



D.7.1.1: Report on the State-of-the-Art of Smart Products in Management Research

WP 7 – Business Cases Scenarios and Socio-Economic Analysis

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HSG, SAP

Delivery Date: 07 / 2009 (M6)

Dissemination Level: Public

Version 1.0

SmartProducts	WP 7 – Business Cases Scenarios and Socio-Economic Analysis
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1 Summary

Work package 7 complements the technical work packages of the SmartProducts project. It covers the socio-economic and managerial aspects of smart products. Its main purpose is to analyze the business potential of smart products and to investigate the main factors which are important for later market success. Finally, the ultimate goal is to provide a generic assessment framework that can be applied to different kinds of smart product applications and implementations for analyzing their business potentials and support investment decisions, taking into account privacy, legislative and risk communication aspects.

In the project, we specifically look into three pilot applications: Philips' Smart Kitchen scenario, Fiat's Smart Vehicle scenario and EADS' Aircraft Manufacturing scenario. Business research into these pilots promises to deliver representative results as the pilots taken together cover product and process innovations, internal users and end users, and all phases of the product life cycle.

For each pilot, we will conduct in-depth business case analyses including estimates for potential revenue increases, cost reductions, and the necessary investments so that we will finally be able to provide a statement on the expected return on investment (ROI). A convincing ROI at acceptable risks is fundamental to persuade companies to invest into smart products.

Further, positive user acceptance is usually crucial for quick adoption by users. Therefore, we will supplement our business case analyses by user acceptance studies, which will allow conclusions particularly about how to design smart products in an appealing way.

This first deliverable is the bedrock for our subsequent analysis. Our work presented here consists of three pillars: first, we present an in-depth review of academic business and management literature to document the research state-of-the-art; second, we evaluate analyst reports to document how smart products are perceived by the market today and how market development is forecasted; third, we discuss the results from the expert interviews we conducted with representatives from inside and outside the consortium to find out about how smart products are perceived from an application-oriented view, to get insights into ongoing research activities that are not published so far, and to broaden our view with respect to other industries, other technologies and other perceptions of smart products as a whole.

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The literature review has shown that – from a business perspective – smart products is a very fragmented topic, which crosses several research disciplines. Only little literature is available that addresses smart products as such. Most of the work covers only some aspects of smart products, either from a technology perspective (e.g. RFID), or from an application perspective (e.g. virtual product models). The same holds true for analyst reports. The more concrete they are, the closer they are focused on a specific technology, mostly RFID. Nevertheless, they commonly predict prosperous market developments for some smart product technologies and concepts.

The expert interviews have shown that the way how value is created and turned into business benefits differs very much between the three different pilots:

The Smart Kitchen scenario aims at developing a product innovation that is oriented towards the consumer. So the critical success factor is an enhanced user experience at moderate additional costs. Consequently, the business case analysis for this scenario will focus on user perception and production costs.

The Smart Vehicle scenario intends to develop two different scenarios, one targeting at a customer-centric product innovation, the other one targeting at a process innovation that focuses on internal optimizations through improved spare parts management. As business benefits from the process innovation are expected to be much higher, further WP7 analyses will concentrate on the spare parts management scenario.

In the Aircraft Manufacturing scenario, smart products will be applied to realize internal process optimizations. Business benefits are expected from reducing manufacturing time and cost. In this scenario, our future WP7 work will provide a quantitative assessment of process improvements that can be achieved by deploying SmartProducts concepts.

Taken together, the results of WP7 will help to close a significant gap in business research on smart products and related concepts. Most of the existing work has a technical focus. So far, no comprehensive business case study is available that analyses the business potential of smart product concepts. Our work will provide in-depth investigations of three very different smart products implementations. It will demonstrate whether and how business benefits can be reaped, and how smart products should be designed such that users are likely to adopt this change in consumer products, industrial equipment, and business processes.

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2 Purpose and Structure of this Document

2.1 Purpose of the Document

The goal of this document is to pave the ground for our subsequent socio-economic analysis. To achieve this purpose, this document consists of two major parts, first an overview over relevant work in management research and analyst reports, and second a summary of several expert interviews we conducted with subject experts inside and outside the consortium. Our conclusions from this work will be taken as a starting point for the socio-economic analysis in the subsequent tasks and deliverables of WP7.

The literature review provided in this document serves two objectives: first it shall be a reference base and information source for related work. Second it shall identify potential influence factors and cause-effect relationships that undergo further investigation when developing business cases for smart products and performing user acceptance studies. The expert interviews shall demonstrate the various perspectives and goals that prevail at different stakeholders and different communities. Further they shall create an initial understanding about the business rationale behind the three pilot applications, which will enable the design of a dedicated business case analysis models for each pilot scenario.

2.2 Structure of the Document

In chapter 3, we provide a literature study on smart products and related research areas. Our analysis comprises academic literature from business research, case descriptions, and business-related literature that seems to be relevant for our application scenarios.

Chapter 4 summarizes relevant analyst reports from related fields like Internet of Things, sensor technologies, context-aware computing.

In chapter 5, we present results from the expert interviews we conducted with four experts from within and outside the SmartProduct consortium. For each interview, we provide a summary and an analysis of what we conclude for our further work.

In chapter 6, we summarize major findings from our work and draw conclusions for our subsequent tasks and deliverables.

The public Annex 1 presents the questionnaires that we sent to our interview partners. There are two different versions, one for industrial partners and one for academic partners. Further, Annex 1 includes the summary templates which were used to transcribe the interviews, summarize each question, and document additional comments provided after the interview.

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In addition to that, we provide a confidential annex to this document (D7.1.1 Annex 2), which includes detailed interview protocols. As agreed with our interview partners, this Annex 2 is confidential and must not be distributed outside the consortium. Further, literal transcripts of the interviews are available upon request directly from each interview partner.

2.3 Relation to other work packages

The whole work in WP7 is strongly linked to the application work packages 8, 9, 10. The information flow here is bi-directional. As WP7 investigates the economic potential of smart products with respect to the three pilot applications, it is vital to know in detail what is planned there from an application perspective. On the other hand, WP7 results provide feedback for the application work packages so that the pilot scenarios may better account for and address the exploitation of future business potentials.

In order to deepen our understanding for the pilot applications and provide feedback on the business perspectives, we participated in several meetings and phone conferences conducted by WP 8, 9, 10 teams. Further, we attended WP1 calls and meetings where requirements have been defined from a technical point of view.

Further, the results we achieved in WP7, and particularly in this deliverable, will contribute to the market and competition analysis, which is one of the tasks and deliverables of WP11. The literature review, case study collection, and analyst report summaries in this document provide a sound foundation for our future work in WP 11.

2.4 Relation to other WP7 deliverables

This deliverable lays the foundation for the socio-economic analysis of smart products, which is the purpose of all subsequent tasks in WP7. Figure 1 illustrates the relationship between all deliverables of WP7.

The state-of-the-art analysis gives an overview of the recent business research activities related to SmartProducts. Our conclusions from this analysis show to which degree we can build on the existing body of work, and to which degree we have to enter a new field of research.

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The expert interviews provide valuable insights where major business benefits are expected from the application scenarios, where impediments might occur, and what the key success factors are. Based on these insights, a business case analysis models and a user studies will be designed in the upcoming work packages.

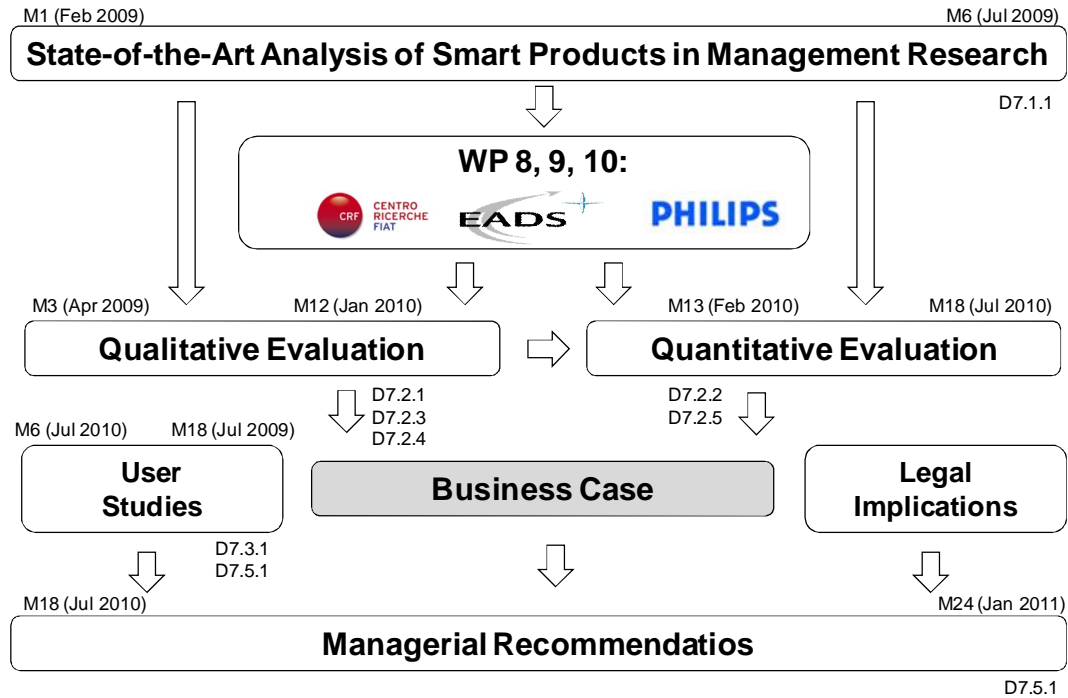


Figure 1: WP7 Deliverables

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3 Analysis of the State-of-the-Art

In this section, we present the state-of-the-art of smart product applications. We start with a definition of key terms that help understanding the later sections. Following this, we depict existing applications for smart products technologies and their design principles. Then, we present work which is strongly related to the three pilot scenarios. This not only includes work directly related to smart products, but takes into account literature about aircraft manufacturing, the automobile industry and home automation as far as it is relevant for this study. The last sub-section summarizes the state-of-the-art of business research on smart products.

3.1 Terms and Definitions

3.1.1 Smart Products

There are many similar definitions for *smart products*, which can be subsumed with (Dhebar 1996) who defines them as "physical products that have IT incorporated in them". In a similar way, (Maass 2007) describes smart products as "hybrids of physical products and information products". However as most electronic products today incorporate some kind of information technology like embedded microprocessors, this definition is not sufficient for delimiting the scope of smart products.

(Aitenbichler et al. 2007) go one step further by saying that "smart products are real-world objects, devices or software services bundled with knowledge about themselves, others, and their embedding". This adds a knowledge dimension to the definition, which indicates the capability of autonomous behavior depending on the context information. (Maass, Varshney 2008) point to a similar direction saying that "Smart products can be defined as products with digital representations that enable adaptation to situations and consumers".

(Mühlhäuser 2008) provides a very comprehensive definition of smart products: "A Smart Product is an entity (tangible object, software, or service) designed and made for self-organized embedding into different (smart) environments in the course of its lifecycle, providing improved simplicity and openness through improved [product-to-user] and [product-to-product] interaction by means of context-awareness, semantic self-description, proactive behavior, multimodal natural interfaces, AI planning, and machine learning."

Other contributions define smart products by listing a number of constituents that are characteristic for them. (Rijsdijk, Hultink 2009) postulate that seven dimensions determine the smartness of a product: autonomy, adaptability, reactivity, multi-functionality, the ability to cooperate, humanlike interaction, and personality. They further point out that the smartness of products is a broad continuum that is determined by the extent to which the seven dimensions are

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fulfilled. In (Rijsdijk et al. 2007), the same authors state that such products "operate somewhat autonomously, cooperate with other products, or adapt to changing circumstances".

(Maass et al. 2008) regard the following six dimensions as constituents of smart products: situatedness, personalization, adaptiveness, pro-activity, business-awareness, network capability.

The various approaches to define or at least delimit smart products show that "smart products exhibit various degrees of behavior relative to situations which places smart products on a continuum between passive and static products and autonomous smart robotics" (Maass et al. 2008). To span this continuum, Table 1 explains and exemplifies the smart product design principles that were introduced by different authors.

Autors	Design Principles	Description	Example
Rijsdijk, Hultink 2009	Autonomy	The ability "to operate in an independent and goal-directed way without interference of a user".	Lawn mower or vacuum cleaner robotics (Philips, Samsung).
	Adaptability	The "ability to improve the match between its functioning and its environment".	Programmable Thermostat that learns how fast the room gets heated to adjust start time of heating (Honeywell).
	Reactivity	The ability to react to its environment as a direct response (in contrast to adaptability, where reactions are based on learning).	Hair dryer that lowers temperature when humidity of hair decreases (Philips).
	Multi-functionality	"The ability to fulfill multiple functions".	Mobile phones, PDAs.
	Ability to Cooperate	"The ability to cooperate with other devices to	PCs, PDAs, mobile phones, printer, scanner

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		achieve a common goal".	
	Humanlike Interaction	"The degree to which the product communicates and interacts with the user in a natural, human way".	Voice production and recognition, e.g. navigation systems
	Personality	"The ability to show the properties of a credible character".	Paper clip in Microsoft Office, toys like AIBO, Furby, Tamagotchi
Maass et al. 2008	Situatedness	"Recognition and processing of situational and community contexts" to adapt behavior and offered functionality.	Products that behave differently in sales vs. usage situation.
	Personalization	"Tailoring of products to buyers' and consumers' needs and affects".	Hair dryer that learns which temperature is preferred by a certain person.
	Adaptiveness	"Change product behavior according to buyers' and consumers' responses and tasks".	A light that dims when the TV set is switched on.
	Pro-Activity	"Attempt to anticipate user plans and intentions".	Smart house that opens the garage door when recognizing that the owner is going to drive.
	Business-Awareness	"Consideration of business and legal constraints defined in contracts".	Coffee machine that allows certain amount of coffee per day. Beyond that, pay-per-item mode.
	Network Capability	"Ability to communicate and bundle (product bun-	Digital cameras capable of being connected with hard

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		ding) with other products and product sets".	drives and printers.
Mühlhäuser 2008	Pro-Activity	See above.	See above.
	Context-Awareness	Ability to sense the environment for recognizing context and situation.	A device offering different services depending on its environment.
	Self-Integration	Ability to integrate into different environments without user interference.	Mobile phones that integrate via GSM, UMTS, Bluetooth and WLAN into different networks and provide different services.
	Multi-modal Interfaces	Ability to interact with users via different kinds of user interfaces.	A navigation system communicates via screen and voice production.

Table 1: Design Principles of Smart Products

To conclude, we can state that smart products are products that fulfill some of the design principles to some degree, so that one can say, the product is smart. As the design principles make up a continuum of properties along several dimensions, it is not possible to make a definite, undeniable judgment of whether a product is smart or not because one product fulfills several dimension to a lower degree whereas another one may only have one smart feature that is regarded to be fulfilled at a very high degree.

For our further work in WP 7, such a definition is rather less important. The important point for our further work is to understand what may make a product smart, and what may differentiate smart products from their non-smart predecessors, so that we can analyse the added value of these smart features of our concrete product ideas.

3.1.2 Smart Product Technologies

Smart products are further characterized by the fact that they make use of specific technologies and design principles mainly from the Ubiquitous Computing domain, to sense and communicate information about themselves, their condition, and the environmental context around

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them. This real-time context awareness gives them the capability to act proactively with regard to internal state and context, adapt to different situations, interact with other smart products, and convey information across lifecycle boundaries. With respect to the research in Ubiquitous Computing, smart products can be regarded as products that realize the vision of Ubiquitous Computing as formulated by (Weiser et al.), namely "a physical world richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives and connected through a continuous network". The following technologies are typically applied in smart products:

- **Auto-ID technologies:** for a seamless integration of the virtual and the real world, the capability of identifying real-world objects and linking them to their digital representations is of paramount importance. Most prominent Auto-ID (automatic identification) technologies are barcodes (1- or 2-dimensional) and RFID (Radio Frequency Identification).
- **Network technologies:** Diverse network technologies enable several kinds of Ubiquitous Computing devices to communicate with each other in an ad-hoc manner or at low configuration effort. Particularly important are wireless network technologies like WLAN, WiMAX, Bluetooth, ZigBee, GSM / GPRS / UMTS for internet access or device-to-device communication.
- **Device coupling technologies:** On top of network technologies like WLAN and internet protocols like IP, device coupling protocols like SUN Microsystems' Jini or Microsoft's UPnP (Universal Plug and Play) allow devices to connect to each other, exchange information about available services and functionalities, and to remotely make use of them. Such protocols are the basis for self-integration capabilities of Ubiquitous Computing devices as they allow devices to collaborate, which did not know each other before.
- **Sensors:** Sensors enable Ubiquitous Computing devices to capture information about their environment such as temperature, humidity, pressure, light, sound, velocity, acceleration,.
- **Actuators:** Whereas sensors convey information from the physical to the digital world, actuators enable devices to manipulate the physical world. Examples for actuators range from engines to robotics or from light bulbs to computer screens.
- **Localization Technologies:** Through localization technologies in combination with Auto-ID, it is possible to capture the geographic location of an object. Outdoor, the most prominent localization technology is GPS. GSM Localization is also available but

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less precise. Indoor, different technologies are available. Typical techniques are (1) triangulation and trilateration based on ultrasound, electromagnetic waves, or light, (2) scene analysis, and (3) proximity analysis.

- **Portable Computing Devices and Product-Embedded Information Devices:** For a seamless integration of virtual and real world, computing power must be integrated into surrounding devices. Besides dedicated portable computing devices like PDAs or net-books, mobile phones turned out to be a well accepted platform for portable computing. Still in its infancy from a Ubiquitous Computing perspective is the integration of computing power into everyday devices. Although modern household appliances include a significant level of embedded computing power, they rarely provide Ubiquitous Computing capabilities as they usually lack of constituents like connectivity, context-awareness, and sensors. Such product-embedded information devices (PEIDs) are a major building block of the concept of smart products.
- **Wearable Computers** are computing devices that are integrated in or attached to clothes so that they can be worn on the body to provide permanent access to them. This facilitates for example installation workers, doctors and other professionals who do usually not work on a desk to gain access to backend information systems without having to change their workplace.
- **Multi-modal User Interfaces:** Usually, computers offer screen, keyboard and mouse as user interface. Working at a desk, this provides sound usability. However in other environments, a different user interface might be better suited. For example, speech production and recognition might be more appropriate in a car, and head-up displays combined with speech control might be a better choice for a manufacturing environment. Products that offer different user interfaces are called "multi-modal". Combined with appropriate device coupling technologies, a seamless integration of smart products with surrounding user interfaces is possible. For example, an MP3-player can export its user interface to an automobile so that a driver can control the player through the buttons and screens that are integrated in the car.
- **Semantic Annotation:** Smart products are capable of interacting with each other, of exchanging information about themselves and their environment, and of offering services to other smart products. To inform other smart products about the meaning of offered information and services, these can be enriched with so-called semantic annotations. These can be implemented for example by using tags or identifiers that are standardized in a common dictionary.

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3.2 Business Research Activities on *Smart Products*

This section summarizes the state-of-the-art in smart products research. The first subsection presents a review of literature that treats smart products as such from a business perspective. However, the body of literature that is dedicated to smart products does not cover all aspects that are relevant for the present work. The Smart Aircraft scenario is strongly related to research domains like Computer Integrated Manufacturing, RFID, or Augmented and Virtual Reality. The Smart Vehicle scenario applies principles from Product Lifecycle Management. And finally the Smart Kitchen follows the research trait of home automation and assisted living. To cover these aspects, a subsection is dedicated to each of the application scenarios, which summarizes the state-of-the-art in each application domain.

Regarding the state-of-the-art of business research on smart products, there are primarily three kinds of research streams prevailing: (1) Marketing and Industrial Design (2) Operations Management, and (3) Case descriptions. The following subsections summarize these research streams.

3.2.1 Marketing and Industrial Design

Product-embedded information devices, which give products the ability to become smart, provide various possibilities for product designers to implement new product features and functionalities. Already in the early nineties, researchers warned that, in an era of smart products, products designers will be faced with an increasing challenge to find a balance between adding new features to products and at the same time maintaining usability. In the field of ergonomics and industrial design, (Feldman 1995), (Freudenthal, Mook 2003), (Han et al. 2001) investigated the central role of interface design for successful smart product innovations. (Buurman 1997), (Holmquist et al. 2004), (Robertson 1992) describe the new opportunities that smart product technologies offer to industrial designers. Further they point to the challenge of how to deal with the great amount of new possibilities. (Dhebar 1996) elaborates on the necessity for designers to restrain themselves from adding too much functionality to smart products. At the same time, product managers should avoid to set up too many product variants, which become inexpensive through software-based features. Both feature-overloaded products and fragmented product lines can have negative effects on consumer perception.

In the field of marketing science, a growing body of work is investigating smart products from a marketing perspective. (Zinkhan 2003) even ranked "Intelligent Products" (a synonym for smart products) number one on a list of the 15 most important topics in marketing science for the next 30 years. (Rijsdijk et al. 2007) measure the influence of product intelligence on consumer satisfaction, mediated through relative advantage over other products, compatibility to

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one's expectations, and product complexity. They present a conceptual framework to operationalize the product intelligence construct as consisting of the six dimensions autonomy, ability to learn, reactivity, ability to cooperate, humanlike interaction, and personality. They conclude that consumers do not appreciate smart products for their intelligence as such, but because of the resultant relative advantage and compatibility. At the same time, consumer satisfaction is negatively influenced through the complexity increase that is inherent to smart products. In a subsequent study, the same authors found out that, whereas product autonomy provides many perceived advantages and only few disadvantages, multi-functionality and the ability of products to cooperate are more problematic with respect to perceived complexity and product risk (Rijsdijk, Hultink 2009). (Chan, Khalid 2003) have shown in experiments with ATMs that speech recognition and control can reduce perceived complexity and has the potential to increase consumer satisfaction of smart products.

(Watson et al. 2002) analyze how smart product technologies affect future marketing. While today marketing initiatives for physical products are usually focused on communicating the advantages of a product and typically do not consider lifecycle phases after sales, future connectedness of everyday-consumables will extend the scope of marketing far beyond the point of sales in order to provide customers with after sales services and thus create further revenues through the connectedness of a firm's products. They term this new marketing approach "u-commerce", which they define as "the use of ubiquitous networks to support personalized and uninterrupted communications and transactions between a firm and its various stakeholders to provide a level of value over, above, and beyond traditional commerce".

3.2.2 Operations Management

Whereas there is a substantial body of work on smart products in the area of marketing and industrial design, only little work in the field of operations management is directly related to the concept of smart products. Most of the present work in this area is concerned with Ubiquitous Computing in general (e.g. Nagumo 2002; Fleisch, Dierkes 2003; Sandner et al. 2006), or refers to specific Ubiquitous Computing technologies, majorly RFID (e.g. Thiesse, Fleisch 2008; Thiesse et al. 2009; Lee, Özer 2007). The major difference of existing research streams in operations management and the present study lies in the degree of embeddedness. Whereas both directions share the same technological basis (auto-id infrastructure, (W)SAN technologies, (wireless) communications technologies), smart products go beyond the more traditional approaches by embedding these capabilities directly into the product. Regarding auto-id as an example, RFID technology usually means that an RFID tag is attached to the product, or more often to a container in which the product is moved through the supply chain. In contrast

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to that, a smart product has this capability embedded in its electronic circuits. It is able to identify itself without any attached RFID tag, and at the same time can identify surrounding items in order to derive information about its context. At the time being, there is no systematic evaluation of smart products in its narrow sense with respect to operations management. Nevertheless, there is a large body of relevant work from the Ubiquitous Computing area and RFID in particular. The results of this work are at least partially transferable to smart products as (1) the presented approaches can mostly be embedded in smart products, (2) are to some degree covered by the pilot scenarios underlying this study, and (3) aim at similar efficiency and efficacy gains through improved operations management. Due to the absence of more directly related work, the following subsections will give a brief overview of recent operations management research results from the Ubiquitous Computing domain and RFID in particular.

