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Service Chain Logistics Management for Increasing Equipment Uptime

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Abstract

Currently, as Industrial Product Service Systems (IPS^2) concepts are becoming increasingly adopted by capital assets suppliers, further increase of equipment uptimes is increasingly gaining attention by academics and practitioners. Uptimes can be managed by both improving the maintenance decision making as well as considering appropriate service supply chain design decisions. Furthermore, the integration of Industry 4.0 tools can further boost the previous with its communication and connectivity ability. Knowledge on these aspects is available in academia as well as in practice, but, as this paper argues, not structured for making decisions that consider all of these aspects in an integrated way aiming at improving equipment uptime. Through literature review, we assess the existing literature on IPS^2. In doing so this paper offers a two-fold contribution: On the one hand, it presents an exploratory literature review to identify knowledge gap and on the other hand, it proposes a suitable future research project.

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Keywords: Industrial Product Service Systems; Industry 4.0; Service Chain Management; Downtime; Maintenance

1. Introduction

The manufacturing industry for stand-alone products and services is increasingly becoming competitive with unpredictable demands, shorter lead times and higher service levels. This market pressure is forcing production companies to seek for other approaches for enhancing competitiveness. One of these approaches proposed in literature is the integration of services into products already during the early design phases of the product life cycle, in order to provide specific customer value and sustain relationships over the whole use product life cycle. In academia, this approach in business-to-business (B2B) is called industrial products service systems (IPS2) also known as product service systems (PSS) in business-to-consumer (B2C). Various reasons have emerged why firms transit to industrial products services. In their study [1] argues that IPS2 helps develops superior customer value, and long term business success for the supplier. Others have argued that by increasing service shares of their product dominant offering, manufactures from all types of industries try to tackle decreasing product sales and avoid threat of imitation [2, 3]. There is evidence that by enriching their product dominant offerings to IPS2, manufacturing firms take the opportunity to enhance their financial performance [4-6].

The organizational challenge with the design and delivery of this business strategy lies with keeping the guarantee for high equipment uptime or availability throughout the product life cycle [7-11].

Based on professional contacts with industrial partners in several industries and companies, examples of these are, systems providers in the semi-conductor industry, systems providers at airports, providers of systems used in the medical industry and providers of processing systems for supermarket chains and distribution centers. We got the idea that downtimes are very large and lead times for after sales services are longer than expected in most cases, thus causing problems to these companies', most of these companies that were contacted are active in the business to business sector. Stemming from this

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initial clue, a research project was initiated to embark on an explorative literature review to find out the extent to which literature is addressing this issue and with what depth and breath. Thus, this paper should be considered as research clarification.

Downtimes can be managed by both improving the maintenance of the spare parts as well as considering appropriate service supply chain design decision. Furthermore, industry 4.0 capabilities can boost the previous by enhancing communication and integration between systems.

The goal of the paper is to find out how literature is addressing the issue of downtimes, and Stemming from this, a future research question is proposed. The rest of this paper is structured as follows; section two outlines the methodology, section three presents results of the literature review and section 4 present the discussion and future research direction and finally the conclusion will be discussed in section 5.

2. Methodology

This section present an exploratory literature review to find out whether or not literature is addressing this issue with sufficient depth. The method that was used to analyze the different literature streams is literature review. We mostly focused on publications in well-known journals, conference papers and some books. Thus, we searched in the following high quality peer-reviewed academic outlets, International Journal of Advanced Manufacturing Technology, Procedia CIRP, Journal of Engineering Manufacture, International Journal of Production Economics, International Journal of Production Research, Journal of Operations Management, and European Journal of Operational Research. To perform the search, Google Scholar, Web of Science, were used to access the aforementioned set of literature outlets.

We performed a key words search in the titles and abstract of these articles to search key words like, Industrial Product Service Systems, downtimes, industry 4.0, Service Chains Logistics. The key words were arranged in key words search algorithms and this brought a total of one thousands articles for the last 10 years. We manually looked at the abstracts of the most recent of these articles and excluded articles that were not focusing on; downtimes, articles that were not dealing with industrial product service systems. Finally, we ended up with the articles presented in section 3.

