The Antecedents of Successful IoT Service and System Design: *Cases from the Manufacturing Industry*

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The Internet of Things (IoT) has enabled manufacturing companies to create significant business opportunities by extending their product-based portfolios with innovative systems that integrate products, services, and customer data. While previous literature has addressed the technical characteristics and commercial benefits of these systems, more research is needed on what makes a successful IoT system design process that can be used as a guideline by designers within the context of manufacturing. This paper aims to address this gap using a comparative case study of two leading manufacturers from the aerospace and trucking industries. Based on empirical data, the commonalities and differences between the two companies are articulated. Further analysis of the cases revealed six antecedents for successful IoT service and system design: *Communicating a well-articulated system design strategy, redefining frontline employee roles and responsibilities, training and recruiting service aware staff, providing guidance to customers on system use, aligning customer focus across the business*, and *utilizing methods/techniques for systems thinking and creativity*. These antecedents are discussed in detail with evidence from two IoT system design projects. Consequently, the findings show that successful IoT implementations require more than solid product design; they also necessitate well-executed service and system design.

Keywords – Digital Transformation, Internet of Things (IoT), Manufacturing Industry, Service Design, System Design.

Relevance to Design Practice – The findings highlight the importance of six factors when designing for IoT services and systems in the manufacturing industry context. Managers and design practitioners can translate these identified antecedents into impactful strategies for designing effective IoT systems that convey superior value for customers.

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Introduction

Ensuring productivity growth and inimitability is becoming increasingly important for the manufacturing industry (Roos, 2016). In order to address the challenges associated with market saturation, product commoditization, and decreasing profit margins, many manufacturing organizations have begun to shift from the production of goods to the provision of services and systemic solutions (Baines & Lightfoot, 2013; Baines, Lightfoot, Benedettini, & Kay, 2009; Manzini & Vezzoli, 2003; Morelli, 2002, 2003). Several aspects of the move towards a systems-oriented approach are related to the discipline of design, such as the analysis of technological potentials and investigation of users' behaviours and attitudes with respect to new products, technologies, and services (Morelli, 2003). The integration of information and communication technologies and sensors into the manufacturing process—referred to as the Internet of Things (IoT)—also has a major impact in this changing manufacturing landscape (Roos, 2016). It has helped manufacturers create significant opportunities by changing their business mix and expanding their portfolio with service offerings delivered to or through products that feature awareness and connectivity (Allmendinger & Lombreglia, 2005); such as pre-emptive services, information services made available for the customer through Internet access, or collaborative remote repair of machines (Wünderlich, Vengenheim, & Bitner, 2013).

The concept of the IoT was initially discussed by Kevin Ashton in 1999, and then became increasingly recognized. Miorandi, Sicari, De Pellegrini, and Chamtac (2012) stated that conceptually "IoT is about entities acting as providers and/or consumers of data related to the physical world" (p.1498). For example, *General Electric* creates value by extracting data from the sensors on its turbines and other wind energy equipment and uses that information for performance optimization (Iansiti & Lakhani, 2014). Similarly, *Caterpillar* integrates sensors into its vehicles to be able to provide operators and service personnel with information about potential problems and appropriate actions to solve them (Wünderlich et al., 2015). Other significant examples include *MAN Trucks'* fleet management system that enables visibility of drivers and vehicle performance (Baines & Lightfoot, 2013), and *John Deere*'s overall farm performance optimization services that connect machinery and irrigation systems with

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information about weather and seed quality, by utilizing technologies surrounding the industrial internet (Kowalkowski, Gebauer, & Oliva, 2017; Porter & Heppelmann, 2014).

The influence of this digital transformation on *product design* practices of manufacturing firms has been studied in general—such as potentially reducing the need for excessive product features, or favouring products designed for ease of repair (Spring & Araujo, 2017). It is also acknowledged that the introduction of IoT technology requires a whole set of new design principles; i.e. designs that enable personalization, and designs that enable predictive, enhanced, or remote service (Porter & Heppelmann, 2014). However, research on the antecedents for successful system design in this new landscape, specifically in the manufacturing context, is limited. In this study, along the same lines as Holmlid, Wetter-Edman, and Edvardsson (2017) and Wetter-Edman, Sangiorgi, Edvardsson, Holmlid, Grönroos, and Mattelmaki (2014), *design* is defined as an activity in the change and reconfiguration processes leading to implementation, as well as an activity or practice in development projects.

The paper is structured as follows: First, a literature review is presented that discusses the potential of the IoT as manufacturers move towards system-oriented approaches. Then, a summary of the research design is provided, followed by the research findings. The last section entails discussion of the research results and conclusions.

