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IFAC-PapersOnLine 49-28 (2016) 138–143

Value-in-use of e-maintenance in service provision: survey analysis and future research agenda

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Abstract: Servitisation strategies entail many benefits to manufacturing industry. In this context, e-maintenance can bring support to new industrial services by enhancing the effectiveness of service delivery processes, thus, improving the ultimate benefits obtained by service provision. This article presents a study on the value-in-use that different technological innovations can offer to maintenance service provision. The final results of a survey capturing experts' knowledge into a method for value analysis are discussed and eventually a future research agenda is suggested to investigate further how the use of e-maintenance technologies can potentiate the value-in-use of industrial service provision.

Keywords: E-maintenance, maintenance technology, value-in-use, value creation, value analysis, servitisation, maintenance services, manufacturing digitization.

1. INTRODUCTION

The global trend of servitisation in manufacturing industry has stimulated a more or less stabilized 30% of manufacturing companies to offer services within their customer offerings (Neely, 2008; Neely et al., 2011). Companies embracing servitisation strategies seek to unify their offerings of products and services into bundled Product Service Systems (PSS) offerings. These PSS offerings can integrate services at the point of sale, related to product use or product life extension, or revalorising the product at the end-of-life (Montt, 2002). PSS will include a product plus a selection of different services to be added to the offering. The final goal is to provide customer support in order to ensure the trouble-free use of the product along its life cycle (Goffin and New, 2001) while manufacturing companies obtain benefits related to higher growth, profit and technological innovation (Dachs et al., 2014).

There are many benefits derived from servitisation strategies in manufacturing. On the one hand, the knowledge on product use and customer contexts will serve manufacturers to technologically improve and innovate their products and offerings. On the other hand, the use of technologies within the PSS offering can improve the delivery of the service, and the benefits obtained by both customer and service provider. These advantages are clear and well discussed – many contributions in literature has focused in answering "why" –, the interest is nowadays shifting on the way – "what and how" – servitisation can be effectively and efficiently deployed. The present paper focuses on this matter and, in particular, on the adoption of ICT and digital resources for the deployment of new services in manufacturing.

Indeed, ICT and digital resources are employed by servitised manufacturers in the delivery of their services (Baines and Lightfoot, 2014; Schroeder and Kotlarsky, 2015). There are different types of technologies that could be used in different PSS offerings in order to enhance customer support during the use of the product. According to Grubic (2014), technologies that provide real-time information from the field can mitigate the risks that manufacturers undertake in certain PSS offerings. Another example is the use of predictive tools to interpret product data as an enabler of product-related services such as condition-based maintenance, provided as an add-on service to product acquisition, or as part of result-oriented PSS in which manufacturers take responsibility on maintenance activities in order to comply with certain availability agreements. Overall, the implementation of e-maintenance technologies could then support the servitised offerings, through ensuring service performance and quality during the whole product life (Iung, 2003).

The increased focus on services has shifted the concept of value associated to customer offerings in manufacturing companies. This new perspective is not based anymore on the value-in-exchange, i.e. exchange of goods and money, but rather on the value-in-use, i.e. the perceived benefits of the service from the customer viewpoint (Vargo et al., 2008; Vargo and Lusch, 2008). Conversely, the understanding of value-in-use is still in its early stages of research, thus, focusing great attention in research communities (Ostrom et al., 2010; Lightfoot et al., 2013). Therefore, customers evaluate industrial services in terms of the benefits offered / gained rather than their solely price. This brings new challenges to industrial PSS offerings; "*the nature of value and its role in the delivery of equipment-based services*" (Smith et al., 2012).

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.11.024

The authors have previously investigated the concept of value for decision making in manufacturing technologies acquisitions (Macchi et al., 2012, Macchi et al., 2014). This article is a further development of an exploratory research on the value-in-use in service provision, added by maintenance technologies (Holgado and Macchi, 2014; Holgado, 2014). In fact, it provides a complete set of results taken from a survey analysis, also suggesting a future research agenda in order to envision how value-in-use could be enhanced by potentiating the use of maintenance technologies. Concretely, this article aims at providing some evidence to answer the following research question: *What is the value-in-use of e-maintenance tools and applications in service provision?*

The article is structured as follows. The next section provides the background, including a list of e-maintenance tools and applications identified, the method for value analysis and the value dimensions used in this research. Subsequently, the main results are presented and discussed in sections 3 and 4. Moreover, Section 4 introduces a suggested research agenda. The article ends with brief concluding remarks.

