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## From Reactive to Predictive Services: the Internet of Things (IoT) Enabled Product Service Systems (PSS) of Innovative and Sustainable Business Model

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**Keywords:** product service systems, ICT, Internet of Things, business model

**Summary.** This paper aims at exploring the emergence of a new trend towards Product Service Systems (PSS) business model among manufacturing companies which are made available by ICT, with a particular focus on IoT and analytics. While PSS have been already widely researched, the impact of new ICT technologies on the value proposition which a company offers to its clients has been explored less. The Internet of Things (IoT) enabled product-service system provides opportunities to transform old business model based on a product delivery into a new business model which allows for offering new ICT based services usable with a product or even instead of a product. Leading manufacturing companies already today are making higher profits from aftermarket service. IoT sensors, Artificial Intelligence (AI) and pervasive computing can create new business opportunities for PSS solutions by delivering data about product usage and its condition to manufacturers, who as a consequence can then make use of it in order to deliver proactive and preventive maintenance. A case study of Rolls-Royce engine manufacturer is used to analyse the impact of IoT, machine learning and analytics on the company service offering and business strategies.

## **Introduction**

This paper aims at exploring the emergence of a new trend towards Product Service Systems (PSS) of sustainable business model among manufacturing companies enabled by ICT, with a particular focus on IoT and analytics.

During the last few years, we witnessed a growing role of ICT in many industrial sectors. At an estimated \$3.9 trillion dollars, Industry 4.0 is widely recognized as the industry with the most to gain from the Industrial Internet of Things (Relayr, 2017). Industry 4.0 refers to digital transformation in manufacturing and relates to the combination of several major innovations in digital technologies, such as: artificial intelligence, IoT and sensors, cloud computing and big data analytics.

As a result of implementations of digital technologies, we can observe movement of manufacturing companies offering goods and associated services, rather than goods alone. Recently this trend has accelerated and is related not only to products with associated services, but also to a new way of handling the relationship with customers. One can observe a shift from offering value added services to offering customised mix of services where a producer maintains ownership of the product and a customer pays only for the provision of agreed results. The transition towards result-based integrated solutions resulted in the shift of focus, i.e. from the product to the functional result. This means that the client no longer buys a product but the output of the product according to the level of use.

This paper adopts methods of literature review about PSS and the case study analysis of Rolls-Royce company.

The paper is structured as follows. The next section outlines theoretical foundations in the literature on PSS and sustainable business models. Section 3 and 4 depict Internet of Things (IoT) enabled product service system (PSS), as well as describe IoT business opportunities. The following sections present real application of IoT and analytics in the case study of Roll-Royce which has employed new ICT solutions in their PSS.

## **Product Service Systems (PSS) - literature review**

Different types of ‘value added’ product service business can be identified in literature on Product Service Systems. The first formal definition of PSS was given in 1999 (Goedkoop, Van Halen, Te Riele, Rommens, 1999) in the project of Product Service Systems, which was commissioned by the Dutch ministries of environment (VROM) and economic affairs (EZ), i.e. “a Product Service system (PS system, or product service combination) is a marketable set of products and services, jointly capable of fulfilling a client’s need”. In this publication, the authors have presented key success factors of PSS implementation, e.g.:

- a) creating value for clients by adding quality and comfort;
- b) customising offers or delivery of the offer to clients;
- c) creating new functions or making smart or unique combinations of functions;
- d) decreasing threshold of a large initial or total investment sum by sharing, leasing, and hiring;
- e) decreasing environmental load;
- f) increase the quality of contacts with clients.

As soon as the first paper by Goedkoop appeared, the number of articles on PSS grew increasingly (Baines, Lightfoot, Evans, 2007; Mahut, Dababoul, Bricogne, Eynard, 2017).

Manzini and Vezzoli (2003) defined PSS as “an innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client demands”.