3. Results From the Literature Review

This section takes a look into the literature to find out the extent to which current literature is addressing downtime of industrial product service systems. To do so, section 3.1 begins by first discussing the causes of downtimes and why decreasing downtimes in industrial product service systems is crucial. Section 3.2 presents the design and delivery strategies of IPS2. Afterwards, section 3.3 discusses the development of the concept of industry 4.0 and finally section 3.4 presents literature analysis on how unscheduled downtimes is currently addressed.

3.1. Causes of downtime

Systems downtimes starts when there is a failure during the operational time and ends when the machine starts running again. Different causes have been attributed to downtime in the literature. Lack of timely or incomplete support, such as spare parts as well as the operating environment is a source of downtime which in turn can cause losses [12]. A report by [13]argues that downtime can be caused by failures of parts. Other researchers have argued that downtime is caused by the design of the equipment e.g. see [14, 15]. Some other studies argue that maintenance and service logistics are key activities that influences systems downtimes and reliability [16]. Two performance measurements related to downtimes in industrial equipment are logistics delay and repair time [15, 17]. Logistics delay can be best addressed by design of service logistics and maintenance concepts. Meanwhile, repair time can be influenced by early design decisions of the equipment [14, 15] and logistics service design as well. Increasing the uptime of industrial product service systems can also be influenced by exploiting the capabilities of the tools in industry 4.0 [18, 19]. Some of these capabilities include connectivity of devices, e.g. sensors, communication e.g. cyber physical systems, internet of things (IoT) as well as the data analytics using big data techniques. A study by [20] argues that downtime can result in (1) lost revenue (e.g. standstill of machines in a production environment), customer dissatisfaction and possible associated claims (e.g. airlines and public transportation), (2) public safety hazard (e.g. military settings and power plants). Some IPS2 such as capital goods are high value equipment, downtimes and the related costs are significant [15, 21]. The figure 1 is an overview of unscheduled downtime in capital goods.

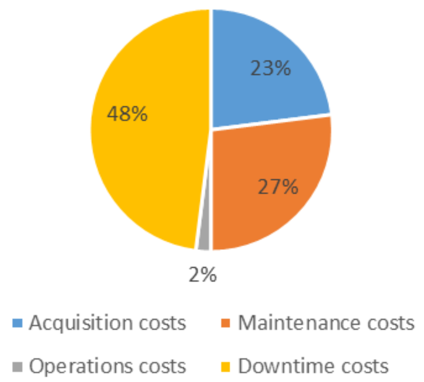

Fig.1. Down time cost in Capital assets adapted from [21].

3.2 Industrial product service systems

The paradigm shift from the sales of stand-alone products to integrated product service offerings is challenging. One of such challenge is to how to design the product and the required service in an optimal way to prevent issues like downtimes in the use phase of the product life cycle. Different design and delivery strategies have been used to describe IPS2. These are; product oriented, use oriented and performance oriented [12].

1. Use oriented: customer only pays for the product usage and does not own the product
2. Performance oriented: is when the customer only pays for

the equipment performance,

3. Product oriented: provider sells the product, but guarantees to sustain the system at a certain level of readiness.

In model 2 and 3 mentioned above, product availability is crucial as in some capital assets, because these type of IPS2 are subject to high requirement of productivity [11]. Therefore, further reduction of unscheduled downtimes especially has received immense importance in this industry, this is also because the value of the item is high and the economic impact of failures during the used life cycle phase is severe e.g. failures of conveyor belt at a large international airport, failure of a train service at a busy train station. This value driven business model of IPS2 requires that the relationship between the buyer and the supplier is enhanced by effective communication. This is because effective communication provides feedback that can be used by the provider to quickly address maintenance issues and improve equipment uptimes. The capabilities of industry 4.0 tools with their communication and connectivity abilities can improve spare parts inventory planning and control thereby decreasing logistics delay time and improving maintenance decisions.

