J Intell Manuf (2018) 29:497–508
https://doi.org/10.1007/s10845-015-1123-8

Design of informatics-based services in manufacturing industries: case studies using large vehicle-related databases

Chie-Hyeon Lim[1] · Min-Jun Kim[1] · Jun-Yeon Heo[1] · Kwang-Jae Kim[1]

Received: 31 March 2015 / Accepted: 1 July 2015 / Published online: 25 July 2015
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Abstract Numerous companies in manufacturing industries have "servitized" their value propositions to address issues on product commoditization and sustainability. A key component of servitization is informatics, which transforms product and customer data into information for customers. In this study, informatics-based service is defined as a type of service wherein informatics is crucial to customer value creation. Despite the importance of this concept, studies on the design of informatics-based services in manufacturing industries are rare. This paper reports on two case studies on such designs. Informatics-based services have been designed for a major Korean automobile manufacturer and the Korea Transportation Safety Authority (TS) based on their large vehicle-related databases. The first case study with the automobile manufacturer aims to design vehicle operations and health management services for passenger vehicle drivers while the second study with TS focuses on the design of driving safety enhancement services for commercial vehicle (i.e., bus, taxi, and truck) drivers. Based on the case studies, this paper discusses various aspects of informatics-based service design in manufacturing industries. This study would assist researchers and practitioners in designing new informatics-based services and contribute to promoting and inspiring research on intelligent services in manufacturing industries under the current information economy.

✉ Kwang-Jae Kim
kjk@postech.ac.kr

[1] Department of Industrial and Management Engineering, Pohang University of Science and Technology, San 31, Hyoja-dong, Nam-gu, Pohang, Gyung-buk 790-784, Republic of Korea

Keywords Servitization · Informatics · Informatics-based service · Product–service system · Intelligent manufacturing · New service development

Introduction

Companies in manufacturing industries encounter various challenges. Specifically, competition in terms of cost and technology leadership has increased with the commoditization of products. Moreover, global environmental regulations have become rigid. Thus, numerous companies have adopted a service-led competitive strategy to distinguish themselves from competitors. Literature calls this trend "servitization" (Baines et al. 2007; Neely 2007). Service—essentially different from product—contributes to innovation by fulfilling the unmet needs of customers, strengthening relations with customers, and increasing freedom in developing environmentally benign offerings beyond the product itself (Tukker and Tischner 2006; Bettencourt 2010; Ding et al. 2015).

Existing studies have investigated a wide variety of servitization in diverse disciplines, such as in business management, engineering design, and information systems (Boehm and Thomas 2013). Literature indicates that available knowledge on and technologies for intelligent manufacturing have contributed to servitization. For example, various researchers have discussed the importance of informatics, the science of transforming data into information, in servitization (Lee et al. 2014; Saarijärvi et al. 2014). Manufacturers of document-related products (e.g., copy machines or printers) monitor the document management processes of business customers, analyze data from these processes, and provide customers with useful information for completing document-related jobs (Rothenberg 2007). Meanwhile, automobile manufacturers analyze vehicle health and operations data collected from inboard devices and provide various types of information (e.g., safety, entertainment, and consumable information) to enhance the experience of drivers and passengers (Lim and Kim 2015).

The current study defines this type of service as informatics-based service, wherein informatics is crucial to customer value creation. These services focus mainly on "creating" information that effectively accomplishes customer goals, whereas traditional information technology (IT)-based services such as e-learning and mobile banking services emphasize the efficient "delivery" of information. Recent buzzwords, such as internet of things (IoT) and big data analytics, are highly relevant to informatics-based services in manufacturing industries. Thus, informatics-based service innovations are expected to develop in manufacturing industries with the rapid advancement of technologies for collecting data from products and customers.

A prerequisite for informatics-based service innovation in manufacturing industries is the creation of new or improved informatics-based service ideas, concepts, processes, and business models, among others. Design of informatics-based service refers to a process for the creation, and this process sublimates available data in manufacturing industries into actual service value creation. In this regard, examining such designs is a critical and timely topic in manufacturing industries under the current information economy. Recent studies have discussed the importance of this research direction (Saarijärvi et al. 2014; Lim and Kim 2015), albeit they do not use the term "informatics-based service". Nonetheless, literature on the design of such services remains limited, and the mechanism behind the utilization of data for service value creation in manufacturing industries is nearly unknown.

This paper introduces two case studies on the design of informatics-based services that the authors recently conducted. Informatics-based services were designed for a major Korean automobile manufacturer and the Korea Transportation Safety Authority based on their large vehicle-related databases. "Literature review" section presents a review of the related studies that served as references for the case studies in "Design of informatics-based services in manufacturing industries: case studies" section. "Discussion on the design of informatics-based services" section provides a discussion of the various aspects of the design of informatics-based services in manufacturing industries. Finally, "Concluding remarks" section concludes this paper by discussing its contribution.

Literature review

This section reviews two research fields that are highly relevant to the design of informatics-based services in manufacturing industries, namely, product–service system and new service development process. The reviewed studies serve as references for the case studies on such designs.

Product–service system

The service-led competitive strategy employed by manufacturing companies has generated specific types of value propositions that integrate products and services in a single system. Recent studies have called this servitized value proposition "product–service system" (PSS) (Mont 2002; Tukker and Tischner 2006). PSS has been investigated in literature as a means of innovating product-based offerings in an economically, environmentally, and socially sustainable manner (Tukker 2015). Over the past decade, researchers have investigated PSS development according to previous conceptual works (Mont 2002; Baines et al. 2007) to facilitate PSS development tasks, such as strategic planning, conception, and implementation. This knowledge includes learning from case studies on PSS development (Rothenberg 2007; Reinartz and Ulaga 2008), types of PSS (Kim et al. 2012), sustainability assessment methods (Lee et al. 2012; Shokohyar et al. 2014), and PSS development frameworks (Cavalieri and Pezzotta 2012; Kuo 2013; Zine et al. 2014) and tools (Kim et al. 2012; Lim et al. 2012; Kim et al. 2015).