Many researchers have presented the concept of Product Service-System (PSS) in relation to sustainability, economy and environment (Brandstotter, Haberl, Knoth, Kopacek, 2003). The above-stated authors were of the opinion that “a PSS consists of tangible products and intangible services, designed and combined so that they are jointly capable of fulfilling specific customer needs. Additionally PSS tries to reach the goals of sustainable development”.

ELIMA (ELIMA, 2005) defined a product service system as a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customer needs, and have a lower environmental impact than traditional business models.

There have also been various attempts to categorize diverse types of PSS arrangements. Most of the classifications proposed in the literature distinguish between three main categories. Below one can find a description of the main categories of PSS (Tukker, Tischner, 2005) that have been generally accepted by researchers in this field.

#### 1. Product-oriented PSS:

- a business model is still mainly geared towards sales of products but some extra services are added.

#### 2. Use-oriented PSS:

- the product does not shift in ownership. The provider has ownership, and is also often responsible for maintenance, repair and control.

#### 3. Result-oriented PSS:

- a provider is in principle completely free as to how to deliver the result,
- three kinds of result-oriented PSS can be distinguished: activity management/outsourcing; pay per service unit; functional result.

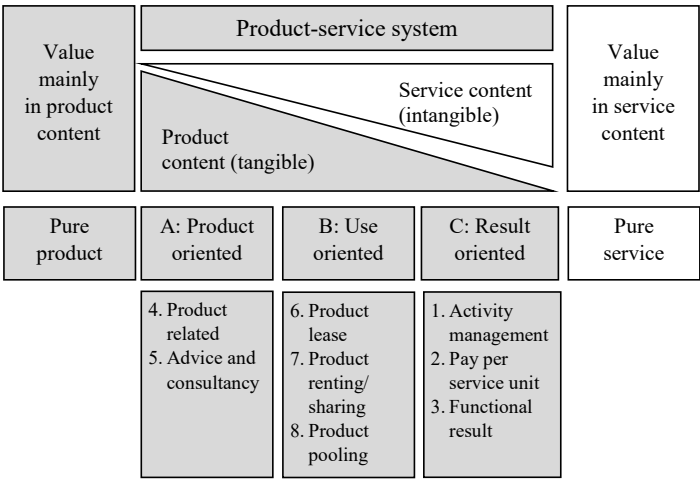


Figure 1. Classification of PSS

Source: Tukker, Tischner, 2005.

PSS in the industrial application have some important implications. In the case of the industry, the product side of the industry is mature, whereas service side is currently increasing. As described by F. Mahut, J. Daaboul, M. Bricogne, B. Eynard (2017), the saturation of historical product sales markets can be considered as a limit to overcome, meanwhile new technologies available enable reaching competitive advantages.

**Internet of Things (IoT) enabled product service system (PSS)**

Growing relevance of the IoT arises from the possibility of tagging, tracking, connecting and analyzing data from various connected objects. In 2020, the number of “things” (IoT/M2M devices) connected to the Internet will be according to various projections 25 billion or 100 billion. IoT implementations are being considered by a wide variety of manufacturing and service sectors. The reason for this arises from the opportunity of IoT to transform an old business model based on product delivery to a new business model which will allow to offer new ICT based services used with the product or instead of the product.

The challenge to address diversity of research on IoT was taken by IEEE IoT initiative. IEEE has published a document “Towards a definition of the Internet of Things” (IoT) where the authors have provided an overview of IoT definitions and the IoT basic architectural models. Authors (Minerva, Biru, Rotondi, 2015) pointed out that it is not easy to find a comprehensive definition of IoT. A definition often depends on a particular vision of the entity that wants to emphasize specific application field of IoT. One of the most relevant definitions of the IoT is:

“Bringing together people, process, data and things to make networked connections more relevant and valuable than before, turning information into actions that create new capabilities, richer experience and unprecedented economic opportunity for business, individuals and countries” (Bradley, 2013).

The description presented above was chosen due to the fact that it represents a point of view of an enterprise and emphasize the benefits of IoT from a business process and economic perspective, which reflect the profit motives as a main driver of IoT adoption.

