Part 1.

Business opportunities through services

INSTALLED BASE INFORMATION UTILISATION IN INDUSTRIAL SERVICE DEVELOPMENT AND OPERATIONS

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Abstract

This paper describes a systematic literature review conducted to determine how installed base information (IBI) is utilised in developing and operating industrial services. We found that the reviewed literature considers IBI useful and relevant for industrial service operations, and that it is mainly used to improve service quality and efficiency. However, it is evident that there is a shortage of empirical studies and further investigations that show concrete applications of IBI in different service activities. The existing research concentrates on particular contexts, such as preventive maintenance and asset management. The asset owner perspective is emphasised in the literature, but the use of IBI for service offerings, service contracts and service sales is rarely discussed. The literature indicates that many companies lack a holistic approach to IBI management, in general, and utilisation as a part of it. It is not uncommon for companies to build large databases, but fail to do accurate analyses based on the collected data.

Introduction

Industrial capital goods manufacturers in developed – and lately also in emerging – markets have been shifting their operations towards the provision of high-value solutions which are innovative packages of products and services tailored to solve specific customer problems. This phenomenon and its implications have been discussed in the literature (Baines et al., 2009; Mathieu, 2001; Oliva & Kallenberg, 2003; Wise & Baumgartner, 1999), especially from the supplier–customer interaction perspective. Services constitute a significant part of the product life cycle and require specific capabilities that prove to be somewhat challenging for industrial firms that are to a large extent product-focused. Suppliers have the task of convincing their customers that they are capable of achieving a desired level of performance both in service provision and in customer support through

their ability to provide value as planned by applying the installed base.

A key question in industrial service development and operations is how well a supplier understands its customer's business. What products have been installed, how are they used by the customer, and what is the customer planning to achieve through utilising and managing these products? This knowledge forms significant input required in the provision of industrial services (cf. Sampson & Froehle, 2006; Sampson, 2000). Accordingly, the information about the customer's installed base is a crucial part of planning and executing successful service operations. For a supplier, the installed base includes all products sold and installed at the customer's premises. Suppliers can potentially apply information about the whole installed base to gain a competitive advantage in different phases of service business – from development to operations – but often the focus is on a single customer. Many industrial firms maintain extensive databases on their customers' sales, deliveries, and contracts, to name a few. However, in many cases the value of this information for different functions is not clear. This can be due to, for instance, insufficient integration between the databases developed for different functions, as well as to no overall installed base overview or incompatibility of different databases or data management systems (Ala-Risku, 2009). This results in a poor understanding of how the data can be utilised for service operations. The purpose of this paper is to provide an overview of the installed base information (IBI) utilisation problems and solutions derived from the literature in the field of industrial services. IBI can be defined as ". . . all available information on the . . . installed base" (Dekker, Pinçe, Zuidwijk, & Jalil, 2013). We set the following question for this study:

RQ: What are the key domains of IBI utilisation in industrial firms' service business?

As for the method, we use the systematic literature review (Kitchenham et al., 2009; Tranfield, Denyer, & Smart, 2003) to be able to rigorously aggregate evidence from the scientific studies available in the field. This method not only allows for discovering and aggregating the existing research on the topic, it also supports the development of evidence-based suggestions for future research as well as managerial applications. After evaluating more than 2000 articles in the field, we outline the main challenges and solutions related to IBI utilisation for successful service operations and development. This helps in finding the most attractive avenues for further research in IBI utilisation.

Method

We decided to use the systematic literature review as the method to reach an explicit understanding of the current body of knowledge regarding the utilisation of IBI in industrial service operations. It should provide a structured, transparent and replicable method to analyse the existing literature in a rigorous way (Kitchenham et al., 2009; Tranfield et al., 2003). Thereby, we aim to build a strong basis for academia and practice to understand the phenomenon. Research papers in this field tend to focus on a particular problem in a given domain. A systematic literature review focusing on IBI allows us to summarise the role for IBI, in general, and also reveals gaps in the existing research. We followed the five general phases of a systematic literature review:

1. Planning the review
2. Identifying and evaluating studies
3. Extracting and synthesising data
4. Reporting
5. Utilising the findings

The first three stages of the process are presented in this section on a general level, while the findings are reported in the following sections. The fifth and final stage is then left after the publication of this paper, and in addition to the authors, it will be carried out by our colleagues and practitioners.

