Remote monitoring technology and servitization: exploring the relationship

**Abstract**

Remote Monitoring Technology (RMT) is recognised as one of the key enablers of servitization. While servitization has been the subject of intense research for years, the role of RMT therein has been less explored. This paper aims to contribute to this important topic by addressing the following research questions: what are the benefits of RMT and how do they support servitization? An exploratory multiple-case study of four manufacturing companies, operating in aerospace, industrial equipment, marine, and transportation sector, was conducted. The research makes three contributions. Firstly, it is the first systematic study of the benefits of RMT and their role in servitization. Secondly, it recognises the centrality of the RMT challenge for the relationship between RMT and servitization. Finally, it explores the implications of the RMT challenge for this relationship. Three implications have been identified, which suggest a novel perspective on the nature of RMT, RMT-enabled services, and their role in servitization.

**Keywords:** Servitization, remote monitoring technology, multiple-case study, benefits

# Introduction

In their seminal paper Vandermerwe and Rada [1] defined servitization as a process of creating value by adding services to products. A commonly commented case of Rolls-Royce is a prototypical example of servitization. The company has moved from selling gas turbines to delivering power-by-the-hour service to its customers, which pay only for the power delivered by the turbine [2]. Other example of servitization is Man Truck and Bus UK. This company provides a service contract known as a pence-per-kilometre [3]. This is based on the realisation that the cost of a truck or bus is less than 10% of its total life cycle cost. A pence-per-kilometre service aims to reduce this cost, for example, by helping customers to save fuel.

To support the servitization process companies are deploying a broad spectrum of information and communication technologies (ICTs). In Man Truck and Bus telematics is a key enabler of servitization [3]. Through telematics they track vehicles, record fuel consumption, and measure driver behaviour. In Rolls-Royce this role is played by engine health management [4]. By deploying sensor-based technologies on turbine blades they trace and track engine performance thus supporting servitization [5]. The importance of technologies such as telematics and engine health management for service provision is immense. Paluch [6] argues that remote services are predicted to become the fastest growing ICT-enabled services within the next years. According to [7] wider adoption of such technologies has the power to reshape the entire manufacturing industry while [8] see these technologies as the key catalyst for the most significant change in manufacturing firms since the second industrial revolution.

While servitization has been the subject of intense research for years, the role of technologies such as telematics and engine health management therein has been less explored. This paper aims to contribute to this important topic. It addresses the following research questions: what are the benefits of Remote Monitoring Technology (RMT) and how do they support servitization? To address the questions we conducted a multiple-case study research. The remainder of the paper is structured as follows. Section 2 presents a review of literature at the intersection between RMT and servitization with specific emphasis on RMT benefits. Section 3 explains the research design while section 4 introduces findings from four case studies on the benefits of RMT and their role in service delivery. Before we conclude, in section 5 we discuss the study’s key contributions while in section 6 we explore their implications for research and practice.

# RMT and servitization: literature review

# Servitization

The key premise behind servitization of manufacturing is provision of solutions to customers by integrating products and services [9]. Through servitization manufacturers benefit from: growth in revenue [10], strengthening provider-customer relationship and greater customer loyalty [11], differentiation and robust market defence to competition [12], and building new revenue streams [13]. However, manufacturers considering servitization should proceed with caution. For example, the servitization paradox, originally put forward by Gebauer et al. [14], states that the increase in revenues from services often leads to reduced profits. The latest research [15] collected evidence that servitization might even increase an organization’s risk of bankruptcy.

Interest in servitization has dramatically increased and has now become an established [16] even mainstream field of study in many disciplines [17]. Kowalkowski et al. [18] found that over 180 scholarly journal articles on this topic are published every year while Rabetino et al. [19] identify 51 literature reviews that have accompanied this progress. The reviews suggest that servitization is not a monolithic field of study but formed by a number of disciplines and fields each bringing their own methods and terminologies. Thus, Lightfoot et al. [12] found that the principal research communities are services marketing, service management, operations management, product-service system (PSS), and service science. The review of servitization literature [19], which encompassed more than 1,000 journal articles, that explores the structure of servitization research, identified three research communities: PSS, the solution business, and service science community. Their key conclusion is that servitization research is a fragmented multidisciplinary domain composed of three sharply bounded communities indicating a theoretically nascent field. This resonates with Brax and Visintin [17] who found that the servitization phenomenon appears fragmented into separate streams and suffering from an abundance of concepts. In relation to the latter, Beuren et al. [11] identify a number of terms used to discuss this phenomenon, including: servitization of the products, PSS, service engineering, service-based businesses, industrial product-service systems, integrated product and service offering, functional products. Although numerous and diverse, these terms often refer to the same thing. In regards to the place of RMT in the wider servitization research, findings by [12] are revealing. Through a thematic analysis of servitization research they identify five key generic research concerns: product-service differentiation, competitive strategy, customer value, customer relationship, and product-service configuration. The concerns show that the role of RMT is overlooked topic. Identical is noticed from the most recent review of servitization research [19] that identifies a number of specific research clusters and streams with no mention of RMT whatsoever. Although recognized by some as an essential enabler of servitization, RMT topic holds a tenuous place in servitization research. This is explained by the unique nature of RMT. Namely, until recently the RMT research was concerned with technology development and was ignorant of its value-creation potential in a business context [20]. On the other hand, servitization research is focused mainly on topics such as customer value and strategy paying little attention to the role of RMT therein.