A series of articles have shown that a design of a product service system is expected to be affected by the fast growing applications of Internet of Things technologies. ICT plays a fundamental role in supporting PSS business model. In this case, new ICT devices and system need to be in place. For example, IoT sensors, AI, pervasive computing can create a new business opportunities for PSS solutions.

Many researchers have explicitly stated that IoT technologies may bring new solutions for existing/hidden problems and inspire new designs. IoT is able to play a crucial role in the implementation of new services by manufacturing companies based on the PSS (Li-Hsing, Yen-Ting, Fenghueih, 2016). Porter and Heppelman (Porter, Heppelmann, 2014) stated that the adoption of digital technologies including sensors may trigger provision of additional services to an integrated product service offer. They pointed out that smart, connected products raise a new set of strategic choices related to the value being created and captured, the utilization and management of prodigious amount of new (and sensitive) data being generated, redefining relationships with traditional business partners such as channels, and the role the companies should play as industry boundaries are expanded.

### **IoT business opportunities**

PSS are supporting the transition from the sale of the product to the sale of use/utilization of the product. Reshaping business model is possible due to implementation of interconnected and embedded technologies which make remote monitoring, controlling and long standing production possible and profitable.

Ole Kjeldsen from Microsoft (Kjeldsen, 2017), pointed out that “the Internet of Things isn’t a technology revolution (...) IoT is a business revolution, enabled by technology”. Microsoft believes that there will be:

- a) more than 21 billion connected “things” by 2020;
- b) market for IoT by 2020 – USD 1,3 trillion;
- c) 70% of value enabled by IoT which will come from B2B scenarios;
- d) USD 1,5 million as an average increase in operating income for digitally transformed enterprises;
- e) 10% of data on earth coming from IoT by 2020;
- f) USD 10 billion market for business process automation tools by 2020.

The main driver for IoT implementation in B2B context is to improve existing business operations and to create new product/offers and business model, such as moving from reactive to predictive maintenance and service – with the Internet of Things; possibility of asset, capacity, production sharing or data insight monetization and outcome based business model.

### **Business case for PSSs: Rolls-Royce**

Rolls-Royce Limited was established in 1906 as a British luxury car and aero engine manufacturing business. Since then, the company has undergone many changes in their business design, from selling cars, jet engines and services for the civil, defence aerospace, marine and energy market to selling flying hours instead of jet engines. Their business customers have to pay a fixed charge per hour of engine operation.

The first step from selling pure product towards selling product oriented and use oriented PSS was the introduction of the ‘Power-by-the-Hour’ services for turbojet engines in 1962 (Rolls-Royce, 2012). Rolls-Royce then extended their offer for the airlines that use its turbojet engines by a complete engine and accessory replacement service offered on a fixed-cost-per-flying-hour basis. The implication of this offer was that airlines only paid for engines that performed well.

In 1990s, Rolls-Royce needed to change its business and service strategy due to a fact that their business model did not generate sufficient cash flows to justify massive R&D investments. As a result a ‘TotalCare’ offer was introduced in the mid-1990s in the civil aviation sector. Until the introduction of a ‘TotalCare’, the maintenance, repair and overhaul of its engine were not a dominant activity. In 1991 services represented only 25% of the company’s total revenue. Under a ‘TotalCare’ contract, Rolls-Royce undertook to provide the operator with a fixed engine maintenance cost over an extended period of time. In general TotalCare program consists of a menu of engine fixing and add-on services. The core elements are service integration, engine health monitoring and comprehensive engine overhaul, plus engine reliability improvements and Rolls-Royce initiated specialist maintenance. Add-on services include technical records management, engine transportation, spare engine support, additional overhaul coverage and the option for the customer to initiate specialist line maintenance (Ryals, 2010).

