. ACM.*

NUNNALLY, J. C. 1978. *Psychometric theory,* New York NY, McGraw-Hill.

OCÉ N.V. 2011. Annual Report 2011 - Océ N.V.

OLIVA, R. & KALLENBERG, R. 2003. Managing transition from products to services. *International Journal of Service Industry Management,* 14, 160-172.

OLIVEIRA, P., ROTH, A. V. & GILLAND, W. 2002. Achieving competitive capabilities in e-services. *Technological Forecasting and Social Change,* 69, 721-739.

OLSSON, T. 2012. *User expectations and experiences of mobile augmented reality services.* PhD Thesis, Tampere University of Technology.

OLSSON, T. & SALO, M. 2011. Online user survey on current mobile augmented reality applications. *Proceedings of10th IEEE International Symposium on Mixed and Augmented Reality (ISMAR).*

OLWAL, A. & HENRYSSON, A. 2007. LUMAR: A hybrid spatial display system for 2D an 3D handheld augmented reality. *Advances in Artificial Reality and Tele-Existence, 17th International Conference on Artificial Reality and Telexistence (ICAT 2007).* Esbjerg, Denmark.

PAGANI, M. 2006. Determinants of adoption of high speed data services in the business market: evidence for a combined technology acceptance model with task technology fit model. *Information & management,* 43**,** 847-860.

PAPAGIANNAKIS, G., SINGH, G. & MAGNENAT-THALMANN, N. 2008. A survey of mobile and wireless technologies for augmented reality systems. *Computer Animation and Virtual Worlds,* 19**,** 3-22.

PARK, H., MOON, H.-C. & LEE, J. Y. 2009. Tangible augmented prototyping of digital handheld products. *Computers in Industry,* 60**,** 114-125.

PARK, J., YANG, S. & LEHTO, X. 2007. Adoption of mobile technologies for Chinese consumers. *Journal of electronic commerce research,* 8**,** 196-206.

PAZ, A., GUENAGA, M. L. & EGUÍLUZ, A. 2012. Augmented Reality for maintenance operator training using SURF points and homography. *9th International Conference on Remote Engineering and Virtual Instrumentation (REV).* Bilbao (Spain).

PERROW, C. 1967. A Framework for the Comparative Analysis of Organizations. *American Sociological Review,* 32**,** 194-208.

PLATONOV, J., HEIBEL, H., MEIER, P. & GROLLMANN, B. 2006. A mobile markerless AR system for maintenance and repair. *Proceedings of the 5th IEEE and ACM International Symposium on Mixed and Augmented Reality.* IEEE Computer Society.

PORCELLI, I., RAPACCINI, M., ESPINDOLA, D. & PEREIRA, C. E. 2013a. Technical and Organizational Issues about the Introduction of Augmented Reality in Maintenance and Technical Assistance Services. *Intelligent Manufacturing Systems,* 11**,** 257-262.

PORCELLI, I., RAPACCINI, M., ESPÍNDOLA, D. B. & PEREIRA, C. E. 2013b. Innovating product-service systems through Augmented Reality: a selection model. *In:* SHIMOMURA, Y. & KIMITA, K. (eds.) *The Philosopher's Stone for Sustainability.* Springer Berlin Heidelberg.

PORTER, M. E. 1980. *Competitive Strategy: Techniques for Analyzing Industries and Competitors,* New York, The Free Press.

PORTER, M. E. 2001. The value chain and competitive advantage. *Understanding Business Processes.* 1st edn., Routledge.

PORTER, M. E. & MILLAR, V. E. 1985. How information gives you competitive advantage. *Harvard Business Review,* 63**,** 149-160.

PRIBEANU, C. 2011. Towards a hierarchical model for the perceived quality of an augmented reality platform. *Proceedings of 1st European Workshop on HCI Design and Evaluation.*

RANASINGHE, D. C., HARRISON, M., FRÄMLING, K. & MCFARLANE, D. 2011. Enabling through life product-instance management: Solutions and challenges. *Journal of Network and Computer Applications,* 34**,** 1015-1031.

RAPACCINI, M., SACCANI, N., PEZZOTTA, G., BURGER, T. & GANZ, W. 2012. Service development in product-service systems: a maturity model. *The Service Industries Journal*.

RAPACCINI, M. & VISINTIN, F. 2008. A conceptual model for selecting mobile & wireless solutions in field-services. *Modern Information Technology in the Innovation Processes (MITIP).* Prague, Czech Republic (CZ).

RASIMAH, C. M. Y., ZAMAN, H. B. & AHMAD, A. 2011. Evaluation of user acceptance of mixed reality technology. *Australasian Journal of Educational Technology* 27, 1369-1387.

RAYKOV, T. & MARCOULIDES, G. A. 2006. *A First Course in Structural Equation Modeling - Second Edition,* New Jersey, USA, Lawrence Erlbaum Associates, Inc.