# RMT: an essential but neglected enabler of servitization

The recent reviews of literature on ICT-enriched products in service delivery [21,22] identify a variety of terminology in use describing this phenomenon. In addition to telematics and engine health management, other terms include: smart technology [2], remote maintenance services [6], intelligent machines [7], remote monitoring technology [21], digitized products [22], smart services [23], remote diagnostics [24], intelligent products [25], prognostics and health management [26], smart products [8,27], and digitalization [28]. Nonetheless the key principle is the same: enriching physical products with digital components [22] that enable real-time monitoring, acquisition, and communication of data about various aspects of products’ performance in service [21]. Here we have followed [21] by using the, more generic, term RMT.

RMT is increasingly being recognised as one of the key enablers of servitization. Oliva and Kallenberg [29] argue that RMT does not add value to customers *per se*; the real value of RMT becomes obvious only when it is used in the context of higher product availability value propositions. Johnstone et al. [30] assert that power-by-the-hour value propositions are too big risk without an on-going real-time product monitoring. Through interviews with 22 manufacturing executives, [31] aimed to identify the key resources and capabilities required to deliver successful servitized offerings. Data on installed base product usage provided by RMT was identified as the key strategic resource and the capacity to process and interpret this data as the key organizational capability. According to [32], technology, particularly engine health management, was a powerful enabling factor facilitating the move of Rolls-Royce, and of the other two main aero engine manufacturers (GE, and Pratt and Whitney), to servitization. Baines and Lightfoot [33] explore the operations that deliver advanced services; defined as outcomes focused on capability delivered through performance of the product. They found as crucial that manufacturers use remote monitoring of product’s location, condition, and use. This resonates with [34] who found that the collection of real-time data is critical for ability to offer advanced services such as outcome-based contracting.

The evidence about the importance of RMT for servitization is in contrast with the level of interest in this topic. For example, [6] reports a gap in the literature on remote services saying that very little, mainly descriptive, research exists that addresses RMT from a management viewpoint. Lerch and Gotsch [7] pointed out that while servitization has been widely discussed, the effect of RMT on servitization has been less well explored. Lenka et al. [28] say that although some servitization studies have recognised the role of digitalization therein, limited insights exist on how digitalization enables manufacturing firms in creating value. Similar is found by [32] who observed that in the literature the move to servitization is normally attributed to economic, demand, and competitive factors, with almost no concern given to the role of technology. This is identical to [34] who noticed that despite the central importance of technology in servitization this relationship has been neglected in the literature. Finally, Ardolino et al. [35] argue that the role of digital technologies in the service transformation of industrial companies has been overlooked by the servitization literature.

Therefore, although being important for servitization, the role of RMT therein has been less explored. This is especially evident in the case of the benefits of RMT and their role in servitization.

# Benefits of RMT and their role in servitization

This section reviews studies that investigate the relationship between RMT and servitization (Table 1). The review was conducted to identify the benefits of RMT and their role in servitization. Namely, understanding the benefits that companies gain from an ICT investment and how these create value for their businesses is the first step of any attempt aiming to shed more light on the relationship between ICT and business. The results from the literature review fall into three groups: (1) benefits for the customer, (2) benefits for the manufacturer or service provider, and (3) the challenge of creating value from RMT-enabled services.

Insert Table 1 here

Benefits for the customer are manifested in: (1a) the minimization of downtime, and (1b) proactively stopping or preventing breakdowns. By using RMT the errors or faults may be remotely detected and activities involved in their resolution prepared for in advance [38]. This results in the minimization of downtime for the customer. Increased reliability [27] is another way in which RMT is found to minimize downtime. In terms of the benefits of proactively stopping or preventing breakdowns Gremyr et al. [39] termed these as “taking responsibility” and “creating security”. According to [23] the benefits of RMT-enabled services for customers involve the removal of unpleasant surprises from their business. This is similar to [24] who found that customers emphasise risk reduction over cost savings.

The review of the literature revealed the following two benefits for the manufacturer or service provider: (2a) insight into customers’ needs, and (2b) cost reduction. In respect to the former, data collected and processed by RMT can be used to learn more about customers and their business [40], which could lead to richer and closer customer relationships [23]. Mainly due to data collected on products in the field, remote services have a great potential to be customized [6], which can create new services and revenue streams [7]. In relation to cost reduction, by gaining more information about the usage of products in the field companies can create more accurate and proactive maintenance plans [34]. By enabling remote detection and diagnosis of problems, RMT reduces the cost of service to the service provider [40]. Because the provider and customer are no longer constrained by the physical distance, services can be produced beyond national boundaries [6] involving no customer contact [24]. This means that the service provider gains direct access to product usage data and avoids receiving potentially erroneous or misleading descriptions from the customer [41].