The IoT as an Enabler of Service and System Design in Manufacturing Firms

The digitization of previously analogue machine and service operations, organizational tasks, and managerial processes has begun to extend with the growth of the IoT (Iansiti & Lakhani, 2014; Porter & Heppelmann, 2014). The IoT can be defined as:

> A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities, use intelligent interfaces, and are seamlessly integrated into the information network. (Vermesan et al., 2011, p. 10)

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Shang, Zhang, Zhu, and Zhou (2016) suggested that the IoT is a technology of system integration; enabling all kinds of devices and systems to work together, getting real-time information as well as feedback. The main benefits of IoT systems include improvement in business transactions, seamless integration of resources, and cost-efficiency (Li, Xu, & Zhao, 2015). More importantly, the internet-enabled connectivity allows for the generation and capture of large quantities of data (Kortuem, Kawsar, Fitton, & Sundramoorthy, 2010), which can be exploited in different ways. This new wave of digitalization through the IoT emphasizes the growing importance of services in the manufacturing industry (Hallward-Driemeier & Nayyar, 2017; Rymaszewska, Helo, & Gunasekaran, 2017). The utilization of the IoT technology opens up the possibility of tracking every object through its whole life cycle; from the manufacturer to every single user it comes into contact with, and even the end-of-life processes of dismantling, recycling, and disposal (Spring & Araujo, 2017). These systems also provide manufacturing firms with detailed information about the location, condition, and performance of their products (Baines & Lightfoot, 2013). Hence, the IoT is a key enabler for manufacturers to capitalize on their product expertise and design tailored services that optimize customer production processes (Hallward-Driemeier & Nayyar, 2017) or offer availability guarantees (Lerch & Gotsch, 2015). These services are also associated with new business models, such as pay-per-use and/or pay-for-results (Kowalkowski et al., 2017). The role of design in this digital transformation is therefore strongly related to development of novel service-oriented business models and the socio-material assemblages that enable them (Blomberg & Stucky, 2017). To develop these models effectively, manufacturing firms should first define the appropriate "service concept"—comprising *what* is to be done for the customer and *how* this is to be achieved (Goldstein, Johnston, Duffy, & Rao, 2002).

Another implication of IoT system implementation for manufacturers is the changing role of customers. Becoming more active and connected, customers can now generate critical information about their behaviour and choices, which can be recorded in real time. The use of the IoT technology offers a unique opportunity for manufacturing companies to gain knowledge about how their products are being used and to achieve closer and better proximity to their customers (Rymaszewska et al., 2017). As a result, they can discover the true preferences of customers and design improved systems. On the other hand, manufacturing organizations should also be aware of the fact that IoT connectivity can never serve as the rationale for the customer purchase (Nelson & Metaxatos, 2016). This highlights the significance of "customer interface" as a theme that can be adopted from the service design literature (Hill, Collier, Froehle, Goodale, Metters, & Verma, 2002; Secomandi & Snelders, 2011). Thus, manufacturing companies must think about how they will design their customer interface, as IoT services and systems promote *recurrent interaction* with customers (Valencia, Mugge, Schoormans, & Schifferstein, 2015).

Porter and Heppelmann (2014) stated that providing these IoT-aided services requires significant investment in technologies and infrastructure; particularly the construction of a product cloud that includes a product-data database, platforms for building software applications, rule engines and analytics platforms, and smart product applications. Moreover, manufacturers need to make a new set of strategic choices on how they will create and capture value, how they will work with traditional and new partners, and how they will secure competitive advantage (Porter & Heppelmann, 2014). This emphasizes another theme from the service design literature; "service delivery system", which can be defined as "the interaction of practices and technologies within the broader operations of the manufacturer that come together to deliver the service offering." (Baines & Lightfoot, 2013, p. 116).

Nelson and Metaxatos (2016) argued that offerings utilizing the IoT technology demand a significantly higher level of design and technology partnership because of their inherent technological integration and ability to create new customer experiences. Blomberg & Stucky (2017) conceptualized these digitally enabled offerings as the "redistribution of labor, assets, and value" (p. 221). They suggest that there are many opportunities for design to contribute to innovation in such services and systems and to define the new relationships they afford; from the design of data producing activities to the design of new customer interfaces (Blomberg & Stucky, 2017). All of these possibilities lead to a major reconfiguration of the mechanisms of value creation in the manufacturing industry.

Methodology

Case study methodology was adopted. This methodology is particularly useful to develop insights about novel research areas (Edmonson & McManus, 2007) and to understand theoretical linkages in detail (Easton, 2010). Case studies were chosen as an appropriate strategy because the main research aim was to study a complex phenomenon in its natural context; the antecedents of successful IoT service and system design (Meredith, 1998; Yin, 2009). This qualitative approach was well suited for the research as it also provided an in-depth understanding of the outcomes within each case (Miles & Huberman, 1994) and allowed for comparison across cases (Eisenhardt, 1989; Yin, 2009).