Many industry reports and whitepapers have been published recently, which promise tremendous business benefits for manufacturing and operations through RFID. Estimates on RFID benefits typically refer to one of the three areas of (1) labor cost savings, (2) inventory reduction, and (3) shrinkage and out-of-stock reduction. For example, an AMR report states that total supply chain costs may be reduced by 3 to 5% through RFID, and revenues can grow by 2 to 7% for early adopters (Abell, Quirk 2003). (Pisello 2004) states that labor costs in distribution can be reduced by 30%, while AT Kearney (A.T. Kearney 2003a and A.T. Kearney 2003b) estimates cost saving potentials for manufacturers at 9% and for retail stores and warehouses at 7.5%. (Booth-Thomas 2003) cites an Accenture study, which guesses the potential of inventory reductions along supply chains between 10 and 30%, while McKinsey estimates this potential to lie between 20 and 40% (Niemeyer et al. 2003). According to IBM, shrinkage can be reduced by two-thirds in manufacturing, and by 47% in retail (Alexander et al. 2002). METRO reported that stock-outs could be reduced by 11% (Johnson 2005) and Wal-Mart experienced a decrease of 26% in stock-outs through RFID, which translated into a sales lift of 1% (Hardgrave et al. 2008). Accenture is cited to assume a sales sales increase by 1 to 2% through RFID-induced out-of-stock reductions (Pisello 2004). Whereas the mere amount of publications about the business value of RFID might create the impression that business value of RFID is well understood, (Lee, Özer 2007) argue that most of these studies lack in scientific rigor and generalizability. Many studies are merely based on expert interviews. The problem with these studies is that most interviewees have never participated in any RFID evaluation or implementation projects. Due to this lack of experience, they can only give "educated" but wild-guesses", which causes a "credibility gap" in most of the RFID studies (Lee, Özer 2007). To overcome this credibility gap, the authors demand a bottom-up approach in operations management research that captures the fundamental operating characteristics of an applica-

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tion domain in analytical models to link them to control decisions and performance measures and finally to conclude with quantitative statements on the business value of RFID.

(Dutta et al. 2007) identified evolutionary phases of RFID deployment, each of them adding more business value to its predecessor. The lowest level consists of pure "Technology Deployment & Integration". Value comes, for example, from saved labor in comparison with barcode, a decrease in error rates, or improved capabilities to track shipments and manage inventory. However, these benefits remain on a pure tactical level, leaving existing business processes widely untouched. The next adoption level is "Integration with Business Processes", which includes major re-engineering of business processes and thus provides much greater value opportunities than the initial stage. Finally, enterprises will enter the "New Business Architecture" phase, which broadens the scope of the RFID-induced change by including people, policies and organizational structures. This phase carries has the largest potential to capture business benefits.

(Thiesse et al. 2009) present a more integrative model of RFID value, isolating informational, transformational, automational and substitutional effects of RFID investments that influence management processes and operational processes, which may increase firm performance. They explicitly advocate for a combination of the process view, thus relating RFID adoption to process variables, and the resource-based view, regarding RFID investments as an increase of information, process, and IT capabilities. These can further be exploited to develop higher-order organizational capabilities or dynamic capabilities, which in turn may lead to sustainable competitive advantage. With this work, the authors contribute to the astonishingly small body of work that relates the investigation of RFID business value to the large amount of literature on the value of IT.

Also advocating for a process view, (Tzeng et al. 2008) investigate the strategic impact of RFID. They conclude that the strategic value of RFID is based on the capabilities it creates for further business process innovations, which in turn may lead to strategic benefits. (Whitaker et al. 2007) take a supply chain perspective when investigating RFID value. They conclude that key success factors for reaping value of RFID implementations are (1) broad IT application deployment, (2) critical mass of RFID implementation spending, (3) partner mandate, and (4) availability and adoption of industry standards.

Under the umbrella of the Aerospace-ID workgroup within the Auto-ID Labs, (Prodonoff et al. 2007) conducted an ROI analysis for RFID support in inbound logistics in the aircraft industry. First, they identify different value drivers for RFID adoption in aerospace manufacturing (Table 2). With regard to existing ROI calculations of RFID deployments, they criticize that those ana-

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lyses typically follow a Net Present Value (NPV) approach, neglecting the risk and uncertainty of not achieving the prospected benefits and costs. Therefore they combine a decision tree approach with the NPV to continuously control costs and benefits before entering the next rollout stage.

Category	Value Drivers
Inventory-related value drivers	Inventory Turns
	Safety Stocks
	Discarded Inventory
	Shrinkage
	Out-of-Stocks
Time-related value drivers	Replenishment Cycle Time
	Lead Time
	On-time Deliveries
Decision Support Value Drivers	Supply Forecasting
Handling Efficiency Value Drivers	Labor Efficiency
	Billing Precision and Invoice Adjustment
	Detention Costs
Other Value Drivers	Liability and warranty costs

Table 2: Value Drivers for RFID Adoption in Aircraft Manufacturing (Prodonoff et al. 2007)

3.3 Applications of Smart Product Technologies and Design Principles

In this section, some examples for existing applications from the smart products domain are presented. Due to a lack of 'real' smart products that embed their smartness into the product, this review also includes RFID applications, which implement scenarios that are typical for smart product approaches.

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3.3.1 RFID-based inventory and work-in-progress tracking

The majority of reported smart products and Ubiquitous Computing applications, which are deployed in a productive manufacturing environment, are limited to tracking and tracing of inventory or work-in-progress goods across warehouse and shop floor. For example, (Günther et al. 2008) report on six case studies from the automotive, steel and mill, and electronics and packaging industries, where RFID has been deployed for the following benefits:

- Accelerating scan processes, improving data accuracy
- Narrowing recalls
- Reducing paper-based data management
- Automating asset tracking
- Reducing back-end interactions
- Unifying labels, avoiding paper label printing
- Documentation of manufacturing process
- Efficient container management

The examples listed above demonstrate very typical application scenarios for RFID in manufacturing. These scenarios have in common that they only make use of RFID as a basic technology. Neither do they comprise fundamental changes of underlying business processes nor do they make use of more advanced technologies and design principles from the Ubiquitous Computing area. However, such implementations represent the majority of today's productive implementations of Ubiquitous Computing technologies.

3.3.2 Tool and Equipment Management

Management of tool and equipment inventory is a major challenge for manufacturing companies. Due to a lack of systematic tracking of resource inventory, resource consumption and resource re-location, many firms face over- or understocking of tools and equipment, maintenance and even procurement of obsolete resources, and a lack of cost transparency related to operating resources. (Bauer et al. 2006) designed an approach for active operating resource management to forecast future resource demand. Location and state of each tool or equipment is continuously captured via sensors. Employees have access to real-time information on any tool or equipment they might be interested in. This allows for more decentralized approaches in resource management in contrast to today's prevailing central approaches, which turned out to be partially ineffective.

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A similar approach is productive at Nordam Group, an aircraft parts manufacturer (Bacheldor 2006). High-value tools are tracked through RFID to ease localization and to document tool usage for regulatory agencies.

3.3.3 Real-time location systems in manufacturing

Real-time location systems combine RFID and localization technologies to track the geographic location of goods on the shop floor. (Thiesse, Fleisch 2008) describe the successful implementation of such a system at Infineon. They show that benefits not only stem from efficiency gains but that further benefits can be realized by adapting production scheduling algorithms to the more fine-grained information that becomes available through real-time location tracking. Their contribution shows that, when more information becomes available, additional benefits that go beyond direct efficiency improvements can only be realized through adaptations of existing business processes and operations.

3.3.4 Remote Diagnostics

Remote diagnostic systems allow manufacturers or service firms to monitor instances of their product in order to recognize operational issues and offer maintenance services before a serious breakdown occurs. For example, General Electric is offering a remote diagnostic service for their gas turbines¹. Up to 1000 parameters can be monitored to detect maintenance needs. Examples for such parameters are engine operating temperatures, pressures, speeds, vibration, alarms. Gas turbines installed on ships can further control trip information and environmental conditions. The parameters are permanently monitored, and an on-site maintenance service is offered if problems are detected. Similarly, *Heidelberger Druckmaschinen* offers maintenance and training services for their printing machines. In addition to mere monitoring of parameters, instantaneous online repairs as well as training services are offered (Wunderlich, Pfeffer 2007).

3.3.5 Manufacturing Control

In conventional manufacturing environments, product items flow more or less anonymously through the production system, while information about the status of the system, production lots and individual orders is derived from information that is collected by the manufacturing equipment. Automated identification systems like RFID enable individual product items to be identified and tracked along the supply chain. Applied to existing production systems, increased visibility can reduce delays, improve operations management, and make finished goods handling more efficient. Further benefits are expected from a paradigm shift, away from

¹ Cf. http://www.geae.com/aboutgeae/presscenter/marine/marine_20000419a.html

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today's central production control hierarchies towards distributed, holonic and agent-based manufacturing systems (McFarlane et al. 2003; Huang et al. 2007). These approaches have in common that decision making (e.g. for routing or production scheduling) is delegated from central systems to distributed systems or even to intelligent objects. Decisions are made through distributed algorithms executed on several autonomous systems. This shall overcome two problems of central production control: first, it shall be more responsive when disturbances like machine breakdowns or material shortages occur. Second, the manufacturing system shall become more flexible and reconfigurable for new products and new production techniques (McFarlane et al. 2003). However, (Shen et al. 2006) conclude from an extensive literature review that, despite tremendous research efforts over the last 20 years, "industrial applications are still rare...", and "No significant advancements in this area can be seen during the past 7 years". They further conclude that this 'reality gap' stems from missing integration of intelligent manufacturing systems with legacy ERP systems as well as with RFID.

(Huang et al. 2007) investigate the potential of RFID and wireless communications in a walking-worker assembly with fixed-position layouts. In such a factory layout, products remain in a fixed location while workers, machines and materials move around the product. These layouts are typical for large and complex goods like aircrafts and ships. For less bulkier goods, flow layouts are often preferred due to higher efficiency, although fixed-location layouts provide better flexibility. The authors conclude from their case study that RFID and sensors together with wireless communications can reduce the efficiency gap of fixed-position layouts through increased visibility and better synchronized material and workforce flow. As a consequence, manufacturing companies can increase flexibility while obtaining their productivity when they switch from flow layout to fixed-position layout while at the same time introducing RFID and wireless communication.

3.3.6 Augmented Reality in Manufacturing

One of the first industrial applications of augmented reality (AR) technology is Boeing's wire bundle forming project at the beginning of the 1990s. In the traditional way, wire bundles were assembled on a so-called "formboard" mounted on an easel, on which a circuit diagram of a specific bundle was glued. This procedure had three major disadvantages: first, for every individual plane, a different wire bundle was necessary, because every plane has a unique configuration. This resulted in thousands of wire bundle diagrams, which had to be designed, plotted and archived. Second, frequent revisions lead to the necessity of updating wire bundle diagrams that were already in use. Due to the paper based procedure, such updates lead to delays and errors. Third, operators required additional information to be able to fulfill their assembly tasks. Changing from the formboard to additional information sources decreased their

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efficiency. To overcome these problems, Boeing equipped their operators with head-mounted displays through which they see the circuit diagram and related information. Using head tracking technology, the diagram appears to be drawn on the blank formboard, on which the wire bundle is assembled. (Mizell 1994) claims that operators were 25% to 50% faster compared to the traditional method. In a later publication however, the same author concedes that "we didn't show a significant productivity improvement" (Mizell 2001), for which he blames shortcomings of the user interface. So far, the system is not used in production at Boeing.

(Regenbrecht et al. 2005) report on 10 augmented reality projects in the automotive and aerospace industry in the following application domains:

- Air filter change in the International Space Station (ISS)
- Diagnostic data and service instructions in vehicle maintenance and in tram maintenance
- Aircraft cabin design
- Collaborative design review
- Aircraft cockpit layout
- Fuse placement in truck production
- Installation of wire bundles in truck production
- Car driver training

The authors conclude that AR applications in an industrial context are still in their infancy. They give several reasons why, despite promising research prototypes, AR is less successful when it comes to roll-out in industry:

First, AR research is focused too much on the fundamental technologies, while the actual challenge lies in integrating huge, complex and diverse data into the AR application. Second, AR technologies have not yet reached a sufficient level of maturity and robustness, which limits the potential number of application areas. Many research prototypes like the truck wire bundle installation support could not be made robust enough for a rough industrial environment. Third, AR researchers tend to use latest but sometimes unstable technology, which makes users lose trust. Users often prefer simple head-up displays connected to PCs over position tracking solutions with overlay graphics. The authors recommend applying well-proven, simple and stable technologies. Fourth, AR research often fails to prove economic advantages over other approaches.

A similar conclusion is drawn by (Ong et al. 2008), who conducted an extensive survey on the state-of-the-art of augmented reality applications in manufacturing. They state that the "main

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challenge in AR-assisted assembly systems is to determine *when, where, and what* virtual information to display in the augmented world during the assembly process". In addition to the examples above, they describe research pilots in the areas of manufacturing layout, telerobotics, and NC machining simulation. Further they provide a collection of commercially available AR hardware.

3.3.7 Wearable Computing in Manufacturing and Maintenance

Wearable Computing is the integration of computing devices with clothes. (Maurtua et al. 2007) analyzed the application of wearable computing technologies to support training and task completion of workers at an automotive manufacturer. While for training, paper-based approaches performed better, task completion could significantly be improved through wearable computing, particularly if speech-recognition was applied at the user interface. In a subsequent experiment, the authors compared user acceptance and performance of head mounted displays versus large screens. This study showed that, while performance was best with large screens, the users preferred head mounted displays.

(Nicolai et al. 2005) studied the potentials of wearable computers in aircraft maintenance. They specified a system that provides access to the following information sources: cabin logbook, self-diagnosis overview, defect reports, maintenance and troubleshooting manuals, location list, aircraft part structure, similar defect reports, error classification, and expert contact information. Further, the mobile device allows for writing an error report without having to leave the aircraft. Through localization techniques, the studied system can provide maintenance workers with this information without having to navigate manually through a database. The authors conclude that potential users appreciate wearable computing; however, process re-engineering remains key to successful deployment.

3.3.8 Product Lifecycle Management

Product Lifecycle Management (PLM) is a strategic approach to manage the products of a company across their whole lifecycle (Stark 2006; Ameri, Dutta 2005). The goal of PLM is to integrate all information that is created along the lifecycle of a product from design over manufacturing to maintenance, repair, and disposal. Originally, PLM was intended to enhance Product Data Management (PDM) as it was applied in product design. While PDM was restricted on managing design and construction data from various sources like CAD (Computer-aided design) or CAM (Computer-aided Manufacturing) systems, PLM was developed to bridge the gap between design and manufacturing phase of a product. So from a data perspective, PLM initially provided an integration of CAD and CAM systems with ERP, CRM and SCM systems (Ameri, Dutta 2005).

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Recently, the concept of closed-loop PLM emerged in the context of smart products (Daconta et al. 2003). While traditional PLM stops as soon as the product has been sold to the customer, the concept of closed-loop PLM makes use of product-embedded information devices (PEID) to capture and store information during subsequent lifecycle phases, which are *usage*, *maintenance*, *repair* and *disposal*. This information can be transferred back to product designers and production engineers, for example to uncover current quality problems or to draw conclusions for future product generations. Further, the products (respectively the PEIDs) can convey information from the design and manufacturing phase to later lifecycle phases. For example, maintenance manuals or variant configuration information can be made available electronically to maintenance engineers, or dismantling information can be provided to recycling companies.

In the course of the EU-funded project PROMISE, several closed-loop PLM pilot scenarios were implemented (Røstad, Myklebust 2005): For the automotive industry, a car was equipped with sensors to determine usage and wear and tear of critical parts. When the car is about to be dismantled, this information can be used to calculate residual values for these parts in order to decide whether to sell them as used spare parts or to recycle them. A similar application was developed for the decommissioning of heavy truck engines. Based on the same technical principals, predictive maintenance applications were developed to foresee service needs of heavy trucks, milling machines, and white goods. In the telecommunication equipment industry, PEIDs were used in network equipment to collect usage data that supports service technicians to become more efficient in their work. Besides information about the usage at the customer site, an electronic service history proved to be helpful for technicians. For use in locomotives, PEIDs were used to collect fine-grained usage data that were fed into a knowledge base to support product designers and engineers in the development of new products and feature.

In the EU-funded project ELIMA, two pilot applications were implemented to investigate the potential of product-embedded sensors for capturing knowledge about user behavior to draw conclusions for future design improvements (Geraghty 2005). In a Sony Playstation II, several sensors were integrated to measure orientation (horizontal or vertical), temperature, humidity, usage patterns, and voltage peaks. In Indesit refrigerators, sensors were integrated to capture door opening and closing events and power consumption. In both cases, a number of devices were delivered to customers to observe their user behavior.

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3.4 Pilot-specific Research Work

The previous section summarized related work on the core concepts underlying our research effort. In this section, additional information related to the three pilot scenarios will be presented.

3.4.1 Smart Aircraft

This section summarizes several pieces of work that relate to applications of smart product design principles in the aerospace industry. We focus on work that shows some relation to our pilot scenarios.

3.4.1.1 Aircraft Design

Aircraft manufacturers are among the most advanced adopters of sophisticated Product Life-cycle Management principles in the design phase of an airplane. Coming a long way from paper-based, 2D and later 3D-CAD design techniques, new planes like Airbus A 380 or Boeing 787 Dreamliner are designed in a completely virtual environment (Kaun 2003; Schmitt 2007). In the age of conventional 2D/3D-CAD, extensive use of physical mockups was required to get a realistic impression of the characteristics of a design model. Building hardware models was a significant cost driver in aircraft development, consumed a lot of time, and could not cope with the variant complexity of aircraft as one physical mockup can only represent one specific configuration.

Therefore, aircraft manufacturers have replaced physical mockups by so-called “digital mock-ups”, which allow for a completely digital design process. Moreover, the completely digital product models allow for an integration of product design and assembly layout, enabling so-called “Concurrent Engineering”: in the traditional way, the aircraft design had to be almost finished before production engineers could start to plan the assembly processes. Concurrent Engineering allows for a parallel development of product design and production process, while product and process engineers are always working on the same models. Design changes can immediately be simulated in a Digital Manufacturing environment in order to evaluate whether the new design is appropriate for efficient assembly.

3.4.1.2 Aircraft Assembly

As major business benefits of the Smart Aircraft scenario will result from optimizing assembly processes, in the following we will summarize work related to this application field.

(Chao, Graves 1998) analyze the significance of flow time optimization for the profitability of an aircraft manufacturer. In their analysis, they describe many details of the aircraft production

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process at Boeing. Major findings of his work shall be summarized in this section to provide the necessary information for further analyses in the context of aircraft manufacturing.

Aircraft manufacturing at Boeing is organized into a network of work centers. Each work center requires a manufacturing flow time to complete its tasks. Then the plane is brought to the next work center, where subsequent tasks are accomplished. If the overall production cycle time is shorter than the flow time, parallel tool positions have to be established for a work center to adapt to the cycle time. So production scheduling follows a "Line-of-Balance" approach. Flow time has three levers through which it drives the overall costs for an airplane: (1) inventory carrying costs, (2) revenue opportunity costs (if there is an order backlog), and (3) variable tooling costs. While inventory carrying costs are directly influenced by flow time variations, revenue opportunity cost reductions require an earlier overall delivery, and tooling costs decrease with fixed decrements that depend on the overall cycle time and the individual flow time of a work center. In addition, there are "intangible elements of flow-time cost" (Chao, Graves 1998): (1) Long flow times increase the time that passes until production problems are recognized, which leads to higher corrective effort. (2) Long flow times reduce a firm's agility so that reaction to changing market demand becomes more slowly.

Due to considerable contractual penalties in case of delivery delays, adherence to schedule is paramount for an aircraft manufacturer. Therefore, delays in an individual work center shall be balanced by passing on the plane to the following center as planned, even if previous work could not be finished. Then an additional "special crew" will try to catch up the delay at the following work center by completing the remaining incomplete tasks. (Chao, Graves 1998) argue that there is a trade-off between the workforce level (which is subject to rationalization efforts) and the flow times. However, as there is a lack of visibility concerning costs that are caused by higher flow times, there might be a systematically suboptimal trade-off resulting in too much workforce rationalization at the expense of too high flow times.

Further, (Chao, Graves 1998) analyzed major effort drivers in aircraft manufacturing. They revealed the following external variances to be responsible for 96% of deviations from the manufacturing plan (in either a positive or negative way):

- Delivery to a new customer (leads to approx. 3000 additional labor hours)
- Part shortages (occurs 3.6 times per plane in average)
- Production revision requests (occurs approx. 277 times per plane)
- Manufacturing of smaller sub-type (leads to approx. 2248 less labor hours)
- Defects (each defect leads to 1.3 additional labor hours)

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- (Missing) learning effects

Defects are a major cost driver (exact figures are not available), and "defect rework is a significant part of total direct labor hours expended in the manufacture of airplanes" (Chao, Graves 1998). Defects are often caused by engineering activities such as engineering changes and engineering errors that lead to defective manufacturing activities.

The authors' findings demonstrate the potential value of the Smart Aircraft scenario. It directly aims at increasing the efficiency of aircraft assembly, reducing the flow time and decreasing error rates.

As a basis for further studies of aircraft manufacturing, (Scott 1994) presents a discrete-event simulation model based on the aircraft assembly at Boeing. The model enables to capture the following features: (1) job precedence relationships, (2) differentiation between different skill levels of installation operators (3) dynamic re-allocation of installation operators, (4) depiction of shifts and overtime, and (5) modeling of spatial constraints and crew movements in the production area.

3.4.1.3 Smart Products in the Aerospace Industry

Several research activities have been initiated that are related to smart product technologies and design principles.

Under the umbrella of the Auto-ID Labs, the Aerospace-ID initiative was founded to investigate and propel RFID adoption in the aerospace industry. (Pátkai, McFarlane 2006) explore potentials and limitations of integrating RFID data with sensor data along the aircraft life cycle to support maintenance and repair processes, aircraft testing, parts tracking, and airport logistics. (Thorne et al. 2007) investigate how identification technologies can improve aircraft turn-around processes (ground operations that are necessary before a landed aircraft can take off again) and reduce the impact of disturbances. Through better visibility, they aim at recognizing disturbances earlier to mitigate flight delays.

Gartner Dataquest performed a study about mechanical CAx system, which also yields good insights for prospected smart product deployments. Gartner interviewed 400 users of CAx systems in four industries (especially aerospace) in five major countries (France, Germany, Sweden, the United Kingdom and the United States). Their survey focused on gathering information about user preferences, application satisfaction and budget plans:

- For CAD decision makers, the most important factors are those related to functionality, ease of use and performance. Less importance is given to the CAD vendors with re-

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gard to their financial stability and long term strategy. Budgets for CAx investments – which Gartner do not quantify – are expected to remain stable.

- Users demand that new CAx technologies should fit in seamlessly with how they work today rather than “requiring them to change how they work tomorrow”.
- For users worldwide, data exchange and translation, software stability, training and CAx implementation problems continue to be stumbling blocks.
- (Internet) security is considered as the most crucial factor among those respondents with concerns about using the Internet for their everyday engineering work – with other potential concerns, such as bandwidth, reliability of the network, accuracy of information, and time needed to find information, being almost nonexistent.
- Users will only accept newer technologies if there is a clearly visible, measurable benefit to their work processes.
- Gartner also presents regional differences, e.g., that in France mechanical companies are currently relying comparatively more on using paper-based catalogues to source components and parts, which apparently makes them more interested in more sophisticated technologies, such as system design tools, mechanical/electrical co-design tools, and CFD software.

3.4.2 Smart Vehicle

This section shall present the current state of smart product-related approaches in the car industry in order to show on what we will build with our further activities.