Various manufacturers have provided informatics-based services as service components of their PSSs. For example, agricultural machine manufacturers provide the precise farming service that delivers farmers information on the exact amount of fertilizer to spray on crops (Bettencourt 2010). This service helps increase yield and minimize the amount of fertilizer used. In this service, information identification is based on the analysis of navigation and operation data collected from agricultural machines. Meanwhile, heavy equipment manufacturers monitor, diagnose, and predict product health through prognostics and health management (PHM) services (Lee et al. 2014). Consequently, equipment managers can cope with potential product breakdowns and maximize product availability for clients. In this service, the manufacturers use PHM algorithms (Schwabacher and Goebel 2007; Zhang et al. 2013; Chien et al. 2014; Mortada et al. 2014; Mehta et al. 2015) to analyze data collected from heavy equipment. Similarly, manufacturers of document-related products monitor and analyze data collected from the document management processes of business customers (i.e., organizations that purchased copy machines or printers) to acquire the necessary information to assist customers in completing document-related tasks at reduced cost, hassle, and consumable use (Rothenberg 2007).

As such, recent studies on PSS have paid attention to advances in informatics-related technologies (Boehm and Thomas 2013; Lee et al. 2014; Saarijärvi et al. 2014). However, reports on real cases of informatics-based service design in manufacturing industries are rare, and understanding of the mechanism behind such designs is limited. The current research addresses this limitation.

New service development process

This paper discusses the design of informatics-based services, which is a new issue in the new service development (NSD) research field. A generic NSD process consists of five steps: opportunity identification, customer understanding, concept development, process design, and refinement and implementation (Kim and Meiren 2010). The first step identifies opportunities for new services or improvements for existing ones. Opportunity is usually discovered through market and technology trends and through the strategic objectives of an organization. The second step defines the target customers and identifies their explicit and latent needs through interviews, focus group discussions, or other formal and informal methods. The third step generates service concepts based on service opportunities and customer needs. A service concept fills in the gap between customer needs and current services. A detailed service concept description, which includes the specific features of the service, is then developed. The fourth step designs the processes through which the service is produced and delivered. In this step, the details associated with the service process are determined, such as the sequence of operational tasks and their interactions, the input and output of each task, and the responsibility of service personnel and technologies. The final step tests the service for refinement and implementation. Following necessary enhancement and adjustments, the service is launched in full-scale and reviewed post-launch.

The scope of informatics-based service design in this paper corresponds to the service concept development (i.e., the first to third steps). A service concept indicates what to offer to customers and how to offer it and mediates between customer needs and the strategic intent (Goldstein et al. 2002). The generation of adequate and innovative service concepts is the core of successful service development (Kim et al. 2012). In the NSD process proposed by Scheuing and Johnson (1989), a service concept is developed based on the idea screened in the previous step. Fisher and Schutta (2003) employed Quality Function Deployment to translate customer needs into the technical requirements of a service concept. Sakao and Shimomura (2007) proposed a computer-based tool to develop functions of a service concept based on identified customer needs. Chai et al. (2005) proposed a problem-solving model for the development of new service concepts based on TRIZ. Kim et al. (2006) proposed a systematic framework to develop new service concepts with emphasis on generating innovative, convergence-type service concepts from the customer perspective. Kim et al. (2012) established a methodology for PSS concept generation that includes a list of general customer needs, a list of PSS models, the PSS concept generation support matrix, and a PSS case book.

The aforementioned studies can support the development of informatics-based service concepts. However, the applicability of the results is limited because these works do not focus on services in which informatics is the key to value creation. By contrast, the current research focuses on concept development, specifically for informatics-based services in manufacturing industries.

Design of informatics-based services in manufacturing industries: case studies

The authors designed informatics-based services with a major automobile manufacturer in Korea (case study 1) and with the Korea Transportation Safety Authority (TS) (case study 2). In case study 1, four vehicle operations and health management (VOHM) services were designed for individual drivers. In case study 2, services to enhance driving safety were developed for commercial vehicle (i.e., bus, taxi, and truck) drivers. The main objective of this study is to enhance our understanding with respect to the various aspects of an overall informatics-based service design process. Thus, this section focuses on introducing the design process itself rather than providing all of the detailed information on each case study.

Figure 1 shows the informatics-based service concept design process that the two case studies followed. This process consists of five steps, namely, (1) data collection, (2) data analysis, (3) service opportunity identification, (4) production of information content related to the identified opportunities, and (5) service concept design for content delivery. This design process is an approach to implementing opportunity identification, customer understanding, and concept development in the common NSD processes (Kim and Meiren 2010) introduced in "New service development process" section. Service designers can utilize the analysis results of collected data to recognize opportunities for new services or improve existing ones, to understand customer behaviors and produce the information contents required by customers, as well as to design service concepts to deliver multiple information contents as a package. "Case study 1: Design of the VOHM service concepts" and "Case study 2: Design of service concepts for enhancing driving safety" sections explain how the authors implemented the aforementioned steps in actual service development projects.

Case study 1: Design of the VOHM service concepts

The automobile manufacturer gathered data on vehicle operations and health through a telematics system and constructed a database called the vehicle relationship management data-