REGENBRECHT, H. 2006. Industrial Augmented Reality Applications. *Industrial Augmented Realities Applications*.

REINHART, G. & EURSCH, A. 2008. A camera-based support system with augmented reality functions for manual tasks in radioactive production environments. *Production Engineering,* 2, 139-147.

REITMAYR, G. & DRUMMOND, T. W. 2006. Going out: robust model-based tracking for outdoor augmented reality. *IEEE/ACM International Symposium on Mixed and Augmented Reality, 2006. ISMAR 2006.* Santa Barbard, CA.

REITMAYR, G. & SCHMALSTIEG, D. 2003. Location based applications for mobile augmented reality. *Proceedings of the Fourth Australasian user interface conference on User interfaces.* Australian Computer Society, Inc.

RHEINGOLD, H. 1991. *Virtual Reality*, Summit Books.

ROGERS, E. 1995. *Diffusion of innovations,* New York, Free Press.

ROSENBERG, L. B. 1992. The Use of Virtual Fixtures as Perceptual Overlays to Enhance Operator Performance in Remote Environments. *Airforce Material command.*

ROTH, A. V. 2000. Service strategy and the technological revolution: The 7 myths of e-services. *In:* MACHUCA, J. A. D. & MANDAKOVIC, T. (eds.) *POM Facing the New Millennium: Evaluating the Past, Leading with the Present and Planning the Future of Operations. POM.* Sevilla.

ROTH, A. V. & MENOR, L. J. 2003. Insight into service operations management: a research agenda. *Production and Operations Management,* 12, 145-164.

RUST, R. T. 2004. If everything is service, why is this happening now, and what difference does it make? *Journal of Marketing,* 68, 23-24.

SACCANI, N., VISINTIN, F. & RAPACCINI, M. 2013. Investigating the linkages between service types and supplier relationships in servitized environments. *International Journal of Production Economics,* http://dx.doi.org/10.1016/j.ijpe.2013.10.001.

SACCO, M., MOTTURA, S., GRECI, L. & VIGAN, G. High values shoes and accessories. Institute of Industrial Technologies and Automation, National Research Council, Italy.

SAMPSON, S. E. 2012. Visualizing service operations. *Journal of Service Research,* 15, 182-198.

SAS 1989. *SAS PROC CALIS User's guide,* Cary, NC, Author.

SCHALL, G., MENDEZ, E., KRUIJFF, E., VEAS, E., JUNGHANNS, S., REITINGER, B. & SCHMALSTIEG, D. 2009. Handheld Augmented Reality for underground infrastructure visualization. *Personal and Ubiquitous Computing,* 13, 281-291.

SCHMENNER, R. W. 2009. Manufacturing, service, and their integration: some history and theory. *International Journal of Operations & Production Management,* 29**,** 431-443.
SCHOENFELDER, R. & SCHMALSTIEG, D. 2008. Augmented Reality for Industrial Building Acceptance. *IEEE Virtual Reality Conference (VR '08).*
SCHWALD, B. & DE LAVAL, B. 2003. An Augmented Reality System for Training and assistance to maintenance in the industrial context. *Journal of WSCG,* 11.
SCHWERDTFEGER, B. 2010. *Pick-by-vision: Bringing hmd-based augmented reality into the warehouse.* PhD Thesis, Techn. Univ.
SCHWIEREN, J. & VOSSEN, G. 2010. ID-Services: an RFID middleware architecture for mobile applications. *Information Systems Frontiers,* 12**,** 529-539.
SENGUPTA, K. & MASINI, A. 2008. IT agility: striking the right balance. *Business Strategy Review,* 19**,** 42-48.
SHANKAR, V., BERRY, L. L. & DOTZEL, T. 2009. A Practical Guide to Combining Products and Services. *Harvard Business Review,* 87**,** 94-99.
SHEN, J. & EDER, L. B. 2009. Exploring intention to use virtual worlds for business. *Journal of electronic commerce research,* 10**,** 94-103.
SHIH, Y.-Y. & CHEN, C.-Y. 2013. The study of behavioral intention for mobile commerce: via integrated model of TAM and TTF. *Quality & Quantity,* 47**,** 1009-1020.
SIELHORST, T., FEUERSTEIN, M. & NAVAB, N. 2008. Advanced Medical Displays: A Literature Review of Augmented Reality. *Journal of Display Technology,* 4**,** 451-467.
SIELHORST, T., OBST, T., BURGKART, R., RIENER, R. & NAVAB, N. 2004. An augmented reality delivery simulator for medical training. *International Workshop on Augmented Environments for Medical Imaging - MICCAI Satellite Workshop.*
SILTANEN, P., YLIKERÄLÄ, M. & KUUKKANEN, H. 2009. Work order and task guidance integration for mobile maintenance applications. *15th International Conference on Concurrent Enterprising (ICE2009).* Leiden, The Netherlands.
SLACK, N., LEWIS, M. & H., B. 2004. The two worlds of operations management research and practice: Can they meet, should they meet? *International Journal of Operations and Pro-duction Management,* 24**,** 372-387.
SMITH, L., NG, I. & MAULL, R. 2012. The three value proposition cycles of equipment-based service. *Planning & Control: The Management of Operations,* 23**,** 553-570.
SPOHRER, J. & MAGLIO, P. P. 2010. Service science: Toward a smarter planet. *In:* KARWOWSKI W., S. G. (ed.) *Introduction to service engineering.* New York: Wiley.
STATISTICA 1998. *User's guide,* Tulsa, OK, Statistica, Inc.
STUART, I., MCCUTCHEON, D., HANDFIELD, R., MCLACHLIN, R. & SAMSON, D. 2002. Effective case research in operations management: a process perspective. *Journal of Operations Management,* 20**,** 419-433.
STUTZMAN, B., NILSEN, D., BRODERICK, T. & NEUBERT, J. 2009. MARTI: Mobile Augmented Reality Tool for Industry. *World Congress on Computer Science and Information Engineering (WRI).*
SUTHERLAND, I. 1968. A Head-Mounted Three-Dimensional Display. *Proceedings of the December 9-11, 1968, fall joint computer conference, part I. ACM.*
SWAN, J. E. I. & GABBARD, J. 2005. Survey of user-based experimentation in augmented reality. *1st International Conference on Virtual Reality.* Las Vegas, Nevada.