The automotive industry is working under high competitive pressure and its global excess capacity is estimated to be as high as 20%. This has led to a situation in which new car sales became a "zero sum game" for car manufacturers (Oliver Wyman 2005). Whereas new car sales are the major source of revenue for an automotive OEM (often more than 80%), spare parts sales and financial services are responsible for 95% of the profit while contributing less than 20% to the revenue (Oliver Wyman 2005; Mercer 2007; PricewaterhouseCoopers 2003 cited in London Economics 2006). New car sales can be regarded as means to capture customers to reap future aftersales revenues. However, spare parts revenues are threatened because parts manufacturers and independent parts distributors increasingly circumvent the car manufacturer and offer spare parts and services directly to the customer (London Economics 2006). This is why spare parts business as well as the development of new profitable services is highly important for car manufacturers, which was the rationale for selecting the application scenarios explained in section 3.4.

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The central idea of the Smart Vehicle scenario is to further exploit sensor data that is stored in the electronic control unit of the car. This data can be used either to develop new services for the customer or to generate value out of this data through analyzing it in other processes of the car manufacturing (e.g. car design, marketing, and quality management).

Whereas onboard electronic systems used to be closed architectures that are not easily accessible for software developers, Fiat and Microsoft have created a telematics platform called Blue&Me that allows for an easy-to-use access to a broad variety of car functions like the onboard entertainment system, the car diagnostics system, and also some actuators like the electric window lift.

Based on this platform, Fiat implemented the EcoDrive² service, which allows car users to connect a USB stick to the car and download fine-grained data on the driving behavior. This data can be analyzed on a PC using a web application from Fiat to recognize potentials to save fuel. To use this functionality, the user has to upload his usage data to the web application, which gives Fiat access to a fine-grained protocol of his usage behavior. Although users have to give away this information, Fiat reported in a personal interview that the majority of customers who have the technical capabilities, make use of this offering (Blue&Me is an optional equipment costing approx. 200 EUR).

Another trend in car design is the increasing integration of online services into the car. As an example, BMW "ConnectedDrive" service offering shall be described in the following³.

Interesting in the context of smart products is the proactive proposal and arrangement of repair and maintenance services. The onboard diagnosis system recognizes the need for regular maintenance service as well as damages that require a repair service. If the car owner agrees, the car automatically connects to the BMW service station and arranges the service. For this purpose, the car is delivered with a telematics system with fixed GSM SIM card and data flat rate, which can also be used for usual internet usage. Further, in case of theft being recognized through the alarm system, the car owner is informed via mobile phone. Then the car owner can initiate a localization of the car through GPS and GSM. Another functionality of "BMW ConnectedDrive" is the integration of Google with the onboard navigation and communication system. Destinations found in Google can be directly copied to the navigation system, and telephone numbers can be used directly in the car phone. Routes can also be planned on the PC and then be transferred to the car navigation system via a BMW web service.

²Cf. <http://www.fiat.com/ecodrive/>

³ Cf. <http://www.bmw.com/com/en/insights/technology/connecteddrive/overview.html>

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Similar services are provided by other car manufacturers, e.g. Mercedes-Benz with its TeleAid offering, Audi and Volkswagen with Telematics, or General Motors with OnStar.

In the car insurance sector, car telematics is used to offer dynamic pricing based on the driver behavior. The "Pay-As-You-Drive" concept charges drivers for each single trip instead of a fixed annual fee. Further, the pricing can differ depending on the time of the day, the kind of road used etc. to better adapt the charged fee to the real risk profile of a trip (Litman 2008). Such a system is offered in Italy by insurer *Sara Assicurazioni*. Insurer AXA-Wintherthur (Switzerland) offers to install a crash recorder in the vehicle through which insures can save up to 15% insurance fee. WGV insurance (Germany) is conducting a pilot called "Young and Safe", in which young drivers are granted a premium reduction of 30% when installing a GPS-based device that records when the allowed speed is exceeded. If the allowed speed is exceeded more than 12 times for more than 15 seconds, the premium reduction is abandoned.

3.4.3 Smart Kitchen

In the context of home automation, there is a large body of research work with respect to the Smart Kitchen scenario. In this section, an overview over recent research activities and commercial offerings shall be given.

(Vastenburg et al. 2007) investigate in a simulated environment, to which degree consumers appreciate home automation applications. They conclude that in general, consumers have a positive attitude towards home automation. Key success factors for home automation applications are ease of use and predictability, the latter meaning that consumers understand and foresee the behavior of the system. After evaluating user acceptance of an intelligent thermostat control, (Freudenthal, Mook 2003) conclude that users carefully weigh benefits and drawbacks of new technologies. Major drawbacks are the difficulty to operate, the insufficient level of control, and privacy concerns, whereas usability is of utmost importance for user acceptance.

Besides scientific analyses on user perception, there are many industrial and academic research initiatives and pilots to develop home automation applications. One of the most comprehensive initiatives is the *Aware Home Research Initiative* at the Georgia Institute of Technology⁴. In a dedicated two-story home, the research initiative explores new Ubiquitous Computing applications in the areas of 'Chronic Care Management in the Home', 'Future Tools for the Home', and 'Digital Entertainment and Media'. The *Service Centric Home* is a research initiative that has developed a home service platform as a basis to deliver Ubiquitous Comput-

⁴ Cf. <http://awarehome.imtc.gatech.edu/research>

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ing products and services to home residents (Schäfer 2007). In the course of the project, a so-called *4 Star Cooking Assistant* has been developed to provide users with cooking recipes and guide the cooking process with videos and explanations. A multi-modal interface design allows for controlling the Cooking Assistant via touch screen and voice recognition. Further, the Cooking Assistant can trigger certain kitchen equipment. For example, an oven can be pre-heated or switched off at the right moment.

Commercially available, Siemens is offering a kitchen that is equipped with a network technology, a central server, loudspeakers and integrated screens⁵. This allows the *SieMatic S1* to integrate with MP3 players and other multimedia devices. Further, the user can send emails, surf the web or use any available PC functionality in his kitchen. As next steps, a recipe assistant shall be offered. Currently, Siemens is collaborating with home equipment manufacturer Miele to better integrate their home automation interfaces with each other.

Whereas in the *SerCho* project, support for a healthy living style was already outlined, it is still questionable how health parameters can be measured to judge a person's health status. Obviously, people will not be willing to analyze blood samples on a regular basis. To circumvent this, Matsushita developed a Healthcare Toilet that measures weight, blood pressure and several health parameters like glucose that can be derived from urine analysis (Nagumo 2002). To support a healthy lifestyle, (Hellenschmidt, Kamieth 2008) describe a shopping assistant that informs its user in a shopping situation on the healthiness of the selected food.

Taking all these efforts together, there are many initiatives on the way, which, taken together, cover a broad area of the envisaged Smart Kitchen scenario. However, there is only very few related work in the business literature that gives evidence for a clear business case that might help commercialize these research efforts.

⁵ Cf. http://www.siematic.com/s1page/index_en.html and at http://www.computerwoche.de/knowledge_center/home_it/1891455/

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4 Analyst Reports

In this chapter, we evaluate analyst reports to document how smart products are perceived by the market today and how market development is forecasted. This evaluation is a useful complement to our research results from the other chapters because the reports look at smart products from a market perspective, and allow deriving some indicative quantitative predictions for the business potential for smart products.

Analyst reports provide insights into how and to what degree new technologies and trends are perceived in business and industry. Typically, a technology is broadly covered by analyst reports when it has left its very early and immature phases, and has entered a sort of early-adopter phase. Smart products is a new domain, and as such, there are no analyst reports available yet, which are exclusively dedicated to this topic, which makes it difficult to set the limits and estimate the potential value of SmartProducts. This is why, in the following, we indicatively present reports which cover important technologies and concepts that are inherent to smart products, such as RFID, (wireless) sensor technologies, or context-aware computing. We also include reports that deal with the “Internet of Things” (sometimes also referred to as “Extended Internet”), which Fleisch and Mattern describe as a vision, in which everyday objects have digital logic and sensors, and the ability to “communicate” about themselves and with each other. (Fleisch and Mattern 2005, translated from German, p.I). Smart products can be considered to be embedded in this vision or even as one possible realization of this vision, so that estimates for the evolution of the Internet of Things are a valuable source to forecast future prospects for smart products.

Our summary of analyst reports is structured along four major technology trends in this domain: the following section covers analyst reports that focus on the Internet of Things. Then, reports on RFID adoption are presented, followed by a section on wireless sensor technologies, and finally a report on context-aware computing. After these report summaries, we present a categorization in which we compare and comment on the reports’ main statements. In the last section we summarize the chapter and draw conclusions for our work in the SmartProducts project.

4.1 Internet of Things

ITU 2005: The Internet of Things

ITU published a report named “The Internet of Things” in 2005 as the seventh in a series of ITU Internet Reports, which was initiated in 1997 under the title “Challenges to the Network”. Like Fleisch and Mattern, ITU describes the Internet of Things as a vision of a world of net-

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worked and interconnected devices, ranging from “tyres to toothbrushes”, whose evolution depends to a high extent on the dynamic technical innovation in its enabling technologies, namely RFID, sensor technologies, embedded technologies, and also nanotechnology. For example, ITU estimated RFID revenues to grow from 1.8 billion in 2004 to 3.5 billion in 2008 and its corresponding integration services from 1.2 billion to 4 billion by 2008 (which makes 7.5 billion in total). Compared to recently published reports which number the market volume of RFID to around \$5 billion in 2008 this estimation turned out to be too optimistic (cf. ABI Research 2009; IDTechEx 2009). But nevertheless, growth in RFID revenues has been and will continue to be substantial (cf. Gartner 2008a). For global revenues from nanotechnologies, ITU cites a Lux Research report from 2004 which estimated a rise in sales from less than 0.1 per cent of global manufacturing today to 15 per cent in 2014, reaching \$2.6 trillion (cf. LUX Research 2004). They state that this is a large step towards miniaturization, and at the same time will be an important driver for the realization of the Internet of Things. ITU also covers potential business models for the retail, car manufacturer, and Telco industries, but lack in quantifying the potential revenue gains. They further discuss potential challenges on the road to the Internet of Things: They emphasize that people-oriented strategies are necessary, i.e. “tighter linkages between those that create the technology and those that use it” (ITU 2005, p.126). This includes safeguarding principles of informed consent, data confidentiality and security. Moreover, protecting privacy must not be limited to technical solutions, but encompass regulatory, market-based and socio-ethical considerations.

Forrester 2003b: The X Internet And Business Profitability

According to Forrester, the Extended Internet (X Internet) is based around the idea to enable firms' information systems to include physical-world links, i.e. to connect to physical assets, products, devices, and employees via a set of technologies, such as Biometrics (to identify employees, consumers, and partners), RFID tags (to specify product location and content), Wi-Fi (to unleash wireless access to enterprise applications), Telemetry sensors (to monitor asset usage and performance) and Presence awareness (to gain insight into people's status). This definition is close to different definitions of the "Internet of Things", e.g. from ITU, but does not explicitly stress the need for technical innovation in these technologies.

In this report dating back to December 2003, Forrester presents the results of an online survey of 172 North American executives across 14 industries about their adoption of X Internet tech-

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nologies. Forrester predicts a cumulated \$2.7 trillion X Internet market until 2014 with manufacturers likely to spend \$1.8 trillion, which makes two-thirds of the total X Internet spending⁶.

The report sketches the X Internet's landscape (as of late 2003), depicting some successful early-deployment-examples of physical-world links:

- Michelin's eTires were based on an add-on sensor system that measures the air pressure and temperature of commercial tires. On the one hand eTires have helped Michelin to comply with the TREAD Act⁷. On the other hand it has also helped truck fleet operators to reduce downtime and to improve fuel economy. eTires is still in operation today. Michelin has also used RFID tags to track their tires along the supply chain to speed up the recall process. Forrester does not quantify the resulting savings.
- Caterpillar rolled out MineStar in 2000 that features a GPS-enabled system to track location and status of all Cat machines in a mining field. According to Forrester, this raised customer loyalty to Cat (by helping prevent costly equipment failure), and enabled Cat dealers to carry up to 50% profit margins for these value-added services.
- Delta Air Lines analyses telemetry data from the engines of its 550 planes. According to Forrester, Delta can potentially save 51% (\$355 million) on its annual maintenance costs.
- Norwich Union, a UK insurance provider, piloted the "Pay as you Drive" model by equipping cars with a black box linked to a telematics system. Because of its high acceptance with the testing volunteers, they eventually rolled out the model in the UK in 2006 (cf. Aviva 2006).

As another element of the landscape, Forrester finds that 81% of firms were still disconnected from the physical world (as of the end of 2003). This number, however, will be decreasing since environmental pressures from government, customers and competition will drive firms across industries to embrace the X Internet. Figure 2 depicts some prominent examples for these influences and their potential effects.

⁶ Compared with more recent analyses, these predictions turned out to be overly optimistic, cf. for example Forrester (2006b) for updated numbers.

⁷ The Transportation Recall Enhancement, Accountability and Documentation (TREAD) Act is a United States federal law enacted in the fall of 2000 which primarily imposes a so-called "Early Warning" requirement, i.e. manufacturers need to report information about defects, injury or death related to its products.

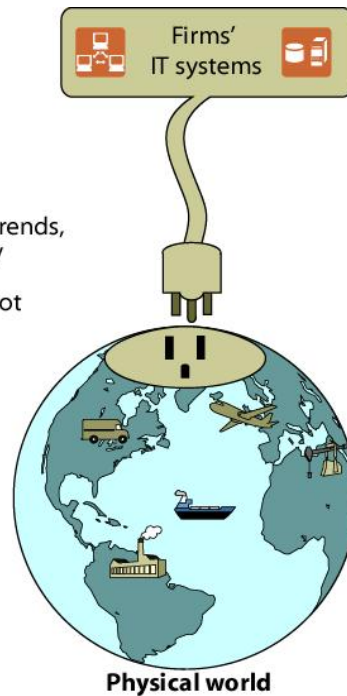
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Competition

- Firms like GE and FMC use their excellent product support record to win multibillion-dollar service contracts to maintain rivals' products.
- By mining the latest fashion trends, reported via wireless PDAs by its globe-trotting marketing, apparel maker Zara can get hot new designs to stores *twice* a week -- an industry record.

Customers

- Wal-Mart has mandated that its top 100 suppliers RFID-tag their shipments to its warehouses, starting in January 2005.
- Defense contractors face a similar deadline imposed by their top buyer -- the Defense Logistics Agency.



Government

- The TREAD Act reprimands auto suppliers' slow response to product quality issues.
- The US Public Utility Commission can sue telcos for SLA noncompliance due to faulty equipment.
- US Customs' CSI and C-TPAT require US firms to track all containers carrying their imports.
- The FDA is pressuring pharma firms to monitor their products to prevent counterfeiting and tampering -- in compliance with the Bioterrorism Act of 2002.

Figure 2: External Factors Drive Physical-World Connectivity Requirements (Source: Forrester 2003b)

Based on the successful deployments and the external factors described above, Forrester argues that by proactively building linkages with the real world using the X Internet, firms can (1) boost regulatory compliance, (2) increase customer loyalty, and (3) drive up margins. But firms do have to scope their X Internet implementation to match their unique business requirements and corporate culture. They can opt for using the X Internet for functional enhancement, which requires minimal investment and cultural change; for optimization of cross-functional process flows and extending them to trading partners, which is appropriate for “[...] process-savvy firms with a risk-tolerant corporate DNA” (Forrester 2003b, p.6); or for reinventing their business model, which suits best for companies which “[...] like to go for bigger bang, or maybe they are in a desperate situation” (Forrester 2003b, p.6).

For future X Internet adoption from an industry perspective, Forrester predicts that Original Equipment Manufacturers with outsourced supply chains will drive investments, which increase supply chain visibility in order to pre-empt failures in their outsourced areas, so that these don't hit the customer.

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For future X Internet adoption, Forrester predicts a marginalization of the CIO role. They hold that the main drivers will be the head of operations in asset-intensive companies, and the Chief Technology Officer in companies that are product innovators. They further envision a general manager to oversee corporate-wide process transformation or business model innovation using X Internet technologies. According to Forrester, such a general manager has already worked successfully in Cat's information product division.

Forrester 2006a: The Extended Internet Voyage

Forrester interviewed more than 40 vendors and users for this report. They conclude from their survey that Extended Internet deployments will become a mainstream technology until 2013 due to a potent mix of business and regulatory pressures and technology enablers. They predict that the deployments will occur in three phases: 1) tactical deployments, 2) adjacent process rollouts, and 3) widespread business process re-definition. Differing in scope, these innovation phases will all be led by business, not IT, so that process-centric ecosystems and process innovations promise the greatest value for the stakeholders.

Among the business and regulatory pressures that will drive adoption, Forrester mentions the following factors:

- raising resource costs (e.g. for oil and electrical energy), which demand more efficient asset use,
- globalization (with supply chains scattered around the globe), which demands more visibility,
- and security and safety regulations (like Sarbanes-Oxley, Food Regulation EU-178/2002, Gramm-Leach-Bliley Act and drug pedigree), which demand more fine-granular monitoring and control of data.

Forrester also regards constantly lowering implementation barriers as another driver for adoption, with cheaper wireless networks ubiquitously in place, evolving data and transport standards and generally available solutions from large vendors like IBM, SAP, Sun Microsystems, and Microsoft. They do not provide any quantification of these effects.

Concerning business, Forrester expects opportunities for both enterprise and consumer lines. For the enterprise lines, they predict that deployments will converge to four process categories, which are depicted in Figure 3.

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	Subprocesses and applications	Technologies	Examples
Industrial maintenance and automation	<ul style="list-style-type: none"> • Predictive maintenance • Line management • SCADA • Energy management 	<ul style="list-style-type: none"> • Sensors • Zigbee • WLAN • Actuators • Predictive maintenance software 	Palo Verde Nuclear Generating Station uses 1,000 wireless sensors for predictive maintenance
Supply chain visibility and control	<ul style="list-style-type: none"> • Product life-cycle management • Demand management • Order fulfillment and distribution • Enterprise asset management • After-market parts and service management • Supply management 	<ul style="list-style-type: none"> • RFID (passive/active) • Collaboration, forecast, planning, and replenishment software • Cellular wireless • WLAN • GPS 	To reduce production delays, Kraft and TrenStar tag 1,000 steel containers that are leased to its suppliers
Internal mobile asset optimization	<ul style="list-style-type: none"> • Customer service (e.g., hospital) • Recovery procedures • Placement optimization 	<ul style="list-style-type: none"> • Active RFID • WLAN • UWB • Location software 	Beth Israel Deaconess Medical Center, in Boston tracks 200 frequently lost items daily to save on costs
Physical control and security	<ul style="list-style-type: none"> • Remote patient care • Surveillance • Government safety oversight • Building security and control 	<ul style="list-style-type: none"> • Biometrics • RFID • GPS • WLAN, cellular wireless • Wireless video cameras • Business intelligence software • Data mining software 	US Department of Veterans Affairs is piloting home healthcare monitoring

Figure 3: Business Adoption will Converge in four Process Categories (Source: Forrester 2006a)

For the consumer lines, they predict that healthcare costs, lifestyle and entertainment demands will push consumer adoption. Prominent examples for these are remote patient-monitoring (e.g. for blood pressure), security services like the Family Locator by Sprint Nextel, which enables parents to track their kids via so-called *geofencing*, context-enriched social peer-to-peer interaction, and time saving services like remotely controlling stove and sprinkler timing.

Independent of process category or business line, Forrester expects the Extended Internet adoption to occur in three stages:

- Stage one: Tactical deployments. Business executives will drive Extended Internet deployments in specific processes to mitigate operational pain points.

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- Stage two: Adjacent process rollouts. Early business success from tactical deployments will invigorate executives to seek other opportunities within related process categories.
- Stage three: Widespread business process agility. Broad executive recognition of success will spur Extended Internet deployments into other distinct process categories. (Forrester 2006b, p.8).

Along these three stages, innovation will continuously shift from hardware (e.g. sensors, networks, tags) to services and software (e.g. data management systems, Business Intelligence, enterprise applications) because “[...] business is moving from transactional to continuous” (Forrester 2006b, p.15).

Based on these predictions, Forrester gives recommendations for the main stakeholders, such as vendors, business strategists, and IT:

Vendors should build process-centric extended internet ecosystems which enable them to provide solutions for real business process pains. The starting point is to know in detail about these pains and to design and build the ecosystem according to these. Forrester suggests to survey customers to dig into this and then to use the results as input for the selection of appropriate partners, which necessarily have to be in line with the ideas about lead generation, channel education, market size and segmentation. For the vendors’ internal efforts, Forrester suggests to “think business, not technology”, i.e. to infuse staff with business expertise.

Business strategists should “peer over the horizon to new business models”, i.e. besides focusing on short-term opportunities, they should also prepare for next-generation business models. Forrester generally suggests messaging the X Internet as business rather than an IT mission; this is to talk in business terms like ROI, productivity improvements, and customer satisfaction. For identification of potential business opportunities, they recommend to screen peer-to-peer sources such as blogs and wikis which are on the pulse of time. Forrester also encourages strategists to spot (and iterate on) new business models when thinking about how the established Internet can be enriched with X Internet capabilities (e.g. Pay as you Drive or remote monitoring and maintenance). Internally, strategists should seek to create a culture of innovation which also accepts failure to avoid stagnation in the labs.

With regard to IT, Forrester sees the challenge in finding the right balance between control and flexibility: They recommend IT to start with teaming with business to identify the business units that are experiencing the most pain operationally and to apply Extended Internet technologies there. They further suggest prioritizing business value over risk-related issues, and

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they emphasize the importance of identifying ecosystem partners aligned with the company's business goals.

Forrester 2006b: Global Extended Internet Forecast: 2006 To 2012

Forrester estimates that Extended Internet technologies will make up a global market for enterprises (both B2B and internal deployments), of \$11.6 billion by 2012 compared to \$963 million in 2006. For their forecast, Forrester interviewed more than 40 vendor and user companies. They conclude that vendors have to focus on business processes to reap the benefits of the Extended Internet, which they define as “[...] a mix of sensors, actuators, software, and services that, collectively, offer physical and time-specific information about objects” (Forrester 2006b, p.3). Compared to ITU, their definition is less bound to technologies and focuses more on the inclusion of required software and services. Forrester further states that there will be no discrete Extended Internet applications market because software is required which is dedicated to and aligned with the specific needs of firms in order to maximize the return.

Forrester considers four major areas of business processes to drive the demand for Extended Internet technologies:

- industrial automation and maintenance to monitor and control equipment in locations like factories and refineries,
- supply chain, finished goods and asset management to establish tracking and monitoring of assets and inventory across distributed multiparty supply chains,
- internal mobile asset optimization to track and monitor assets in localized environments or facilities,
- physical control and security “[...] from automated meter reading (AMR) to biometrics-enabled airport security checkpoints” (Forrester 2006b, p.6).

Figure 4 displays the forecasted growth in each of these four processes, revealing the greatest growth potential of about 4000% for internal mobile asset optimization from 2006 to 2012.