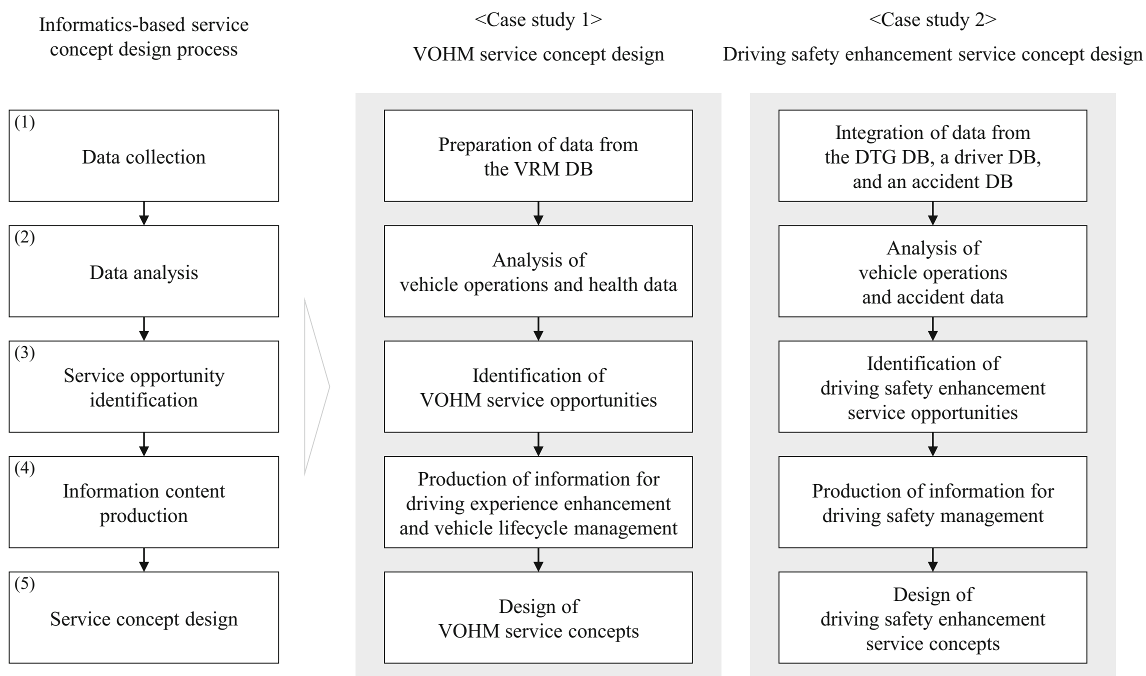


Fig. 1 Overview of the case studies

base (VRM DB). The company aimed to develop new and attractive VOHM services by analyzing this database. The process of VOHM service concept design is presented in Fig. 1.

The types of data prepared in Step (1) include vehicle operations data (e.g., trip start/end time, average trip speed, average trip distance, and idle time) and vehicle health data (e.g., warning code, engine temperature, and revolutions per minute). A trip starts and ends when the engine starts and is deactivated, respectively. Vehicle operation data were collected during each trip, and health data were recorded for 7 s whenever a warning code was triggered. A total of 7.6 million trip data were analyzed with respect to driving of 18,943 vehicles in 2011 (operations data). In addition, 3662 cases of warning code occurrences from 2009 to 2012 (health data) were analyzed.

The data analysis results in Step (2) include descriptive statistics of the driving patterns of customers, relationships among the key variables that determine driving characteristics, customer clustering results, and relationships among warning codes. Figure 2a, b depict some of the data analysis results generated in Step (2). Figure 2a shows the distribution of total mileage in a trip. This distribution follows the Pareto principle, and 80 % of the customers drive for <22 km during a trip. Thus, the automobile manufacturer should note that most driving experiences are short trips when designing products and services. In addition, services that support short and long trips should be differentiated. Figure 2b displays the relationship between car stalling and warning code occurrences. The warning codes are confidential and are thus not shown in this paper. This figure provides important information to predict and prevent sudden stalling. For example, such stalling frequently occurs during winter. Prior to this event, the warning code type 17 was frequently triggered.

We defined the service opportunity for VOHM as an opportunity to address customer needs during vehicle-related activities such as vehicle purchase, driving, and maintenance. As exemplified above, the data analysis results provided cues for identifying service opportunities in Step (3). We analyzed VRM DB from multiple perspectives, such as driver age, vehicle type, and driving time and area. As a result, we identified 26 service opportunities. Figure 3 illustrates the opportunity identification process and highlights the types of data analysis that contributed to the discovery of certain groups of opportunity. The group for driving capability enhancement includes opportunities for safe driving guidance and driving school services. The group for context-aware driving support includes guidance opportunities for city/highway and winter driving. The customer relationship management group includes opportunities for customized car selection support and mileage-based insurance. The car and life service group includes opportunities for traveling support and entertainment content delivery.

The information contents produced in Step (4) include daily/monthly vehicle operation review information, the ability of the customer to drive safely, customer ranking information, and the remaining lifetime of consumables. The

