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A Conceptual Framework for Designing Informatics-based Services in Manufacturing Industries

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Abstract

Numerous manufacturing companies have "servitized" their value propositions to address product commoditization and sustainability issues. Service—essentially different from a product—contributes to the fulfillment of customers' unmet needs and increases the freedom of finding an environmentally more benign offering beyond simply offering the product. Informatics is a key to the design of services in manufacturing companies. Informatics facilitates the collection of various types of data from products and customers and enables the production and delivery of useful information for customers. This paper (1) proposes a conceptual framework for designing informatics-based services in manufacturing industries, (2) introduces a service design case study that the authors recently conducted with a major car manufacturer in Korea, and (3) suggests future research issues. This paper is expected to contribute to product–service integration in manufacturing companies in this information economy.

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Keywords: Servitization; Product-service system; Informatics-based service

1. Introduction

Product-based companies face various challenges. Given the commoditization of many products, getting ahead of competitors in terms of cost and technology leadership in production is becoming increasingly difficult. Furthermore, global environmental regulations are becoming progressively rigid. With such intense product-led competition, many product-based companies have begun to adopt a service-led competitive strategy to distinguish themselves from competitors [1, 2]. Service—essentially different from a product—contributes to innovation in terms of fulfilling customers' unmet needs, strengthening relations with customers, and increasing freedom in finding an environmentally more benign offering beyond simply offering the product [3, 4].

Existing studies have discussed a wide variety of product–service integration from diverse disciplines such as information systems, business management, and engineering and design [5]. Various researchers have discussed the importance of informatics in servitization (e.g., [5, 6, 7, 30, 39]). A key to the service design of manufacturing companies is informatics, which is the science of data and information processing and involves the whole spectrum of data collection, information production through data analysis, and information delivery. Informatics enables and facilitates the collection of various types of data from products and customers, supports the identification of service opportunities, and enables the development of information content for customers by data analysis.

This paper proposes a conceptual framework for designing informatics-based services in manufacturing industries (Section 3). This paper defines informatics-based service as a type of service wherein the service provider collects and analyzes customer-related data (e.g., data from customers' products and behaviors) and provides derived information to customers to assist in their goal accomplishment. The aforementioned studies [5, 6, 7, 30, 39] indicate that designing

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informatics-based services is critical and that timely research is needed by manufacturing companies in this information economy. However, despite such recent studies, knowledge on the design of informatics-based services in manufacturing industries still remains limited.

The proposed framework encompasses the value-creation mechanism of informatics-based service. The framework was constructed by analyzing relevant service cases and reviewing related literature and actual service design projects. The authors have conducted informatics-based service design projects with the industry (car manufacturing, telecommunication, and IT companies) and with the Korean government (transportation safety and health insurance divisions). This paper introduces an informatics-based vehicle operations and health management service design project with a major car manufacturer in Korea as a case study of the proposed framework (Section 4). This paper also suggests future research issues on informatics-based service design in manufacturing industries (Section 5). This paper will contribute to product–service integration in manufacturing companies in this information economy.

2. Literature review

Two research fields are highly relevant to informatics-based services in manufacturing industries, namely, the product–service system (PSS) and information-intensive service (IIS) research fields. Representative PSS providers provide IISs as service components that complement their product offerings. For example, car-sharing [10] companies built a smartphone-conscious information system and dramatically improved the efficiency of information delivery. By using information-intensive processes, customers can explore, reserve, and unlock their cars via their smartphones. This section briefly reviews existing studies on PSS and IIS. Furthermore, this section discusses how the two notions are linked in terms of informatics-based services in manufacturing industries. The set of reviewed studies serves as an academic basis of the informatics-based service design framework (Section 3) and the informatics-based service design case study (Section 4).

2.1. Product-service system

The service-led competitive strategy of product-based companies has generated specific types of value propositions that integrate products and services in a single system. Recent studies have introduced this type of “servitized” value proposition and called it the PSS [3, 9]. Representative examples of PSS include the precise farming solution [4], car-sharing scheme [10], and document management solution [11]. The precise farming solution guides farmers in spraying the precise amount of fertilizer on crops to increase yield and minimize the amount of fertilizer used. The car-sharing scheme provides cars to be shared by citizens and visitors in various cities. The document management solution providers (i.e., document-related product manufacturers) monitor and diagnose the document management process of business customers (i.e., organizations who bought copy machines or printers) and assist customers in completing document tasks effectively and efficiently.