Planning the review involved forming the research group, narrowing down the focus of the topics, designing the search string,

and deciding on which databases to use. We formed a group of five researchers working on the same research project who eventually became the authors of this article. The selection of topics was influenced by our participation in a research project on industrial services. Developing the review protocol, however, was a rather resource-consuming task, mostly because the existing studies on IBI belong to a range of diverse research fields that are not all interconnected.

We listed the topics of interest to develop keywords for the search: for instance, "management and collection of IBI" and "challenges" related to aspects of "industrial services". We developed a number of potential search strings and ran trial searches with each one to acquire an understanding of how broad the yield of the results, in terms of publications, would be. We also tested the proportion of previously identified central research papers that appeared in the search results. After numerous trials with greatly varying results by different search strings, as well as corrections based on the results, we were left with the final search string:

Title, abstract, or keywords/subject ("installed base" OR "service base" OR "asset base")

We ran searches with this string in all major databases that we were able to access (via two large Northern European universities) with the intention of seeing the breadth and quality of the results and their dependence on the database. Based on this analysis, we decided to use the following databases: Academic Search Elite, Business Source Complete, ProQuest, Scopus, and Web of Science.

To maintain the focus, we decided to exclude articles that discuss sales and marketing of new equipment, product development or other company functions without a direct relationship to industrial services. This is purely due to the scope of this paper: the usage of IBI, data and knowledge on industrial services. Duplicate reports of the same study are also excluded.[1] To further constrain the scope, we ruled out studies focusing on detailed methods, e.g. algorithms, for the use of IBI in health assessments, diagnostics, and prognostics of equipment condition. Only reviewed works were included in this study. This refers to journal articles and conference papers, where the whole paper is peer-reviewed, but also theses. Further, the search was restricted to works written in English, although when carrying out the forward and backward searches (see below), also German, Swedish, Russian, Finnish and French studies were included if they met the criterion of relevance.

After reaching the initial sample of studies via the database search, their relevance was evaluated first based on title and abstract, and then on full text. If an article was deemed potentially relevant, it was passed on for full-text evaluation. The database search identified 2,479 potentially relevant studies. Ultimately, 54 of these papers were deemed relevant. They were extracted based on the protocol below, and their reference lists were analysed to identify potential additional studies to be included in the sample (we call this process backward search or backward snowballing).

The data was extracted from each study based on the following structure:

- The source (journal or conference) and full reference
- Research metadata (approach, qualitative-quantitative, method(s))
- Application domain
- Quality appraisal (rigor, trustworthiness, practical relevance, practical applicability)
- Validation of the results in the article

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[1] By duplicating results, we refer to situations when one and the same study was reported in, for example, different journals or other outlets. To avoid duplication, we included only one and the most complete version of the study.

- Definition of IBI applied in the paper
- Description of contents on IBI
- The applied point of view – user, service provider, manufacturer
- Main contribution of the paper
- IBI collection, generation and sharing: central ideas and anecdotes
- IBI utilisation: central ideas and anecdotes, claimed benefits
- IBI management: central ideas and anecdotes
- References for backward search
- Other information identified as relevant for the article

A forward search, or forward snowballing, was also carried out by identifying studies that cite the studies in the original sample. All relevant studies added to the sample were extracted, and further forward and backward searches were run on those according to the same protocol. Snowballing added 60 studies, thus the total number in the final sample was 114. To terminate the snowballing that had progressed, in many cases, to four rounds, inclusion criteria were tightened. In order to be included in the sample, the article had to make a clear contribution not covered by the earlier included studies. Figure 2 below presents the distribution of papers on different core topics (application domains). Some papers discussed several topics, meaning that the topic volumes do not add up to the sample size, but to a larger number.