Finally, the literature recognises the challenge of creating value from RMT-enabled services. In a study of remote maintenance services in the medical equipment industry Paluch [6] found that (p. 647): “...customers are not completely aware of remote service benefits.” Mainly due to intangibility of remote services and inability of the service provider to determine their future benefits, the customers were not fully convinced in their potential. Similar is found in [37] where inability to build value propositions from smart services is recognised as one of the key barriers. One of their interviewees expressed this in the following way (p. 1647) “We are really struggling to develop a value proposition. This technology is just emerging, developing.” Through two case studies [24] found only a few RMT-enabled service contracts that puzzled the case study companies, which invested heavily in the new business. After further investigation they found that sales departments in both companies were confused about the potential benefits of RMT-enabled services for customers; hence they avoided their promotion. This is evocative of the survey of German machine tool manufacturers [38] where it is found that the biggest problem is to convince customers in the benefits of such services. Kowalkowski et al. [34] found that although ICT-enabled services have the potential to enhance both the provider’s as well as customer’s competitiveness, this value can be difficult to realise in practice. This resonates with [42] who surveyed UK manufacturers to investigate the adoption and use of diagnostic and prognostic technology. They found that more than half of adopters have experienced a gap between potential and realized benefits. This is due to an inadequate understanding of all the benefits of diagnostic and prognostic technology and means necessary to translate those benefits into tangible value propositions.

* 1. **Research gaps**

The preceding review found that RMT is an essential enabler of servitization yet the role of RMT therein has received limited attention in servitization research. This is especially evident in the case of the benefits of RMT and their role in servitization. The number of studies in Table 1 may leave an impression that this is an active research topic. However, even a cursory glimpse would suggest that a significant number of studies provide no information on the benefits companies gain from investing in RMT. The situation is somewhat better with the studies that offer some insights into RMT benefits. The problem here is that the insights do not result from any careful investigation into RMT benefits. Instead, they appear to be incidental and secondary products of studies with other aims in mind. Furthermore, the insights are fragmented and diffused across diverse sources offering no coherent account. Finally, the literature recognises the challenge of creating value from RMT-enabled services yet it offers no explanation for this.

The above is translated into the following two research gaps. No study exists that *specifically* investigates RMT benefits and the challenge of converting those into a servitized value proposition. Also, the literature is silent about the *role* of RMT benefits in servitization. On the basis of these gaps this paper explores the following research questions: what are the benefits of RMT and how do they support servitization?

# Research Design

To investigate the benefits of RMT and their role in servitization we adopted an exploratory case study design. A qualitative case study design enables observation of actual practices and provides much needed exploratory depth [45], thus enabling a greater understanding of the nature and complexity of the research phenomenon [45-47]. Yin [47] defines case study research as an empirical inquiry that investigates some contemporary phenomenon in a real-life setting where the boundaries of the phenomenon of interest and environment are not clear. The steps involved in case study research include [47]: (1) selection of case studies, (2) designing a data collection protocol, and (3) case study analysis.

* 1. **Case study companies**

Multiple-case study design has distinct advantages and disadvantages compared to single-case study design. The multiple-case study design increases the external validity, recognised as a significant issue in case study research [47]. Furthermore, theory built from multiple cases is considered more robust and generalizable than that from single-case research [48]. However, conducting a multiple-case study design requires more resources and time. Hence, every case should be selected carefully to serve a specific purpose in the overall research. Due to resource constraints we decided to conduct four case studies. The selected companies (Table 2) are from aerospace, industrial equipment, marine, and transport sectors serving global customers who operate in a variety of industry sectors.

Insert Table 2 here

There are two main reasons for selecting these companies. First, all four case studies are established and globally recognised manufacturing companies with long experience in delivering RMT-enabled services. Three case studies are based in the UK. The fourth (Marine Co.) operates from Norway, serving the oil and gas industry, and Finland, serving the cruise and ferry industry. Transportation Co. serves UK customers only while the other three companies have customers worldwide.

Second, the selected companies provide the diversity of contexts. The nature of their products covers a wide spectrum, from purely mechanical (Equipment Co.), electro-mechanical (Aerospace Co. and Transportation Co.), to electronic (Marine Co.) products. These take different hierarchical positions in their customers’ businesses. For example, Equipment Co. provides RMT-enabled services on bearings (parts or components), Aerospace Co. and Marine Co. on subsystems, and Transportation Co. is a system integrator. Finally, the services offered on these products and the role of RMT therein also varies from case to case. Thus, the most complex services, involving availability guarantees, are by Aerospace Co. and Transportation Co. while the most complex services offered by the other two companies are condition monitoring services (Equipment Co.) and support and remote services (Marine Co.). This diversity of contexts provides a rich source of data on the benefits of RMT and their role in service delivery.

Table 3 details specific RMT systems in use by the case study companies.

Insert Table 3 here

* 1. **Data collection protocol**

A data collection protocol is an instrument that ought to ensure the collection of data necessary to address the research questions. It must identify the subjects to be interviewed, the questions to be asked, and specify any secondary data required. The main source of evidence is qualitative data gathered via semi-structured interviews. These were structured in three sets of questions and used on three different levels: (1) company, (2) operational and (3) service. Each set of interview questions covered three broad areas: (1) general company, (2) product-service offerings, and (3) RMT.

The company level questionnaire is used with a senior person who is responsible for RMT and its business development in the company. The operational level questionnaire is used with persons responsible for key customers or customer segments of the company. The questions here try to capture details about specific product and service combinations offered by the company and the role and contribution of RMT in those offers. The service level questionnaire is used with maintainers, technicians, and service engineers delivering the RMT-enabled services. The intention is to understand their activities, roles, and responsibilities of using the RMT in service delivery on a day to day basis.

In addition to semi-structured interviews a variety of other data was also collected, including, company presentations and reports, commercially available information on RMT and services offered, and personal observations. Multiple sources of data were used to increase the construct validity [47].