PSSs create economic, environmental, and social values for a diverse pool of stakeholders. Companies can solve customer needs effectively through the integration of complementary products and services [1, 12]. Greater customer satisfaction can contribute to higher company gains. Providing services allows companies to build close relationships with their customers, anticipate future businesses, and achieve long-term success [11, 13]. Product deliveries that are coursed through supplementary services make material consumption and waste emission controllable. Such services contribute to the reduction of the adverse environmental impact of consumption [3]. PSSs encourage people to make mature choices because it promotes a balanced propensity to consume [14]. Thus, PSS serves as a means of innovating company offerings in an economically, environmentally, and socially sustainable manner [15].

Expectations for PSS as a sustainability and competitiveness creator have led to a renaissance of research on PSS [15, 16]. Studies that introduce PSS and its cases have been conducted (e.g., [1, 12]). Over the last decade, researchers have investigated knowledge for PSS development on the basis of previous conceptual works to facilitate PSS development tasks such as strategic planning, conception, and implementation. The knowledge includes learning from PSS development case studies (e.g., [11, 13]), types of PSS (e.g., [17, 18]), sustainability assessment methods (e.g., [19, 20]), PSS development frameworks (e.g., [16, 21]), and so on.

Along with advances in informatics technology, recent studies have paid attention to informatics-based PSS design (e.g., [5, 6, 7, 30, 39]). However, reports on real informatics-based PSS design cases are rare and the understanding of the mechanism behind such design is limited. This study responds to this research necessity.

2.2. Information-intensive service

We live in an “information economy,” wherein information is increasingly exchanged in tasks in the global economy [22]. IIS is a type of service in which customer value is primarily created via information interactions, rather than via physical and interpersonal interactions, between the customer and provider [35]. Examples of IIS offerings include online language learning, mobile map application, and remote vehicle diagnostic services. Recent innovations in information and communication technology have created various types of IIS in education, telecommunication, healthcare, and car manufacturing. Recent buzzwords, such as smart devices, Internet of Things (IoT), big data analysis, cloud computing, and social networking, are highly relevant to IIS.

Understanding the generic structure of a complex service system and its value-creation mechanism in question is a prerequisite to its innovation [26]. [25] proposed a conceptual model of the IIS value-creation process. Fig 1 is an extended version of the model in [25]. The top row in Fig 1 illustrates a general IIS value-creation process. Other rows show examples in news, vehicle diagnostic, and wearable device-based fitness services. Fig 1 shows that the IIS value-creation process is decomposed into three sub-processes: (1) data collection, (2) information production though data analysis, and (3) information delivery. Compared with the previous model [25], the data collection process is added to the current model. Such an extension is warranted considering the recent advancements in data collection technology such as IoT and telecommunication technologies.

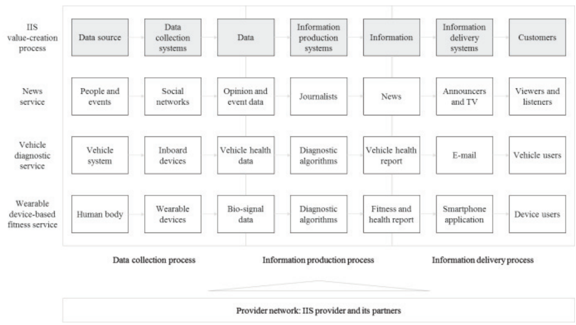

Fig. 1. IIS value creation process: an extended version of [25]

Although most researchers have investigated PSS and IIS independently, these notions are highly relevant in real-world manufacturing industries. Representative PSS providers provide IISs as service complements to their product offerings. For example, precise farming solution providers collect navigation data (e.g., global positioning system and real-time kinematic data) from agricultural machines and provide farmers information to spray the precise amount of fertilizer on crops to increase yield and minimize the amount of fertilizer used. Document management solution providers analyze data from the document management processes of customers and provide them useful information for completing document-related jobs with less cost, hassle, and consumable use.