Using theoretical sampling (Eisenhardt, 1989), two cases that would provide comparative data were purposefully selected, meaning that the choice of cases was based on their suitability for theory development and for illuminating relationships among constructs (Eisenhardt & Graebner, 2007), rather than the uniqueness of each case. Both manufacturers were formally committed to IoT service and system development projects of strategic importance, provided appropriate access to information and informants, and they were leading players in their markets. On the other hand, they were from two different industries—aerospace and automotive. The two distinct industry structures also convey differences in terms of customer-facing relationships and the nature of the ecosystem that supports the service business. Hence, it was anticipated that the companies might demonstrate variation in their shift from products to continuous delivery IoT services, which would then enable a comparative analysis. Moreover, both industries are considered as exemplars of the shift from products to services (Gaiardelli, Songini, & Saccani, 2014; Johnstone, Dainty, & Wilkinson, 2009; Mahut, Daaboul, Bricogne, & Eynard, 2017; Oliva & Kallenberg, 2003). The cases, therefore, provided a good understanding of the phenomenon of interest (Yin, 2009). The unit of analysis was specific IoT system design projects from the manufacturing companies: an on-wing care system and a fleet management system. Both projects involved employees from multiple units and required extensive communication and collaboration. The on-wing care system developed by *Aerospace Co.* (pseudonym used to retain anonymity) was a successful offering, whereas the fleet management system developed by *Truck Co.* (pseudonym used to retain anonymity) failed to achieve the anticipated sales goals. Choosing comparative cases enabled the gathering of rich detail into the antecedents and dynamics of design processes and the identification of contrasting patterns in the data (Eisenhardt & Graebner, 2007). An overview of the cases is presented next.

Overview of the Cases

The first manufacturer, Aerospace Co., is a large, global company that provides airplane engines for the commercial and defence aerospace sector. Their offerings cover a spectrum of activities from time and material type contracting, to spares and repairs as a legacy of being in the manufacturing business all the way through to more advanced availability contracting. The contracting mechanism is typically about selling the availability of an engine, or of power per flying hour. Hence, their value proposition is comprised of guaranteeing the availability of the engine and incentivizing customers to keep their aircraft and engine working for as long as possible. This innovative and highly customizable system entails a combination of original equipment and related services, designed to suit the needs of individual customers. With the opportunities of IoT technology, the system has evolved into a comprehensive service offering that manages the maintenance of the engine through its life on wing, by capturing engine performance data in real time. The data collected on engine performance enable Aerospace Co. to detect potential problems quickly, reduce unplanned workshop visits and maintain asset value. The provision of this system has caused a fundamental shift in the company's business model; from a reactive, short-term, transaction-based model to a proactive, long-term, service and relationship-based model. Thus, very close customer collaboration and in-depth understanding of airline operations is required.

The second manufacturer, *Truck Co.*, is a large, multinational company in the automotive sector. The case study focused on the design process of a monitoring system that used the IoT technology to help customers better manage their fleets and to ensure operation at optimal performance levels. It has been developed in partnership with a pioneering vehicle tracking and fleet management solutions provider and a mobile telecommunications company. The system collects data through sensors integrated into the infrastructure of its new generation vehicles in order to assist customers with the analysis of driver-behaviour and fuel consumption. It can provide 25 different reports, allowing for rapid response to mechanical problems and changing road conditions. Data obtained from the system are delivered to both customers and company service shops. Maintenance of the vehicles is carried out in accordance with these data, which can also be shared and analyzed through *Truck Co.*'s corporate web site. The utilization of the system helps customers save up to 20% in fuel consumption; develop economic driving habits; reduce idle time; assure the compliance of drivers to appropriate routes with the right arrival times; reduce maintenance, repair and communication costs; obey the speed limit; and reduce the risk of accidents with safer driving. Moreover, driver profiles that are developed from the reported vehicle driving information enable customers to reorganize their driver training activities. The characteristics of the two companies and selected projects are shown in Table 1.

Data Collection and Analysis

For this study, the primary data source was semi-structured interviews with key informants who were involved in the design and decision-making processes of the IoT projects. Triangulation through a variety of secondary sources (e.g., organizational documents, newspaper/magazine articles, internal reports, and company websites) complemented internal validity. The roles and titles of the interviewees included innovation managers, business development managers, directors, and field service managers. Essentially, all respondents were asked the same questions to ensure consistency. Further probing was done when some issues were not clear. All interviews were conducted face-to-face, recorded, and transcribed; with each lasting between 1,5 and 2 hours.

The interview guide entailed questions about the design process of the project, enablers and barriers for development and implementation, and key actors, their roles and responsibilities. Cases were first analyzed individually, by reading through the interview transcripts and other textual material to build an initial picture of how the IoT systems were designed. Adopting an inductive approach, themes were allowed to emerge without prescribing a coding structure (Patton, 2002), and higher-order categories were developed through an iterative process. Individual case reports were then prepared and sent to the key contact in each company, who checked the content and made suggestions for improvement. After this validation, cross-case analysis was performed to identify where similarities and differences existed (Eisenhardt, 1989). As the cases were purposefully selected from two different industries, the analysis process focused on articulating the different paths followed in the shift from product to service design and explaining the factors that influenced the success of IoT services and systems.

Findings

Taking the differences between the industry structures, customer-facing relationships, and offerings of the two companies into account, a detailed comparative analysis was deployed in order to build an understanding of the requirements for a successful IoT service and system design process. In the following sections, findings from the cases are presented using three themes from the service design literature: service concept (Goldstein et. al, 2002), customer interface (Hill et al., 2002; Secomandi & Snelders, 2011), and service delivery system (Baines & Lightfoot, 2013; Goldstein et al., 2002; Ponsignon, Smart, & Maull, 2011). Furthermore, the Johnson, Menor, Roth, and Chase (2000) new service development model was adopted for a more comprehensive discussion: in this model, the service development process is divided into two macro phases—the "planning phase" comprising the design stage, and the "execution phase" comprising the implementation stage (Johnson et al., 2000). Thus, in both cases, the service concept, customer interface, and service delivery system were investigated during the planning/design and execution/implementation phases. This way, it was possible to identify what was required in each phase, and to what extent the companies could meet those requirements.