* 1. **Case study analysis**

In total, 27 interviews (Table 2) were conducted across the four case studies that involved people with different roles, e.g. general manager, business development manager, contract managers, sales managers, chief engineers, service operations manager, service support engineer, etc.

Each interview, together with observational and secondary data, was transcribed and then coded in software for qualitative data analysis. The coding initially focused on the five categories of: minimization of downtime, proactively preventing breakdowns, insight into customers’ needs, cost reduction, and other. The first four were identified in the literature and served initially as tentative constructs. Specifying a priori constructs is recommended practice when building theories from case study research [49]. The fifth category was intended to capture any other benefits not previously identified. To decide whether to include a benefit we relied on the following criteria: (1) Is the benefit applicable beyond the immediate context? (2) Did multiple participants mention the benefit? (3) Does the benefit provide any interesting and useful conclusions?

An individual case study report was then produced for each company and subsequently verified by them. Cross case analysis was then undertaken. This involved a search for patterns in the benefits and their interconnections. We also employed the relevant literature, the role of which is recognised as essential in this stage of case study research [49]. Theory-building from cases occurs through recursive cycling between the case data, emerging theory, and extant literature [48].

Figure 1 shows the overview of all findings from the cross case study analysis. When referring to a specific RMT system from a particular case study we will use the generic RMT term.

Insert Figure 1 here

# Findings

The presentation of findings follows Figure 1 and is arranged into two sections: (1) Benefits from RMT, and (2) Challenge of determining benefits from RMT.

* 1. Benefits from RMT

The findings on benefits are grouped under three main headings: (1) Mitigation of risks, (2) Efficiency and effectiveness benefits, and (3) Improving knowledge about the performance of product in service.

* + 1. *Mitigation of risks*

The reasons to adopt RMT are driven by a change in strategy that focuses on providing high-value complex services. These are increasingly centred on product performance and availability guarantees. The key benefit of such value propositions is the outsourcing of risks, from customers to service providers, with non-availability of the product and its suboptimal performance as the *primary* risks. Although these benefits result from the new value propositions and not from RMT, the latter is seen as an indispensable enabler.

*“Information provided by the RMT is fundamental for our service delivery process. We cannot operate our availability contracts without this technology.” [Chief of RMT for Civil aerospace, Aerospace Co.]*

For Aerospace Co. and Transportation Co., RMT enabled their new servitized strategy that centres around availability and performance guarantees (BA1 and BT1). Without this technology the risks associated with delivering these value propositions would be too great. Namely, RMT is a key means for averting a potential threat thus averting disruptions to service delivery.

*“The role of RMT is to be aware of the asset’s condition, as much as we can, at any one time. So in terms of a performance guarantee that means that we understand that the equipment is being operated within the specification and the customer is not operating it at for example, 130% of power or whatever, because we would not want to put any guarantees on that.” [Service Operations Manager, Aerospace Co.]*

In addition to reducing the risks of non-availability of the product and its suboptimal performance, RMT is also used to reduce other kinds of risks. For customers of Equipment Co. the main risks include the danger of losing people and health and safety risks (BE1). In the past their customers would invest in the development of the necessary RMT skills in their people and then later lose them as they become more appealing to the market. So the risk of losing skilled people is thus shifted to Equipment Co. This somewhat resonates with the experience of Marine Co. The key business driver for their Oil & Gas customers is to minimize downtime as any disruption in their operations brings a hefty cost (circa $500,000/day) if they cannot pump or transfer oil. Mainly due to frequent crew changes these customers often lack on-board diagnostic expertise in the areas of electronic and electrical products (BM1). This is recognised by Marine Co. as an area where their expertise can bring value; hence this has become the key application domain of their RMT-enabled services. RMT can also improve safety. In the case of Equipment Co. health and safety risks occur in situations where data cannot be collected manually from a machine (e.g. there is guarding around a machine) or this is not allowed by legislation (e.g. in chemical processes).

* + 1. *Efficiency and effectiveness benefits*

RMT has brought a number of benefits that improved the efficiency and effectiveness of services. For example, through advanced planning Aerospace Co. achieved early failure detection and reduced costs (BA2). This came from reducing the time to troubleshoot problems and the time spent on unplanned maintenance work arising from not detecting a problem and mobilising costly activities. The information collected by the RMT also helps to focus maintenance work thus reducing costs and time as well as eliminating interference with properly-functioning equipment. Similar is found in Equipment Co. By promoting condition-based maintenance, RMT reduces cost (BE2) by reducing the amount of preventive and scheduled maintenance activities thus increasing the uptime (BE3), extending the life of a machine, and keeping its functionality and performance in line with requirements. Reduction of preventive and scheduled maintenance also helps in avoiding negative by-products in the form of unwanted induced faults (BE4).

By enabling remote detection and diagnosis of problems, RMT reduces the cost of service to the service provider, which allows customers to reduce operating costs and increase productivity. Transportation Co. benefited from a reduction in the material and labour used for maintenance (BT2). For example, by monitoring trains, Transportation Co. can diagnose faults before they return to the depot which saves them time and labour. This also reduces the amount of unplanned maintenance which is acknowledged as a significant cost and helps Transportation Co. to better plan and schedule maintenance activities. A further benefit is the reduction of in-service costs due to reduced delays and cancellations as well as penalties. RMT has helped to avoid penalties due to non-availability and penalties arising due to in-service failures (BT3). These arise in two principle ways. Firstly, when Transportation Co. does not deliver availability as agreed with the operator. Secondly, when a train fails in-service and brings disruptions to the operator and any other operators on that line, so called ‘delay attribution’. Real-time information about a train and its performance can benefit this process as it can better illuminate what caused the delay and therefore who should be picking up the cost.