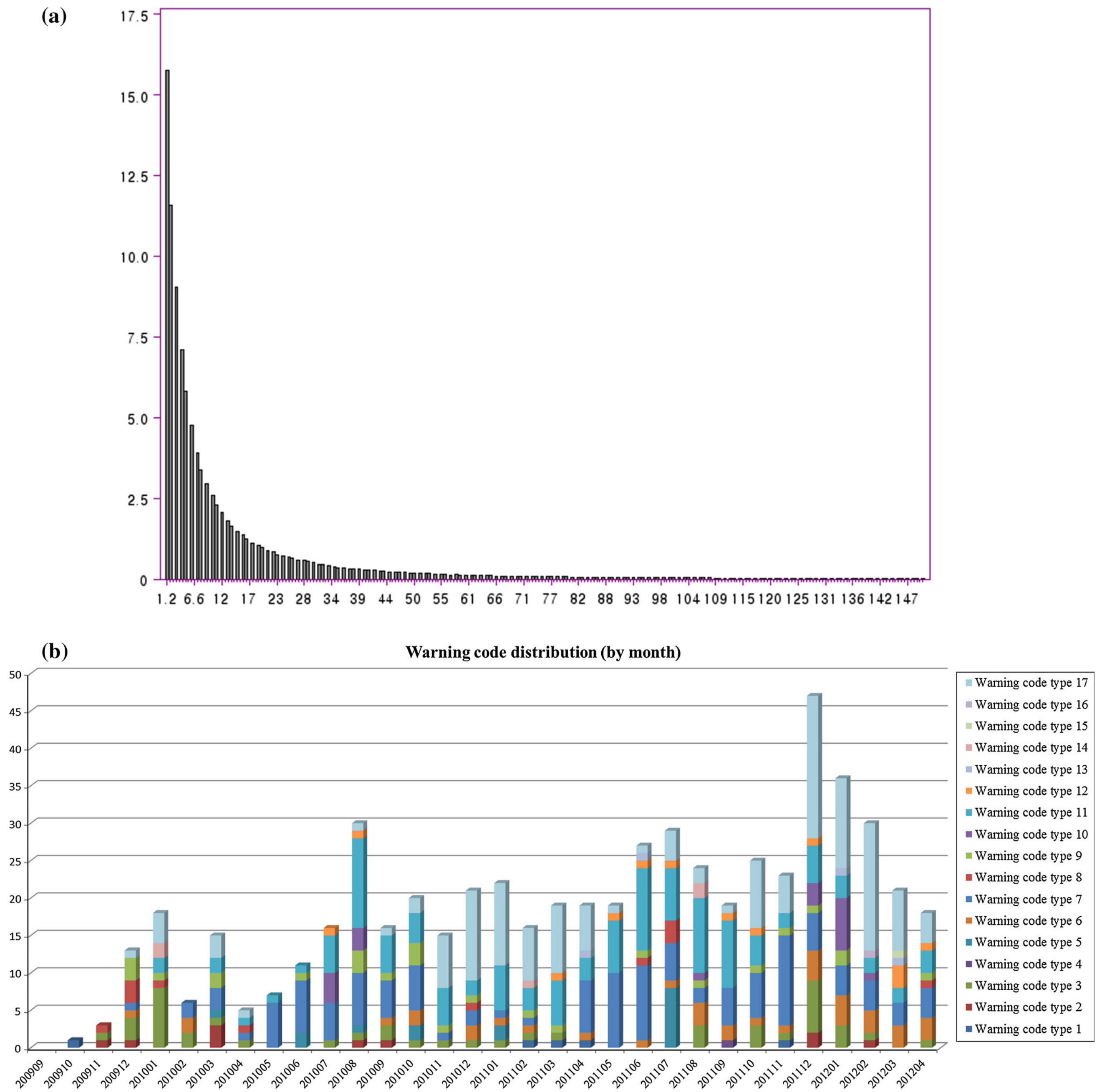


Fig. 2 Sample data analysis result. **a** Distribution of total mileage in a trip. **b** Relationship between car stalling and warning code occurrences

four service concepts designed in Step (5) are services for fuel-efficiency improvement, driving safety enhancement, consumable replacement support, and prognostic maintenance support. In particular, services for fuel-efficiency improvement and driving safety enhancement review the driving patterns of drivers and guide them from the perspectives of mileage and driving safety, respectively. Consumable replacement support service manages the life cycle of consumables that are customized to the driving patterns of drivers, such as engine oil, tires, and batteries. Prognostic maintenance support service monitors vehicle health to predict and prevent the sudden breakdown of vehicles. Table 1 shows the main characteristics of these service concepts based on four dimensions, namely, information, information delivery system, information production system, and partner companies.

Case study 2: Design of service concepts for enhancing driving safety

The second case study involving TS focuses on the design of driving safety enhancement services for commercial vehicles