SZAJNA, B. 1996. Empirical evaluation of the revised technology acceptance model. *Management Science,* 42, 85-92.

TAN, A. R., MATZEN, D., MCALOONE, T. C. & EVANS, S. 2010. Strategies for designing and developing services for manufacturing firms. *CIRP Journal of Manufacturing Science and Technology,* 3, 90-97.

TAYLOR, S. & TODD, P. A. 1995. Assessing IT usage: the role of prior experience. *MIS Quarterly,* 19, 561-570.

TERZIS, V. & ECONOMIDES, A. A. 2011. Computer based assessment: Gender differences in perceptions and acceptance. *Computers in Human Behavior,* 27, 2108-2122.

TJAHJONO, B. 2009. Supporting shop floor workers with a multimedia task-oriented information system. *Computers in Industry,* 60, 257-265.

TRAN, G. 2011. *Mediating mediums* [Online]. http://vimeo.com/24860709. [Accessed 14/11/2013.

TUKKER, A. 2004. Eight types of product-service system: eight ways to sustainability? Experiences from SusProNet. *Business Strategy and the Environment,* 13, 246-260.

TUMLER, J., MECKE, R., SCHENK, M., HUCKAUF, A., DOIL, F., PAUL, G., PFISTER, E. A., BOCKELMANN, I. & ROGGENTIN, A. 2008. Mobile Augmented Reality in industrial applications: Approaches for solution of user-related issue. *IEEE International Symposium on Mixed and Augmented Reality* Cambridge, UK.

ULAGA, W. & REINARTZ, W. J. 2011. Hybrid Offerings: How Manufacturing Firms Combine Goods and Services Successfully. *Journal of Marketing,* 75, 5-23.

URBAN, E. C. 1995. The information warrior. *IEEE Spectrum,* 32, 66-70.

USORO, A., SHOYELU, S. & KUOFIE, M. 2010. Task-Technology Fit and Technology Acceptance Models applicability to e-Tourism. *Journal of economic development, management, IT, finance and marketing,* 2, 1-32.

VAN KREVELEN, D. W. F. & POELMAN, R. 2010. A Survey of Augmented Reality Technologies, Applications and Limitations. *The International Journal of Virtual Reality,* 9, 1-20.

VANDERMERWE, S. & RADA, J. 1988. Servitization of business: Adding value by adding services. *European Management Journal,* 6, 314-324.

VARGO, S. L. & LUSCH, R. F. 2004. Evolving to a New Dominant Logic for Marketing. *Journal of Marketing,* 68, 1-17.

VENKATESH, V. & BALA, H. 2008. Technology Acceptance Model 3 and a research agenda on interventions. *Decision Sciences,* 39, 273-315.

VENKATESH, V. & DAVIS, F. D. 1996. A model of the antecedents of perceived ease of use: development and test. *Decision Sciences,* 27, 451-481.

VENKATESH, V. & DAVIS, F. D. 2000. A theoretical extension of the technology acceptance model: four longitudinal field studies. *Management Science,* 45, 186-204.