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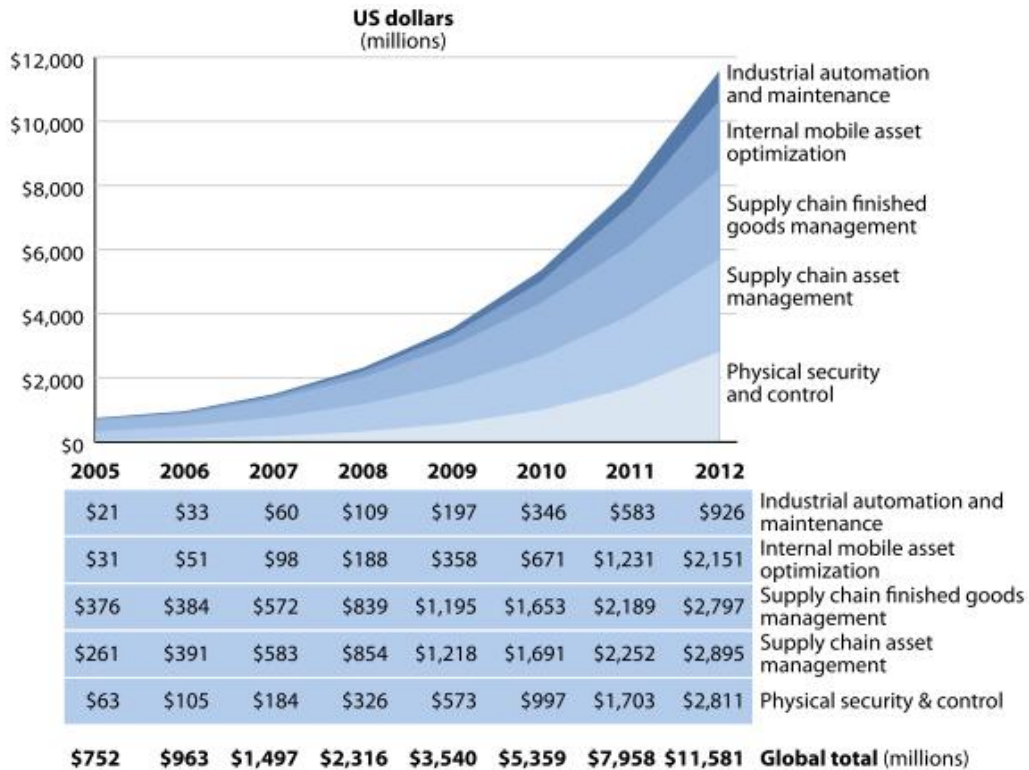


Figure 4: Forecast: The Global Extended Internet by Process, 2006 to 2012 (Source: Forrester2006b)

Forrester also covers a sample of adoption factors and, as displayed in Figure 5, states that they vary significantly for each of the four processes (however they do not reason about the causes for these differences). It can still be derived from their analysis that the potential for business change is (overall) considered to be the major driver for adoption.

	Low cost	Business changing	Indispensable	Radically different	Depends on adoption by other enterprises
Industrial maintenance and automation	4	4	3	3	5
Internal mobile asset optimization	4	3	3	4	5
Supply chain finished goods management	3	5	5	1	1
Supply chain asset management	2	5	5	1	1
Physical security and control	4	4	4	3	3

(1 = No; 5 = Yes) A higher score means broader adoption

Figure 5: Growth Factors Influence Extended Internet Adoption by Process (Source: Forrester2006b)

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Their final recommendation is that vendors ought to abandon tactical offerings and technology-focused sensor and RFID services in favor of process innovation and process-centric solutions. This should be achieved by enriching existing processes with Extended Internet data and then ultimately using this enhanced visibility as the basis for new business processes. They suggest focusing on the support of a small number of processes (to meet user need for specialization), raising sales and marketing in these, and creating partner ecosystems that support bundled Extended Internet solutions.

As a final remark to this report, it needs to be clarified that their forecast is restricted to the enterprise market – Forrester assumes that “[...] a related but discrete market will emerge for consumer services that rely on Extended Internet technologies” (Forrester 2006b, p.2), however they do not provide any further details.

Forrester 2007b: Manufacturers Embark On The X Internet Voyage

This report is specifically dedicated to the manufacturing industry and is meant to extend the two Forrester reports from 2006. The main statement of this report is that fully exploiting the business benefits of the Extended Internet Voyage requires “connecting shop floor to top floor” (Forrester 2007b, p.4), which is to synchronize and tailor the information, which is gathered via X Internet technologies and processed by enterprise applications, to multiple stakeholders, so that “[...] the entire manufacturing organization can be collectively aware of real-time changes and respond in concert” (Forrester 2007b, p.4).

The report sketches the current landscape and notes that manufacturers are currently seeing modest productivity gains in their plant-level projects, particularly in the areas of industrial maintenance and automation and internal mobile asset optimization, which are the two most relevant business processes for manufacturers out of the four ones presented in Forrester 2006b. These gains could be realized because former barriers for implementing these technologies have largely come down, with shop floors usually featuring wireless networks, with RFID tags featuring faster read rates and more robust designs and with lower costs for tags, sensors, actuators, and readers. In short, it is the X Internet technologies’ advance, coupled with the “closed loop” nature of plant-centric projects (which avoids many of the collaboration barriers in fully-fledged supply chain visibility initiatives), which have driven the success.

“Phase 2” of the manufacturer’s “X Internet Voyage” is what Forrester calls context-driven insights achieved by the merger of real-time X Internet data with transaction-level and eventually end-to-end process-level enterprise data. These insights will allow further increases in

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efficiency and effectiveness. They give examples in *sense-and-response operator safety*, where BP's Hazardous Goods Management pilot aims to eliminate unsafe hazardous goods conditions (cf. especially the detailed study in CoBIs 2007), and *improved asset life-cycle management*, where Boeing has already started tracking about 2000 mission-critical parts on each of its latest 787 jetliners with passive RFID tags to help identify unapproved parts and facilitate maintenance and repair – with the next step being to record service jobs onto the tags and establish a precise repair history, configuration traceability, and maintenance insight at the part level with the help of enterprise applications.

Forrester's deployment recommendation for the manufacturers is to plan for the future, but to build the business case for now. In particular, they suggest that

- plant managers should concentrate on those X Internet projects that address specific pain points in the production process while delivering a justifiable Return on Investment,
- the IT-department needs to acquire or build up internal know-how in flexible SOA software to avoid high investments for external system integrators,
- companies should look for leading software vendors like IBM, Oracle, and SAP to provide solution flexibility and continuity across an evolving range of process improvement cases,
- additional capabilities from X Internet technology should be aligned with the plant's operations strategy (competing on cost, quality, delivery, or innovation) to improve the business case and improve buy-in across stakeholders.

4.2 RFID

Forrester 2002: RFID: The Smart Product (R)evolution

This early report differs from the other reports mentioned in this section in that it gives estimate on the application of RFID in the consumer packaged goods industry (CPG), which was then supposed to be one of the main beneficiaries of RFID. Forrester predicts that RFID will roll out in four stages: field tests, shipping assets, cases, and then products within a timeframe of six years. They do however not quantify this evolution in monetary numbers.

The report gives a market overview as of 2002 covering both early deployment successes and barriers. The benefits described span improvements in asset management, supply chain execution, payment transactions, and process speed. Examples for these are the UK brewery Scottish & Newcastle which, using RFID, saves \$25 million on beer keg purchases annually; Procter and Gamble who found that automated data capture using RFID increased accuracy

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in inventory counts from 95% to 99%; Mobil's Speedpass system based on RFID which cut the average gas purchase from 3.5 minutes down to 30 seconds and has had great success in the following years (cf. Exxon Mobil Corporation 2009); and the UK retailer J Sainsbury which reduced receiving time of refrigerated goods from 2.5 hours to 15 minutes.

Since RFID was at an earlier stage in 2002, the report covers in detail implementation barriers like tag and reader incompatibility, tag and data overload, lack of standards, etc. Forrester concludes that only few RFID deployments make sense by 2002 and that CPG firms should focus their RFID efforts on supply chain aspects first, and only then continue with item level tagging, where they see a prime potential for health, beauty, and tobacco products due to their high cost and their theft and grey market threats.

Forrester estimated that by 2009 tag prices will reach \$0.01, and that 2% of CPG products will have RFID tags, primarily the over-the counter drugs mentioned. RFID-enabled POS systems and store shelves, and smart recycling and automated replenishment will begin to be rolled out. This forecast turned out to be overly optimistic in the retrospective. Neither the predicted tag price was hit (according to IDTechEx 2009, the one cent tag will be commonly available only in 2019), nor are over-the counter drugs being tagged in 2009. In this way, the report can be considered to reflect the (over-)enthusiasm about RFID that existed at the turn of the millennium.⁸

Forrester 2004: Evaluating RFID Middleware

For this report, Forrester interviewed 13 RFID middleware vendor companies including RFID pure plays, platform giants, supply chain application vendors, and integration specialists. Forrester discusses strengths and weaknesses of the vendors' middleware solutions as of 2004 (for details, cf. Forrester 2004, p. 8-15) and gives an estimate about future evolution of RFID middleware.

Without quantifying monetary values, Forrester predicts that RFID middleware will remain a valuable field for vendors. Even though reader integration will turn into a commodity, coordination and configuration of a growing number of readers and other auto-ID devices (potentially from different vendors) will keep the demand of middleware solutions high. Forrester further expects a growing functionality of middleware with respect to “[...] filtering and routing logic that require inputs from multiple readers, sophisticated business logic, or introspection to external data sources” (Forrester 2004, p.16). With companies beginning to build and willing to

⁸ Gartner speaks of this (over-) enthusiasm as “technology hype” (cf. Gartner (2008b)).

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manage more dynamic composite applications, tools like partner management, process automation, and data management will become the killer apps. Overall, RFID middleware solutions have to provide a balanced combination of core infrastructure and packaged application features, which will favor platform giants like IBM, Oracle and SAP in the long run.

Forrester 2008b: The ROI Of RFID For Supply Chain Visibility

In this report, Forrester presents the results of a Total Economic Impact™ (TEI)⁹ analysis of RFID for item-level visibility across manufacturing and distribution operations. Forrester therefore interviewed 13 vendor companies and systems integrators whose input they use to shape a hypothetical – but typical – manufacturer and distributor supply chain on which they run the TEI analysis.

They include:

- **Scenario 1:** minimum integration, in which where RFID identification events are handled just as bar code scans from the legacy systems
- **Scenario 2:** full integration to enterprise applications,

over a time frame of 5 years, assuming 80% of tagged products and applying today's prices for tags, equipment, wages, and system integration (for details about all underlying assumptions, s. Forrester 2008b, p. 7-11).

The result is that minimal systems integration produces an overall ROI of -56% for the sample supply chain; full systems integration produces an ROI of 13%. This result is based on the observation that only the second scenario allows to capture a significant portion of what Forrester calls "top-line revenues" like reducing lost sales from stock-outs or shipping errors (cf. Figure 6), because most of them cannot be realized without systems integration (for a detailed discussion, s. Forrester 2008b, p. 10f).

⁹ TEI is a trademark from Forrester. It is a methodology to evaluate projects instead of relying on industry averages or factors that are applied to all organizations. According to Forrester TEI provides a holistic view of the decision by including an analysis of costs, benefits, flexibility, and risk in light of an organization's current state and future goals (s. Forrester (2003a)).

Revenues/Efficiencies	Scenario 1	Scenario 2
<u>Recapturing top-line revenues</u>		
• Reducing payouts for recalled product	x	✓
• Reducing payouts for returned product	✓	✓
• Reducing lost product and sales from shipping errors	(✓)	✓
• Reconciling invalid order claims /charge backs	(✓)	✓
• Reducing lost sales from stock-outs	x	✓
<u>Improving bottom-line efficiencies</u>		
• Saving direct labour required to receive, ship, and store product	✓	✓
• Reducing inventory shrinkage	✓	✓
• Reducing losses due to product expiry or spoilage	x	✓
• Reducing inventory levels and associated holding costs	x	✓

Figure 6: Benefits of RFID for Supply Chain Visibility, according to Forrester 2008b

In the first scenario, the sample manufacturer's initial investments in systems and infrastructure are followed by recurring negative cash flows caused by ongoing tag costs, which makes the ROI negative. On the contrary, the sample distributor is able to regain his investments between years 3 and 4 as expected business benefits then exceed ongoing costs. Even

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though increasing the level of systems integration in scenario 2 means a further increase of the initial investments, these investments plus the ongoing costs will start to pay off after 4.2 years for manufacturing and after 2.8 years for distribution.

It needs to be noted that the ROI conclusions presented by Forrester are highly dependent on the number of tagged products. Their assumption of 80% of tagged products does not seem to be realistic for the near future (e.g., one German retailer announced in June 2009 that it stopped its RFID efforts for inbound logistics, cf. LOGISTIK inside 2009). Figure 7 shows that supply chains with full systems integration need at least 20% of tagged products to achieve a positive ROI.

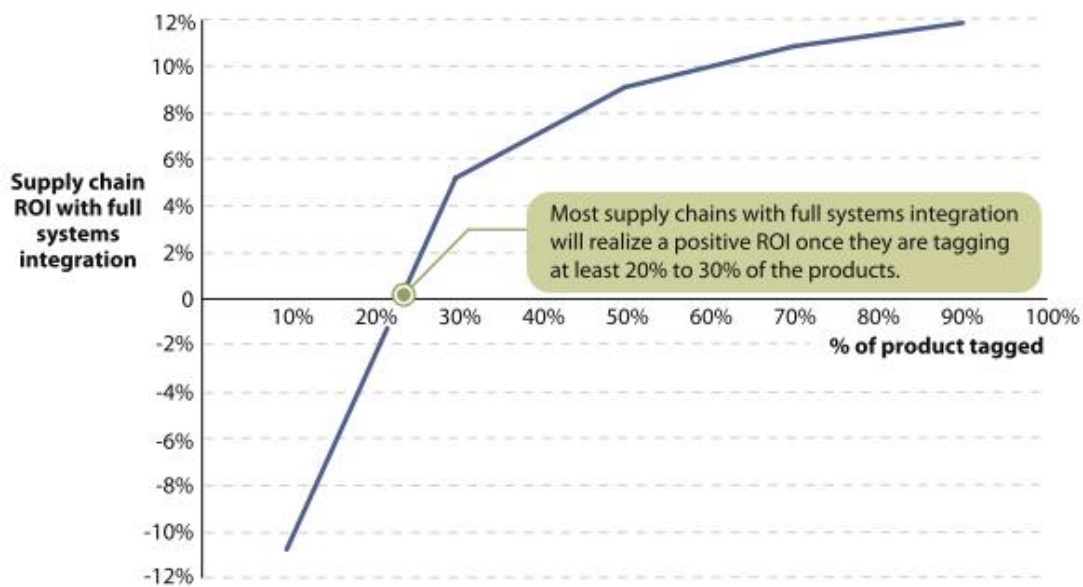


Figure 7: Value of RFID for Supply Chain Visibility varies by Percentage of Products Tagged
(Source: Forrester 2008b)

Forrester 2008a: The ROI Of RFID For Asset Tracking

In this report, Forrester presents the results of a Total Economic Impact™ (TEI)¹⁰ analysis for asset tracking using active RFID over Wi-Fi. Forrester therefore interviewed 13 vendor companies and systems integrators whose input they used to shape two hypothetical – but typical

¹⁰ TEI is a trademark from Forrester. It is a methodology to evaluate projects instead of relying on industry averages or factors that are applied to all organizations. According to Forrester, TEI provides a holistic view of the decision by including an analysis of costs, benefits, flexibility, and risk in light of an organization's current state and future goals (s. Forrester (2003a)).

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– asset intensive companies; one being an auto parts supplier tracking reusable containers, the other being a hospital tracking mobile equipment like wheelchairs and infusion pumps, each company tagging more than 1,000 assets in a three-year period. Forrester further assumes today’s prices for tags (\$70 for an active tag), equipment, wages, and system integration (for details about all underlying assumptions, s. Forrester 2008b, p.6f).

In the auto parts supplier scenario, where a good level of inventory control typically already exists without active tagging, the biggest benefit is the time saved by inventory audit staff to count, inspect, and rebalance containers. With initial investments including network infrastructure enhancements, hardware, and start-up and long-term staff, an overall ROI of 9% after three years is the expected result (s. detailed course of costs and benefits in Figure 8).

In the hospital scenario, in which inventory audits are less frequent and lack of inventory control causes high effort for searching assets, implementing an active RFID asset tracking solution yields – considering all necessary investments like internal labor, professional services and other consultants – an expected ROI of 69% after three years (s. detailed course of costs and benefits in Figure 9). They conclude that the frequency a certain asset is searched for has a greater influence on the expected ROI than the actual value of the asset. In the investigated case, tracking lower-valued but search-intensive wheelchairs turned out to be more beneficial than tracking infusion pumps, which have a higher value but are less often searched for.

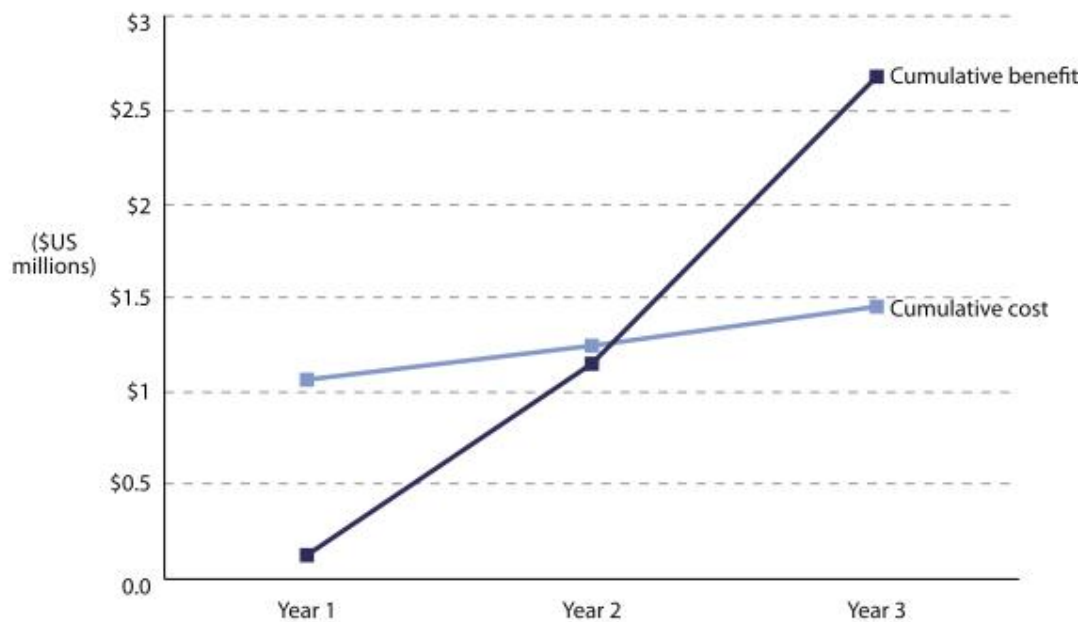


Figure 8: Container asset tracking: Cost versus benefits (Source: Forrester 2008a)

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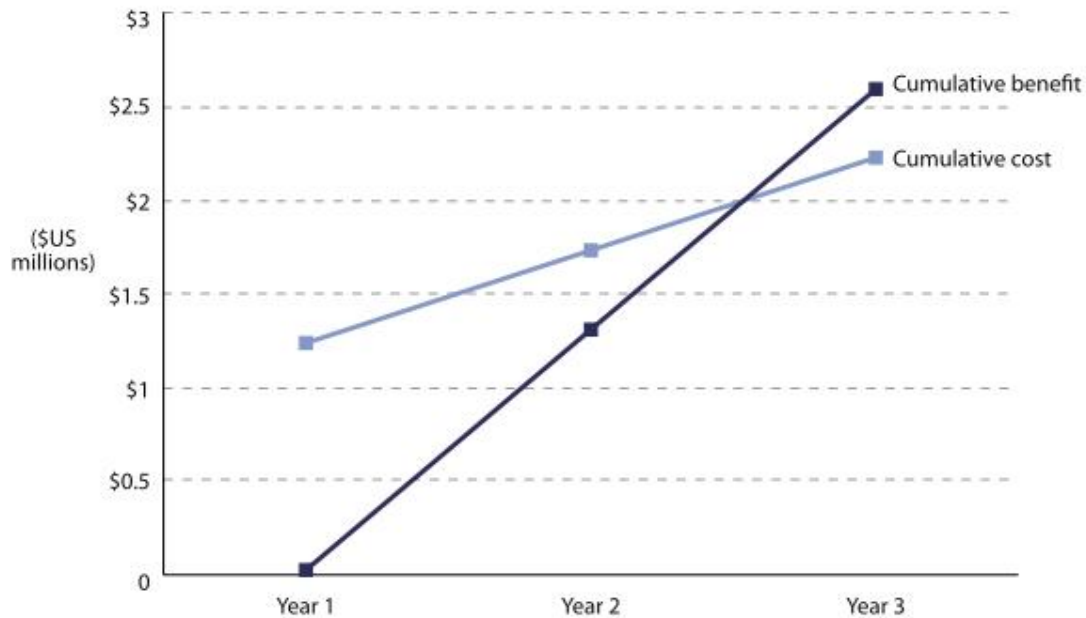


Figure 9: Hospital asset tracking: Cost versus benefits (Source: Forrester 2008a)

Forrester further outlines possible future rewards which go beyond tactical concerns. These can be achieved by using the data obtained through a tracking solution to analyze and continuously improve process flows in areas like inventory distribution across multiple facilities or asset procurement. They do however not quantify these potential rewards.

AMR Research 2002: ePC/RFID And Its Imminent Effect on the Supply Chain

In this early report, AMR depicts the successes of deployments of RFID on pallet and case level, primarily in the retail and CPG industries (Wal-Mart, Woolworth's, Tesco, Sainsbury, Scottish Courage Breweries), which unveiled a 3% to 5% cost reduction in the supply chain and 2% to 7% increases in revenue from inventory visibility. According to AMR, these deployments exhibit that technology improvements have already increased the value of implementing RFID so that its further success does not necessarily depend on the "\$0.05 tag", but rather on the ability of companies to incrementally build upon their existing application infrastructure to support the collection, storage, and processing of RFID data. AMR states that even though "RFID is still an option, [...] it will cause disruption in the business environment, resulting in winners and losers" (AMR Research 2002, p.9). That is why they recommend companies to prepare for incremental deployments.

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The report includes some quantitative forecasts on future market development, but like the early Forrester report (s. Forrester 2003b), the predictions for tag sales and prices (15 billion tags by 2006 at \$0.05 each) turned out to be too optimistic in the retrospective. However, their expectations for the application of RFID in tracking and monitoring perishable products, and for fighting theft within the supply chain have met current developments (cf. for example SToP 2009).

AMR Research 2009a: RFID Lessons for All

This report gives recent information about Boeing's RFID initiative for the 787 Dreamliner and some of the company's other tactical projects and derives some lessons learnt from these projects.

Originally, the Dreamliner was supposed to have more than 1,000 parts tagged with RFID by the end of 2008 for use in both manufacturing and maintenance processes. Each tag would hold a maintenance history of the part it was attached to, allowing technicians to save time by reading only the tag (instead of paper-based maintenance logs). Boeing encountered delays in the supply of extended memory tags. In addition to that, there was slow approval by the Federal Aviation Administration (FAA) so that the project is far behind its schedule now. However, AMR reports about other RFID-projects that implemented active tracking of tools and other assets, where Boeing achieved a positive ROI. The positive effects resulted from the reduction of time that is necessary for searching parts or checking on-board inventory (e.g. life-jackets).

For the lessons learnt from Boeing, AMR recommends to establish an enterprise-wide RFID strategy (as Boeing did), which should account for starting with closed-loop systems to prove a positive ROI, and which should avoid to rely on immature technology (as Boeing did when ordering tags for the Dreamliner which did not exist by then).

AMR Research 2009b: RFID in the Service Supply Chain: Where's the ROI?

In this recent report, AMR finds that "[...] the use of RFID in the service supply chain has not extended beyond the early forms of maturity [...]": so far, a positive ROI along the supply chain can be identified mainly in closed-loop systems when RFID is applied in shipping-, receiving-, and works-in-progress processes. They give some examples for such applications, which include companies like Boeing, CHEP and Cisco, but they do not quantify their ROI. Among the challenges for more wide-spread and more open-loop deployments covering the whole lifecycle, they identify technology issues such as memory limits (needed for on-tag storage), lack of industry data standards and high costs for tags, and collaboration-related issues such as who in the Supply Chain is to shoulder this cost burden. For companies willing to ex-

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exploit and drive RFID deployments, AMR recommends to create a vision of usage up-front, to proceed with concentrating on the ROI-promising tactical projects, and then to go for the realization of the more visionary plans. Companies should look for applications where they can get multiple uses out of the same tags and select providers that are experienced in deployments in the company's industry.

AMR Research 2009c: RFID Journal Live: The Good, the Bad, and the Ugly of RFID

This report about the recent RFID Journal Live event in Orlando from April 27th to 29th categorizes current RFID developments into "the good, the bad and the ugly".

Among "the good", AMR finds most noticeable that vendors have shifted their focus away from technology toward solving particular business problems such as replenishment in retail stores or asset tracking in IT, manufacturing, and logistics. As a consequence, solutions are now focused on closed-loop applications of RFID, as opposed to earlier cross-enterprise visibility efforts.