Because the relation between IPS2 provider and industrial customer changes from transaction-based relation to a relation based over the whole life cycle, the provider is challenged to ensure the performance most valued by the customer according to chosen design and delivery strategy is sustained, otherwise long term relationships will be hindered. Research have shown that the delivery of IPS2 is a cumbersome process, the manufacturer cannot entirely provide all required resources for its delivery [22]. In (IPS2), the issues stated above can be addressed from different perspective;

1. The perspective of the IPS2 provider (manufacturer of the system).
2. The perspective of service provider (in case service provision is outsourced to third party).
3. The perspective of the customer (the buyer or the user of the equipment).
4. The perspective of the module supplier.
5. Perspective of the society.

These perspectives basically concerns the research on the interest, roles and responsibilities of the stakeholders in enhancing performance of the asset. For instance the manufacturer, service providers, customer, spare parts supplier perspective is when these stakeholders are directly responsible to provide services to their customer, thus seeking for new ways to improve equipment performance for mostly economic reasons. The society perspective is focusses on making sure there is sustainable equipment performance so as to decrease environmental impact as a results of equipment use. The contribution of [23] has clarified this perspective.

At the used equipment life cycle, the delivery of industrial product service systems go through a network of organizations or stakeholders that includes; service providers, IPS2 provider, spare parts suppliers, the industrial customer, and the module supplier. Given the many stakeholders involved for the design and delivery of IPS2, communication between them is an issue [11]. For instance communication between the customer and the IPS2 provider can improve equipment performance. This is because effective communication provides information that can be used by the provider to quickly address maintenance issues and improve equipment uptimes. Furthermore, communication between spare parts suppliers, service providers and module suppliers can decrease lead time for the deployment of resources used during maintenance activities. Finally communication with the government can ensure that the provider is always aware of the ecological threshold requirement. The capabilities of industry 4.0 tools with their communication and connectivity abilities can promote quick exchange of information between suppliers and customers and the establishment of new ways of cooperation and collaboration of buyer and supplier relationships, characterized by interaction over a long time covering the product life cycle.

Therefore the effective and efficient design of logistics system should include appropriate network design elements, management of relationships, coordination and control. For instance information about the network design can be used to improve maintenance planning and delivery as well as the overall performance of the product service system [24].

3.3 Technological tools of industry 4.0

This section outlines the technological development in manufacturing and the opportunities that can be exploited in enhancing industrial product service performance. According to [25], Industry 4.0 is the integration of internet of things (IoT) and relevant physical technologies, including analytics, additive manufacturing, robotics, HPC, artificial intelligence and cognitive technologies, advanced materials, and augmented realities that complete the physical-to-digital-to-physical cycle. The rise of industry 4.0 has a remarkable influence on the manufacturing industry in terms of value creation [26].

Since the beginning of industrialization, over the years technological leaps of production and automation have led to the so-called "industrial revolution". The first of these revolutions was supported by steam and water power, the second by electrical power and then digitalization and finally the fourth is based on advanced digitalization combining internet technologies and future oriented technologies in the field of "smart" objects i.e. machines and products [27]. It was first introduced in Germany as a proposal for its economic policy development based on high-tech strategies [28]. The pivotal aspect of the fourth industrial revolution is cyber-physical-cycle, internet of things and internet of service [27]. The communication via internet bridges the cyber-physical-cycle by allowing continuous interaction and exchange of information between humans, humans and machines, and between machines [29]. This cyber-physical interaction will generate big data that is capable of uncovering significant value in areas like product and market development, operational efficiency, market demand prediction, decision making and customer experience and loyalty [30]. This high value data can be used to predict for instance demand for spare parts and planning of maintenance activities, and this can increase equipment uptime.