Immediate access to vessels and equipment from anywhere in the world have enabled Marine Co. to deliver a faster and more reliable service as they no longer depend on the crew for information about the incident (BM4). This has also improved employee satisfaction as RMT provides them with the necessary information which reduces the frustration of searching for it. But the biggest benefit for Marine Co. came from reduced warranty cost (BM3). RMT brings transparency in fault finding and diagnosis that may prevent unnecessary costs arising from dispatching service engineers. Through RMT Marine Co. can see if a fault was caused by their equipment or by other equipment on the vessel. This prevents them from unnecessarily dispatching engineers to a vessel only to see that the fault was not caused by their equipment. Even if the fault was caused by their equipment, information provided by RMT can help them in preparing better by identifying the right spare parts and tools needed for the job. By giving customers a single access point and communication route to multiple Marine Co. specialists and service engineers, and greater transparency into the condition of the equipment on the vessel, troubleshooting is now done much faster. This reduces downtime (BM2) and with it the loss of profits for customers. Marine Co. reports that 90% of all cases are solved in this way, thus reducing the cost of and the need for service engineers to visit vessels. In a case reported by Marine Co., a customer managed to save the yearly fee for the RMT-enabled services when a problem was resolved remotely.

* + 1. *Improving knowledge about the performance of product in service*

RMT provides companies with real-time data about the performance of their products in service and how customers interact with them. Although highly subjective and open to interpretation, this data can be translated into valuable information, even to knowledge, in a number of ways. For example, the wealth of data collected by RMT can be used when negotiating new contracts (BA4).

*“The business team will use some of the data because under our availability contracts one of the elements how much you pay is how hard you drive the engines. So, we capture the data on how hard the airlines are driving the engines. The customer business team will look at that to find if we owe the customer money for giving the engines an easy ride or does he owe us money for giving it a harder ride.” [Service Operations Manager, Aerospace Co.]*

This data is essential for product improvement (BM5) as well as for new product development.

*“We know an awful lot more now on how the fleet has been operated than we ever used to. We get data on 90 odd % of flights so we can look at what sort of temperatures are running, altitudes, day temperatures the engines are exposed to. So, when engineers are trying to understand how engines are actually used in service when they are designing the next generations of engines, we have got far more and much better data than we ever had before. So, that certainly feeds into a new product design.” [Operations Centre Manager, Aerospace Co.]*

Having a bird’s eye view of products in the field not only has benefits for product design, there are also more immediate benefits for the currently operated fleet. From a control room from which they monitor all their fleets, Transportation Co. was able to gain benefits that arise from having a more holistic or multi-fleet view (BT4). This enables sharing of cross-fleet experience and learning, crucial for improving train designs and reliability (BT1), and for developing better maintenance plans. Aerospace Co. currently monitors and manages about 3,500 engines from their civil aerospace operations centre in the UK. This brings a wealth of data that can be used for various purposes. One is having a better insight into the health of the whole fleet (BA3). This assists in devising necessary measures that will bring improved reliability and availability but it also helps Aerospace Co. fleet managers to determine which engines are best ‘to pull’ and which are best to keep in order to reap benefits of the extended life on wing. There are also benefits of cross-fleet learning as the Aerospace Co. may realise that they have an issue in the fleet of one operator and they can quickly deploy that knowledge to all of their other customers. This benefit was not possible before a centralised data management capability was developed in Aerospace Co. Having this capability helps in developing a knowledge base of symptoms and diagnoses and the actions required to prevent failures. The richness of data also helps in specifying more reliable time-to-failure limits.

Data collected by RMT can also be used to generate insights that may lead to new services and revenue streams. Transportation Co. have devised a way to exploit RMT to reduce energy costs for one of its customers (BT5). Thus, RMT enables several energy saving modes that, for example, allow the operator to switch off some of the lights and engines when the train is idle. This brought benefits to the operator and Transportation Co. The operator benefits from saving fuel and reducing the negative effects of their operations on the environment while Transportation Co. benefits from prolonging the time between engine overhauls.

* 1. Challenge of determining benefits from RMT

This is largely implied in the first two findings. Namely, RMT brings the reduction of costs and incidents of unplanned maintenance ensuing from unwanted faults induced during planned maintenance. Such incidents can seriously disrupt service delivery. The challenge, however, is to determine the benefits that result from preventing such incidents. This challenge is even more clearly expressed in the first finding. That is, RMT promises to avert the product fault or failure that may disrupt the service delivery. The challenge is to determine the benefits that result from preventing or avoiding the fault or failure. More precisely, how to proceed to prove the occurrence of and calculate the benefits from something that never happened? This challenge is very clearly expressed in the following excerpts.