Among "the bad", AMR stresses the lack of diversification as almost all vendors address the same business problems mentioned.

This is related to "the ugly", which according to AMR is the large amount of small companies that either manufacture or assemble RFID hardware, but are not capable to stem large roll-outs. AMR sees a need for intensive consolidation which is hindered by a chicken-egg scenario because "[t]he market won't consolidate until customers start to invest big, but they're reluctant to do so when they're relying on small start-ups that may not have the scale to support a global rollout" (AMR Research 2009c, p.2).

Overall, AMR predicts that even though 2009 will be another lean year for RFID due to the economic crisis, the adoption RFID will proceed in the long run.

Gartner 2008a: Market Trends: Radio Frequency Identification, Worldwide, 2007-2012

Key statements from this report are that Gartner identifies a starting consolidation in the RFID market, and a focus shift from RFID as technology to comply with mandates towards RFID as enabler for business process innovation.

As displayed in Figure 10, Gartner forecasts a raise of the RFID market¹¹ from 900 million in 2007 to 3.5 billion by 2012, which corresponds to a compound annual growth of about 31 per cent.

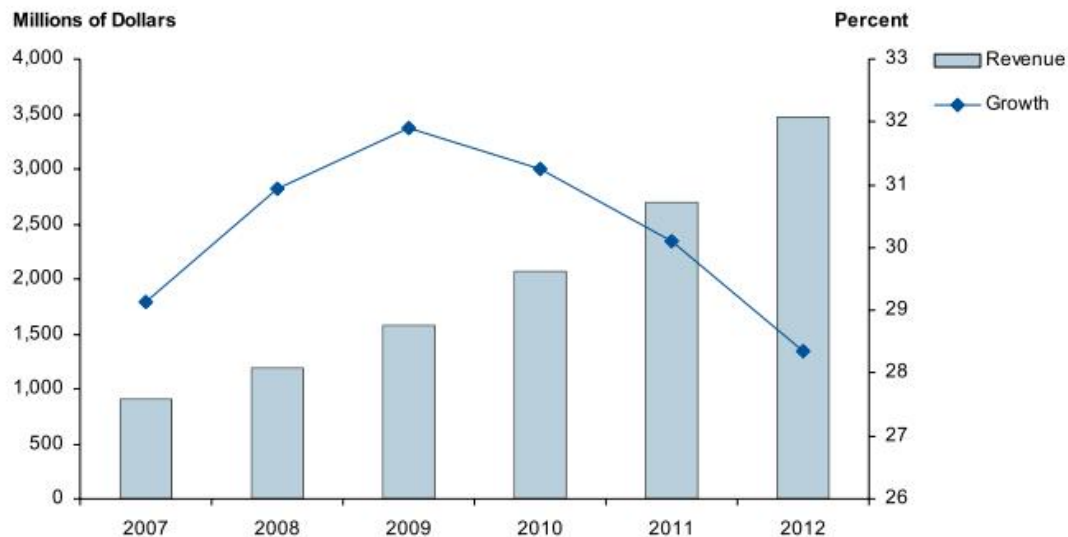


Figure 10: Total RFID Revenue, 2007-2012 (Software and Hardware) (Source: Gartner 2009)

As a primary driver of this predicted growth, Gartner mentions globalization, which makes companies seek to shorten time-to-market and improve their business competitiveness on a global scale. Some companies will deploy RFID solutions to enhance existing business processes while others will use it as a means to establish “disruptive, new, unique business processes”. According to Gartner, companies will particularly account for RFID in the fields of asset management (to manage non-maintained or disposable assets) and in-store inventory management, because business cases in these fields are already very promising. Moreover, there will be fewer investigative projects yielding fuller-scale deployments, which carry more revenues for both hardware and software.

The potential merits of the combination of environments and technologies (e.g. RFID and GPS) will further contribute to the adoption of RFID.

The current and predicted developments favor larger vendors that can move beyond technology deployment. For these vendors, Gartner suggests to focus on solutions for particular in-

¹¹ According to Gartner, only the applications and hardware that are used within a supply chain environment were included, i.e. consumer uses (such as contactless smart cards or passports) were not considered in their forecast.

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dustries by developing industry expertise and partnering with complementary technology and services organizations.

In 2007, Discrete Manufacturing had 21%, Healthcare 12%, National and International Government 20%, Process Manufacturing 13%, Retail Trade 14%, and Transportation 20% of the global market share. Gartner gives global revenue forecasts for certain industries: shares will shift in favor of Healthcare and Process Manufacturing by 2012 due to the expected benefits of asset management and process innovation mentioned above.

Gartner also covers a detailed regional revenue forecast where North America and Europe carry the lion's share with 88% of 2007's revenue, but other regions like Asia/Pacific and Japan share a consistent adoption pattern (for detailed information about regional differences, cf. Gartner 2008a, p.8-12).

Gartner 2009c: RFID in the 2009 Supply Chain: Overview and Best Practices for Maximum Investment Value

In this report Gartner sketches current developments in the RFID market and presents best practices for RFID deployments in the supply chain.

Gartner finds that companies currently revisit their business cases for RFID deployments. They often reduce scope and increasingly aim at addressing specific business needs. Gartner sees inventory management, based on passive RFID and mobile asset optimization, often based on active RFID, as primary applications for RFID, because these areas often yield a promising ROI. They do not quantify this ROI, however.

Even though “[t]here is no Magic Quadrant for RFID”, because “[...] different industry solutions are at different levels of maturity and adoption”, Gartner identifies the following best practices in the context of the typical supply chain:

1. Start with the business case and realistically examine alternatives.
2. Focus on the business processes.
3. Align hardware capability with the environmental situation.
4. Decide on closed-loop versus open-loop deployments.
5. Don't neglect data quality.
6. Select vendors that understand your problem.
7. Narrow the scope, address security and simplify the architecture.

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(Gartner 2009c, p.3).

The best practices hence follow a top-down approach, starting with the business case and going down as far as addressing security issues and architecture refactorings. Besides these seven practices, Gartner additionally emphasizes the importance of the RFID middleware, which can be a key factor for larger-scale deployments for the alignment of RFID technology and business processes.

4.3 (Wireless) Sensor Technologies

ON World 2007: Wireless Sensor Networks for Smart Industries

A study from ON World Inc. projects that Wireless Sensor Network (WSN) systems and services will be worth \$4.6 billion in 2011, up from about \$500 million in 2005. The authors estimate that by 2012, \$25.1 million WSN units will be sold for smart home solutions only, which reflects a high increase from the 2 million in 2007 (ON World 2007). It is important to note that the ON World study only accounts for the physical node hardware - neither the physical gateway hardware, nor any independent system software components, neither enterprise software components and system integration services nor other ancillary services. Hence, their forecast for WSNs does not capture all relevant areas of revenue.

Forrester 2007a: Making Sense Of Sensor Data

In this report, which is closely related to Forrester 2006b, Forrester does not address the sensor technologies market itself, but discusses sensor data impact on the X Internet software market, which Forrester expects to reach \$2.7 billion by 2012 (for numbers about the overall X Internet market, s. chapter 4.1). A pre-requisite for this growth is to successfully incorporate sensor data into applicable business processes for corrective or pre-emptive action, so-called “Dynamic Business Applications” (Forrester 2007a, p.12). On the one hand, Forrester predicts that this will drive vertically aligned ecosystems of vendors, each focused on its specific product expertise in one of the fields as device management, data management and integration- and analytics tools. On the other hand, they also expect industry consortiums to play their part in supporting network-wide dynamic business applications like cross-enterprise supply chain visibility. However, they do not provide detailed estimates about specific time frames for and intensity of these developments.

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4.4 Context-Aware Computing

Gartner 2009b: Predicts 2009: Context-Aware Computing Gains Momentum

Gartner has identified context-aware computing as one of the 10 most disruptive technologies of the next five years (s. Gartner 2009a), which will be moving toward mainstream computing within the next 10 years. They call the associated offerings “context-enriched services”, which are a cross-discipline, cross-technology way to enhance user experience by including sensor, presence, location, and other indirect information.¹²

Gartner predicts that by the end of 2012, 20% of non-video Internet traffic will consist of data from sensor-based inputs. By 2012, 10% of consumers in Western Europe and North America will use context-aware services for items of interest near their locations, 25% of global Internet users will provide device-generated geo-location data to other sites and authorized people, and in 2011, 85% of context-enriched services will have interfaces based on location or presence information.

Based on these estimates, Gartner recommends investigating push-models that anticipate user’s needs, which makes location-based marketing particularly attractive. Another opportunity for companies is to use location and presence to optimize their business processes. Gartner does not quantify these potentials.

4.5 Categorisation, analysis and interpretation of the reports

To compare and analyze patterns and differences in the reports presented throughout the last chapters, we again cluster them primarily according to the technology they cover (Internet of Things, RFID, Sensor technologies and Context-Aware Computing). For each of these clusters, we create a matrix which presents the respective reports in the vertical and the following technology, company and market related attributes in the horizontal:

¹² In this sense, Context-Aware Computing can be seen as a synthesizer of information rather than a technology.

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	Report 1	Report 2
Main Technologies		
Global Market estimates		
Cost estimates (for equipment)		
Main Drivers for adoption		
Main Success factors (market)		
Main Success factors (company)		
Deployment strategy		
Main areas of benefit (company)		
Main areas of benefit (industry)		

Table 3: Blueprint for the categorization of the report

To enhance comparability for the large quantity of RFID reports, we additionally introduce a categorization with regard to the report type for them, i.e. *market forecasts*, dedicated *ROI case studies* and *experience reports*. Since case studies and experience reports differ from market forecasts with regard to structure and scope, we slightly modified the attributes listed in Table 3 so that they better reflect the nature of these reports.

We will analyze and interpret each cluster separately, and we will close this chapter with a summary of the conclusions for smart products.

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4.5.1 Internet of Things

	ITU 2005	Forrester 2003b	Forrester 2006a	Forrester 2006b	Forrester 2007b
Main Technologies	<ul style="list-style-type: none"> • RFID • Sensor technologies • Embedded technologies • Nanotechnology 	<ul style="list-style-type: none"> • RFID • Sensor technologies (telemetric) • Biometrics • Presence awareness 	<ul style="list-style-type: none"> • RFID • Sensor technologies (telemetric) • Biometrics • Presence awareness 	<ul style="list-style-type: none"> • RFID • Sensor technologies (telemetric) • Biometrics • Presence awareness • Software & Services 	<ul style="list-style-type: none"> • RFID • Sensor technologies (telemetric) • Biometrics • Presence awareness • Software & Services
Global Market estimates	<ul style="list-style-type: none"> • RFID Hardware (2008): \$3.5 bill. • RFID Software (2008): \$4 bill. • Nanotechnology (2014): \$2.6 trill. 	<ul style="list-style-type: none"> • Extended Internet (2014, cumulated): \$2.7 trill., thereof \$1.8 trill. by manufacturing 	n/a	<ul style="list-style-type: none"> • Extended Internet (2012, enterprise market): \$11.6 bill. 	n/a
Cost estimates (for equipment)	<ul style="list-style-type: none"> • RFID (2006): 0.05 [\$/tag] 	n/a	n/a	n/a	n/a
Main Drivers for adoption	n/a	<ul style="list-style-type: none"> • Mandates • Competition 	<ul style="list-style-type: none"> • Mandates • Globalization 	<ul style="list-style-type: none"> • Potential for business change 	<ul style="list-style-type: none"> • Closed-loop deployments

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		<ul style="list-style-type: none"> • Customers • OEMs 	<ul style="list-style-type: none"> • Raising resource cost • Maturing enabling technologies • Raising healthcare cost • Lifestyle/ Entertainment demands 	<ul style="list-style-type: none"> • Low cost • Indispensability • Competition 	<ul style="list-style-type: none"> • Maturing enabling technologies
Main Success factors (market)	<ul style="list-style-type: none"> • People-oriented • Confidentiality & security • Protecting privacy • Ethics • Compliance 	n/a	n/a	n/a	n/a
Main Success factors (company)	n/a	n/a	<ul style="list-style-type: none"> • Identification of business process pain points • Building of strong Extended Internet ecosystems 	<ul style="list-style-type: none"> • Concentration on small number of business processes • Building of strong Extended Internet ecosystems 	<ul style="list-style-type: none"> • Alignment with operations strategy • Build up internal SOA know-how • Building of strong Extended Internet ecosystems
Deployment strategy	n/a	n/a	1. Tactical deploy-	1. Abandon tactical	1. Build business case

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			<ul style="list-style-type: none"> 2. Adjacent process rollouts 3. Widespread business process re-definition 	<ul style="list-style-type: none"> 2. Adjacent process rollouts 3. Definition of new business processes 	<ul style="list-style-type: none"> now (Tactical deployments) 2. Improve process efficiency and effectiveness
Main areas of benefit (company)	n/a	<ul style="list-style-type: none"> • Supply chain visibility 	<ul style="list-style-type: none"> • Industrial maintenance and automation • Supply chain visibility and control • Internal mobile asset optimization • Physical control and security 	<ul style="list-style-type: none"> • Industrial maintenance and automation • Supply chain visibility and control • Internal mobile asset optimization • Physical control and security 	<ul style="list-style-type: none"> • Industrial maintenance and automation • Supply chain visibility and control • Internal mobile asset optimization • Physical control and security
Main areas of benefit (industry)	<ul style="list-style-type: none"> • Retail • Automotive • TelCo 	<ul style="list-style-type: none"> • Retail • Automotive • Aircraft • Insurance 	<ul style="list-style-type: none"> • Retail • Healthcare • Manufacturing 	<ul style="list-style-type: none"> • Retail • Manufacturing 	<ul style="list-style-type: none"> • Manufacturing (focus report)

Table 4: Analyst Reports: Internet of Things

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Analysis

All reports mention RFID and sensor technologies as two of the enabling technologies for the Internet of Things (IoT). For the other technologies ITU takes a more miniaturist view by adding embedded technologies and nanotechnology, whereas Forrester includes Biometrics and also Presence awareness, which indicates the idea of adding some sort of “intelligence”. Forrester further extend their view on the enabling technologies in later reports, where they consider software and services as explicit part of the Internet of Things.

Market estimates for the IoT differ across the reports. Later reports adjust the overly optimistic estimates from the earlier ones, whereas the latest estimate from Forrester from 2006 (\$11.6 billion for the enterprise market by 2012) still appears to be too ambitious.

Only the ITU report gives an estimate on the development of costs. Especially the more recent Forrester reports argue that the success of the IoT does not depend so much on hardware costs, but rather on generating long-term business benefits (cf. Forrester 2006a, Forrester 2006b, Forrester 2007b).

For the drivers for adoption, some reports focus more on the endogenous (e.g. technology maturity) and some more on the exogenous factors (e.g. globalization, mandates, raising resource and healthcare cost). One Forrester report also includes the sociological trend for a growing demand for lifestyle and entertainment.

ITU features the only report which includes success factors for market development. They primarily regard adequate addressing of privacy and security aspects as key for success. With regard to the success factors on the company level, the Forrester reports underline the importance of identifying appropriate business processes, and of building a strong ecosystem.

The deployment strategy is not consistent among the reports – two reports recommend to start with smaller tactical deployments to harvest the “low hanging fruits” and to prove a positive business case, while one opts for directly stepping into more process-centric solutions with a larger impact. At a later stage, all reports see the opportunity to redefine existing business processes and possibly to define new ones to enhance business.

The reports commonly mention retail and manufacturing, two of them automotive, as the main benefiting industries. The favored domains in these industries span industrial maintenance and automation, supply chain visibility, mobile asset optimization, and physical control and security.

Interpretation and conclusion for SmartProducts

The reports indicate that there is a large growth potential for Internet of Things technologies. This is also promising for smart products because they will probably build on the same under-

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lying technologies, e.g. identification (RFID), sensor technologies and context awareness. Smart products in this sense can be considered as part of the larger context of the Internet of Things – whereas the Internet of Things mainly introduces the idea of connectivity and information exchange of everyday objects, smart products are more product-centred and carry the idea of introducing intelligence and smartness to these products (cf. chapter 4.1).

With EADS and Fiat, the SmartProducts project involves two of the main benefiting industries mentioned in the reports (manufacturing and automotive). Based on the reports' recommendations, especially the Aircraft Manufacturing scenario from EADS and the Spare Part Management domain in the Smart Vehicle scenario from Fiat appear to be promising for a positive business case, because they deal with tactical deployments to optimize internal processes. Such closed-loop areas of application do not involve coordination and interoperability issues with other supply chain members, which is one of the main reasons why they are supposed to pay off faster. The interviewee from CRF supports this view: his estimate is that there is a several times higher potential to create business benefit when smart products are applied to internal processes compared to client-centered enhancements. As a consequence for the business case analysis in the SmartProducts project, it appears to be beneficiary to focus on these closed-loop scenarios first to prove the value as early as possible.

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4.5.2 RFID

4.5.2.1 RFID Market Forecasts

	Forrester 2002	Forrester 2004	AMR Research 2002	Gartner 2008a
Main Technologies	<ul style="list-style-type: none"> RFID 	<ul style="list-style-type: none"> RFID Middleware 	<ul style="list-style-type: none"> RFID 	<ul style="list-style-type: none"> RFID
Global Market estimates	<ul style="list-style-type: none"> RFID Hardware (2009): 2% of CPG products will have RFID tags 	n/a	<ul style="list-style-type: none"> RFID tag sales (2006): 15 bill. tags 	<ul style="list-style-type: none"> RFID Hardware and Software (2012; no consumer uses): \$3.5 bill. (CAGR ~ 31%)
Cost estimates (for equipment)	<ul style="list-style-type: none"> RFID (2009): 0.01 [\$/tag] 	n/a	<ul style="list-style-type: none"> RFID (2006): 0.05 [\$/tag] 	n/a
Main Drivers for adoption	n/a	<ul style="list-style-type: none"> Growing number of readers and other auto-ID devices Need for coordination and configuration of these 	<ul style="list-style-type: none"> Successful field trials proving value (3% to 5% cost reduction in the supply chain; 2% to 7% increases in revenue from inventory visibility) 	<ul style="list-style-type: none"> Globalization (esp. business competition) Merits of the combination of environments and technologies
Main Success factors (market)	<ul style="list-style-type: none"> Tag and reader compatibility Filtering data 	n/a	<ul style="list-style-type: none"> Tag and reader compatibility Standards 	n/a

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	<ul style="list-style-type: none"> Standards 			
Main Success factors (company)	n/a	n/a	n/a	n/a
Deployment strategy	<ol style="list-style-type: none"> Focus on Supply Chain (tagging of pallets, cases) Item level tagging 	<ul style="list-style-type: none"> Provide a balanced combination of core infrastructure and packaged application features 	<ul style="list-style-type: none"> Incremental deployments 	<ul style="list-style-type: none"> Focus on solutions for particular industries (by developing industry expertise and a partner ecosystem)
Main areas of benefit (company)	<ul style="list-style-type: none"> Supply chain execution Asset management Payment transactions Process speed 	<ul style="list-style-type: none"> RFID middleware solutions 	<ul style="list-style-type: none"> Supply Chain visibility Inventory visibility 	<ul style="list-style-type: none"> Asset management In-store inventory management
Main areas of benefit (industry)	<ul style="list-style-type: none"> Consumer Packaged Goods (especially health, beauty and tobacco) 	<p>Vendors:</p> <ul style="list-style-type: none"> Platform giants like IBM, Oracle and SAP 	<ul style="list-style-type: none"> Fast moving consumer goods Health, Beauty & Accessories Apparel Pharma Consumer Electronics Media 	<ul style="list-style-type: none"> Discrete Manufacturing Healthcare Government Process Manufacturing Retail Trade Transportation <p>Vendors:</p> <ul style="list-style-type: none"> Larger vendors

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Table 5: Analyst Reports: RFID Market Forecasts

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Analysis

Early reports from Forrester and AMR in 2002 have mainly focused on the application of RFID within the supply chain, whereas the more recent Gartner report focuses on closed-loop applications like asset management and in-store inventory management. This switch is consistent with the observation we already made when we analyzed the IoT reports. Gartner further underlines that the merits of RIFD will increase when it is applied in combination with different environments and technologies. This reflects another evolution in thinking about RFID solutions: from technology-oriented “tagging scenarios” towards RFID as one of a plethora of different technologies (such as sensors, middleware, analytics systems, etc.), which jointly help to mitigate business pain points. While all reports mention Retail (or Packed/Fast Moving Consumer Goods) as one of the major benefiting industries, one report explicitly mentions Consumer Electronics, and another Discrete Manufacturing.

Interpretation and conclusion for SmartProducts

The reports indicate that there is still a substantial growth potential for RFID technologies even though early estimates turned out to be overly optimistic. Since smart products will probably include RFID for identification and potentially also data storage purposes, this outlook is also promising for smart product adoption. With the (discrete) Aircraft Manufacturing scenario from EADS, the Smart Kitchen (Consumer Appliances) scenario from Philips and the Smart Vehicle scenario from Fiat, the project covers some of the most promising domains mentioned in the reports.

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4.5.2.2 RFID ROI Studies

	Forrester 2008b	Forrester 2008a
Main field of application	<ul style="list-style-type: none"> • Passive RFID • Supply Chain Visibility • Manufacturing & Distribution operations 	<ul style="list-style-type: none"> • Active RFID • Asset Management
Set-up	<ul style="list-style-type: none"> • 1 scenario with minimal integration • 1 scenario with full integration 	<ul style="list-style-type: none"> • 1 scenario for auto parts supplier (reusable containers) • 1 scenario for hospital (wheelchairs and infusion pumps)
Timeframe	<ul style="list-style-type: none"> • 5 years 	<ul style="list-style-type: none"> • 3 years
Assumptions	<ul style="list-style-type: none"> • Equipment, wages and systems integration cost as of 2009 • 80% tagged products 	<ul style="list-style-type: none"> • Equipment, wages and systems integration cost as of 2009
ROI	<ul style="list-style-type: none"> • Scenario 1: -56% • Scenario 2: 13% 	<ul style="list-style-type: none"> • Scenario 1: 9% • Scenario 2: 69%

Table 6: Analyst Reports: RFID ROI Studies

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Analysis

The two ROI studies cover different domains (supply chain visibility and asset management) and technologies (passive and active RFID) and as such cannot be directly compared with each other. Nevertheless they allow for a valuable insight: even though active RFID carries a higher one-time investment, it may yield a higher ROI in a shorter period of time when applied in asset intensive domains than the use of passive tags can achieve when applied for supply chain visibility. Another take-away is that supply chain visibility currently only appears to pay off if it is realized with full system integration.

Interpretation and conclusion for SmartProducts

Out of the large number of reports which have been published about RFID and related technologies, the two studies described here are apparently the only ones which cover a dedicated ROI analysis. The backdrop of these studies is that they are based on simulations, i.e. they have not been tested or verified in the field yet. As a consequence, the SmartProducts project should aim to do a thorough ROI assessment; because proving a positive ROI is essential for the adoption of smart products (otherwise management will not take the necessary investments). Another insight for the project is that the applications that are developed should feature as much system integration as possible.

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4.5.2.3 RFID Experience Reports

	AMR Research 2009b	AMR Research 2009a	Gartner 2009c
Main field of application	<ul style="list-style-type: none"> • Passive and active RFID • Closed-loop systems when (shipping-, receiving-, and works-in-progress processes) 	<ul style="list-style-type: none"> • Passive RFID • Boeing 787 Dreamliner 	<ul style="list-style-type: none"> • Passive and active RFID • Closed-loop systems
Main Success factors (company)	<ul style="list-style-type: none"> • Identify applications with multiple uses out of the same tags and inlays • Identify experienced providers with industry knowledge 	<ul style="list-style-type: none"> • Avoid immature technology 	<ul style="list-style-type: none"> • Effective RFID middleware
Deployment strategy	<ol style="list-style-type: none"> 1. Create a vision of usage up-front 2. Concentrate on the ROI-promising tactical projects 3. Realize the more visionary plans 	<ol style="list-style-type: none"> 1. Create a vision of usage up-front 2. Concentrate on the ROI-promising tactical closed-loop projects 3. Realize the more visionary plans 	<ol style="list-style-type: none"> 1. Start with the business case and realistically examine alternatives. 2. Focus on the business processes. 3. Align hardware capability with the environmental situation. 4. Decide on closed-loop versus open-loop deployments. 5. Don't neglect data quality. 6. Select vendors that understand your problem.