The above cases show that IISs, particularly informatics-based services, greatly contribute to the innovation of product-based companies. The potential of informatics-based service design has been also confirmed through the authors' projects with the industry and the government; one of these projects will be presented in Section 4. The rapid improvements in informatics technology will foster informatics-based service designs to complement various types of existing products. This research aims to support such informatics enabled or facilitated service innovation in manufacturing industries.

3. Conceptual framework for designing informatics-based services in manufacturing industries

Fig 2 shows a conceptual framework for designing informatics-based services in manufacturing industries. The framework consists of three parts, namely, (1) data collection points throughout the product lifecycle from a customer perspective, (2) types of informatics-based service that support customers throughout the product lifecycle, and (3) informatics-based service design process from a company perspective (i.e., service designer perspective). First, data are collected throughout several product lifecycle phases from a customer perspective, namely, purchase, use, maintain, and dispose. Second, the types of informatics-based services throughout the product lifecycle include recommendation service (at the purchase phase), product use/operations management service (at the use phase), product health management service (at the maintain phase), disposal support service, loyalty program (at the dispose phase), and so on. A service at a phase can utilize the data collected from other phases. For example, a car recommendation service utilizes the use and maintenance data of the customer's previous cars. Third, the design of such types of service is conducted through five steps, namely, data collection, data analysis, service opportunity identification, information content production related to identified opportunities, and content delivery service concept design.

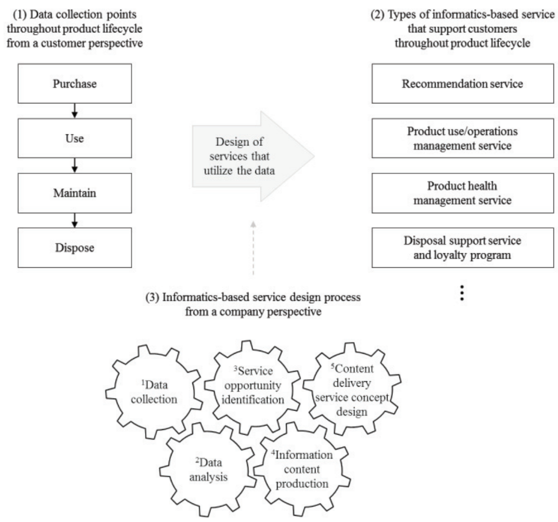

Fig. 2. Conceptual framework for designing informatics-based services in manufacturing industries

The development of such a framework was initiated by understanding the nature of PSSs and IISs on the basis of a literature review, case investigation, and our informatics-based service design projects. We reviewed a wide range of existing studies relevant to PSS and IIS, such as the studies introduced in Section 2. For example, [27] discuss the service infusion throughout a product's lifecycle. The informatics-based service design process featured in Fig 2 is based on studies on the new service development (NSD) process, such as [31, 32]. [24, 33] discuss various types of IIS, while [18, 34] classify PSS models. We also reviewed various studies on business analytics. For example, [36] discusses data, information and analytics as services, [37] reviews data analytics techniques for recommendation service, while [38] reviews applications on data mining techniques in customer relationship management. We also investigated and classified various PSS and IIS cases in manufacturing industries. On the basis of such a literature review and service case investigation, we identified the essential attributes of informatics-based service value creation. Our previous research results are exemplified in [25, 29, 30, 34]. Such an understanding served as a basis for developing the current version of the framework to represent informatics-based service design in manufacturing industries.

Parts (1) and (2) in Fig 2 represent a customer perspective. Part (1) shows customer-related data collection points, while part (2) shows the types of service for customers. Various types of informatics-based services support customers on the basis of the data collected throughout the product lifecycle. For example, the recommendation service identifies products that are customized to a specific member (i.e., customer) of the company and recommends the products to the said member in the purchase phase. Such a service is available by analyzing the members' demographic, purchase history, and rating data collected throughout the product lifecycle. A representative example of the product health management service is vehicle diagnostics service, which collects vehicle operations and health data throughout the vehicle lifecycle and diagnoses vehicle health to enhance customer driving experience and vehicle lifecycle management.