3.4 Literature analysis and findings

Current contributions of downtime reduction in the literature of industrial product service systems using industry 4.0 tools and key technologies lacks depth and breadth. For instance a recent study by [31] present a multi-criteria resource planning method and tool for optimizing planning design, production, delivery and installation of industrial product service systems using software-as-a-service web oriented application. Similarly the work of [32] present a collaborative platform that supports customers and engineers to configure and design the product services as a result of life cycle performance monitoring that include; quality, environmental impact and energy. In their paper [9] proposed a framework for remote diagnossis that addresses both internal and supply chain disturbances for improving the robustness of industrial products service business models. The rsearch conducted by [8] addressed the issue of heterogrnous data resulting from partner network and knowladge based management. Their concept provide contribution to improve maintenance repair and overhaul (MRO) in both customers and service partners sites, in order to decrease unscheduled downtimes. In their study [10] provide a proactive maintenance approach in use oriented business model that is capable of improving machine availability and enhance organisational competitiveness. The framework proposed by [9] offers an important contribution for increasing the internal and external robusteness of manufacturing systems. Their work outlines how to identify the allocation of task, activities and responsibilities in industrial product service systems. The study by [33] proposed a cyber physical systems framework for a fleet of machines capable of predicting machine health using big data for improving maintenance scheduling aimed at downtime reduction. The study of Mulder focused on integrating maintenance in the early design phase of equipment life cycle, to improve efficiency and effectiveness of industrial products. In his work, [14] made a significant contribution on how developers in the high tech market can be supported in addressing maintenance aspects successfully in production systems. Furthermore, Mulder recommended the extension of industrial product service systems literature to other relevant fields such as supply chains (service chains) and production systems development. This can be extremely useful, especially combining it with Industry 4.0 phenomenon. In his study [34] describe the acquisition of serviceable assets in the context of railway industry from service provider perspective. His work was focused on how maintenance can be addressed in acquisition projects, thus presenting a different view from Mulder. The study by [24] investigate how to intergrate knowladge from different stakeholders in the maintenance and service planning process. Their study proposed a collaborative content management system to connect different stakeholderds and intergrate their knowledge in the maintainace planning process.

3.5. Concluding Remarks

Literature analysis depicts that knowledge is already available in academia for increasing uptimes in IPS2. However, this body of knowladge is still in its infancy as it is not currently addressing how to adequately combine service chains logistics, maintenance and industry 4.0 with sufficient depth to support service chains management design decisions of industrial product service systems focusing increasing equipment uptimes. Downtime cost in industrial product service systems are significant. Ignoring this issue in IPS2 can affect long term relationship between the industrial buyer and the industrial customer, and this can affect long term profitability in a negative way. It could be impacted by service logistics design decisions; such as resource planning and control of inventory, maintenance, the choice and integration of industry 4.0 tools. Based on this, future research proposed should provide address how technological tools of industry 4.0 can be used to enhance the service logistics design decisions in combination with maintenance to improve uptimes of IPS2.

4. Discussion And Direction for Future Research

The goal of this study was to find out the extend to which literature is adresing donwtime issue and to identify a future research project. In this vein, we applied literature review methodology to synthesise theoretical contributions on downtimes issues in IPS2. Unscheduled downtime is a significant issue that affects industrial equipment and industrial product service systems as well. The main causes of unscheduled downtime from literature studies are equipment design, the availability of resources used to perform maintenance activities. Furthermore, many have argued that Industry 4.0 technologies and tools has been found to have an impact on modern supply chains and manufacturing efficiency [26, 31, 33, 35, 36] and this can decrease downtimes. However, to fully exploit these tools, the relationship between maintenance, service supply chain and industry 4.0 need to be completely understood. The IPS2 provider perspective for addressing this issue is dorminant.

It is evident after this literature analysis that the three main aspects i.e. industrial product service systems, maintenance and industry 4.0 have not been studied simultaneously, broadly and with sufficient depth to tackle the issue of downtimes in industrial product service systems during the use equipment life cycle phase. Some of the current approaches for increasing the uptimes and the performance of industrial product service systems have mostly concentrated on addressing maintenance in the early design phase of the equipment life cycle from the manufacturers perspective e. g see Mulder [16]. Other studies have focussed on addressing maintenance during acquisition projects [34]. Other studies mainly address the issue of downtimes from industry 4.0 and maintenance perspective [24, 31, 33]. Even though the framework of [8, 9] provide a good contribution in this subject matter by focussing on maintenance and service chains, the authors still calls for improving the granularity of their work.