Table 1. Characteristics of the cases.

Cases		*Aerospace Co.*	*Truck Co.*
Company Size		Large (>50,000)	Large (>1,500)
Selected IoT System		On-wing care system	Fleet management system
Description		An IoT system that enables condition monitoring and maintenance of asset value. Aircraft engine performance data are captured in real time. The analysis of the customer data provides opportunities for early prediction and planning of repairs, data driven aircraft performance optimization services and customization.	An IoT system that enables condition monitoring with sensors embedded in the trucks. Extensive data collected from customers enable tracking services and performance statistics. The analysis of the customer data provides opportunities for performance reporting services, maintenance scheduling and customization.
Main differences between the offerings of the companies	Value proposition	Providing pre-emptive servicing to reduce downtime, complex service offering	Helping customers monitor and better manage their fleets, simpler service offering
	Revenue stream	Higher margin offering, more secure revenue stream	Lower margin offering, less secure revenue stream
	Ownership of the assets offered to the customer	Retained by Aerospace Co. (engines), takes over responsibility of ensuring availability of engines	Not retained by Truck Co. (the trucks belong to customers)
	Risks faced by the company	Higher	Lower
	Nature of the service delivery system	Global	National, based on the existing dealer network

Findings from Aerospace Co.

Planning/Design Phase

In *Aerospace Co.*, the IoT technology was the foundation of a service concept that was focused on minimizing downtime of the engines through collecting real-time data in flight. This required a shift in the business model from “sale of product” to “provision of power by the hour”. In other words, the customers paid to use the engine rather than to own it. As *Aerospace Co.* was responsible for ensuring the availability of the engine, they were compelled to equip themselves to resolve the technical issues related to the offering as well. The nature of the service concept required closer relationships with customers. Hence, customer contact centres needed to be established, particularly in strategic operational locations that allowed the company to be highly responsive to customer requests. Lastly, customers were based across the world, so responding to their service needs required a global reach. The global scope of the service delivery network necessitated the acquisition or building of partnerships with local service workshops.

Execution/Implementation Phase

In the beginning, shifting to a service-based business model was a risky initiative for *Aerospace Co.* An extensive global service delivery system was required and they needed to continuously monitor a complex technology—aero engines. The engines were high-value items, but servicing them was of lower-value and involved many risks (some known and some unanticipated). For example, regarding the service delivery system, *Aerospace Co.* realized that they needed to introduce a new customer contact centre in Singapore soon after the launch of the offering, in order to overcome operational delays related to time zone differences. Initially, they also could not predict when and how often the engines would fail. This made the financial viability and market success of the service less certain. So, although the company had a lot of resources for system development, it was not known exactly in what time scale to accommodate the risks as they emerged. Thus, it was only when *Aerospace Co.* signed up enough customers and the service system worked smoothly and reached maturity that they had a better understanding of the costs and risks of providing the service. They were then able to price it correctly. This shift to a service-based business model provided a more stable and secure revenue stream compared to the traditional product-based “time and material” model, ultimately accounting for a major share of the company’s total revenue.

As an essential element of the customer interface, technically skilled field service engineers gathered first-hand insights from the field, acting as mediators and relationship-builders. In this way, *Aerospace Co.* could improve its service offering based on regular feedback. The company also recruited staff from the customers (airlines) to better anticipate and address servicing needs. This shows the significance of buying-in and gaining experience based on the operation of the IoT system as a key strategy in order to be successful in service design and implementation. Edgerton (2008) also highlighted this issue by arguing that in the aerospace industry, engine maintenance schemes, programmes, and costs are not programmable in advance, so maintaining them more efficiently is learned by experience. The summary of findings from *Aerospace Co.* is presented in Table 2.

Findings from Truck Co.

Planning/Design Phase

Truck Co. designed a lower-margin service that was based on providing the data collected from the trucks to the customers for more efficient management of their fleets. Therefore, it was relatively simple compared to the service provided by *Aerospace Co.*, entailing much fewer risks. The costs of the risks were lower as well. However, although it was a simpler offering, the company did not constrain the resources needed in the planning/design phase of the service concept and was able to develop an IoT system that could produce three times as many reports as other similar systems in the market. The monitoring systems were successfully installed on the new generation trucks, but the company did not anticipate that they would generate technical queries during use. Hence, they did not plan how, and from whom the customers could get technical support. The IoT service was developed with an appropriate technology partner. The partner company had experience in resolving technical queries related to these systems, but their involvement in the customer interface was

Table 2. Summary of findings from Aerospace Co..