*“One issue is how to calculate the benefits of RMT. That has always been a problem. We are a bit better but we can still do with more help. This is because RMT avoids costs. So how do you prove that cost would have been there had we not had the RMT in place?” [Chief of RMT for Civil aerospace, Aerospace Co.]*

*“We see real benefits in terms of cost savings because by using RMT we avoided a number of cancellations, delays, etc. But how you attribute those to RMT is open to debate.” [Chief of RMT for Civil aerospace, Aerospace Co.]*

 *“Because you can say to someone, ‘this can pick up the failure and then at the end of the year when you sum all the failures you identified, you will have a certain amount of savings.’ But the problem is how to prove it would happen and save them that money, because it never happened. It is all a little bit grey and that is a problem.” [General Manager for Reliability Systems, Equipment Co.]*

Turning this grey area into objective values that both customer and service provider can agree was the key reason for Equipment Co. to stop providing contracts that involve risk and revenue sharing. They found it challenging to make accurate calculations about benefits of RMT, especially because customers considered these to be prone to manipulation. When referring to their RMT-enabled services, some Equipment Co. customers call them a ‘black art’.

The key findings from our case studies are summarised in Table 4.

Insert Table 4 here

# Discussion

In this section we discuss our findings by comparing them with the relevant literature. We identify three areas where our study makes contributions: (1) systematic study of the benefits of RMT, (2) recognition of the centrality of the RMT challenge for understanding the relationship between RMT and servitization, and (3) new perspective on this relationship.

* 1. **Systematic study of benefits of RMT**

Our study has identified three broad groups of benefits that are brought by the adoption of RMT: (1) Mitigation of risks, (2) Efficiency and effectiveness benefits, and (3) Improving knowledge about the performance of product in service. The key benefit of RMT is in enabling new servitized value propositions that centre on the outsourcing of risks. That is, servitization deals with a transfer of risks, from the customer to service provider. In this respect the key benefit of RMT is that it promises to avert a potential risk (of product fault or failure) thus averting disruptions to service delivery. This is in agreement with accounts that recognise RMT’s role in servitization as removing unpleasant surprises [23] and taking responsibility [39].

We have also identified a number of instances in which RMT brings efficiency and effectiveness improvements. Some are congruent with existing studies and include: creation of more accurate and proactive maintenance plans [34] and reduction of time to troubleshoot the problem [40,41]. In addition, we identified that RMT brings reductions in interference with properly functioning equipment, which leads to the reduction in incidents of unwanted induced faults. This further contributes to the key benefit of RMT of averting potential risks. Finally, our study provides additional evidence that views RMT as a vehicle for providing insights into customers’ needs [23]. We make further contributions here by identifying the use of RMT-enabled data in contract negotiation, new product development and improvement, and for further service innovation.

The resonance between the literature and our findings is clear. Our first contribution is systematic investigation of benefits of RMT. With a more complete understanding, we gain a ‘big picture’ of benefits of RMT. This has enabled the identification of the challenge of determining benefits of RMT as central for understanding the relationship between RMT and servitization.

* 1. **The RMT challenge as central for understanding the relationship between RMT and servitization**

One of the key benefits of RMT is in averting the product fault or failure that can disrupt service delivery to customers (Table 4). The finding finds clear support in the literature. For example, Waters [4] says that the primary role of engine health management in Rolls-Royce is to avert a potential threat before it has a chance to develop into a real problem. Ulaga and Reinartz [31] found that the capacity to assess and manage product failure risks is the key strategic capability in the delivery of servitized offerings and data provided by RMT is identified as the primary resource for this. Reim et al. [50] studied operational risks associated with servitization, which they defined as consisting of technical (unexpected product breakdown), behavioural (less careful product treatment from the customer), and delivery competence risks (lack of capability to provide the offer). They found that operational risk reduction in general, and reduction of technical and behavioural risks in particular, is based mainly on establishing ICT to collect data, via sensors and telematics, necessary to monitor delivery of product-service offer.

Therefore, RMT promises to avert a potential risk thus averting service disruptions to customers. The challenge, however, is to prove and to determine the benefits of preventing an event, e.g. a product failure that would have disrupted the service delivery, which never happened. This is reminiscent of the challenge of creating value from RMT-enabled services identified in literature review section. For example, Paluch [6] talks about intangibility of remote services and inability of the service provider to determine their future benefits while Töytäri et al. [37] see the inability to build value propositions from smart services as one of the key barriers. But the resonance between our findings and the literature goes beyond the phenomenon of RMT and servitization. Namely, the challenge finds support in two further empirical facts, that is, the problems of determining: (1) the value of services, in particular their price [51], and (2) the business value from ICT investments [52,53]. Hence, the challenge seems to have much wider empirical support. For this reason we propose that this challenge, which we call the RMT challenge, is central for understanding the relationship between RMT and servitization.

However, servitization research has failed to recognise the importance of and provide an explanation for the challenge. In that respect our study makes two further contributions. The first is the recognition of the centrality of the RMT challenge for understanding the relationship between RMT and servitization. The second is the exploration of its implications for this relationship.

* 1. **New perspective on the relationship between RMT and servitization**

This section explores the implications of the RMT challenge for the relationship between RMT and servitization. The results are summarised in three key implications (Table 4). What seems to be emerging is a new perspective on the nature of RMT, RMT-enabled services, and their role in servitization. We view this as our key contribution. In developing the new perspective we utilised findings from our research and of others in the field investigating this phenomenon.