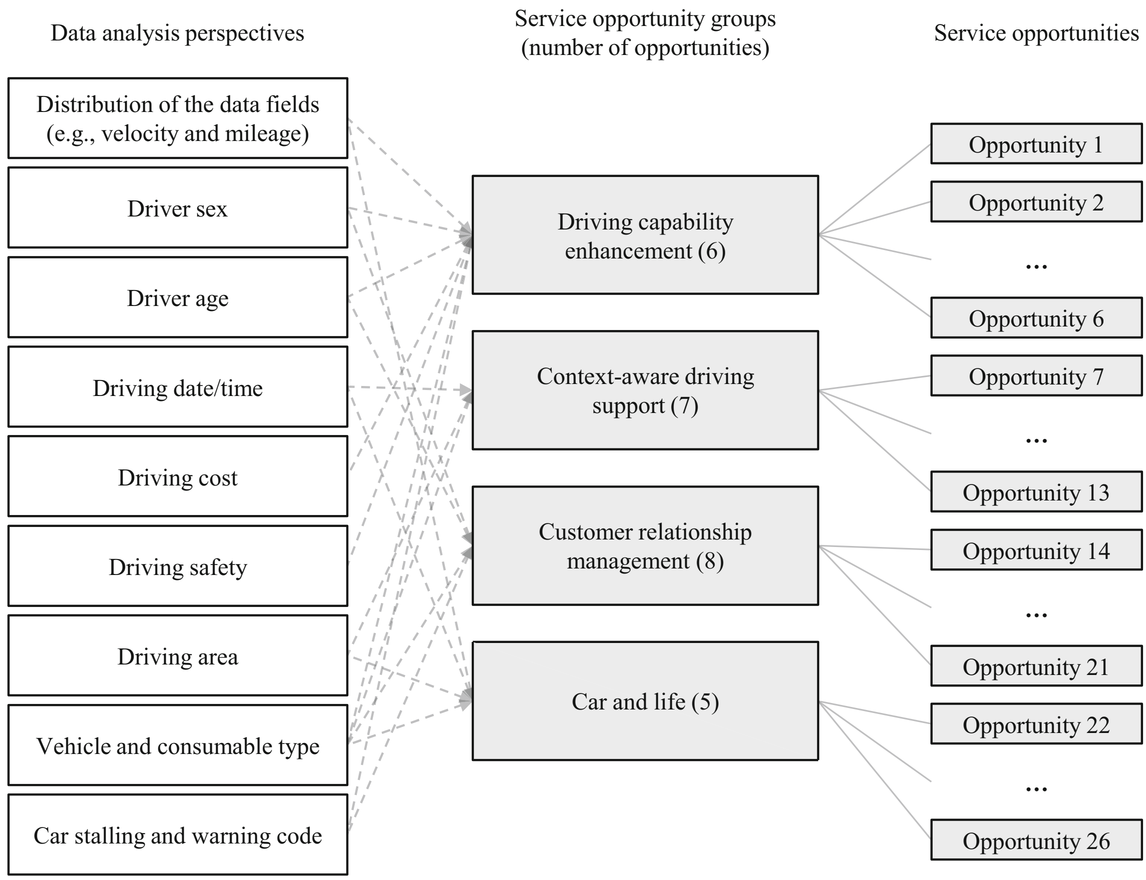


Fig. 3 Service opportunity identification through data analysis

Table 1 Main characteristics of the four VOHM service concepts

Key components	Service components			
	Fuel-efficiency improvement	Driving safety enhancement	Consumable replacement support	Prognostic maintenance support
Information	Review of driving from a standpoint of economic feasibility	Safety driving indices and ranking	Consumable life cycle management report	Prognostic maintenance scheduling
Information delivery system	Smartphone application	Onboard device for information display	E-mail	Phone call
Information production system	Onboard device for data collection	Algorithm for safe driving analysis	Algorithm for engine oil change	Stalling prediction algorithm
Partners	Applicationdeveloping companies	Insurance companies	Consumable management shops	Repair shops

(i.e., buses, taxis, and trucks). TS oversees such vehicles, and this organization collects operation data of commercial vehicles through digital tachograph (DTG) devices. As a result, TS has constructed a database called DTG DB. In South Korea, all transportation companies must install DTG devices in each vehicle and regularly report the recorded vehicle operation data to TS. This institution aims to provide services for driving safety enhancement using these data. The design process of service concepts for enhancing driving safety is presented in Fig. 1.

The types of data prepared in Step (1) include DTG (e.g., velocity, GPS, brake on/off, and RPM), driver (e.g., driver name, driving date, and car plate number), and accident (e.g., accident type, time, and place) data. DTG data are collected every second and archived in TS. Driver data are collected and managed by transportation companies. Accident data are

Driver data

Date	Name	ID card number	License number	…	Car number
2013-04-01	Driver A	770225-1xxxxxx	Seoul 39-0987xx-xx	…	Seoul 22-1234
…	…	…	…	…	…
2013-05-30	Driver K	570421-1xxxxxx	Seoul12-1234xx-xx	…	Seoul 33-1234

Accident data

Name	ID card number	License number	Location	…	Penalty points
Driver K	570421-1xxxxxx	Seoul 12-1234xx-xx	Gangbuk	…	10
…	…	…	…	…	…
Driver AA	800712-1xxxxxx	Seoul 34-1234xx-xx	Gangnam	…	20

DTG data

Company code	Car number	Date	Time	…	Accel. y (m/s2)
15678	Seoul 33-1234	2013-05-30	00:00.0	…	-2.1
…	…	…	…	…	…
15678	Seoul 33-1234	2013-05-30	50:19.0	…	-2.1

Keys to data integration

Integrated data

Driver information			Traffic accident information			Driving behavior information		
ID	Name	…	# of accidents	Penalty points (average)	…	# of rapid accel. per 1 hour	# of rapid stop per 1 hour	…
1	Driver K	…	3	13.3	…	12.5	0.018	…
2	Driver C	…	0	0	…	10	0.05	…
…	…	…	…	…	…	…	…	…

Fig. 4 Integration of driver, accident, and DTG data

collected and managed by the National Police Agency. In this study, we collected DTG data on 278 buses, 46 taxis, and 931 trucks from April to May 2013; driver data at 2013; and accident data on 4289 bus, 1550 taxi, and 490 truck drivers from 2004 to 2013. The three types of data were then integrated to analyze the driving behaviors of a particular driver. Consequently, we were able to investigate the difference in driving behaviors between drivers with and without accident records. Figure 4 presents an illustration of the data integration.

The data analysis results in Step (2) include the correlations among risky driving behaviors, risky driving behavior frequency information in specific routes, and the comparison of different driver groups according to their risky driving behaviors. The 11 types of risky driving behavior defined by the Korean government were applied to determine driving safety. Figure 5a, b presents the results of the risky driving behavior analysis. Figure 5a shows the correlations among three types of risky driving behaviors: rapid left-, rapid right-, and rapid U-turn. Figure 5b shows the results of the analysis of the difference between the driving behaviors of intra-city bus drivers with accident record and those without accident record from 2004 to 2013 (i.e., accident vs. no-accident group).

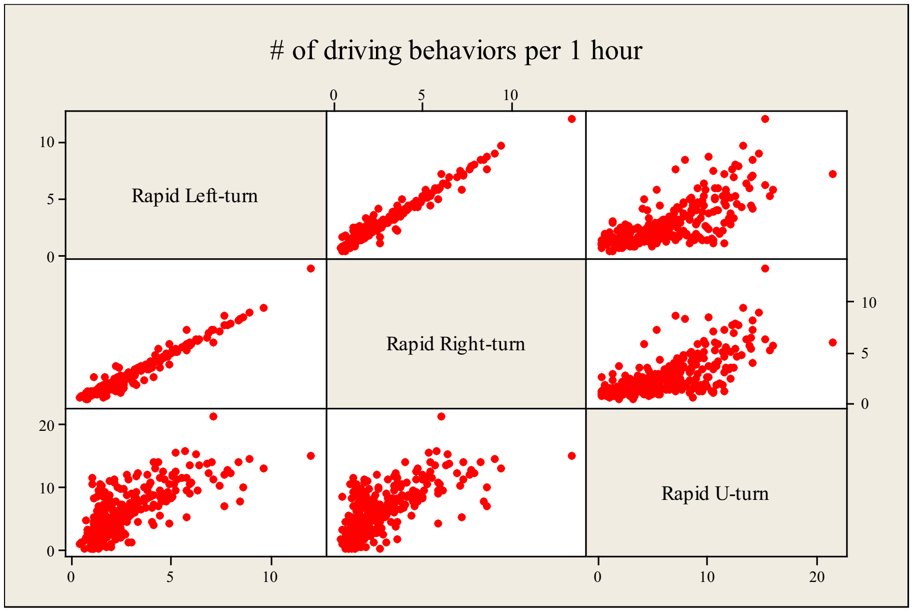
We defined the service opportunity for driving safety enhancement as an intervention opportunity that transportation companies could provide to drivers to reduce risky driving behaviors. Similar to case study 1, the data analysis results exemplified in Fig. 5a, b provided cues to identify service opportunities in Step (3). As shown in Fig. 5a, significant positive correlations exist among the three types of risky driving behaviors (p value <0.05). These behaviors appear to be managed better simultaneously than individually. Figure 5b shows that the total number of risky driving behaviors per hour in the accident group is higher than that in the no-accident group (p value <0.1). Moreover, the average numbers of rapid deceleration and lane change per hour in the accident group are higher than those in the no-accident group (p value <0.1). This result indicates that driving safety enhancement services should be provided to the accident group rather than to the no-accident group. In particular, the services for reducing rapid deceleration and lane change should be presented carefully.