Regarding data extraction, we utilised the process described by Kitchenham et al. (2009, p. 9): One researcher extracted the data and another checked the extraction. The procedure of having one extractor and one checker is not consistent with the medical standards summarised in Kitchenham's guidelines, but is a procedure we had found useful in practice. Similarly to Kitchenham's (2009) approach, we also coordinated data extraction and checking, involving all of the participating researchers. In order to do that in a proper manner, we kept a master spreadsheet, which covered all of the studies to be extracted, and noted whose responsibility each extraction and check was. We proceeded as described by Kitchenham et al. (2009, p. 9): Allocation was not randomised,

FIGURE 2.
The number of papers discussing each of the defined core topics (n = 114).
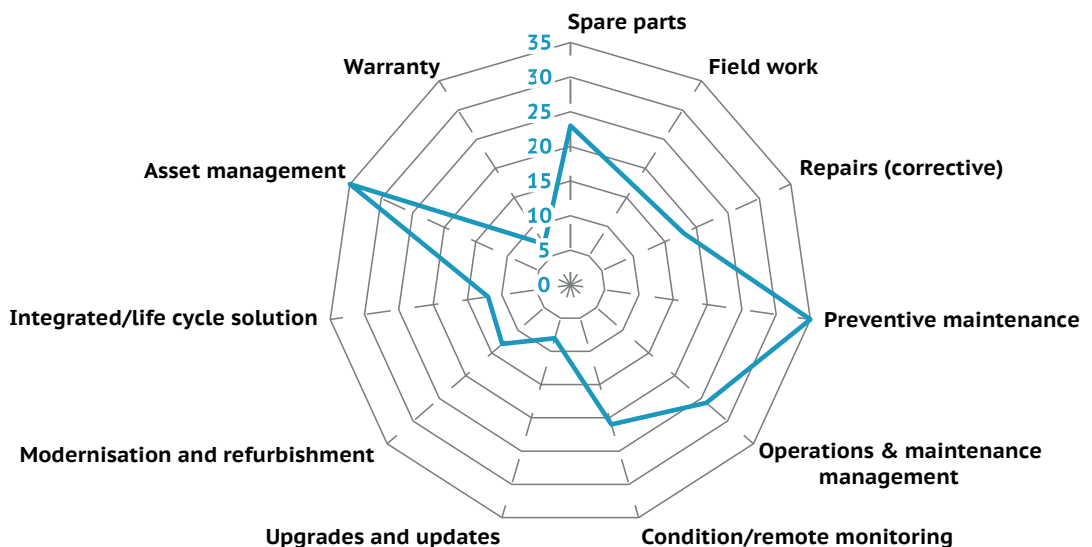
it was based on the time availability of the individual researchers. When there was a disagreement, we discussed the issues until we reached agreement. In addition, we took into account areas of expertise of our multi-disciplinary researcher team when allocating papers for extraction and validation.

Our search results covered a wide array of topics. However, for the purpose of this article, we will focus on the topic of IBI utilisation in industrial service development and operations. Within this scope, we cite 53 of the 114 articles. In the following chapter, we present findings of the systematic literature review pertaining to the research questions outlined at the beginning of this article. Table 1 below cross-tabulates the sample based on the core topics covered by each paper and the industry domains covered. The number of papers concerning asset management and preventive maintenance in the water industry is notably high. Note that many papers discuss more than one core topic and some more than one industry domain.

TABLE 1.
Summary of articles reviewed on IBI utilisation in industrial service development and operations.

Number of papers in total in the sample	INDUSTRY DOMAIN / CORE TOPICS	Automobiles	Aviation	Electrical utilities	Electronics	Elevators and escalators	Emergency services	Energy	Engineering	Facilities	Healthcare	Heavy machinery	Industrial utilities	Infrastructure	ICT	Logistics	Manufacturing	Military	Mining	Oil and Gas	Process industry	Telecommunications	Transportation	Water utilities	Consumer products	Generic
	Number of papers in total in the sample	2	7	3	3	3	1	2	1	4	4	4	8	1	6	3	12	3	3	4	1	1	3	25	2	24
23	Spare parts		4	2					1	1			3		4	1	4	2	1			1		1	1	5
17	Fieldwork		1	2	1	1				2	1	1	4			1	4	1	2				1	3	1	1
18	Repairs (corrective)		2	1		1				2	1		3		1	1	3	3	1	1			1	5	1	1
35	Preventive maintenance		2	2	1	2	1			2	1	1	3	1	1	1	2	2	2	1	1		1	14	1	3
26	Operations & maintenance management		2	1	1	1			1				3		4	1	4	2	2	1			1	5	1	7
21	Condition/ remote monitoring		3	1			1		1	1			4			2	1	1	1	1	2		2	7	2	5
8	Upgrades and updates		1	1			1		1	1			2			1	2	1	1	1			1	4	1	
13	Modernisation and refurbishment		1				1			1		1	1		1	1	1	1	1	1	1		1	8	1	
12	Integrated/life cycle solution		2				1			2	2		2	1	2	2							2	2	1	3
35	Asset management		2	2	1			1		1		1	2		1	2	2	1	1	1	1	1	3	15	2	7
16	Warranty	2	1		1				1				2		1	3	1	1					1		1	1