The core of the movement to more service-oriented business model was to better align the support network by capture and use of data in order to make the whole process more intelligent and efficient. Therefore, main transformation of the core of the company’s business model was possible due to the adoption of new ICT technologies. Due to the creation of some additional data handling capabilities, Rolls-Royce could enhance its engine health monitoring with the intention

of eradicating unscheduled repair or maintenance events. The evolution of Rolls-Royce services is presented in Figure 2.

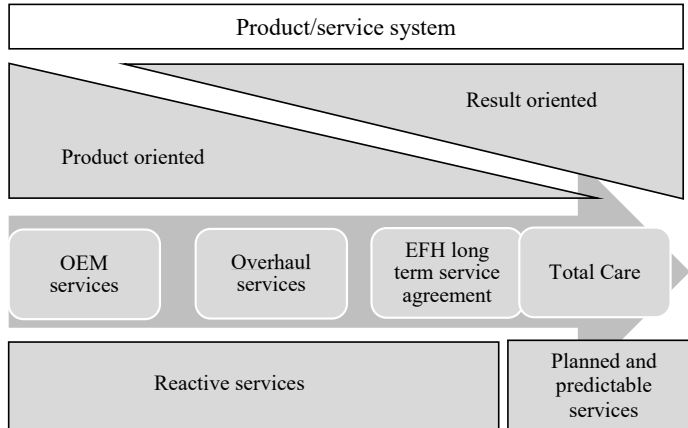


Figure 2. Evolution of Rolls-Royce services

Source: own elaboration based on Morris, 2014.

Every year, 60 million kB of engine health data is generated within TotalCare program which covered 23 million flying hours flown by 12,500 engines in 2010 (Ryals, 2010).

Even though this model was very successful, the company has recognized an important opportunity to expand its services by using IoT, machine learning and analytics. Since July 2016, Rolls-Royce has been using Microsoft Azure IoT Suite (cloud computing platform) and Cortana Intelligence Suite (data analytics package) to enhance their business offering. Company claims that the IoT will become an important part of the Rolls-Royce TotalCare programme which is based on earning revenue when aircrafts fly, rather than when engines are serviced. Microsoft will provide Azure IoT Hub service to connect to devices in the real world and gather data along with storage and analytics services. Cortana Analytics is a suite of fully managed Business Intelligence (BI), Big Data, and Advanced Analytics service offerings from Microsoft in the Azure Cloud. Cortana Intelligence will allow to process data from a variety of data sources, transform data, apply advanced analytical techniques (Data Mining, Machine Learning, etc.), and extract actionable insights which enable business to take intelligent and timely actions (Microsoft, 2017). The key pillars of Cortana Intelligence Suite offerings are: Information Management; Big Data Stores; Machine Learning and Analytics; Dashboards and Visualizations and advanced intelligence services. Cortana Intelligence Suite fits very well in Rolls-Royce business activities. Rolls-Royce has more than 13,000

engines for commercial aircrafts in service around the world (Rolls-Royce, 2017). By using a new ICT platform, Rolls Royce will be able to constantly monitor the engines and collect the data over time, which as a consequence will allow while accurately detecting operational anomalies and scheduling the maintenance accordingly to prevent potential downturns.

New ICT technologies have enabled Rolls-Royce to offer new services. Having the machine-generated data, Rolls-Royce is well positioned to provide predictive maintenance (replacing underperforming components), and value the service competitively. With the IoT, information on engine health, air traffic control, route restrictions and fuel use can be collected from hundreds of sensors inside the engines, and analysed to detect any operational anomalies or signs of developing faults.

The ongoing change in customer value propositions, such as “charging for engine use per hour” is an example of outcome-based value propositions in the form of Anything-as-a-Service (AaaS). AaaS proposals are very attractive for customers because risks are pushed upstream towards the suppliers of equipment and the need for non-core investments is minimized (Koychev, 2015). IoT enables a shift in this industry where outcomes can now be measured via sensors embedded in engine. In this case, we can see a general move towards higher utilization of equipment, and the use of predictive maintenance.