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			7. Narrow the scope, address security and simplify the architecture.
Main areas of benefit (company)	n/a	<ul style="list-style-type: none"> • Reduction of time looking for parts • Less time for inventorying and examining items 	<ul style="list-style-type: none"> • Asset management • Inventory management
Main areas of benefit (industry)	<ul style="list-style-type: none"> • Aircraft • TelCo • Transportation 	<ul style="list-style-type: none"> • Aircraft 	n/a
Challenges	<ul style="list-style-type: none"> • Technology issues (e.g. memory limits) • Lack of industry data standards • High costs for tags • Collaboration-related issues 	<ul style="list-style-type: none"> • Approval by the Federal Aviation Administration (FAA) 	n/a

Table 7: Analyst Reports: RFID Experience Reports

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Analysis

Two of the three reports presented cover the domain of supply chain management; one covers the learnings from the RFID efforts for the Boeing Dreamliner. Even though the domains are different, the reports give a similar set of recommendations for the deployment strategy for RFID, mainly to concentrate on ROI-promising tactical projects. While AMR puts a higher emphasis on creating a vision up-front, Gartner regards the development of a business case as the paramount starting point. Another take-away is that mature technology and experienced providers are important success factors, and that collaboration-related issues and approvals by authorities like the FAA have proven to slow down deployments considerably.

Interpretation and conclusion for SmartProducts

The SmartProducts project has already developed visions for the three application scenarios and will be accompanied by a business case analysis. In this respect, the project is in line with best practice recommendations presented in the experience reports. Because the project scopes closed-loop applications which do not include supply chain partners, there will be no supply chain collaboration-related issues. However, the project and the business case analysis in particular should account for possible challenges with regard to company and industry regulations that might slow down or impede adoption, or even legally preclude deployment.

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4.5.3 (Wireless) Sensor Technologies

	ON World 2007	Forrester 2007a
Main Technologies	<ul style="list-style-type: none"> Wireless sensor network systems 	<ul style="list-style-type: none"> Sensor technologies
Global Market estimates	<ul style="list-style-type: none"> Physical node hardware (2011): \$ 4.5 bill. Physical node hardware (2012, cumulated): 25.1 mill. units 	<ul style="list-style-type: none"> Extended Internet software market (2012): \$2.7 bill. (“Dynamic Business Applications”)
Cost estimates (for equipment)	n/a	n/a
Main Drivers for adoption	n/a	n/a
Main Success factors (market)	n/a	<ul style="list-style-type: none"> Vertically aligned ecosystems of vendors Industry consortiums to provide cross-enterprise supply chain visibility
Main Success factors (company)	n/a	<ul style="list-style-type: none"> Successfully incorporate sensor data into applicable business processes for corrective or pre-emptive action
Deployment strategy	n/a	n/a
Main areas of benefit (company)	n/a	n/a
Main areas of benefit	<ul style="list-style-type: none"> Smart Home Solutions 	<ul style="list-style-type: none"> Retail

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(industry)		<ul style="list-style-type: none"> • Healthcare • Manufacturing
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Table 8: Analyst Reports: (Wireless) Sensor Technologies

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Analysis

There is a significant growth potential for both the hardware, i.e. the sensors, and the software that builds on the data generated by the sensors. ON World predicts that sensor technologies will especially be applied in Smart Home Solutions, however without quantifying the business potential for such products (from the perspective of the vendors of such solutions). The market for software solutions is considered highest for retail, healthcare, and manufacturing (cf. the paragraphs about the Internet of Things).

Interpretation and conclusion for SmartProducts

The Smart Kitchen scenario of Philips is an innovation in the field of Smart Home Solutions. Therefore, the business case for this scenario will fill the gap of a lack of business value estimates for Smart Home Software Solutions.

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4.5.4 Context-Aware Computing

	Gartner 2009b
Main Technologies	<ul style="list-style-type: none"> Context-aware computing
Global Market estimates	<ul style="list-style-type: none"> Internet traffic (2012): 20% of non-video Internet traffic will be data from sensor-based inputs Context-aware services (2012): 10% of consumers in Western Europe and North America will use them Geo-location data (2012): 25% of global Internet users will provide device-generated geo-location data Location-based interfaces (2011): 85% of context-enriched services will have such interfaces
Cost estimates (for equipment)	n/a
Main Drivers for adoption	n/a
Main Success factors (market)	n/a
Main Success factors (company)	n/a
Deployment strategy	<ul style="list-style-type: none"> Establish push-models that anticipate user's needs Use location and presence to optimize their business processes.
Main areas of benefit (company)	<ul style="list-style-type: none"> Marketing Business processes
Main areas of benefit	n/a

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(industry)	
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Table 9: Analyst Reports: Context-Aware Computing

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Analysis

Context-aware computing will grow substantially, enabling to introduce tailored, location-based marketing, and to optimize business processes by including location and presence-related considerations.

Interpretation and conclusion for SmartProducts

The predicted growth of context-aware services will foster the adoption of smart products, because context-awareness is one substantial feature of smart product. All three application scenarios include use cases which involve such context-awareness: For the Smart Kitchen, an example is to tell the cook to add salt and some other ingredients when the context is recognized as “the water is cooking”. For the Fiat scenario it is, for example, to notify the user to mount snow chains when the context is “it is snowing heavily”, and for the EADS scenario it is, for example, to automatically provide the operator with information about his work order when the context is “operator is entering the cockpit”.

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4.6 Summary

Our research has shown that there are no analyst reports available yet which are exclusively dedicated to smart products. This is because smart products is a new research domain and as such it is not targeted yet by the analyst reports, which deal principally with ready-for-market technologies that are at least in an early adoption phase. So we indicatively researched for reports which cover important technologies and concepts related to smart products (the “Internet of Things”, RFID, (wireless) sensor technologies, and context-aware computing) which allowed us to get an estimate on the market potentials of these technologies and provided us with insights in best practice for (new) technology deployments.

Market forecasts indicate that there is substantial growth for both smart product related hardware (such as RFID and sensors) and associated middleware and enterprise software solutions. The estimations presented in the reports can be taken as an indicative trend in the market, which underlines the great potential of smart products for various domains and industries such as retail (especially inventory management), manufacturing (especially automation of manufacturing and maintenance processes), and consumer electronics (e.g. smart home appliances). With the Aircraft Manufacturing scenario from EADS, the Smart Kitchen scenario from Philips and the Smart Vehicle scenario from Fiat, the SmartProducts project covers a significant range of these promising fields of application.

Our research has also revealed that most of the available reports related to smart products are about RFID. The more recent RFID reports are not as much technology-centered as they used to be at the beginning of this decade and as such have become more compelling to give insights for smart products. A general learning from these reports is that the focus has shifted from supply chain applications with aspired open-loop deployments towards closed-loop industry scenarios with a strong focus on process improvements. This is mainly because the latter promise a higher chance to yield positive ROI within a shorter time frame, and they do not have the same challenges and risks with regard to coordination. One could interpret this trend as a kind of disenchantment taking place here. Whereas a couple of years ago, reports described rather complex visions that might become possible through adopting technologies like RFID in open-loop supply networks, recently a more realistic perspective has been adopted, which is based more on experiences from early implementation projects than on visionary scenarios that have never been implemented.

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An evident shortcoming of these reports, and also all the other reports discussed in this chapter, is that they do not provide a field-tested quantification of an ROI. They do however emphasize that having a reliable business case is key for the success of deployments of new technologies (such as RFID and sensor technologies). We conclude from this recommendation that carrying out a thorough business case analysis for all the three application domains in the SmartProducts project will be absolutely crucial for later success of smart products. Since the reports do not provide a framework or methodology about how to obtain such business cases, we need to design a suitable approach for each of the three application scenarios.

In accordance with deployment strategies suggested in the reports, which is to initially start with addressing significant pain points on the process level, our current assumption is as follows: especially the EADS aircraft manufacturing, which focuses exclusively on process improvements, and the Fiat PLM scenario, which also focuses to some extent on process improvements (e.g. the spare parts management), promise a good chance to yield a positive ROI. It is still an important part of the business case analysis to identify and specify in detail the “low-hanging fruits” in each of the scenarios.

Another insight we gained from the reports is that analytics and business intelligence will play a growing role to reap benefits from the growing amount of available real-time data. The challenge here is to aggregate and mine the real-time data collected in such a way that it becomes valuable for decision support – both on the operative level as well as on the executive level to support the overall operations strategy. It remains an interesting and challenging field of research to answer the question of how such “High resolution management” (cf. Fleisch, Sarma et al. 2006) can effectively be realized in real-world deployments. It is very hard to quantify these potentials, especially at such an early stage of maturity, which is why we will not include a detailed analysis in the business case. Nevertheless, the architectural and organizational designs of smart products need to account for the requirements such analytics systems might impose in future. On the technical level, this might for example mean that data is made available in relational databases to allow for fast analytical processing by Business Intelligence Tools. At the organizational level, it is important that an enterprise builds up in-house capabilities to access, run and modify the whole system, and further to sophisticate data retrieval and analysis. It will be important that the organization can continually improve data exploitation and decision support, so that an evolutionary path will be entered to increasingly reap the potential benefits that become possible on the basis of the vast data pools generated by smart products.

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We conclude that for smart product related technologies, we are still in the dawn of a new era, and in the early phases of Rogers' technology adoption lifecycle (cf. Figure 11). While technologies as RFID and Sensor technologies have already entered the early adopter phase, smart products' fundamental concepts like context-awareness and proactivity have not yet left the innovators' stage. As a consequence, the SmartProducts project needs to successfully integrate these concepts and demonstrate their value in real-world applications such that adoption of smart products takes up. In the long run, we expect that the smart products market will be cross-domain and cross-industry, i.e. spanning more than the three scenarios we investigate in the project.

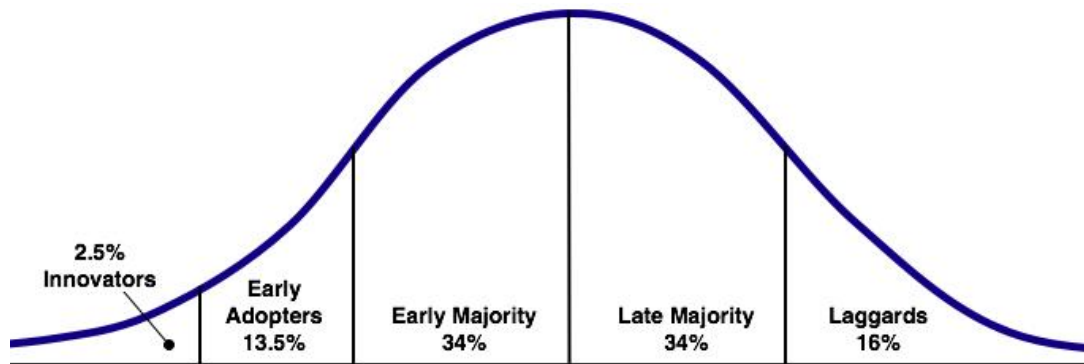


Figure 11: The technology adoption lifecycle (cf. Rogers 2003).

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5 Expert Interviews

The previous chapters provided a thorough literature review including different kinds of data sources. As a result we can state that the research area of smart products is very fragmented and with respect to business literature still in its infancy. Most of the literature body is covering early technology prototypes and fancy product ideas. However there is a significant shortcoming of detailed smart product business case analyses. This lack is mainly because there are no real-world applications yet that go beyond research prototypes, which makes it impossible to conduct an ex-post evaluation based on real-world experiences from a business perspective.

Therefore it was necessary to broaden the foundation of our upcoming business case analysis by conducting explorative interviews with experts in the area of smart products. Three of the interviews have been conducted with the experts from our project consortium, namely Andrew Tokmakoff (PRE), Julien Mascolo (CRF), and Jerome Golenzer (EADS). Additionally, we could win Prof. Wolfgang Maass as an interview partner, who is Professor for *Computer Science in Media* at Furtwangen University (Germany), and head of the research group *smart products* at the Institute of Technology Management (ITEM) at the University of St. Gallen (Switzerland). He is an established expert in the area of smart products, having published many related articles.

It is the purpose of our work in WP 7 to evaluate the business potential of the work carried out in the three application work packages WP 8, 9, 10. At the beginning of the project however, the planned pilots were not yet defined clearly enough so that a business case analysis could be conducted. Therefore it was necessary to acquire further information from our partners to narrow the scope of our analysis, learn about what knowledge is already available, understand rationales and business needs behind the envisaged pilots, and uncover the most important uncertainties with regard to the business cases, which require further investigations.

Having these goals in mind, we designed a questionnaire consisting of 30 questions to guide our expert interviews. The questions were intended to be very open and general to stimulate the interviewees to think about their pilot scenarios from a business perspective, and share their views with us. To underline the explorative nature in the interviews, ad-hoc questions from the interviewers were permitted to either clarify statements or answer spontaneous questions. The interviews were planned to last one hour, however it was intended not to finish the interview if the time was over.

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The questionnaire was structured into five blocks:

1. Professional background of the interviewee
2. Personal View of smart products
3. User Perspective
4. Vendor Perspective
5. Market Perspective

Questions on the professional background in the first block allow for a better interpretation of the statements of the interview. For example it is important whether the interviewee has a technical or business background, whether he has a strong professional background in his industry, or how long he is working in the area of smart products.

In the second block, we wanted to learn how the interviewee thinks about smart products as a concept, and what he considers to be important in his application domain.

In the third block, the interviewee was asked several questions with regard to the user perception of smart product concepts. The purpose is to understand how the developed solutions shall serve user needs, how value is created from a user perspective, and to which degree such potentials have already been evaluated.

In the fourth block, the questions are intended to understand how the vendor may turn smart product concepts into a business benefit. It is the goal of the questions in this block to create a better understanding which effects contribute to better profitability, either directly through higher sales and lower costs, or indirectly through better product quality and higher brand or product value.

In the last block, interviewees were asked to share their view on the whole market their companies are active in. The success of technical innovations often depends on trends and circumstances that are not under control of a single vendor. Examples are market maturity for a certain technology, regulatory burdens, competition and the like.

Two versions of the questionnaire were created: one version for the interviewers, and one version for the interviewed persons. The version for the interviewers provides a short statement about the goals for each question to help the interviewers to check during the interview

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whether question was already answered in a satisfying way. These explanations were not provided to the interviewers.

The interviews were recorded and then transcribed. After preparing the transcription, we briefly summarized the answers on each question. Finally, a summary for each interview was compiled, which is provided in the following sections of this document.

The transcripts, including summaries for each question, were sent to the interview partners for approval. They were further asked to provide additional comments, which can be found in the detailed interview summary in Annex 2 to this document.

Due to confidentiality issues, the transcripts are not published in any deliverable. They are available from the interview partners upon request. The detailed summaries of all questions are included in the confidential Annex 2 to this deliverable, which can be accessed by all consortium partners, but must not be distributed outside the consortium. The questionnaires and transcript templates are provided in Annex 1 at the end of this document.

The major purpose of the interviews was to have a better foundation for the subsequent business case analyses. In the following sections, we will summarize each of the interviews and then share the conclusions we have drawn from the interviews for our further analysis.

Disclaimer:

All statements made in the interviews summarized below reflect the personal opinion of the interviewed persons. They do not necessarily reflect the position of their company or organisation.

5.1 Interview with Philips

5.1.1 Interview Summary

Application Scenario

In the interview, PRE demonstrated their strong customer orientation in research and product development. The utmost goal with respect to the Smart Kitchen scenario is creating an enhanced user experience at moderate additional costs. At the first half of the project, PRE will therefore focus solely on developing a Smart Kitchen environment with the main focus on user

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perception. Later in the project, product lifecycle management aspects might be further investigated as Philips sees some potential there with respect to sustainability.

The Smart Kitchen concept is driven by Philips Research. It is the goal to develop a prototype that will convince internal stakeholders that it offers value to the customers. An investment decision will be made afterwards.

Value Creation

Value shall be generated for the customers on two ways: firstly, an enhanced user experience will directly create value, for example through additional product features. Secondly, synergies among different smart products, which then create a smart environment, will further enhance the perceived value of a Smart Kitchen solution

A single function or feature that delivers most of the overall benefit, and thus a unique selling proposition, is not yet clearly worked out. So it will be a major task for the project to identify those functions and features that will be taken up most positively by potential customers.

From a conceptual point of view, the most important smart product features in this scenario are adaptiveness, situation-aware behavior, and collaboration between different products. Based on these properties, compelling product features have to be developed.

For a successful market introduction, it is important that smart products can be used just as conventional products. The smartness only offers additional options, which need not be used. As an example, a water boiler or a coffee machine must be able to be used in an absolutely conventional way. However, if the customer is interested, he can make use of advanced features provided on the basis of smart product concepts, which might be for example a notification on a mobile device if the water is boiled or the coffee ready to drink.

This means that there is an evolutionary (as opposed to a radical) adoption path should be designed into the product. Neither should users have to learn a new way of handling their kitchen equipment if they only want to use them in the conventional way, nor should customer be enforced to buy a whole set of new kitchen equipment or even a new kitchen. An evolutionary adoption path means that new and conventional kitchen equipment can be used side by side, allowing the customer to move gradually from the traditional kitchen world to the new Smart Kitchen world.

Plans for a combined device / service offering do not exist, but PRE stated that this could be an interesting option for the future. Philips has the capabilities to offer services to complement their product line as already demonstrated in the home entertainment market. Further analy-

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ses with respect to services that complement the Smart Kitchen scenario would be valuable for Philips, but are not planned to be included in our business case analysis.

Considering 3rd party services, PRE made clear that an open innovation model is not appropriate. Philips would always retain control over the platform in order to decide which products may be bundled with their offering. However, co-innovation as such is appreciated, as long as Philips keeps control of the platform and the offering built on top of it.

Business Potentials

To summarize the business potentials of the Smart Kitchen scenario, we have learned from the interview that PRE sees both, potentials for revenue increase as well as for cost reductions.

Higher sales are expected to stem from compelling new features that would not have been possible before and thus directly stimulate customers to buy the respective products, perhaps even at a higher margin than conventional products. In addition to this direct effect, synergies arise for the customer if he owns several smart products, which leads to so-called network effects in the Smart Kitchen market. Once a customer has bought a smart product, there is a strong incentive to buy more of them, which further increases the sales volume.

On the long run, additional revenue might be generated if 3rd party manufacturers offer complementary products, which are able to collaborate with Philips products. In this case, license fees might be generated for granting access to the respective protocols and interfaces. The larger the Smart Kitchen market grows, the more incentives are prevailing for 3rd party manufacturers to develop complementary products, which further increase the value of the platform.

Cost savings might arise through better product lifecycle management. In the following four areas, smart product concepts might help to reduce costs: (1) maintenance and repair, (2) return, warranty claims, (3) quality surveillance and improvement, (4) recycling. So far PRE has not further investigated these potentials, and they are not part of the project plan. In a later project phase however, these aspects might be included in the project. Typically, product innovations are ranked higher by Philips product groups than proposals for cost cuttings. This is particularly true because many products are manufactured by 3rd parties so that it is difficult to implement cost cutting measures that incorporate different enterprises along the supply chain.

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Key Success Factors

Asked for the key success factors for Smart Kitchen, PRE mentioned the following four properties:

- Positive user perception
- Superior user experience
- Affordability
- Usability

Further, it will be important that complementary products will be available in an early phase so that synergies arise for the customer when buying several Smart Kitchen products that are capable of working together. It will be a key challenge to overcome this kind of chicken-and-egg problem.

Related Business Case Analyses

So far, several initial user tests were conducted to evaluate how potential customers perceive Smart Kitchen products. Whereas these early partial tests produced promising results, a broad user study, which evaluates the Smart Kitchen concept as a whole, is still outstanding and thus in the focus of our project work.

5.1.2 Conclusions for the business case analysis

Smart products will not find market acceptance because of their smartness as such, but because they deliver superior features or a better user experience compared to non-smart products. Further, building an ecosystem of complementary, collaborating products seems to be promising with respect to a compelling value proposition. Delivering additional value to end users is the utmost critical point. Only if users acknowledge the superiority of smart products, market success might arise.

That means that for our business cases analysis, we will have to focus on two key points: first, we will investigate how users perceive the value of the Smart Kitchen and how much they are willing to pay. Second, we will provide cost estimations for additional production costs to see whether Smart Kitchen products can be offered at a price that the customers will accept.

For our managerial recommendations, we will analyze in more detail the aspects of building a Smart Kitchen ecosystem. A major part of the value for customers will stem from the synergies that arise when several smart products are used together. However, Philips only offers a limited part of the equipment used in a kitchen. Standardization and collaboration with other ven-

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dors is required to build an ecosystem that comprises all kinds of kitchen equipment to maximize customer value.

The role of these network externalities should further be investigated. As described above, direct network effects will occur because the value for the customer increases when he buys more Smart Kitchen products. Further there are community services planned to share recipes and experiences. This adds another direct network effect as the value for the individual customer increases with the size of the installed base. In addition to that, indirect network effects are prevailing as there is an increasing incentive for 3rd parties to develop complementary products when the installed base gets larger. This in turn will further increase the value of the smart products for each customer. The consequences of markets with strong network externalities are twofold: on the one hand, there is a hold-up situation when such a market is underdeveloped because potential customers are waiting for the market to reach a certain (unfortunately unknown) threshold size. On the other hand, such markets enter a phase of self-enforcing growth once this threshold is reached. For our case, it is important to know how strong these network effects might become because this has strong consequences on how such a market must be approached. If there are strong network externalities, it will be very important to reach a large installed based within a short period of time, and engage in standardisation and collaboration with partners in an early market development phase.

5.2 Interview with Fiat

5.2.1 Interview Summary

Application Scenario

In the automotive industry and at Fiat in particular, smart product concepts are already deployed to some degree in the form of self-diagnosis, voice control, communication capabilities, and telematic platforms. Fiat has already sold 500.000 cars with the telematic platform Blue&Me on board. Other OEMs like Ford use the same software kernel based on Microsoft Windows for Automotive to build their own telematic devices. These platforms provide access to all kinds of data exchanged between on-board systems on the so-called CAN-Bus, and allow connecting to the outside world by means of different communication protocols.

Value Creation

From Fiat's point of view, it is their goal for the SmartProducts project to further exploit the Blue&Me platform by enhancing the end user experience in the car, and by improving internal processes through making use of the data collected in the Blue&Me devices.

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Fiat intends to apply smart product concepts on three different domains:

1. For the user domain, an electronic handbook called eLUM will be developed to offer pro-active, context-sensitive support for the user in operating his vehicle. It shall give useful hints and tips during the use of the car, and it shall support users when a problem occurs.
2. With respect to internal processes, Fiat intends to make use of on-board sensor data to achieve several process improvements. Vehicle data shall be exploited to improve vehicle and component quality, better adapt the functionalities to the user needs, reduce testing efforts before a new car is launched, reduce fuel consumption, and optimize spare parts supply.
3. Combining both approaches, more efficient maintenance repair processes shall be achieved. Improved self-diagnosis allows for an automatic determination of the necessary repair work, which is sent to the garage before the vehicle is brought there. As a first effect, this allows for better order scheduling in the garage and shortens the time the garage requires for diagnosis. As a second effect, the garage can improve spare parts disposition by ordering necessary spare parts based on the self-diagnosis information received from the car. This allows for lower parts inventory at the garage and at the same time speeds up the repair process because all necessary parts are available once the repair work has started.

Business Potentials

Comparing the three application domains, Fiat expects the highest benefits to come from improved internal processes and from improved spare parts management in particular. Explicitly asked for potentials in manufacturing, Fiat stated that only low benefits are expected there.

Key Success Factors

Regarding the key success factors that are a prerequisite for the different scenarios to become a market success, we again have to distinguish applications for the end user and solutions aiming at process improvements.