The information contents obtained in Step (4) included the distribution information on the risky driving behaviors of an individual and benchmarking information on the frequency of risky driving behaviors. The concept of a driving safety enhancement service that delivers such information to drivers with accident records was designed in Step (5). Through the service, drivers can receive feedback regarding their previous driving behaviors on their smart devices when they check their driving schedules before departure. If drivers overspeed while driving, an alarm for overspeeding is sent through their onboard devices. At the end of the day, feedback on their driving behavior during that day is relayed to drivers through onboard or smart devices.

Discussion on the design of informatics-based services

This section discusses various aspects of the design of informatics-based services. "Informatics-based service value creation process" section presents a conceptual model of the

(a)



(b)

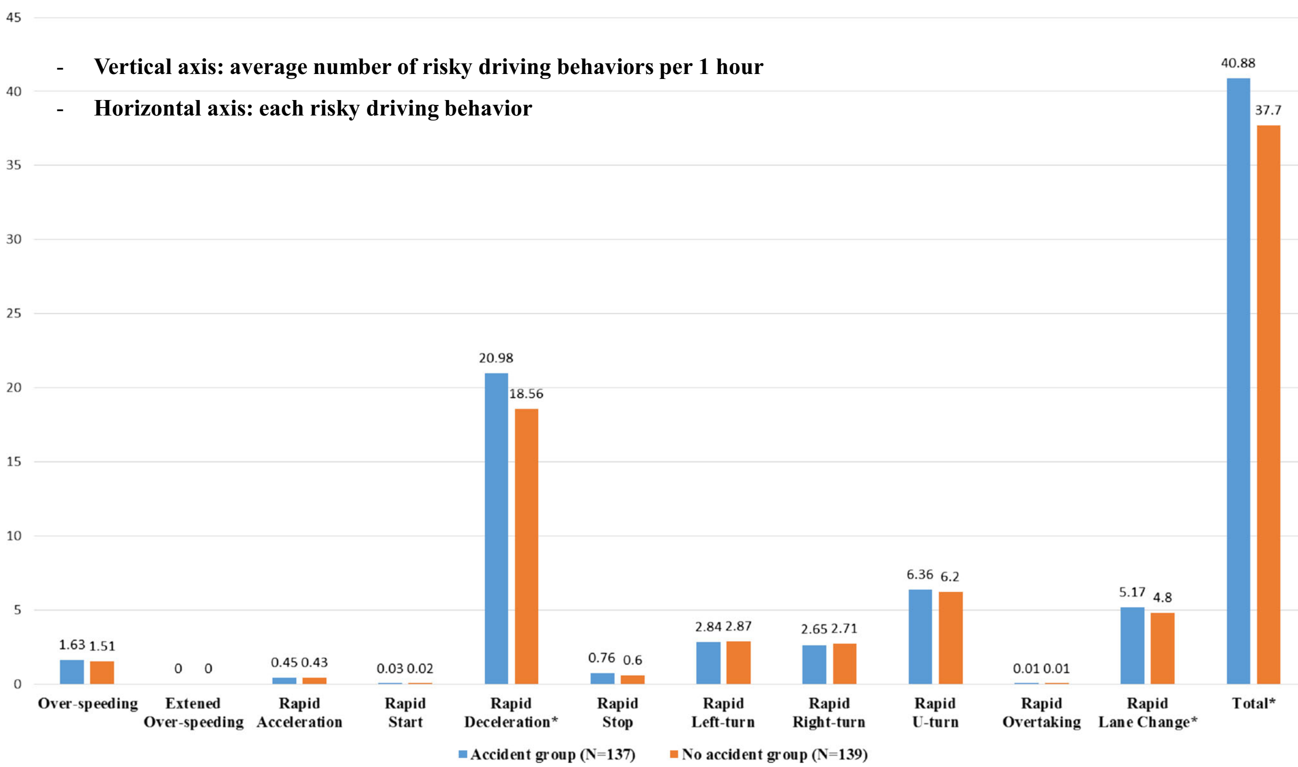


Fig. 5 Analysis of risky driving behaviors. **a** Correlations among three types of risky driving behaviors: rapid left-turn, rapid right-turn, and rapid U-turn. **b** Comparison of the risky driving behaviors between the accident group and the no-accident group

informatics-based service value creation process in manufacturing industries. The model embraces various types of informatics-based service, including those introduced in the case studies. "Challenges in designing informatics-based services" section presents the challenges in informatics-based service design in manufacturing industries. "Future research issues" section discusses future research issues to overcome these challenges.