* + 1. *RMT-enabled services are constituted by diverse interactions*

Our first point argues that RMT is only an element in an intertwined web of other resources that in tandem deliver services. Some of those other resources have been indicated in the findings section and include: skills (4.1.1), product improvement/new product development capabilities (4.1.3), control rooms (4.1.3), maintenance plans (4.1.3), centralised data management capabilities (4.1.3), and knowledge bases (4.1.3). Such a holistic view on RMT also finds support in the literature. For example, in a recent service research priority-setting paper Ostrom et al. [2] say (p. 136): “...shedding the historical narrow view of services and instead considering services part of ecosystems and complex networks opens up exciting new avenues for further research.” This suggests that services should be understood from the perspective of interactions, i.e. a network they are part of. This has a clear empirical support in a finding from a case study of an availability-based contract for defence avionics [54]. The study found that to deliver the contract the interpretation of the availability concept would need to go beyond the narrow technical terms from reliability engineering with which the concept is typically associated. Instead, availability ought to be defined in terms of the wider socio-technical system, involving a number of actors, resources, and activities that delivers it.

The above implies that RMT ought to be perceived as part of a wider service delivery network rather than in isolation. This, however, creates difficulties for determining the direct benefits from RMT, i.e. determining the proportion of servitized value proposition that can be attributed to RMT alone. This could explain the RMT challenge. But viewing RMT-enabled services as outcomes of the interactions of diverse elements is not a complete explanation. Rather, it is only the first step. Namely, if RMT-enabled services are constituted by diverse interactions, then the concept of emergent property becomes central for understanding services in general and for understanding ICT-enabled services in particular.

* + 1. *The benefits from RMT-enabled services are of emergent nature*

The concept is associated with complexity sciences whose central role for service innovation has been revealed by Vargo and Lusch [55]. They presented a review of perspectives on service innovation and found that all the perspectives identified have clear links with the complexity sciences. This was evidenced in concepts of emergent property or emergent structures. Chae [56], who also approaches ICT-enabled services from the lens of complexity sciences, proposes that such services are best understood as structures or properties that emerge from the interaction of diverse elements. This has an empirical support. For example, [54] found that (p. 31) “‘avionics availability’ is not a service output that can be directly attributed to a specific function or an organization; rather, it should be regarded as an emergent property of a PSS.”

To view the benefits of RMT-enabled services as being of an emergent nature would explain some findings from our case studies. An example of realising a new use from the RMT, and consequently novel benefits, from Transportation Co. is particularly revealing here. This company experienced unexpected benefits from RMT (Figure 1). In addition to Transportation Co. several other stakeholders from the UK rail industry experienced benefits from their adoption of RMT. However, these were not identified at the time they were developing the business case. For example, Network Rail, a publicly held UK company, which owns and maintains railways and leases those to train operators, realized that by monitoring trains Transportation Co. can provide them with information necessary to detect some types of infrastructural problems with tracks and power supply.

The idea that benefits from RMT-enabled services are of emergent nature can be explained if we adopt views on technology proposed by [57,58]. According to [57] functionality of technology is not an intrinsic characteristic of the technology itself; technology has no intrinsic functionalities. For example, a CD-ROM can be used to read data or as a coffee cup holder. A technology’s function is dependent on how it relates to other things rather than being fixed from the inside. This is similar to the concept of technology affordance, which is an action potential or what an individual or organization can do with a technology [58]. Such views lead to a realization that the functionality of technology and the benefits that ensue from its use are not properties of technology but properties of interactions the technology is but only one element (5.3.1).

Understanding the benefits of RMT as being of an emergent nature suggests that the full benefits of RMT investment can only be determined relative to the functionality the investment is expected to deliver. Since RMT does not possess any innate functionality and the latter emerges through the user-technology-context interaction, we cannot know all the benefits before this functionality arises. The benefits should rather be understood as outcomes of a process that captures the evolution of user-technology-context interaction. As shown next, this interaction has been changing since the early days of RMT and is expected to change even more so in the next several years.

* + 1. *Evolving nature of RMT-enabled services*

Since RMT-enabled services are formed by the interactions of diverse elements (5.3.1) and their benefits emerge from those interactions (5.3.2), and since elements constituting those interactions are *continually* changing (e.g. users, customer needs, contexts of use, etc.), then there is *no such thing* as finished RMT-enabled service, only an evolving one. This view finds support in our findings. All four companies had RMT, or at least key elements of it, before they seriously embarked on deploying that expertise to support servitization (Table 3). For example, in Aerospace Co. a lot of RMT currently in use was originally driven through separate and independent developments in jet engine control systems. The company first improved the technologies of controlling the engine and once these were developed they have then been co-opted to support service provision. Hence, RMT had existed in Aerospace Co. long before they decided to venture into servitization. Similar is found in Marine Co. A lot of hardware and software which underpin their RMT were originally developed for propulsion and drive control systems. They then realised that this could be applied to support their new services.

The preceding finds a clear support in the literature. Smith [32] found that engine health management capabilities by Rolls-Royce have been made possible by the development of engine control system (FADEC) in the 1990s. Although it may appear to be a relatively recent development, RMT is at least four decades old. Küssel et al. [38] report how US machine tool manufacturer Kearney and Trecker, in the mid-1970s, designed a data-transmission system to reduce travelling costs of its service department.