Aerospace Co.	*Planning/Design Phase*	*Execution/Implementation Phase*
Service concept	IoT technology enabled the design and development of an advanced service offering that aimed to minimize downtime of the engine.	The service concept was optimized through learning and experience.
Customer interface	Closer relationships with customers were required. Customer contact centres needed to be established in strategic operational locations.	Successfully implemented. A customer contact centre was opened in an opposite time zone (Singapore), to overcome operational delays. Skilled field service engineers gathered first-hand insights from the field. Staff were recruited from the customers (airlines).
Service delivery system	Global. Because engines belonged to customers located in different parts of the world, service delivery required global responsiveness.	Successfully implemented. The company built partnerships with regional organizations and acquired service workshops around the world.

limited. The scope of the service delivery network was national and the existing dealer network was used to sell the service. A total of 29 dealers were involved, but they had limited knowledge and experience regarding how the system could be fixed when problems occurred. The company should have developed a technical support help line to help dealers resolve these problems, but as they assumed that the existing dealer network would be adequate, they did not take action in this direction. For *Truck Co.*, this corresponded to a failure in service concept design.

Execution/Implementation Phase

Truck Co. faced significant challenges in the execution/implementation phase. Firstly, they launched their IoT service concept but there were several unanticipated problems, such as customers not willing to pay the high price for the service (it was twice the price of competing systems in the market). This was an indication of the service concept failure. Secondly, the company did not take some of the necessary actions that would help them better comprehend customer preferences, like establishing appropriate customer contact points. In fact, *Truck Co.* assumed that the dealers would continue to provide their customer facing role and they would not have any difficulty when the new IoT system was up and running. They did not anticipate what kind of queries and issues would arise with the IoT system when it was in operation, and therefore did not provide the dealers with the right information to handle these queries. Lastly, the company did not develop an in-depth understanding of what the implications of this new service would be. For example, they did not recognize that the new system would require more customer interaction and that customers would have more diverse service needs related to the technology and its operation on the trucks. The existing service delivery system was not sufficient to address these needs.

The findings from *Truck Co.* show that training is a key aspect of successful implementation of an IoT service concept. The existing dealer network was not equipped to meet the new servicing needs and the company failed to put in place the appropriate training activities and materials, which resulted in failure during implementation. Table 3 presents the summary of findings from *Truck Co.*.

The Antecedents of Successful IoT Service and System Design

Building on the analysis of the two cases, six antecedents of successful IoT system design were identified: “communicating a well-articulated system design strategy”, “redefining the roles and responsibilities of the frontline personnel”, “training and recruiting service aware staff”, “providing guidance to customers on system use”, “aligning customer focus across the business”, and “utilizing methods/techniques for systems thinking and creativity”. In the following sections, all of these antecedents are discussed in detail, with representative quotes. Table 4 presents the summary of key findings from the companies.

Communicating a Well-Articulated System Design Strategy

The first major discrepancy between the two cases was related to the communication with their partner companies in order to clarify design strategies and operational responsibilities. According to Charnley, Lemon, and Evans (2011), forming appropriate partnerships in system design projects brings significant advantages such as “the access to multiple perspectives and expertise, the opportunity to identify linkages between components of a design solution, and the opportunity for improved innovation” (p. 164). A well-articulated system design strategy means creating a shared understanding of IoT system concepts, goals, and requirements within different project teams. In this way, potential conflicts that may arise from vague task descriptions can be reduced and a better offering can be provided to the customers. For instance, in *Aerospace Co.*, operational roles related to the IoT system were jointly discussed by partners and an integrated design approach that covered the business, supply chain, and programme management aspects of a project was employed. As noted by the quote below, the company utilized the data collected through the IoT technology to build synergy between product, service, and information components of the design process, to overcome internal resistance regarding the implementation of the system, and to explain the actions necessary for successful service delivery.

Table 3. Summary of findings from Truck Co..

Truck Co.	*Planning/Design Phase*	*Execution/Implementation Phase*
Service concept	The data collected from the trucks through the IoT technology were provided to the customers for more efficient management of their fleets.	The cost of providing the IoT service was too high for the customers to pay, resulting in failure of the offering in the market.
Customer interface	The company installed the monitoring systems on the trucks but they did not anticipate that the systems would generate technical queries. Customers could not find the right people who could help them with their technical problems. Limited involvement of the partner company.	Not successfully implemented. The company assumed that the existing customer contact points at dealers would be sufficient to deliver the service.
Service delivery system	National. Existing dealer network (29 dealers) was used to sell the new IoT system.	Not successfully implemented. The dealers were not familiarized with the service offering beforehand. They were unable to process customer issues due to a lack of training.

Table 4. Antecedents of successful IoT service and system design in the cases studied.