Solutions for the end user must be simple and understandable, and they must be perceived to be useful and usable. Otherwise they will not gain market acceptance. Further, it is indispensable that there is no doubt about their safety. If this is not guaranteed, Fiat management will not accept and therefore not invest into such an innovation. This is particularly critical if third party providers are included in a solution, either by delivering the software itself or a complementary service. In this case, a comprehensive certification program must be developed. This

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is by the way, why Fiat declines any kind of open innovation model. Although Fiat is open to offer services from third parties like insurance companies, an iPod / iPhone-like business model, where everyone can develop applications on the Blue&Me platform is said to be impossible because safety cannot be ensured anymore. Whenever third parties develop for the Blue&Me platform, Fiat will control its deployment and require the provider to undergo a certification process.

Internal solutions targeted towards process improvements underlie different requirements. First of all it is important that the collected data is meaningful from a business perspective. Second, the actual innovation lies in the transformation of such data into a business benefit by improving logistics and after-sales processes.

Related Business Case Analyses

Although Fiat has been working for several years on developing new applications, a detailed business case analysis concerning the envisaged pilot scenarios has not been conducted so far, although such analyses in the EU-funded research project PROMISE have come up with a positive result with respect to predictive maintenance applications.

5.2.2 Conclusions for the business case analysis

The interview improved our understanding for Fiat's business goals significantly. From the gained insights, we have drawn a number of conclusions for the business case analysis, which are summarized in the following.

The highest business potential is expected to result from process improvements that are enabled by exploiting information, which is collected during usage, maintenance and dismantling of a car. Within the many possibilities to optimize internal processes, spare parts management promises the highest potentials. However it is quite unclear how the collected data can be turned into a business benefit. The focus of the business case analysis should be set on analyzing and evaluating which data should be collected and even more important, how it can successfully be turned into a business benefit. Based on the resulting business process re-design, a business case analysis, which includes estimation for the return on investment, can be provided. At the time being, a definite statement cannot be given on which concrete scenario shall be investigated. Since Fiat stated that the biggest business potential is expected from an improved spare parts management process, we intend to start our further work here. Later, our analysis can be expanded to incorporate garage processes, but at the moment it is not clear whether this scenario will be driven further.

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As there is a clear statement from Fiat that the business potential of internal process optimizations outweighs by far the potentials stemming from an enhanced user experience, the focus should be on the former. With respect to the final customer, we will conduct an end user study to evaluate the perception of the electronic handbook. A fully-fledged business case in the sense of an ROI study is not appropriate here because neither costs nor revenue changes can be forecasted accurately.

The incorporation of other process improvements is still under discussion. Smart product concepts can reduce testing efforts, help to improve the quality of cars and components, and collect information how drivers use their car to enable Fiat to improve the car design. Whether this is taken into account in the course of our work depends on whether Fiat will evaluate it in their pilot scenarios.

Potentials in the area of manufacturing are not apparent for the moment. If new ideas come up here, this can be analyzed in a later phase. For the moment, manufacturing is not planned to be covered in the business case analysis (and also not in the project as a whole).

The development of additional services based on an open innovation model is not in the focus of the project and should not be part of the business case analysis.

5.3 Interview with EADS

5.3.1 Interview Summary

Application Scenario

To better understand where we are starting from in this scenario, we investigated the status quo of aircraft manufacturing at EADS in the interview. We gained the following insights: The production of every plane spans multiple manufacturing stages across different locations and countries. In each of the affiliated countries (Spain, France, and Germany), there is a heterogeneous system and tool landscape, which still impedes data exchange at a larger scale.

Today, working instructions (so-called 'work orders') and associated documentation is primarily paper-based, and the digital 3D representation of the aircraft (the so-called "mockup as designed") is created only once and remains static during the manufacturing process. Studies at Airbus have further shown that data retrieval today makes about 50% of the manufacturing operators' total working time.

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The interview confirmed that the primary focus for the application of smart products within EADS is on the optimisation of aircraft manufacturing and, at a later stage, potentially also aircraft maintenance processes. The main objective here is to reduce the time of data retrieval, which is considered as bottleneck for faster production and delivery of aircrafts in the demand driven aircraft industry. The application scenario aims at proactively building information that is gathered throughout the assembly process, and at providing this information to the operators in real-time tailored to the specific context and in an easy-to-handle fashion. The main artefact for this will be a centralised and synchronised 3D digital mockup of the airplane, which supplements the existing 3D geometry models by the additional information about the assembly process and the manufacturing status that is co-constructed together with the real product.

Value Creation

Due to excess demand for aircrafts, Airbus has prior interest in accelerating the production time of its aircrafts so that more aircrafts can be sold per year, and consequently sales can be increased. From the perspective of EADS Innovation Works, in the smart products project, the highest contribution to this overarching objective is supposed to result from the envisioned centralised and synchronised 3D mockup of the plane:

- On the shop floor level, the mockup improves the mobility of the operators due to the availability of context-tailored data, which will save time for data retrieval, thus positively affecting production flow time, and also reduce errors.
- On the level of manufacturing coordination, centralising all manufacturing data will improve cross-site and cross-country collaboration and allow for the management of shared resources. This promises to reduce aircraft production cycle times.

Because it typically also involves assembly processes, time can also be saved for aircraft maintenance. The time saved in maintenance carries further value since faster maintenance allows for a potential price premium when the aircraft is sold to the airlines. Improvements in spare parts management (cf. the Smart Vehicle scenario) were not mentioned by the interviewee, but we think that investigations in this field could also be worthwhile at a later stage in the project.

The potential value for Airbus for additional service offerings on top of smart product concepts, such as sophisticated on-board entertainment services for the aircrafts, is not yet clear and hard to estimate. This is because, from a management perspective, such offerings are outside of Airbus' core competencies. Nevertheless, according to the interviewee from EADS Innova-

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tion Works, there will be discussions with Airbus about the possibility to become engaged in this field. An open innovation approach, that is to develop a widely open platform where 3rd parties are allowed to offer additional services for an aircraft, are not a conceivable business model for Airbus, because all major aircraft innovations require certifications.

Business Potentials

The business potentials for Airbus can be summarised as to lie in the domain of internal process improvements, especially in the reduction of manufacturing cycle times and flow times to meet the order backlogs.

Further potentials may arise from optimized maintenance processes, which may result in a price premium compared to today's aircrafts.

Key Success Factors

The key success factors for the Aircraft Manufacturing scenario can be grouped into two categories, which are the success factors (1) for acceptance by the internal users, i.e. the aircraft operators, and (2) for acceptance by the decision makers of the company, i.e. Airbus.

On the operator's level, the most important factor for positive acceptance is usability. This means for the technical side of smart products that the user interface has to remain simple, so that operators can intuitively work with it. For the non-technical, rather psychological side, this requires that smart products are seamlessly integrated into the operator's original working procedures, so that they will be more open towards and willing to adapt smart product.

On the decision makers' level, the most important factor will be that the smart products approach delivers a measurable value. According to the interviewee, (one-time) investments will play a minor role then because with an operating time of ten to thirty years the prospected benefits will finally outweigh the initial cost. Besides the natural requirement of value delivery, maintaining richness of data and compliance to the large quantity of official rules and regulations that exist in the aircraft industry are crucial factors. The latter is because achieving new certifications by the European Aviation Safety Agency is a cumbersome and time-intensive process (cf. also the Boeing case in section 4.2). Another success factor for management acceptance is that smart products adequately resolve compatibility issues with regard to the heterogeneous environments across the sites and countries of Airbus.

One overarching factor for deployment success at Airbus and market success in general is that the architecture of smart products will be able to cope with the vast amount of data asso-

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ciated with aircrafts; more precisely, the solution needs a high degree of scalability and robustness.

Related business case analyses

There were some former efforts to improve data management at EADS in the EU project called Tatem. The project conducted a cost/benefit analysis for some of the integrated technologies and techniques, but without proper field tests and without evaluating the overall business potential of it. At Airbus, there are some internal projects about smart product technologies. We will try to get in contact with responsible persons.

With regard to user acceptance studies, there haven't been any tests or user evaluations of smart products and its technologies yet. It is crucial to run such tests and evaluations so that the operators' needs can be addressed and their potential reservations can be overcome. Only then will it be possible to reap the business benefit that decision makers expect from smart products.

5.3.2 Conclusions for the business case analysis

In the interview, we have got the clear statement from EADS that the primary goal of the prototype to be developed is intended to demonstrate the potential of smart products for cutting the overall time needed to manufacture an aircraft, as this will result in a sales increase due to order backlogs.

For the methodology of the business case analysis of this scenario, this has several consequences: First, we will concentrate our analysis on manufacturing, possibly including maintenance at a later stage of the project. Second, the main part of the business case analysis will deal with time and cost reduction potentials – sales increase potentials can then be derived from the reduction of manufacturing time, as long as current and estimated future order backlogs will be accounted for. Third, reducing the overall time needed to manufacture an aircraft requires that both flow and cycle time are reduced, so that we will cover both shop floor processes (intra-site) and collaboration processes (inter-site).

Initially, we intend to focus on the shop floor processes, the optimisation of which mainly affects the flow time. We will inquire in more detail the pain points of the operators (like data retrieval) and analyse and evaluate their existing work procedures. The on-site visit in Toulouse, the planned involvement of Airbus representatives, and the qualitative studies we are about to conduct will contribute to sharpen our view in this respect. Based on this increased

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understanding, an essential part of the business case analysis will be to define and quantify the success criteria (such as “the operator’s time for data retrieval drops by 10%”) for later assessments, and to define design goals for smart products tailored to the shop floor processes which we will later test out in the user acceptance studies.

We will then expand our analysis to the potential of cross-site and cross-country collaboration optimisations, which are supposed to reduce (mainly) the production cycle time. This analysis will include an assessment of the “as-is” of workflows, and the tools und compatibility issues Airbus is facing today. However, a fully-fledged business evaluation will be hard to do here because it depends on the information we receive from the affiliated manufacturing sites. So in some areas, it will only be possible to provide an analysis model without a proper instantiation.

The development of additional services based on an open innovation model is not in the focus of the scenario and should not be part of the business case analysis done in this project.

5.4 Interview with Prof. W. Maass

5.4.1 Interview Summary

Smart Products Concept

Asked for the constituents of smart products, the interviewee mentioned the following attributes:

- **Situatedness:** the product has the ability to recognize and process its situative, i.e. physical and social, context.
- **Personalization:** the product can adapt its principal behavior to the sentiments and requirements of the user (relates to the principal, not the situative behavior).
- **Adaptivity:** the product changes its behavior as a reaction to user actions; it is able to understand what a person does and can adapt appropriately.
- **Proactivity:** this is an advancement of personalization and adaptivity. The product does not only react to user actions, but it recognizes the intention of its users, and thus can plan ahead.

These four attributes were mainly formulated by the Ambient Intelligence Task Force. In

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addition, the interviewee regards two more attributes as constituents:

- **Business Sensitivity:** products have the ability to embed some kind of contracts that regulate what may be done with the product, offer additional services, or payment models.
- **Connectivity:** the ability to connect to other products and configure and establish a joint network of smart products.

Value Creation

Smart product concepts can improve two major dimensions: *communication* and *control*. In the B2C sector, improved communication between product, customer, manufacturer, and service provider will be in focus, with the ultimate goal of delivering an enhanced user experience to the customer. Due to the fact however that consumers have become very sensitive with respect to privacy issues, increased control, e.g. by monitoring consumer behavior to improve product quality, will probably not be accepted on the market.

In contrast to that, the B2B sector will probably focus on the control aspect of smart products, for example to increase supply chain efficiency, discover and solve quality issues, or offer remote support services. Such offerings may be successful in the B2B sector as privacy discussions appear to play a less important role there.

Business Potentials

The interviewee finds that the starting point for uncovering value potentials for vendors is to think about business models, and then to pass on to plan to implement them by making use of smart product technologies. This argument is related to the fact that there is a trend for convergence towards products, i.e. a switch towards putting the products instead of business processes in the center of thinking. This evolution in thinking will take some time but it will leverage the business opportunities which become possible through smart products. One example is the way of communicating between the vendor and the customer: In B2C today, vendors typically connect with end consumers via a retailer. Vendors cannot track the use of their products once they are sold, and as there is a retailer as intermediary, they know little about the user. In this sense, the sales process is the endpoint of interaction between the vendor and the product and its affiliated user. Offering smart products turns this inside-out: smart products can function as entry point to the interaction with the users, because they allow for gathering information about their use and the user's habits in using it.

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Moreover, from his discussion with middle-sized companies (between 500 Mio. and 1 Bn. EUR revenue), the interviewee concludes that they are discussing smart product concepts very intensely with respect to combined product / service offerings, and they regard this as very promising for their future business success. Smart products technologies allow for integrating products and services. Most prominent are support and maintenance services that are embedded into the product. The role of services can be summarized as to intelligently integrate and connect smart products such that they enhance the interaction with the (end-) user.

With respect to business process optimization, the interviewee states that, as soon as products have the ability to adapt and communicate and cooperate with each other, and – as a prerequisite – are seamlessly integrated into information systems, companies will be able to improve processes in terms of time, quality and costs. Considering cost and time, the increase in available real-time information will, for example, ease and speed-up in-store inventory management in retail; but it will also be valuable for manufacturing, where especially the concept of adaptability helps to raise automation and flexibility. Considering quality, data collected on the component level during manufacturing will significantly simplify product quality controls and make these more effective. In this context, smart products also give valuable support for anti-counterfeiting efforts along all stages of the supply chain. Data collected when the product is in use will, for example, enable remote diagnosis, which will improve service quality. Moreover, it will allow for real-time monitoring of components, which will give valuable insights about their wear and tear of.

Key Success Factors and Future Challenges

The interviewee mentioned the following three key success factors for a successful smart products market development:

- First, smart products should be positioned far away from RFID on the market. The reason is that RFID has got a very negative image due to privacy issues. If smart products are associated too much with RFID and privacy issues, this will hamper future market development.
- Second, "Keep it simple" is a key success factor (s. section below).
- Third, we need a general and comprehensive smart product infrastructure, which provides robust connectivity, enables product-service integration, and allows for processing context information. Our infrastructures today (e.g. WLAN) will not be capable to handle thousands of products that start communicating, for example within a retailer's

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showroom. So we need either completely new infrastructures or at least smart ideas of how to adapt existing infrastructures. Either way, it will be very cost-intensive.

Specifically for user acceptance, the following three aspects are relevant:

- Firstly, good and careful product designs. Design should be done from a user-centered perspective, and not a technology-centered approach, to best meet the user's needs. The focus should be on maximum usefulness and not on what is technologically feasible.
- The second factor is, that new adequate design methods need to be developed, which both include material and communication aspects. For smart products, this means that design should span two phases: the first including "Tags and Information Systems" and the second designing the appropriate communication to mitigate fears about intrusion into privacy.
- The third factor is that aspects of psychology and sociology need to be included to better understand how a fully-fledged smart products embed into social interaction, and in which way this affects the individual. For B2B and B2C applications these considerations may differ substantially.

A successful market introduction of smart products will require enormous investments, particularly in infrastructure. However at the moment, there are only "playful" applications, which are not yet substantial from a business point of view. The interviewee argues that supporting the necessary investments is a general problem in the EU: the whole research budget invested so far into things like semantic web, ambient intelligence, RFID is close to what Google invests into hardware for YouTube this year: around 750 Mio. USD.

Further he states we need more collaboration among EU projects to share our expertise, our resources and our platforms. This is why it is very important to kick off an international discourse in this subject, which incorporates not only those communities that are dedicated to smart products, but also other communities that work on related concepts. Here it is important to discuss not only on a technological but also on a business level. The goal must be that we create visions and design practical applications so that we will not fall behind the US in Europe.

Related business case analyses

The interviewee conducted two business case analyses related to smart product concepts, one with a fashion company and another with a kitchen vendor. The fashion case resulted in

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very positive business cases. Particularly valuable was the cross-selling potential, which was facilitated by the smart products' properties to interact with the consumer (in this case, to function as a recommender for related products). The case has shown that even conservative estimates on these potentials suffice to yield a positive ROI. For the kitchen case, further information will be provided to our SmartProducts project as soon as it is available.

The interviewee has conducted some other experimental studies in the retail sector, where he is currently researching to which degree smart products influence buying decisions. The preliminary results are promising, as well as some results from field studies. He will provide the SmartProducts project with documentation about the results of these studies.

5.4.2 Conclusions for the business case analysis

The interviewee's experiences support our view that real world applications of smart product concepts face many uncertainties with regard to the business case.

He argued that the principal uncertainty for business is cost, which he experienced in many discussions with responsible persons who did not accept the investments that smart products would require. He emphasizes, that the investment for smart products needs to be as low as possible to gain a take-up.

This statement appears to be in contrast to what recent analyst reports say; the reports recommend focusing on demonstrations for the value potentials (especially for process improvements) such that they will outweigh initial investments and make discussions about the "five cent tag" obsolete.

We believe that both arguments are legitimate. For the business case analysis, both (low) cost and process improvement potentials will have a significant influence on its outcome. Our oncoming analysis will reveal which of the two will prove to be more influential in the end.

Further, he stressed the problem of building up an appropriate infrastructure for transferring and processing the collected data. Whereas in this work package, we will not investigate technical restrictions, we will explicitly analyze cost aspects that arise out of this issue.

With respect to privacy issues, we learned from this interview that executives regard this issue as a real and important problem. Therefore we will put some effort in analyzing the consequences of privacy issues from a business perspective.

Finally, we conclude that it will be more important to focus on a qualitative and quantitative evaluation of the different potentials that smart products provide, rather than on meticulous

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cost counting. This is because costs are hard to predict and are subject to change with technological progress.

5.5 Comparison of interviews

As already exposed in earlier chapters, the perception of smart products as a concept as well as the scope and focus of our application scenarios differ in many ways. Neither is there a common definition for smart products, nor is there a common understanding how such products look like. This is reflected in the three SmartProducts application scenarios: There are only few commonalities, although they are based on common principles and technological foundations. If we contemplate the scenarios from a business and application perspective, they become even more different. Consequently, we will have to develop dedicated business case analysis approaches for each of the three scenarios.

In this section, we will elaborate on the commonalities and differences between the perceptions of smart products in general, and between the three pilot scenarios in particular. For this purpose, we first provide a summary on how our interviewees rated the importance of certain smart product attributes from their point of view. Then we compare what these persons regard as market drivers in the moment. Finally, we summarize in a table how certain aspects of smart products are regarded by our interview partners.

5.5.1 Rating for the importance of selected smart product attributes

The individual ratings that were given by the interviewees from CRF, PRE, and EADS for the importance of selected smart product attributes are depicted in Figure 12. They will be discussed in the following paragraphs.

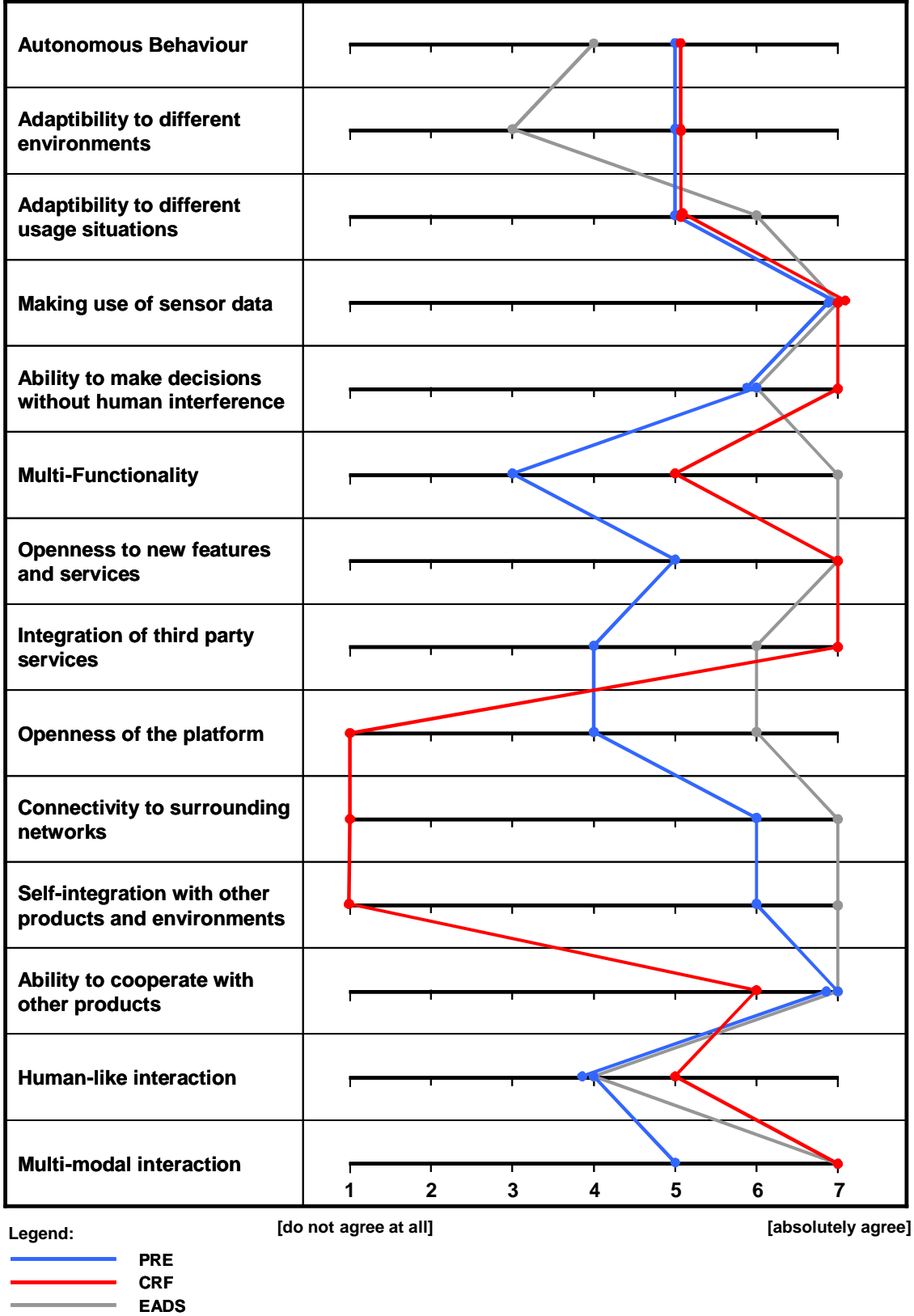


Figure 12: Rating for the importance of selected smart product attributes

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The most distinctive attributes which are shared by the ratings for all three scenarios are “Making use of sensor data”, the “Ability to make decisions without human interference”, and the “Ability to cooperate with other products”. These attributes appear to be fundamental.

The logic behind the rating can be explained as follows: smart products need to make use of the sensor data mainly due to two aspects:

Firstly, from a product perspective, sensor data enables the smart product to “feel” what is happening with it, which is fundamental for making it smart.

Secondly, from a platform perspective, sensor data is supposed to contain valuable information, for example about the pressure of a tire, which should be gathered, filtered and evaluated by smart products such that it can be used to improve business processes.

In the example of the tire, a warning would be generated automatically as soon as its pressure would drop beyond a certain limit.

The ability to make decisions without human interference reflects the idea that smart products include some sort of intelligence and autonomy. Especially in manufacturing, this allows for accelerating processes and makes them less prone to error. One sample application is dynamic production control, which automatically balances the load for the available assembly lines without any human interference. For a Smart Vehicle this could mean to automatically turn on the lights if the brightness outside is not sufficient.

Smart products have significantly more capabilities when they cooperate with each other, which is why this attribute was rated very high. In the Smart Kitchen scenario, for example, the smart cooking guide cooperates with the smart stove, so that the guide can tell the user exactly when to insert the meal into the stove. In the Smart Vehicle scenario, interaction between the car and other products like the user’s mobile phone or also car-to-car communication are viable use cases. Finally, for the EADS scenario, the communication of different smart products within the manufacturing environment with the operator’s PDA is essential.