Results

IBI utilisation:
creating value for the customers

The main use of IBI in industrial service delivery relates to the general goals of ensuring service quality and service delivery efficiency (Ala-Risku, 2009, p. 125; Holmström, Främling, & Ala-Risku, 2010). Service assets should be managed flexibly for the purpose of effective and profitable service delivery (Cohen, Agrawal, & Agrawal, 2006). To achieve this, Cohen and his colleagues (ibid.) propose investing in processes and information technology to collect, analyse and disseminate relevant information in a timely and collaborative manner. On a general level, it is claimed that IBI improves the planning of service operations (Ala-Risku, 2009), which is useful for enabling the delivery of timely and cost-effective services (Borchers & Karandikar, 2006). Furthermore, IBI provides customers and service providers with a common basis for analysing and improving product and service performance (Holmström et al., 2010). In sum, effective and profitable service provision is based on managing service assets and fulfilling service demand in a flexible and integrated manner.

The customer relationship is at the core of the utilisation of IBI. The extent of the different services available to be offered to each customer correlates with the level of mutual trust, because some parts of IBI can only be acquired through a trustful relationship (Ahonen, Ojanen, Reunanen, & Lanne, 2008). The acquired IBI can then be used for enabling the delivery of tailored services, discovering patterns of service jobs, ensuring service quality and service delivery efficiency, and for predicting future service needs (Ala-Risku, 2009; Bakirov & Stich, 2011). For example, Cohen, Zheng and Wang (1999) found that the optimal utilisation of IBI contributed to their case company's operational efficiency by reducing late shipments by over 90% and inventory investments by 37%, and at the same time, the case company could improve its customer service level (in terms of parts availability).

Sharing real-time information enables service providers and their customers to co-create value by increasing transparency and dialogue (Coyne, 2011), and possessing a detailed understanding of customer operations will contribute to improved quality and accuracy of service provision (Kowalkowski, Brehmer, & Kindstrom, 2009). Increased transparency and visibility created by smart products may bring the provider and customer closer to each other and increase the understanding between the parties (Coyne, 2011). Thus, some risks can also be mitigated, providing significant value to the customer (Brax & Jonsson, 2009). In addition, for long-term optimisation of investments, the provider and customer both need to acquire the knowledge regarding several issues: what is installed and in what kind of condition the equipment is, the expected investments and their costs, and the development of both industry regulation and demand (Banyard & Bostock, 1998). Therefore, acquiring, managing, and utilising IBI optimally is crucial.

Although important, sometimes the discussions on IBI concentrate heavily on aspects of information availability and quality. It is essential to emphasise the importance of how the information will be used in industrial service operations to reap the best value (Turunen & Toivonen, 2011). For example, a great proportion of the value of smart products comes from increased visibility and the utilisation of real-time information, both of which provide a competitive advantage by increasing the service lock-in of customers (Coyne, 2011). This is due to the service provider being able to understand customer needs on a completely different level than competitors, because of having access to the real-time information, while the competitors might struggle even with the spare part planning as a result of poor visibility (Jalil, 2011). Information based on failure and service events can provide insights of high value, provided that the information can be aggregated in a manner that properly reflects the behaviour of different types of machines (Richardson, 2008). The application areas where IBI can provide the most value include

equipment replacement and upgrade, forecasting service demand, equipment health diagnostics for supporting operations, carrying out reliability analyses for designing and pricing maintenance contracts, and finally, communicating customer value through utilising IBI and calculation tools (Colen & Lambrecht, 2013; Saccani, Alghisi, & Borgman, 2013; Vijayaraghavan, 2006). In addition to these, Yoder and Delaurentiis (2003) identified three usage areas of IBI: tailored publications and catalogues, for example, for regulatory audiences; development of applications in situations where reports can be automatically generated; and scenario analysis in which "what if" scenarios can be tested by decision makers.