Rolls-Royce annual reports contain a detailed description of business, including the operations, performance and financial condition of the company. Annual reports can give the reader a lot of important information about a company transformation towards more service oriented PSS. In 2001, 40% of Rolls-Royce revenue came from service and aftermarket activities (Rolls-Royce, Annual report, 2001). From 1991 to 2006 we can notice increasing contribution from services revenue. Since 2006, Rolls-Royce services revenues account for over 50% of total revenue (Rolls-Royce, 2007).

Table 1

Service revenue as a per cent of total revenue

Rolls-Royce	1991	2001	2006	2012	2016
Service revenue (%)	25	40	53	52	52

Source: Rolls-Royce Annual reports, 1992, 2006–2007, 2012, 2016.

Rolls-Royce has also developed a new category of engine service and support aimed at the specific needs of aircraft lessors called LessorCare. In 2014, under TotalCare programme, leased aircraft accounted for over 1.7 m flying hours and over 800 m miles flown, which means that lessors constitute 16% of Rolls-Royce customers. In February 2016, lessors accounted for a third of its customers



and Rolls-Royce expects them to increase the importance to 50% in the future (Aftermarket revolution, 2016). Therefore, Rolls-Royce unveiled Lessor-Focused Aftermarket Services in January 2017 (Rolls-Royce, LessorCare, 2017).

## Conclusion

PSS creates long term relationship among manufacturing companies and their clients. PSS is not a standardized business model, but a new way to provide tailored solutions for specific needs and problems. In the future we can expect that more product manufacturers will move towards more service oriented business models. This change of the strategies is a result of introduction of new ICT technologies i.e.: IoT and AI, which make this transformation possible and we therefore can observe a move from services on schedule towards services on demand.

This paper has highlighted new ICT developments as significant factors for reshaping business strategies. Rolls-Royce case can clearly demonstrate the move of manufacturing company towards the company offering goods and associated services rather than goods alone. IoT sensors, AI, pervasive computing have allowed to create long term relationship between Rolls-Royce and their business customers. The relationship will not be one time model as in the case of selling any kind of tangible product where the ownership is transferred. The transition towards long term service agreements has caused a paradigm shift in the business model for this company.

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**Od usług reaktywnych po usługi predykcyjne:  
innowacyjny i zrównoważony model biznesowy  
systemów produktowo-usługowych wspieranych przez IoT**

**Słowa kluczowe:** systemy produktowo-usługowe, ICT (technologie koordynacyjno-informacyjne), Internet rzeczy, model biznesowy

**Streszczenie.** Celem artykułu jest zbadanie pojawienia się nowego trendu w kierunku modelu biznesowego Systemów Produktowo-Uslugowych (PSS – Product Service Systems) wspieranych przez ICT, wśród firm produkcyjnych, ze szczególnym naciskiem na Internet Rzeczy i analitykę. Chociaż PSS są już szeroko badane, wpływ nowych technologii ICT na propozycję wartości, jaką firma oferuje swoim klientom, jest mniej rozpoznany. System produktowo-usługowy wspierany przez Internet rzeczy (IoT – Internet of Things) umożliwia przekształcenie starego modelu biznesowego opartego na dostarczaniu produktu na nowy model biznesowy, który umożliwia oferowanie nowych usług bazując na technologiach informacyjno-komunikacyjnych, które można wykorzystać przy produkcji lub nawet zamiast produktu. Wiodące firmy produkcyjne już teraz osiągają większe zyski z obsługi posprzedażnej. Czujniki IoT, sztuczna inteligencja (AI), wszechobecne komputery mogą stworzyć nowe możliwości biznesowe dla rozwiązań PSS przez dostarczanie danych o użytkowaniu produktu i jego kondycji producentom, którzy mogą następnie wykorzystać dane do konserwacji zapobiegawczej i proaktywnej. Studium przypadku producenta silników Rolls-Royce’a użyto do analizy wpływu Internetu rzeczy, uczenia maszynowego i analityki na ofertę usług firmy oraz strategię biznesowe.

### Citation

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