With regard to differences in the rating, most noticeable are the attributes “Openness of the platform”, “Connectivity to surrounding networks”, and “Self-integration with other products and environments”. These attributes belong to the architectural level, and their rating appears to be mainly influenced by the business strategy the industry partners want to pursue with smart products. The rationale behind this is as follows: In the Smart Kitchen scenario, the openness of the platform is not especially desirable, because Philips wants to put an incentive for buying particularly the products which are provided by them. For the same reason, self-integration is very important for Philips so that when a potential customer buys a new smart product, he can seamlessly integrate it into his existing Smart Kitchen environment. Connectivity to surrounding networks in this scenario means connectivity to the kitchen and its smart

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product environment. This connectivity is fundamental to create the envisioned value stemming from a network of interconnected smart products (cf. section 5.1.1).

In the Smart Vehicle scenario, openness of the platform does not appear to be an option at all. Vehicle operations are often safety-critical so that Fiat wants to avoid manipulations of the platform, which would become easier the more open the platform is. Also for safety reasons, connectivity to surrounding networks is not desired because Fiat does not want networks which are beyond its control to interact with the Smart Vehicle. The self-integration with other products and environments is also not required, because the Smart Vehicle can be considered as a self-contained smart product. The self-integration must not, however, be mistaken with communication and cooperation abilities, which a Smart Vehicle needs to provide (as we argued in the previous paragraph).

In the Aircraft Manufacturing scenario, the openness of the platform, the connectivity to surrounding networks and the self-integration with other products and environments were all rated very high. The surrounding network in this scenario is the information systems of the shop floor, which are supposed to be the gateway for smart products to include data from and synchronise with the 3D digital mockups stored on some dedicated server of EADS. The connectivity to this dedicated server is essential, and so is the connectivity to the local surrounding network to allow for fast WiFi-access to the server. The interviewee took openness as extensibility of the platform, which explains the high rating for this attribute (cf. section 5.3.1). Self-integration is considered to be crucial in order to make the utilization of smart products transparent to the operators so that they do not need to think about switching from one environment or product to another one (the interviewee sees the PDAs as the self-integrating smart product).

5.5.2 Rating for the forces that drive the market

The results of the interviewees' rating for the forces that drive the market are depicted in Figure 13 and will be analyzed in the following paragraphs.

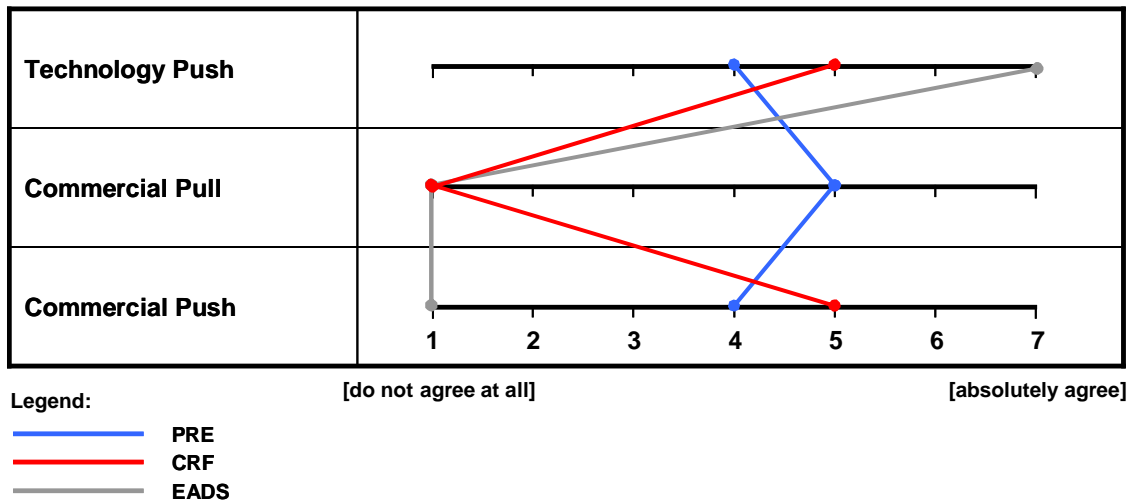


Figure 13: Rating for the forces that drive the market

For all three scenarios there is a significant technology push. We think that this is typical for research projects because they deal with technologies that are visionary and still some years away from market readiness. That is why prototypical implementations are necessary, and these prototypes create – if they show clearly the opportunities and potentials inherent in the technology – what we consider as technology push. The rating is most distinctive in the EADS scenario, which is because a commercial pull and a commercial push do not apply here, which we explain in the next two paragraphs.

The Smart Kitchen scenario from Philips is the most end-user centric scenario. This can be considered as explanation why there is the highest degree of a commercial pull out of the three scenarios. On the contrary, the Aircraft Manufacturing scenario for EADS does not involve market end users, which is why there is no commercial pull. In the Smart Vehicle scenario – even though there are customers involved – they are not the driver for smart product deployments, because the business value for internal process improvements is considered much higher by Fiat than the one for product innovations (cf. section 5.2.1).

A commercial push is most distinctive in the Smart Vehicle scenario. This can be explained by the fact that Fiat strives to position itself as a technology leader in the automotive industry (cf. section 5.2.1). For the Smart Kitchen scenario, the commercial push could arise from the product groups' expectation for higher sales if compelling new features are added to existing products (cf. section 5.1.1). For the Aircraft Manufacturing scenario, it is not a commercial push because Airbus does not explicitly ask for smart products, but for addressing the main

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pain points in aircraft manufacturing and maintenance by whichever technology is appropriate (cf. section 5.3.1).

5.5.3 Structured comparison of the scenarios' core properties

In the following table, we present conclusions from the expert interviews for the three pilot scenarios.

Category	PRE Scenario	CRF Scenario	EADS Scenario
Key application(s)	Cooking Guide	<ul style="list-style-type: none"> • Spare Parts • Garage processes • Quality • Electronic manual 	<ul style="list-style-type: none"> • Digital Mockup • Maintenance
Value Creation	Enhanced user experience	<ul style="list-style-type: none"> • Optimized spare parts inventory • Higher service level • Quality increase • Enhanced user experience 	<ul style="list-style-type: none"> • Effort reduction • Improved communication • Cost reduction • Sales increase • Quality increase
Business benefit	<ul style="list-style-type: none"> • Increased sales • Increased brand image • Network effects 	<ul style="list-style-type: none"> • Cost reduction • Improved brand image 	<ul style="list-style-type: none"> • Reduced flow time • Increased profitability • Price premium
Innovation type	Product Innovation	<ul style="list-style-type: none"> • Primary: Process innovation • Secondary: Product Innovation 	<ul style="list-style-type: none"> • Process innovation
Radicalness	Incremental innovation: important for user acceptance	Radical innovation: completely new processes and user perception	At new programs radical changes possible, at running programs smooth migration necessary
Role of user acceptance	Crucial	<ul style="list-style-type: none"> • Moderate: internal processes • High: electronic manual 	High but not crucial
Key success factors	<ul style="list-style-type: none"> • Enhanced user experience • Moderate additional costs 	<ul style="list-style-type: none"> • Cost savings • Enhanced user experience • Safety 	<ul style="list-style-type: none"> • Efficiency gains • Legal requirements • Operator acceptance
Value-added ser-	Possible and inter-	Possible, but not	Not under discussion

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vices	esting	planned	
Openness to 3 rd parties	Possible	Rather not	Not possible
Focus of business case analysis	User perception	Process improvements	Process improvement

5.5.4 Scope of the Scenarios

The objective of this research work is to evaluate the business potential of *smart product* technologies. Thus it is necessary to cover a broad spectrum of use cases in different domains. The scenarios outlined above cover such a broad spectrum in terms of product complexity as well as life cycle span. Figure 14 illustrates how the three application scenarios compare to each other in relation to these two dimensions.

The first dimension of this classification is the complexity of the product in which the *smart product* technologies are embedded. The most complex product in terms of the number of constituent parts is an aircraft, followed by vehicles, followed (with large distance) by home appliances.

The second ordering dimension is the lifecycle each application spans. In general, a product lifecycle consists of the following phases Design, Production, Usage, Maintenance / Upgrade and Disposal. The three application scenarios are related to very different lifecycle phases:

- The *Smart Aircraft* scenario covers mainly the Design and Production phase. Virtual product models from the design phase are used in the manufacturing phase in order to visualize the manufacturing status of an individual aircraft. In this sense, generic design models are instantiated for each aircraft that is assembled. Having captured a plethora of information on the manufacturing process and integrating information from subsequent maintenance, further design improvements shall be derived from this data. It is further planned to make use of this data in the maintenance phase so that maintenance workers can retrieve detailed information on aircraft configuration, on used part numbers, and even on the repair history.
- The *Smart Vehicle* scenario is intended to span all lifecycle phases of an individual automobile. Sensory information from the usage phase shall be used to improve spare parts management, car design and manufacturing. This shall enhance quality, improve service levels, and reduce costs. Maintenance information will uncover quality issues and find correlations with certain usage conditions. Additionally, functional enhancement shall be offered on the basis of the consumer behavior. In the disposal phase,

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usage and maintenance data can be evaluated in order to calculate the residual value of certain parts.

- The *Smart Kitchen* scenario is quite different from the two preceding scenarios in that it only spans the usage phase of the kitchen appliances, which are equipped with *smart product* technologies. Here, *smart product* technologies are not used to convey information from one lifecycle phase to the other, but to implement the desired functionality for the usage phase of the product.

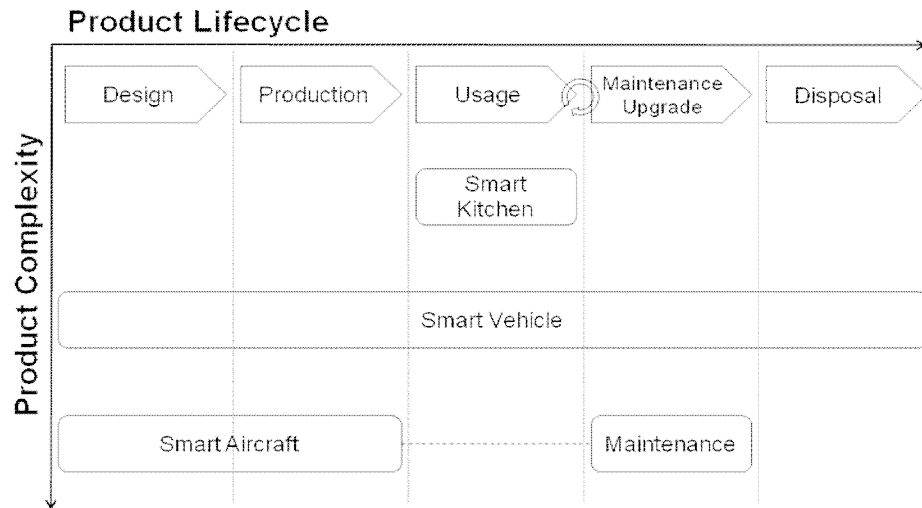


Figure 14: Comparison of Applications Scenarios

The three scenarios are also characterized by representing different innovation types (Figure 15). *Smart Aircraft* is a pure process innovation. It solely aims at improving manufacturing processes in terms of efficiency and quality. Thus the manufacturer itself is the beneficiary of this innovation. In contrast to that, the *Smart Kitchen* represents a pure product innovation, which aims to provide new solutions to the consumer. The *Smart Vehicle* includes constituents of process and product innovations. On the one hand, automatically collected usage and maintenance information will allow for faster design and quality improvements. As this improves the car design and manufacturing process, it represents a process innovation. On the other hand, usage information will also be used to propose updates and complementary services, or to adapt certain characteristics of the car to the user behavior. Further, an electronic manual shall enhance the user experience by offering situation-aware, pro-active support to the driver in order to ease the handling of the highly complex functionalities of modern cars.

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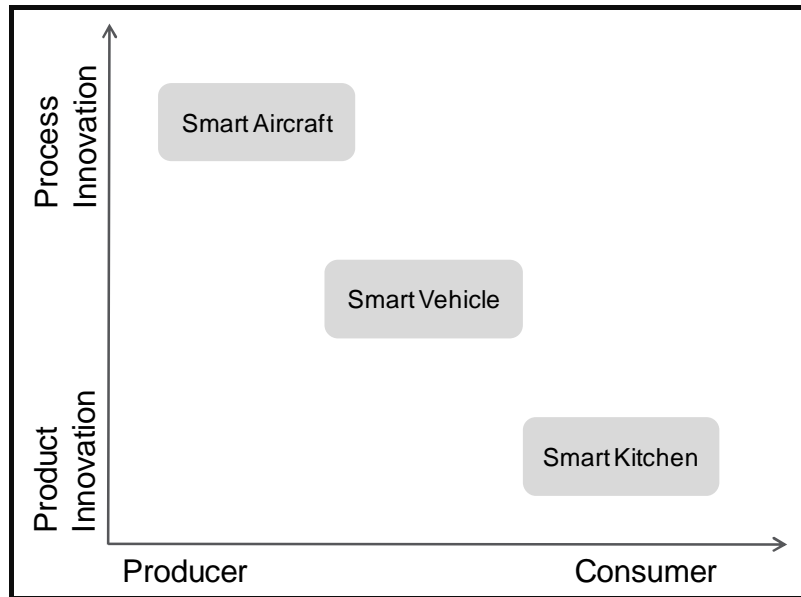


Figure 15: Innovation Types and Target Groups

6 Conclusion and Outlook

From the literature review, we can conclude that there is only a very limited body of work related to business aspects of smart products.

Literature, which refers explicitly to smart products, usually describes visions and rather generic potentials how value could be created by making use of smart product concepts. The more concrete business analyses become, the more limited they are in their scope. Some detailed business case analyses are available for RFID adoption in a very narrow scope. With respect to Ambient Intelligence applications, there are some results considering manufacturing and maintenance applications. However, as our concepts go far beyond that, we can conclude that there is no existing work with a scope as broad as ours.

We could also learn from our literature review that there are several synonyms for smart products, and that there are many overlapping but not identical definitions for these concepts. We conclude that the term smart products describes objects that fulfill certain attributes to a certain degree. It cannot clearly be decided whether a product is smart or not, as smartness is defined within a continuum of properties.

From the analyst report, we learned that there is substantial growth potential for both smart product related hardware (such as RFID and sensors) and associated middleware and enterprise software solutions, especially in industries such as retail (especially inventory management), manufacturing (especially automation of manufacturing and maintenance processes),

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and consumer electronics (e.g. smart home appliances). With the Aircraft Manufacturing scenario from EADS, the Smart Kitchen scenario from Philips and the Smart Vehicle scenario from Fiat, the SmartProducts project covers a significant range of these promising fields of application.

Our expert interviews and our collaboration with the industrial partners have resulted in many insights concerning the pilot applications and our subsequent socio-economic analysis.

The three pilot applications differ very much in how and to whom they create value. The EADS pilot is primarily a process innovation targeted at manufacturing processes at EADS. The Fiat pilot is both a process and a product innovation. Added value shall arise both for end customers and for Fiat internally. The Philips scenario is clearly targeted towards the consumer.

This has significant consequences for our further work. Product and process innovations require different analysis approaches. For process innovations, we will have to document as-is processes, design to-be processes, and then measure potential improvements. For product innovations, customer perception and satisfaction are the most important success factors. So these scenarios will be investigated primarily by means of user acceptance studies.

Beyond the measurable aspects of the business cases, it will be necessary to provide a broad qualitative analysis of potential benefits. The total business cases will be too complex to be investigated in all details. So the general procedure will be that we conduct quantitative analyses for the core aspects of each case, whereas further potentials, but also further risks and impediments will be described and evaluated in a qualitative way.

We also learned that there are different success factors for the pilots. For EADS, it is most critical that the theoretical potentials of the extended 3D digital mockup can be turned into a business advantage by reducing time and effort in aircraft manufacturing. For the Fiat scenario, the key question is how data collected along the lifecycle of a car can be turned into value for both the user and Fiat. Here, we will start by investigating whether spare parts management is a beneficial area for smart product concepts. Finally, for the Philips scenario, the most important success factor is to deliver a superior user experience at a moderate price.

In the following WP7 deliverables, we will develop a business case analysis model for each pilot, which will contain cost and revenue aspects, investment aspects, and user acceptance aspects. The following figures illustrate the different research approaches that we will follow for each of the pilots.

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With this work we intend to close the gap we identified in the literature today, that is a sound business analysis of smart product applications, such that adoption of smart products takes up. In the long run, we expect that the smart products market will be cross-domain and cross-industry, i.e. spanning more than the three scenarios we investigate in the project.

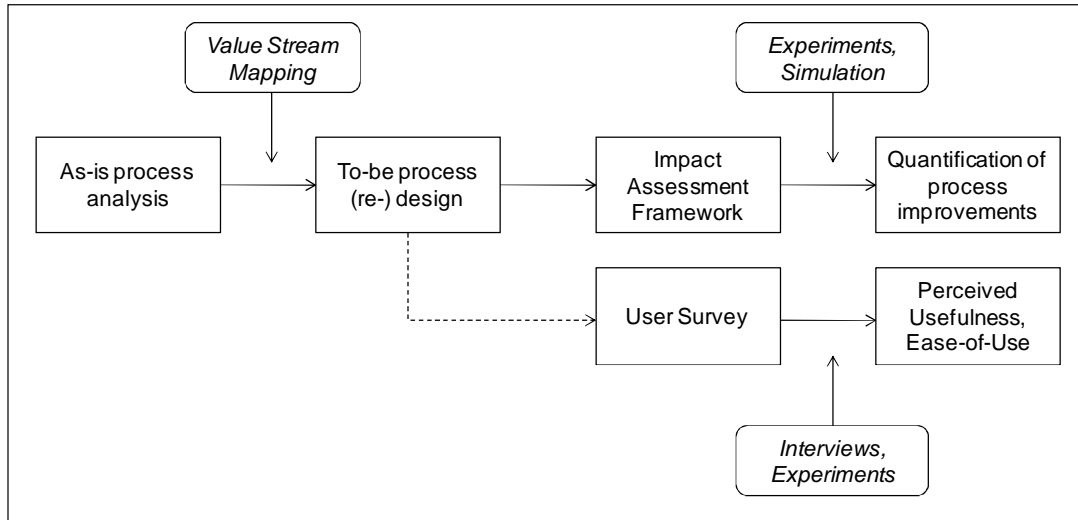


Figure 16: Research Approach EADS Scenario

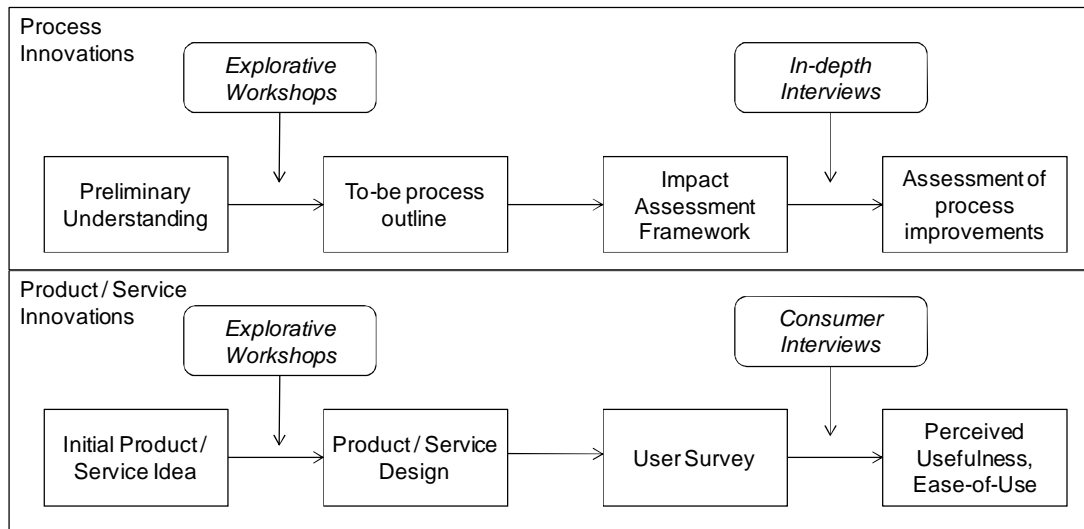


Figure 17: Research Approach CRF Scenario

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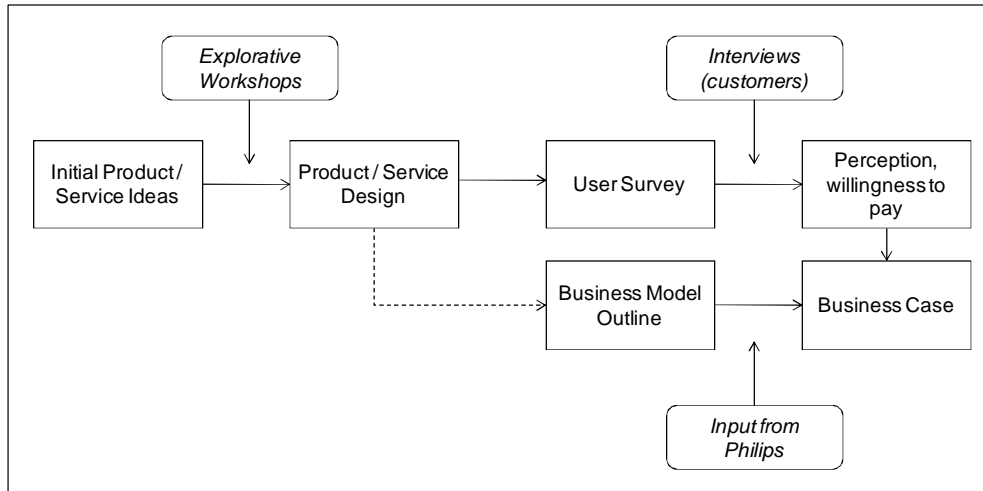


Figure 18: Research approach PRE Scenario

Finally, the following figure summarizes the approaches planned for all three scenarios and gives an overview over the whole WP7 research approach.

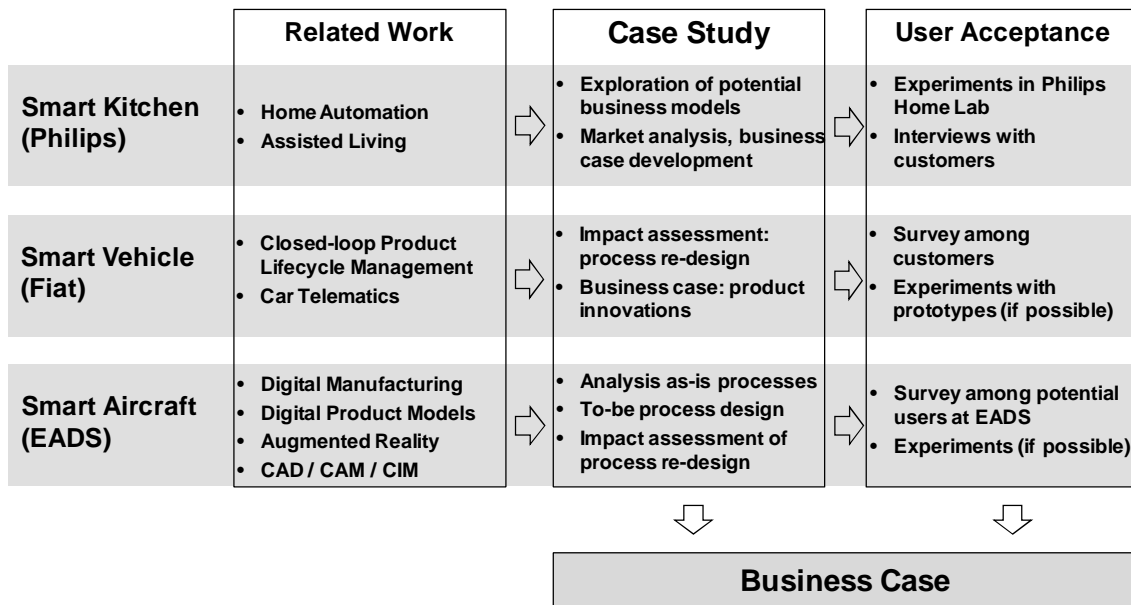


Figure 19: WP7 Research Approach

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