Part (3) in Fig 2 represents a company perspective (i.e., the service designer perspective). The relationship between part (3) and other NSD processes should be discussed. [32] reviewed multiple NSD processes and proposed a common NSD process that consists of five steps, namely, (i) opportunity identification, (ii) customer understanding, (iii) concept development, (iv) process design, and (v) refinement and implementation. The informatics-based service design process featured in part (3) is an approach for conducting steps (i) to (iii). Service designers can utilize the data collected throughout the product lifecycle to (i) recognize opportunities for new services or improvements in existing ones, (ii) understand customers' behaviors throughout the product lifecycle phase and produce information contents needed by customers, and (iii) design service concepts to deliver multiple information contents as a package.

In short, the framework integrates insights within the evolving informatics-based service related literature from both customer and provider perspectives. The framework shows a big-picture of the value-creation mechanism of informatics-based service; the framework shows how product-based companies can consider each product lifecycle phase as a customer-related data collection point and use the collected data to design services (i.e., to create customer value). Furthermore, the framework also suggests a step-by-step procedure for the service design. The next section introduces how the authors followed these steps in an informatics-based service design with a manufacturing company.

4. Case study: design of vehicle operations and health management services

The authors have designed informatics-based vehicle operations and health management (VOHM) services with a major car manufacturer in Korea (the number of employees is more than approximately 60,000). Fig 3 shows an overview of the case study. As shown in Fig 3, we conducted the case study by using the informatics-based service design process introduced in Section 3 (i.e., part (3) in Fig 2). This section will serve as a reference for researchers and practitioners in designing new informatics-based services in manufacturing industries.

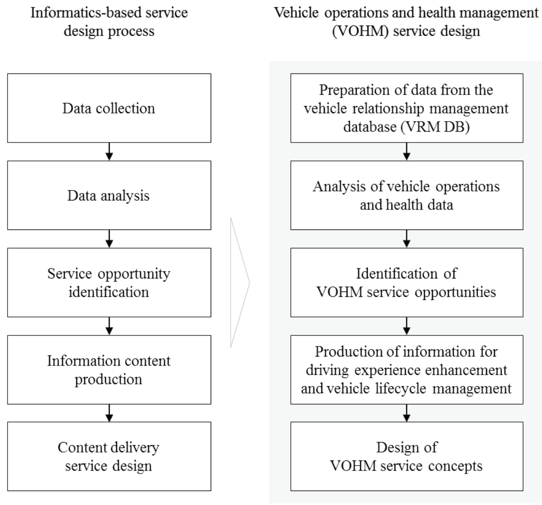

Fig. 3. Overview of the case study

The car manufacturer gathered data on vehicle operations and health through a telematics system and constructed a database called the vehicle relationship management data base (VRM DB). The company aimed to develop new attractive VOHM services on the basis of VRM DB analysis. This project was motivated by and conducted with a customer relationship management department to enhance its competitiveness using the VRM DB. People in the department expected to derive various insights from the VRM DB for their customer relationship management works.

As Fig 3 shows, the project was conducted by the following steps: (1) preparation of data from the VRM DB, (2) analysis of vehicle operations and health data, (3) identification of VOHM service opportunities, (4) production of information for customers' driving experience enhancement and vehicle lifecycle management, and (5) design of VOHM service concepts.

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 in a trip) and vehicle health data (e.g., warning code, engine temperature and RPM when a warning code occurs). Vehicle operations data are collected in every trip, whereas health data are recorded for 7 seconds when a warning code occurs. The authors analyzed a total of 7.6 million trip data of 18,943 vehicles (operations data) and 3,662 cases of warning code occurrences (health data). The data analysis results in step (2) include customers' driving patterns, correlation among key variables that determine vehicle operations characteristics, and customer clustering results. The service opportunities identified in step (3) include consultation for new vehicle purchase (at the purchase phase in vehicle lifecycle), provision of vehicle operations and health history review report (at the use phase), and so on. In step (3), the authors also analyzed competitor services and customer complaints to identify a variety of opportunities. The information contents produced in step (4) include information of daily/monthly vehicle operations review, customers' ranking information in terms of eco-efficiency, and remaining lifetime information of consumables. The four service concepts designed in step (5) are (i) eco-efficiency improvement, (ii) driving safety enhancement, (iii) consumable replacement support, and (iv) prognostic maintenance support services.

Fig 4 shows the main characteristics of the service concepts based on four IIS dimensions [25], namely, information, information production systems, information delivery systems, and partners. For example, the eco-efficiency improvement service provides driving history review information to drivers from the eco-efficiency perspective. Such a service requires a smartphone application as an information delivery system component, an on-board data collection device, an eco-efficiency analysis algorithm as information production system components, and an application developing company as a partner.