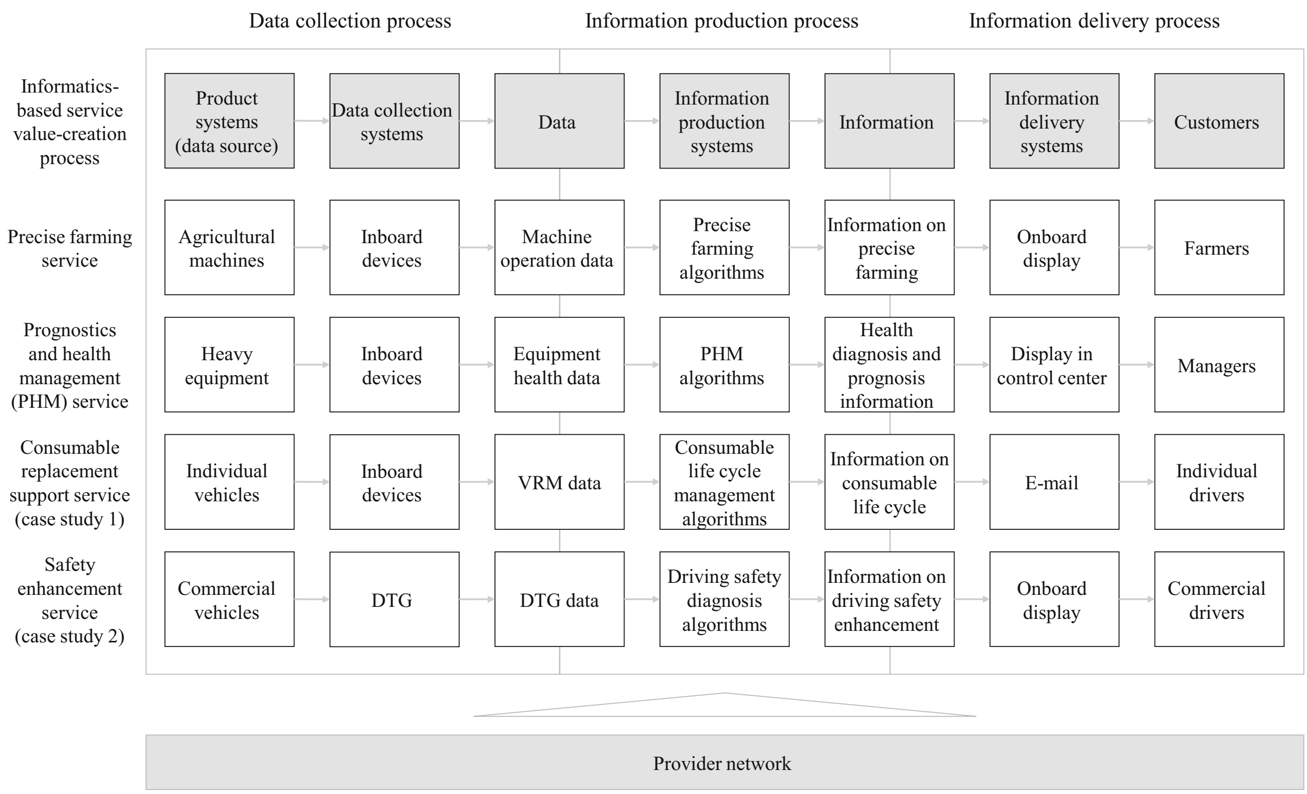


Fig. 6 Conceptual model of the informatics-based service value creation process

Informatics-based service value creation process

This section presents a conceptual model of the informatics-based service value creation process. The model serves as a basis for discussing challenges and future research issues in the design of informatics-based services for manufacturing industries.

Understanding the generic structure of a complex service system and its value creation mechanism is a prerequisite for innovating such a system (Zomerdijk and Voss 2010; Lim et al. 2012). Based on the literature review in "Literature review" section and the case studies presented in "Design of informatics-based services in manufacturing industries: case studies" section, we developed a conceptual model of the informatics-based service value creation process (Fig. 6). The topmost row in Fig. 6 presents the general informatics-based service value creation process. The other rows provide examples, namely, precise farming service, PHM service, the consumable replacement support service in case study 1, and the safety enhancement service in case study 2. As indicated in Fig. 6, the informatics-based service value creation process is divided into three subprocesses, namely, data collection, information production through data analysis, and information delivery.

Figure 6 extends the IT-based service value creation process model (Lim and Kim 2014). Compared with the model of Lim and Kim (2014), the data collection process is added to the current model. Such extension is warranted considering the recent advancements in data collection technology, such as IoT and telecommunication technologies, as well as the importance of informatics in service innovation. As indicated in Fig. 6, informatics-based service value creation can be defined according to eight dimensions (the shaded diagrams in Fig. 6): (1) product systems (data source), (2) data collection system, (3) data, (4) information production system, (5) information, (6) information delivery system, (7) customer, and (8) provider network (network of the service provider and its partners). These dimensions encompass the key areas in informatics-based service design, which include designing (5) what to deliver, (7) to whom, (1–4) how to produce it, (6) how to deliver it, and (8) who produces and delivers it.

Challenges in designing informatics-based services

An understanding of the challenges in the design of informatics-based service can function as a basis for facilitating future designs of such services in manufacturing industries. We encountered the following challenges when we conducted the case studies: (1) collecting the right data for services, (2) identifying the right information for customers, (3) planning the data analysis, and (4) designing the appropriate service delivery process. The first challenge lies in the data collection process, as shown in Fig. 6. The second and third challenges are related to the information production process. The fourth challenge is concerned with the information delivery process.

The first challenge was to collect the right data for services. We observed that a gap exists between manufacturing-related (e.g., engineering and product design) and service-related (e.g., marketing and after-sales service) departments in the automobile manufacturer. The VRM DB structure in case study 1 was developed by the engineering department, which gave little consideration to the application of data on customer services. Consequently, VRM DB was useful in diagnosing and maintaining vehicles for engineers, but provided limited understanding on the driving patterns of customers. Thus, VRM DB was limited in terms of service design and operation for customers. For example, GPS data were not collected, and vehicle operation data were collected in the form of aggregated data in each trip (e.g., average speed and number of rapid accelerations in a trip). Therefore, information on where and how customers drive was limited. This limitation hindered us from collecting and using the right data for customer services. Similarly, the DTG DB in case study 2 was developed by manufacturing companies that gave little consideration to their utilization in particular services.

The second challenge was to identify the right information for customers. In an information provision service, identifying appropriate information in terms of content and form is a key factor in improving service value creation (Lim and Kim 2014). In case studies 1 and 2, previous services did not appeal to customers because the service provider offered affordable information to customers rather than catering to their needs. However, identifying the right information from a large candidate space is a challenging task. We observed that classifying customer type and information provision timing helps identify right information for customers. For example, the right information for drivers and transportation companies can be different in terms of safety enhancement service design (case study 2). Similarly, the right information before, during, and after driving could differ.