Yoo et al. [58] argue that organizational theories, which have assumed that technology is fixed and immutable, must now consider the possibility that the technology is dynamically changing, thus triggering consequent changes in organizational functioning. This is in agreement with our case studies which show that RMT use changed several times in the past; the most recent being to support servitization. Moreover, we may now be witnesses of the next wave of evolution of RMT-enabled services. Porter and Heppelmann [27] say that smart, connected products are transforming competition and have a potential to expand the boundaries of an industry. For example, should manufacturers of home lighting consider integration of their products with those of other home systems (entertainment and climate control systems) and create value propositions that would meet more complete needs of its customers? By pointing to potentially new RMT-enabled services these questions also point to the next stage in the evolution of RMT use.

RMT does not have any innate functionality. The functionality is motivated by a particular need and purpose, which in turn are being shaped and conditioned by an ever changing context. Without knowing what the RMT will be used for we will not be able to determine the exact benefits from its use. The RMT’s general lack of functionality may even be seen as a catalyst, which, paradoxically, enables it to evolve, thus serving as an engine for further service innovation.

## Implications for research and practice

## Implications for research

By presenting a detailed account of RMT benefits and their role in servitization this study makes some advances in our understanding of this relationship. However, several areas are identified where further research is needed. More research is required to validate and further enrich the findings on benefits of RMT with those from other companies; preferably operating in other industry sectors. There is also a need to quantify the RMT benefits. In that respect, our research may be seen as providing a map necessary for more detailed quantitative exploration. Furthermore, we propose that the key benefit of RMT is its ability to avert a potential risk that may disrupt service delivery. This, however, faces companies with a challenge of determining benefits from preventing an event that never happened. Further research is needed to establish the prevalence of RMT challenge.

The challenge has implications for the field of product-service system engineering. This field suggests that a product-service offer must be planned and designed in advance [10-12]. By demonstrating the complexity of RMT/servitization relationship our study seems to challenge such ideas. Namely, the three implications derived from an investigation of RMT challenge make certain propositions. The first states that RMT is only an element in an intertwined web of other resources; hence RMT-enabled service ought to be understood as being formed and constituted by those interactions. The second implication states that RMT does not have a functionality due to which the benefits that ensue from its use are not properties of RMT but properties of the network the technology is only one element. That is, benefits of RMT-enabled services are emerging from the interactions and are systemic properties rather than innate features of the technology. The third implication states that because all elements constituting this network are constantly changing, it follows that there is no such thing as finished RMT-enabled service, only an evolving one. The three implications create a challenge for determining the benefits of RMT-enabled service and consequently for the idea that product-service offer can be planned and designed in advance. More research is needed to investigate this.

The three implications offer a new perspective on RMT, RMT-enabled services, and their role in servitization. The perspective suggests a novel interpretation of the servitization paradox [14]. It recognises an intertwined, uncertain, emergent, and evolving nature of RMT-enabled services. These features promise to offer an explanation for the problem of determining the value of services, in particular their price [51]. As such they may provide a useful lens for exploring the servitization paradox. Further research is needed to investigate the usefulness of the new perspective for this.

## Implications for practice

It is argued that the most significant challenge facing researchers and practitioners of servitization is how to transform a manufacturing organization [13]. Our study sheds more light on the complexity of this transformation. Of particular interest to practitioners may be our finding on the challenge of determining benefits from RMT. It implies that the key benefit of RMT, averting disruption to service delivery, is hard to determine and is largely unknown. What is known, however, is that without RMT the servitized strategy would not work or its risks would be too great. A possible way to mitigate those risks would be to acknowledge the new perspective on the RMT proposed here. This creates a challenge for the management of RMT. And since RMT is one of the key enablers of servitization this also creates a challenge for the ways of managing servitization process, which is widely seen as a linear and planned process [59].

# Conclusion

RMT is increasingly being recognised as one of the key enablers of servitization. Yet the servitization research makes only casual mention to the use of RMT to support the servitization process. This is especially evident in the case of the benefits of RMT and their role in servitization, which is identified as prerequisite for developing an understanding of the relationship. The literature has also identified the challenge of creating value from RMT-enabled services yet it offers no explanation for this. These limitations motivated the following research questions: what are the benefits of RMT and how do they support servitization? In attempting to address these questions the paper has made three contributions. Firstly, it has identified three broad groups of benefits of RMT: (1) Mitigation of risks, (2) Efficiency and effectiveness benefits, and (3) Improving knowledge about the performance of product in service. This makes our research the first systematic study of benefits of RMT and their role in servitization. This was instrumental in deriving the other two contributions. The second contribution is drawing our attention to the RMT challenge. The challenge is to prove and to determine the benefits of preventing an event, which would have disrupted the service delivery that never happened. By drawing our attention to the centrality of the RMT challenge for understanding the relationship between RMT and servitization the study adds further value. The final contribution is the exploration of the implications of RMT challenge for this relationship. As a result we provide an explanation for the challenge of creating value from RMT-enabled services encountered in the literature. Three implications have been identified, which suggest a new perspective on RMT, RMT-enabled services, and their role in servitization. We view this as our key contribution.

Several areas are identified where further research is needed. More research is required to validate and quantify the benefits of RMT. Further research is needed to establish the prevalence of the RMT challenge in other companies and industry sectors. The three implications seem to challenge the idea that product-service offer can be planned and designed in advance. They may even offer a novel interpretation of the servitization paradox. Further research is needed to investigate both topics.

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