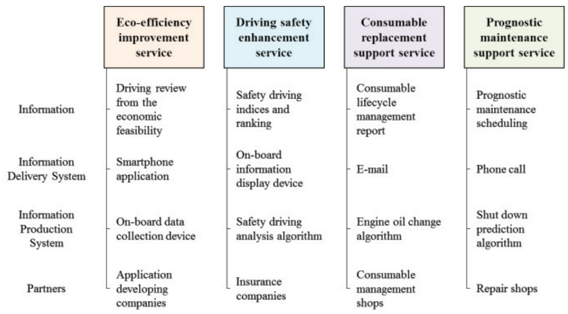

Fig. 4. Main characteristics of the four VOHM service concepts

Through the case study, we could identify several managerial implications for managers and executives of car manufacturers from the perspective of the informatics-based service design framework (Fig 3). For example, we observed that the gap between informatics related (e.g., engineering and IT) and service related (e.g., marketing and design) departments is a main cause that hinders informatics-based service design. The structure of VRM DB was developed by an engineering department with little consideration to data application, service operation, and design from an engineering-oriented perspective. Meanwhile, a marketing department, a customer-oriented department, had also disregarded the VRM DB for a long time despite the great insights on customers that contained in the DB. Thus, we suggested that the company enhance the capability of VRM DB (i.e., the capability to collect and store more data) with informatics-based service design purpose. The achievement of such a purpose requires a consideration of product lifecycle phases as customer-related data collection points, as well as various types of informatics-based service that support customers throughout the product lifecycle. The achievement of such a purpose strongly requires a collaboration between informatics- and service-related departments from both customer and provider perspectives. At the end of the project, the company decided to enhance the capability of VRM DB to find and realize more service opportunities.

5. Concluding remarks

We are living in a service economy and an information economy [35]. The rapid improvement of informatics technology will allow informatics-based service innovations to persist in various areas of the economy, such as healthcare, transportation, and manufacturing. This paper proposes a conceptual framework for designing informatics-based services in manufacturing industries. This paper is an original work that develops such a framework by integrating insights within the evolving informatics-based service related literature (e.g., the PSS and IIS literature). This paper also discusses how these different research fields are linked in reality. Furthermore, this paper introduces a service design case study that the authors recently conducted with a major car manufacturer in Korea. The utility of the proposed framework for informatics-based service design is validated through such a case study. This paper is expected to contribute to product–service integration in manufacturing companies in this economy.

Future research may address several issues in facilitating informatics-based service design in manufacturing industries. First, the framework proposed in this conference paper should be refined to a more solid and detailed form. The framework can be used in a different way from the examples in this paper. A refined version of the framework will embrace more scenarios of its application. We believe that more relevant studies should be incorporated in the refinement work. For example, insights from studies on the enterprise architecture management (e.g. [8, 24]) and the service oriented technology and management (e.g. [23, 28]) will and should be incorporated in the refinement.

More informatics-based service design case studies should also be incorporated in the refinement. Although this conference paper introduces a case study, the authors have designed informatics-based services with the Korea Transportation Safety Authority (TS), a maritime business company, and an IT company. The study with the TS involves designing a driving safety enhancement service for commercial vehicles (i.e., bus, taxi, and truck) on the basis of an analysis of the driving history data and accident history data of commercial vehicles. The studies with the maritime business company and with the IT company involve designing ship operations management and wearable device-based fitness services, respectively. We will also incorporate more relevant case studies conducted by other researchers in the refinement work.

Second research issue is to elucidate the key characteristics of informatics-based services. Informatics-based service is characterized by a diverse set of dimensions such as data, information, and provider network. Thus, general principles on the management and design of this service type are difficult to identify. The comparison of different service cases through service classifications will help make sense of such diversity by identifying categories of services that share a number of similar attributes. Such insights and related case information will serve as resources for new service designs.

Third, more interdisciplinary studies are required to tightly connect the informatics and PSS research fields. Such interdisciplinary studies will create a great synergy between the expertise of the two fields. For example, the prognostics and health management (PHM) society and the PSS research society can cooperate to apply advanced PHM algorithms in PSS development projects with heavy equipment manufacturers.

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