The selection and integration of industry 4.0 tools can influence the two key performance indicators; repair time and logistics delay e.g see [15, 17] and this can lead to increase in the uptimes of IPS2. A structured and systematic analysis of the choice and integration of industry 4.0 technologies on key service logistics functions and maintenance, and how supply chains will be influenced by this combination will decrease logistics delay and maintenance repair time.

4.1 Direction for future research

A future project can research the main question, “how can industry 4.0 techniques and tools be used to support the maintenance and supply chain management of spare parts of industrial product service systems aiming at improving uptimes”?

The goal of such a study can help to provide design support to industrial product service managers for the management of service logistics using the tools and technologies of industry 4.0. The tools and technologies of industry 4.0 offers can help to; (1) influence logistics delay and (2) maintenance repair time. Both of these parameters will increase equipment uptime. This research will ultimately improve the management of service logistics activities of industrial product service systems. Figure 2 is a conceptual framework of how such research can be conducted.

A future project in this light will help managers of IPS2 providers to improve communication and planning of activities, this will ultimately decrease lead time to support and improve maintenance decision making. The connectivity and communication, as well as data analytical abilities of industry 4.0 tools, will help to increase equipment uptime of IPS2. This will be achieved by improving quality of design decisions such as maintenance strategy selection and planning, spare parts inventory management. Improving the design decisions will help to improve logistics delay and repair time, and this will improve the management of service chains logistics and maintenance, and the combine effect will increase equipment uptimes.

5. Conclusion

From the presented literature analysis, it is evident that various authors have approached this issue from different perspective. The most dorminant of these is the provider perspective. Some scholars have studied different factors, e.g the influence of equipment design, others have decided to look at industry 4.0 in combination of maintenance. Some others have decided to study service supply chains and industry 4.0. Nevertheless, the literature presented in this paper is not currently combining knowledge simultaneously with sufficient depth and breadth on the previously mentioned aspects to support service chains management design decisions of industrial products service systems. Downtime cost in industrial product service systems are significant. Ignoring this issue in IPS2 can affect the long term relationship between the industrial buyer and the industrial customer and this can affect long term profitability in a negative way. It could be impacted by service logistics design decisions; such as resource planning, maintenance, and the choice and integration of industry 4.0 tools. Based on this, the research proposed in this paper should provide insights on how technological tools of industry 4.0 can be systematically investigated to improve IPS2 uptimes by combing maintenance and service chain logistics knowledge.

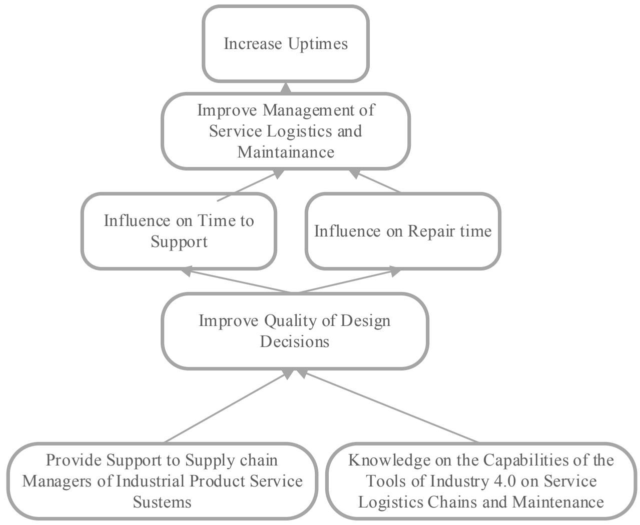

Fig. 2. Conceptual framework and intended research effect.

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