2. BACKGROUND

2.1 E-maintenance Tools and Applications

Dachs et al. (2014) empirically found a positive relationship between innovation in products and processes and servitisation strategies. This may be partly due to their potential capability to enable new services. Indeed, e-maintenance has been defined as "*maintenance support which includes the resources, services and management necessary to enable proactive decision process execution*" (Muller et al., 2008) and it is seen as a means for supporting customers anywhere and anytime (Lee, 2001).

The following is a non-exhaustive list of 10 categories of e-maintenance tools and applications that either alone or combined can provide new functionalities, thus, enabling new maintenance related service offerings: Smart devices & sensors, e-CMMS, Inspection tools, Diagnosis tools, Prognosis tools, Cloud-based tools, Simulations tools, Location & tracking tools, Augmented reality (AR) tools. Table 1 presents a summary of the key functionalities that each category is envisaged to enable. A more extended review and description of the different categories and their functionalities can be found in Holgado and Macchi (2014).

Table 1. Functionalities provided by the e-maintenance tools and applications (adapted from Holgado and Macchi, 2014)

Category	Functionalities	References
Smart devices	Support operator in the field and take remote action from anywhere	Crespo Marquez and Iung, 2008; Iung et al., 2009
Smart sensors	Identify and report any malfunction of system or equipment. Remote configuration and calibration	Zhang et al., 2004
e-CMMS	Fast and flexible scheduling; monitor and manage preventive maintenance activities	Iung et al., 2009
Inspection tools	Detect equipment or system failures and indicate equipment or system under-performance	Kumar et al., 2009
Diagnosis tools	On-line fault diagnosis, isolation and root cause identification	Jardine et al., 2006; Crespo Marquez and Iung, 2008
Prognosis tools	Estimate the remaining useful life (RUL) of system, equipment or components, based on current condition and projected usage	Jardine et al., 2006; Crespo Marquez and Iung, 2008
Cloud-based tools	On-demand network access to a shared pool of information resources	Dillon et al., 2010
Simulation tools	Compare the effects of different maintenance policies and different scenarios for equipment deterioration and failure	Takata et al., 2004; Crespo Marquez et al., 2009
Location and tracking tools	Support operator, component and equipment identification. Storage of conventional data on the machine and traceability of the past maintenance actions. Enable geolocalisation.	Adgar et al., 2007; Iung et al., 2009
AR tools	Support man/machine or man/man exchange of information. Guidance to operators for maintenance intervention execution	Takata et al., 2004; Iung et al., 2009; Espindola et al., 2013

2.2 Method for Value Analysis

The value analysis has been done according to a particular method to evaluate the value added by the above categories of e-maintenance tools and applications to the provision of maintenance services (Holgado, 2014). This method consists of three steps.

The first step defines the dimensions of value to be used. The dimensions have been selected from the available literature and focus on the delivery of the service as a main point of contact between the customer and the service provider. They are the following (Ali-Marttila et al., 2013; Sinkkonen et al., 2013): Service Reliability, i.e. the service is performed how and when it was agreed; Operator knowledge, i.e. the service personnel has the adequate know-how to perform the service; Safety at work, i.e. the service is done according to safety policies and increases equipment operational safety; Environmental safety, i.e. environmental safety hazards are mitigated / eliminated during the service; Service price, i.e. price of the service with respect to the received / provided activity; Technical quality, i.e. the service outcome is obtained as expected and during the agreed time.

The second step defines a rating scale. A 7-point Likert-type scale was selected ranging from very negative contribution (1) to very positive contribution (7), with an intermediate score for "indifferent/no knowledge" (4). This numerical double approach allows a simpler calculation of average values for each category analysed and visual representation.

The third step defines a method to visualise the results. A radar chart was suggested by Ali-Marttila et al. (2013) as an adequate means to visualize the value gap between customer and provider perceived benefits. It is also adopted here due to its flexibility to represent one or more categories in the same chart and comparability between different charts.