Antecedents of successful IoT service and system design	*Aerospace Co.'s on-wing care system*	*Truck Co.'s fleet management system*
Communicating a well-articulated system design strategy	Significant effort was put into creating a shared understanding of system goals and requirements.	A shared understanding of the new system's requirements and implications could not be created.
Redefining the roles and responsibilities of the frontline personnel	Design capability was expanded to field service representatives who were provided with advanced technology, clear action plans were developed.	Role definitions of frontline employees were unclear and they lacked experience in dealing with problems related to the offering.
Training and recruiting service aware staff	People who could deal with the customer interface were recruited.	Customer support was unsatisfactory due to frontline employees' lack of knowledge about the offering.
Providing guidance to customers on system use	Customers (airlines) were provided guidance on more effective flying techniques, informative materials were designed about how the IoT system worked.	Customers were expected to be proactive about entering the system and getting the analysis results they needed, no additional informative material was provided.
Aligning customer focus across the business	Synergy among different teams was achieved through active discussion and communication with regular meetings and online forums.	Customer focus was limited to design and development teams, it could not be extended to the delivery teams.
Utilizing methods/techniques for systems thinking and creativity	An "innovation portal" where customers can contribute to idea generation through narratives was set up, "innovation facilitation workshops" were organized, and a formalized systems design methodology was used.	No empirical evidence was found about the utilization of methods/techniques such as stakeholder mapping and narratives.

> You have to have that language that you can talk to the engineers and they understand why you want to make that change. If they spend a lot of time designing, why would you want to change it? You have to be very robust and have a lot of data to justify why you're asking for that change. (Aerospace Co., Senior Vice President & Director)

By contrast, *Truck Co.* experienced difficulties in communicating the expected outcomes and value of the IoT system to the actors in the business network. During the early stages of the system design process, it is essential to include different stakeholders' opinions and knowledge on the offering to understand operational requirements and the roles expected from each actor in the implementation and delivery phases. In *Truck Co.*, a coherent and explicit system design strategy that can unify diverse actors around a common goal was lacking. Thus, project requirements could not be addressed in all respects.

Redefining the Roles and Responsibilities of the Frontline Personnel

The second main difference between the two companies was related to the roles and responsibilities of the frontline employees. Kindström, Kowalkowski, and Alejandro (2015) have identified two distinct new roles in manufacturing firms moving towards system-orientation: solver of customers' problems and deliverer of brand value to the customer. In *Aerospace Co.*, the firm's design capabilities were extended to field service representatives who played a critical role in IoT service delivery and had direct customer contact. The field service representatives then worked with the back office to constantly reengineer the offering and to reassess where they wanted to take it in the future. This was an outcome of the company's changed view of the role of customer-facing units:

> Back in the day our field representatives were almost like the grubby end of the operation, they were the guys in oil who were out there, looking after the engine and they were almost out of sight, and we said 'Well, that's completely wrong. These are the guys who've got the real insights. They are the people who are touching the customer every single day of the year, and also have a huge knowledge of the products and how we can improve them.' So we spun it around. (Aerospace Co., Capability Lead for Field Services)

On the contrary, in *Truck Co.*, frontline employees who were responsible for sales and delivery were not involved in the development process of the offering and their technical knowledge about the IoT service was limited. It was also challenging for them to balance their traditional product-oriented roles with the new service-oriented roles. Therefore, when customers had problems with their device and needed support, they had to contact the partner company, as they were unable to get sufficient help from *Truck Co.* employees. That caused a significant delay in responding to customer problems. According to the business development manager of *Truck Co.*, the main reason for this problem was the vague role definitions in the terms of agreement with the partner company:

> When there are unclear operational issues with your partner company, this directly influences the service you provide. There should not be any vague statements in the terms of agreement about 'who does what' in service implementation and delivery. (Truck Co., Business Development Supervisor)

As a consequence, although *Truck Co.*'s technology partnership was appropriate for achieving the design requirements, customers could not get assistance at first hand, which had a negative impact on their overall experience.

Training and Recruiting Service Aware Staff

Ulaga and Loveland (2014) stated that the ability to engage deeply with customers' operations, the ability to deal with the "fuzzy front-end" of service specifications, and the ability to develop strong networking skills for managing multiple stakeholders are some of the key proficiencies of sales employees. *Aerospace Co.* was aware that selling an IoT system was different from selling a product and therefore aimed to find and recruit the right personnel who could deal with the customer interface, talk to the customers on a daily basis, and gain feedback for system design reviews. Hence, they recruited staff from the customers (airlines), meaning that they bought in experience of the service in operation. Furthermore, a group of specialist field system engineers was backed up by a team of fully trained and equipped expert technicians, who were ready 24/7 to fly with their specialist equipment wherever a problem occurred, fix the aircraft and get it back online. The knowledge and expertise of the on-wing care staff maximized engine availability and minimized reaction time, costs, and potential impact to customer fleet schedules.

On the other hand, in *Truck Co*., the existing frontline staff were unable to meet their role expectations due to a lack of experience, and this was coupled with limited training activities. Additionally, although the company dedicated a considerable amount of time and resources in the design and development phase of the IoT system, the knowledge accumulated during those phases was not used to create tangible materials that would guide employees in the sales and delivery phase. For example, it was found that customer purchasing preferences were not as expected. *Truck Co.* was selling the offering as a complete package, including the IoT device and the mobile service with an annual contract. However, a majority of customers preferred to buy the service from any operator they chose, making monthly payments. These kinds of unanticipated problems hindered the quality of the customer experience as the employees were not informed beforehand about possible solutions.