The third challenge was planning data analysis. In both case studies, only a limited number of data analysis plans were implemented because of limited resources. Thus, we identified and focused on data analysis plans for services that are highly expected to attract customers. In this regard, identifying the right information is a prerequisite to data analysis planning. However, even if the right information is known, data analysis planning for service design remains challenging because this task requires various types of knowledge, including domain knowledge on the problem. With regard to domain knowledge, case study 1 required knowledge on vehicle health and operations, whereas case study 2 required knowledge on the mechanism of traffic accidents. Thus, we conducted data analyses in both studies based on the advice of several vehicle experts as well as the literature review (e.g., Ki et al. 2010; Guo and Fang 2013).

The last challenge was designing the appropriate service delivery process. Designing the service delivery process involves several decision points such as determining when, where, by whom, how, and through which sequence should information be delivered to customers (Lim and Kim 2014). For example, similar information can be delivered to customers in different manners according to the information delivery channel (how) and the company (by whom). In case study 1, vehicle diagnostic information can be delivered via e-mail or a smartphone application. Similarly, such information can be delivered directly by the automobile manufacturer or through an outsourcing company. Classifying the candidates for each decision point (e.g., potential information delivery channels and partners) helps in designing the service delivery process. In case study 1, we classified the channel into e-mail, phone call, smartphone application, or onboard display.

Future research issues

There exist several methodological issues for facilitating the design of informatics-based services in manufacturing industries. In the following paragraphs, six future research issues (namely, definition, characteristics, representation, quality scales, design framework of the informatics-based service, and service-oriented informatics) are discussed.

The first research issue is defining informatics-based service in manufacturing industries. Informatics-based service innovations are expected to flourish in manufacturing industries in the near future. However, a missing link exists between informatics and service value creation in literature, which requires the foundations of the basic notion of informatics-based service. Such studies will help build a theoretical background of informatics-based service, stimulate debates on such services at the academic and company levels, and finally, foster informatics-based service value creation in manufacturing industries.

Second, studies are required to elucidate the key characteristics of informatics-based services. An informatics-based service is characterized by a diverse set of dimensions. The dimensions may include the data source, data collection system, data, information, information delivery system, and information production system. However, details on such dimensions remain unknown. Comparing different service cases through service classifications would help clarify key characteristics by identifying service categories that share a number of similar attributes. Although several classification studies on IT-based service are available (e.g., Glushko 2010; Schumann et al. 2012), most of these studies focus on information delivery rather than on information production.

Third, a systematic representation of informatics-based services should be investigated once key characteristics are understood. Representing an informatics-based service would be helpful because it allows people to efficiently build and use their mental model and enhance dialogues among those involved in the discussion. Although several frameworks for service representation are available (e.g., White 2004; Booch et al. 2005; Lim and Kim 2014), their customized versions or new frameworks are required for representations that are specifically related to informatics-based service analysis and design.

Fourth, developing scales for informatics-based service quality evaluation is another important research issue. The scales for service quality evaluation evolved from those for traditional service (Parasuraman et al. 1988), electronic service (Ladhari 2010), and mobile service (Akter et al. 2013). The perceptions of informatics-based service quality are not well-known because this type of service is new. Novel quality scales may be required if customers perceive informatics-based service differently from other service types.

Fifth, a design framework for informatics-based service can be developed based on further design studies on such service. The components of such a design framework may include a process and tools for designing informatics-based service. A preliminary version of this process is the design process that we have employed in the case studies (Fig. 1). The tools should help the designers to perform the data analysis, service opportunity identification, and service concept design.

Sixth, a fundamental notion to connect data and informatics-based services in manufacturing industries should be defined. Various directions of data analysis (e.g., for product improvement and service design) can be taken. Such a notion would facilitate data analysis that is specifically designed for informatics-based service, and we propose service-oriented informatics (SOI). SOI can be defined as the process of collecting, transforming, and analyzing data to discover useful information for the informatics-based service in question and new service design. SOI is a notion that is highly relevant to all the aforementioned challenges and future research issues. The notion of SOI is similar to that of service-oriented architecture (SOA), which is a paradigm for coherently organizing distinct pieces of software to meet ultimate service functionality (Erl 2004). By nature, the design of informatics-based services is a “soft” task that requires human activities. The project team should ideally be formed as a cross-functional team with members from various functional units, including planning, design, engineering, IT, and marketing. A coherent perspective (i.e., SOI) is required to merge various perspectives into a single framework. We believe that the effectiveness and efficiency of designing informatics-based services can be increased considerably when various informatics-related tasks (e.g., data collection and analysis) are oriented toward ultimate service functionality as SOA has contributed to coherent software development. In fact, the two case studies were conducted with the notion of SOI in mind. We prepared and analyzed data with the objective of discovering useful information to recognize opportunities for new informatics-based services and produce useful information for customers. The applicability of this notion can be tested in future informatics-based service design studies.

Concluding remarks

We live in an information economy where information is increasingly exchanged. A recent advanced technology in this economy is data collection technology, which has emerged with the rapid improvement of IoT and telecommunication technologies. As a result, manufacturing companies have begun actively utilizing product and customer data to provide services as complements to the products that they are offering.

Informatics, the science of transforming data into information, has greatly contributed to service innovation in manufacturing companies. Informatics-based services will continuously complement various types of existing products. This paper reports on an original work that introduces case studies in the design of informatics-based service in manufacturing industries. It also discusses the value creation process of informatics-based service, as well as challenges and future research issues involved in designing informatics-based service. Such discussions will offer an improved approach for designing informatics-based service in manufacturing industries in the future. This study contributes to service innovation in manufacturing industries under the current information economy.

Acknowledgements This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT, and Future Planning (NRF-2014R1A1A1005356 and NRF-2014R1A2A2A03003387).

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