VENKATESH, V. & MORRIS, M. G. 2000. Why don't men ever stop to ask for directions? Gender, social influence, and their role in technology acceptance and user behavior. *MIS Quarterly,* 24, 115-139.

VENKATESH, V., MORRIS, M. G., DAVIS, G. B. & DAVIS, F. D. 2003. User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly,* 27, 425-478.

VISINTIN, F. 2012. Providing integrated solutions in the professional printing industry: The case of Océ. *Computer in Industry,* 63.

VOSS, C., TSIKRIKTSIS, N. & FROHLICH, M. 2002. Case research in operations management. *International Journal of Operations & Production Management,* 22**,** 195-219.

VOSS, C. A. 2005. Paradigms of manufacturing strategy re-visited. *International Journal of Oper-ations and Production Management,* 25**,** 1223-1227.

WAGNER, D. & SCHMALSTIEG, D. 2009. Making Augmented Reality practical on mobile phones, Part 1. *Ieee Computer Graphics And Applications,* 29**,** 12-15.

WANG, T., LIU, Y. & WANG, Y. 2008. Infrared Marker Based Augmented Reality System for Equipment Maintenance. *International Conference on Computer Science and Software Engineering.*

WANG, W., QI, Y. & WANG, Q. 2011. An Augmented Reality Application Framework for Complex Equipment Collaborative Maintenance. *In:* LUO, Y. (ed.) *8th International Conference on Cooperative Design, Visualization, and Engineering (CDVE'11).* Springer-Verlag Berlin Heidelberg 2011.

WANG, X. 2009. *Mixed-reality based collaborative virtual environments: specification, prototype, and evaluation in design and construction*, VDM publishing.

WANG, X. & DUNSTON, P. S. 2007. Design, Strategies, and Issues towards an Augmented Reality-Based Construction Training Platform. *ITcon* *http://www.itcon.org/2007/25*, 12**,** 363-380.

WEBEL, S., BOCKHOLT, U. & KEIL, J. 2011. Design Criteria for AR-Based Training of Maintenance and assembly tasks. *In:* SHUMAKER, R. (ed.) *Virtual and Mixed Reality.* Springer-Verlag Berlin Heidelberg.

WHEATON, B. 1987. Assessment of fit in overidentified models with latent variables. *Sociological Methods & Research,* 16**,** 118-154.

WHEATON, B., MUTHÉN, B. O., ALWIN, D. F. & SUMMERS, G. F. 1977. Assessing reliability and stability in panel models. *In:* HEISE, D. R. (ed.) *Sociological methodology 1977.* San Francisco: Jossey-Bass.

WINDAHL, C. & LAKEMOND, E. 2010. Integrated solutions from a service-centered perspective: Applicability and limitations in the capital goods industry. *Industrial Marketing Management,* 39**,** 1278-1290.

WISE, R. & BAUMGARTNER, P. 1999. Go downstream: The new profit imperative in manufacturing *Harvard Business Review,* 77**,** 133-141.

WOMACK, J., JONES, D. T. & ROOS, D. 1990. *The machine that changed the world,* New York, NY, Rawson Associates.

WU, C.-S., CHENG, F.-F., YEN, D. C. & HUANG, Y.-W. 2011. User acceptance of wireless technology in organizations: a comparison of alternative models. *Computer Standards & Interfaces,* 33**,** 50-58.

YAN, C. & LIHUA, H. 2008. Mobile technologies adoption: an exploratory case study. *Tsinghua Science & Technology***,** 300-305.

YEN, D. C., WU, C.-S., CHENG, F.-F. & HUANG, Y.-W. 2010. Determinants of users' intention to adopt wireless technology: An empirical study by integrating TTF with TAM. *Computers in Human Behavior,* 26**,** 906-915.

YIM, H. B. & SEONG, P. H. 2010. Heuristic guidelines and experimental evaluation of effective augmented-reality based instructions for maintenance in nuclear power plants. *Nuclear Engineering and Design,* 240**,** 4096-4102.

YIN, R. K. 1994, p.46. *Case Study Research: Design and Methods,* Thousand Oaks, CA, Sage.

YIN, R. K. 2003. *Case Study Research: Design and Methods,* London, Sage Publications.
YIN, R. K. 2009. *Case study research,* Thousands Oaks, CA, Sage Publications.
ZHOU, F., DUH, H. B.-L. & BILLINGHURST, M. 2008. Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR. *7th IEEE/ACM International Symposium on Mixed and Augmented Reality.*
ZHOU, T., LU, Y. & WANG, B. 2010. Integrating TTF and UTAUT to explain mobile banking user adoption. *Computer in Human Behavior,* 26**,** 760-767.
ZHU, J., ONG, S. K. & NEE, A. Y. C. 2012. An authorable context-aware augmented reality system to assist the maintenance technicians. *The International Journal of Advanced Manufacturing Technology***,** 1-16.