Providing Guidance to Customers on System Use

The fourth difference between the two projects was guiding customers on system use. A product-oriented perspective views customers mainly as passive recipients of the value created and provided by organizations. However, in the case of IoT systems, customers take a more active role as they can measure their own data at a specific moment in time and create personalized overviews of the measured data (Valencia et al., 2015). Due to the continuously evolving and interactive nature of IoT systems, it is significant for managers and designers who are responsible for setting the system requirements to activate the knowledge and experience of different customers, making them count (Holmlid et al., 2017). Furthermore, IoT systems have an open-ended aspect—customers can interact with them and use the provided data in the way they desire. Thus, it is advisable to transform the data into graphs, diagrams and other pictorial representations that customers can understand easily (Valencia et al., 2015). In the case of the fleet management system, customers were expected to make sense of their data on their own, without any specific assistance from *Truck Co.* The role of the company was therefore limited to "selling the system", although a wide range of services could be developed around helping customers design their driver training activities. However, in *Aerospace Co.*, guidance from expert advisors and the use of visual materials helped customers better understand the boundaries of the system and increased their ability to interpret the information provided by it. For example, besides relying on the collected engine performance data, an operations advisor from the company worked with the customers (airlines) and exchanged information with pilots about more efficient flying techniques. The scope and duration of these activities were planned thoroughly, since the major aim was to enhance customer skills for more effective system use:

> We look at the whole customer community and we are conscious of the fact that they have different agendas and different priorities. We are hopefully influencing and helping them. Not by simply telling them what to do, but by guiding them to make good decisions, considering the whole system. (Aerospace Co., Senior Vice President & Director)

Aligning Customer Focus Across the Business

The comparative analysis showed that the two cases differed in terms of aligning customer focus. Provision of IoT systems increases the complexity of business operations and requires manufacturers to pay more attention to internal integration for ensuring customer centricity at different organizational levels. Zhang, Zhao, Voss, and Zhu (2016) stated that internal integration enables manufacturers to develop an integrated interface to work with customers. In the first case, *Aerospace Co.* had a specific group of engineers involved in the design process. Although they came from an engineering background, they also had experience in servicing, so that they could bridge both the product and service side of the IoT system. Furthermore, regular cross-functional meetings were held to exchange information and to make joint decisions. Lastly, the company built a corporate system for bringing and aligning all parts of the business to the same standard:

> What has become more prominent is the interface with the customer […] There is a fully integrated group of people that do different jobs but they are all part of the customer experience. (Aerospace Co., Senior Vice President & Director)

By comparison, *Truck Co.* was unable to extend the customer-centric approach that was followed by its design and development teams to the service delivery teams. Formal procedures for internal integration that facilitate the interplay and collaboration across various functional boundaries were scant. Secondly, the company described itself as a "manufacturer of trucks", rather than a provider of integrated systems and solutions. This product-oriented company culture impeded their customer relationship-building activities. Still, the firm was able to observe the current trends in its sector and planned to change the ways they interacted with their customers in the long term to provide a more responsive system:

> In our industry (automotive), IoT systems and related services are becoming more prevalent. We cannot ignore this trend. We will certainly need to take action in this respect, mainly by strengthening our customer communication channels and collecting customer feedback in the field. (Truck Co., Business Development Specialist)

Utilizing Methods/Techniques for Systems Thinking and Creativity

The last major difference between the two IoT system design projects was the utilization of methods/techniques for systems thinking and creativity. *Aerospace Co.* developed an integrated approach to control the business and technical aspects of the IoT system design process. With this structure, the company aimed to ensure that they looked at the system and the emerging behaviour as a whole, not as an entity consisting of separate component parts. It also ensured that the focus was on managing and reducing risks, identifying and sharing best practice, and standardizing the technical and business review process. Some other benefits of this integrated approach were better performance, defined ownership of responsibilities, identification of gaps and priorities, and a constructive relationship between stakeholders. In parallel with this framework, the company also introduced a formalized systems methodology, which predominantly covered the preliminary and full concept definition stages of the design process. This was aimed at doing more work upfront to better understand customer requirements so that they could design a better IoT service and system. The innovation manager of *Aerospace Co.* explained the process as follows:

> Systems design methodologies that I mentioned a couple of times is really key. They are about the discipline of requirements management and the elicitation of customer requirements. We often find that our customers come to us with a specific challenge or problem, and they may well have a preconceived idea or solution. But by taking a systems design approach, we try and look at what it is they want to do, or what it is they want to achieve as opposed to just what it is they want. (Aerospace Co., Innovation Manager)

Key design tools that the company used as part of this methodology included stakeholder mapping, process diagrams, and functional means analysis. The methods used in the development process were supported by an "innovation portal", in which the questions that were challenging the business were raised. This open portal encouraged people from different positions and departments to share their ideas for solutions. Anyone in the business—on some occasions the customers as well—could contribute their answers in the form of narratives, and were incentivized and rewarded for doing so. The utilization of narrative-based methods brought several advantages. As Çelikoğlu, Öğüt, and Krippendorff (2017) suggested, designers can make use of narratives to develop an understanding about situations that evoke positive emotions and to find out about expectations of and possible responses to innovation. The established innovation culture also facilitated creative idea generation processes. For example, the company organized "innovation facilitation workshops" and increasingly involved people who were trained in innovation facilitation both within the business and within specific innovation catalyst teams. In short, *Aerospace Co.* aimed to bring people with different perspectives together by creating an environment conducive to problem solving, idea generation, and innovation so that they could incubate new ideas and become more responsive to new trends in the market.

On the contrary, *Truck Co.*'s project managers stated that they needed to "gather more in-depth feedback from the field and their customers". Their market research activities were limited to attending industry fairs, analyzing competitors' actions, and gathering information from global websites and online portals. No empirical evidence was found regarding the company's utilization of methods/techniques such as stakeholder mapping or narratives in the design process. Thus, they could not gain detailed information on customer preferences, purchase patterns, and negative experiences that caused resistance to the purchase and use of the system.

Discussion and Conclusion

This study aimed to investigate the antecedents of IoT service and system design success in the manufacturing industry context. IoT implementations from two leading manufacturers were investigated as cases. The first case was an aero engine fitted with sensors to enable condition monitoring and maintenance scheduling, provided as a service to airline customers. The second case was a truck condition monitoring service provided to companies for efficient fleet management. Firstly, the main research findings derived from the cases were presented in accordance with three themes from the service design literature: service concept, customer interface, and service delivery system. These three themes were used to analyze the cases during the phases of "service planning/design" and "service execution/ implementation". In each phase, the operational actions and facilities that were required by the IoT services and the extent to which the companies could address them were investigated. Lastly, the insights from this analysis were used to identify and articulate six antecedents for successful IoT service and system design.

The main results from the two cases showed that in the context of manufacturing, successful IoT implementations require more than solid product design; they also necessitate well-executed service and system design. Secondly, the shift from products to services calls for a reassessment of what needs to be designed. Companies that focus too much on designing technology features might miss the conditions by which they can succeed in service implementation and delivery. Thus, besides developing and embedding the right technology into their products, manufacturers should also establish appropriate customer contact points, put in place extensive training activities, and design informative materials to meet the new customer service needs. Another finding is that if manufacturers do not develop an understanding based on experience of operation of the service offering, they are less likely to anticipate and address the various service needs that would arise. In any case, it is very difficult for manufacturing firms to anticipate beforehand what the implications of an IoT service would be. Therefore, they either need to build or buy in experience of the service in operation (for example, in the aero engine case, the company recruited service personnel from its customers).

The shift to continuous delivery IoT services also involves many risks, including unanticipated risks, making the financial viability more uncertain. Even if companies allocate a lot of resources and funding to their service business, there may still be issues that they do not anticipate as necessary in the planning/design phase but that become necessary when the service is in operation—in the execution/implementation phase. For instance, the truck case did not anticipate the need for additional customer contact points or dealer training materials, which impaired the quality of the customer experience. Hence, it is critical for manufacturing companies to be responsive to the risks and challenges as they emerge during service operation. To increase responsiveness and to achieve success in IoT service and system development, six antecedents need to be taken into consideration. The first antecedent, communicating a well-articulated system design strategy, refers to articulating the boundaries, parameters, limits, and value of the offering to the actors in the service delivery network. Furthermore, it necessitates the creation of a common understanding of service and system design among the different teams involved in the offering development. The second antecedent, redefining the roles and responsibilities of field service representatives and sales employees, means that clear action plans for the design process need to be developed and joint initiatives should be built with partner organizations. Otherwise, conflicts are likely to occur when responding to customer requests. The third antecedent is training and recruiting service aware staff. Existing frontline employees are required to develop additional skills to communicate the value of the IoT system to the customers. Manufacturers thus need to recruit people who can deal with ambiguity, manage the customer interface, and take responsibility to improve interactions in the service business ecosystem.

The fourth antecedent, guiding customers on system use, helps customers understand which activities they need to perform in order to achieve their business targets, make more informed decisions, and feel motivated to continue using the system. Aligning customer focus across the business is the fifth antecedent, calling attention to customer centricity at different organizational levels. Managers of IoT system development projects should facilitate dialogue and frequent knowledge exchange among cross-functional teams. They should also prioritize relationship-building activities and put proactive effort into building knowledge of customer purchase and use patterns. The last antecedent, utilizing methods/techniques for systems thinking and creativity, emphasizes the use of visual resources and design tools, such as process diagrams or stakeholder mapping, to communicate and clarify staff responsibilities. Additionally, narrative based methods and approaches are helpful in addressing the behavioural and experiential aspects of IoT systems. The usage of these methods and techniques reduces role uncertainty among employees, enhances coordination and collaboration between different organizations and processes, and increases the understanding of customers' operations.

Consequently, the findings of this study provide practical insights for manufacturers that are aiming to pursue growth opportunities through service and system development. Advanced technologies like the IoT are significant tools for manufacturing firms to design new and improved service offerings. By shifting from products to continuous delivery services, manufacturers are able to build longer term customer relationships in contrast to short-term transactional relationships and gain competitive advantage in their market by locking out competitors. In order to take full advantage of these opportunities, companies should place emphasis on learning from and adjusting to the service in operation; they should improve their responsiveness to customers; clarify role descriptions; facilitate knowledge-enriched relationships with their partners and customers; and also put mechanisms for internal integration into effect. These are critical for successful IoT system design and implementation.

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