Most of the studies were done in connection with actual industrial applications and can be seen as case studies. Attempts to generalise are often based on modelling the observed relationships and validating the models on different cases. The value created depends both on the availability and quality of IBI, and on the accuracy of the model. In some cases, other models already work so well that relatively small benefits can be gained. For example, demand-based spare parts management systems have reached such accuracy that relatively little can be gained by adding IBI into the mix (Wagner et al., 2012).

IBI in decision-making

In respect to decision-making, many studies discuss IBI as an essential input for root cause analysis of failures, preventive and corrective maintenance, and budgeting of service operations (Ahonen, Reunanen, Heikkilä, & Kunttu, 2006; Ahonen et al., 2008; Goh & McMahon, 2009; Schwenke, Vasyutynskyy, Röder, & Kabitzsch, 2011; Skytte af Sätra, Christensen, Tanase, Koppervik, & Rokke, 2011). The utilisation of IBI is particularly important in industrial service delivery and in field services, where operational efficiency and effectiveness can be improved by linking the information of individual products, use locations and events (Holmström et al., 2010; Lehtonen, Ala-Risku, & Holmström, 2012). The research

investigating statistical approaches supporting decision making received much attention, highlighting the importance of data aggregation (Bufardi et al., 2007), visualisation (Schwenke et al., 2011) and the correlation between different parameters (Miles & Andrews, 2008), in order to specify, plan, budget and deliver different service activities, both preventive and corrective.

Service supply requires information corresponding to demand chain activity where the offer is targeted (Holmström, Brax, & Ala-Risku, 2010). As IBI is utilised in decision-making, typically, various types of information items are brought together, originating from both the supplier and the customer (Ahonen et al., 2008). Skytte et al. (2011) state that having more relevant information available combined with both system embedded and human competence will yield better decisions on timing and prioritisation of maintenance activities. However, obtaining representative data is described as problematic. For example, according to Fenner (2000), for both technical and financial reasons, field measurements in urban drainage systems are limited in both space and time. It follows that operational and maintenance decisions are often made on insufficient and unrepresentative data, leading to investment and operational costs far in excess of the cost of making the missing field measurements.

The research also identifies aspects when IBI contributes not only to services but also to the issues of product development. For example, information on usage patterns provides feedback for product development (Johnson & Mena, 2008). An IBI database can be used to identify relationships between products (Bakirov & Stich, 2011). Intelligence about the use and reliability of the equipment is an important contribution for equipment design and the marketing department (Colen & Lambrecht, 2013). It helps in predicting and defining new parameters for future products (Coyne, 2011).

The relevancy of information for improved decision-making is one of the factors addressed

in the literature. Various types of information items originating from both supplier and customer are usually combined (Ahonen et al., 2008). In many industrial segments, field measurements are limited both time-wise and in terms of the amount of measured elements due to financial and technical reasons. As a result, unrepresentative data is used for operational and maintenance decisions. This leads to the fact that investment and operational costs exceed the cost of obtaining field measurements (Fenner, 2000). Event data, new technology/system change data, and failure records are critical for decision-making on maintenance (Ahonen et al., 2006).

Factors affecting data usability

IBI is available from many different sources. These include customer service, contract data, spare parts demand and sales, test and simulation data, calculations performed for product dimensions, expert estimations and value analysis (Fleischer, Weismann, & Niggeschmidt, 2006). However, the usability of IBI to a large extent depends on the way it is collected, the targets and purpose behind the collection methods, as well as the required quality and detail. It should be noted that in some industries the collection of information is regulated, which dictates what information is collected (minimum may become de-facto) (Fenner, 2000). In the literature, the collection of information is typically depicted as purpose-driven, where information is collected in order to achieve a specified business objective, be it operational (cf. Honari & Donovan, 2007; Miles & Wastling, 2003; Wagner & Lindemann, 2008; Wu & Meeker, 2002) or strategic (cf. Holmström et al., 2010), or to sustain a business function (cf. Banyard & Bostock, 1998). Information can also be collected for business intelligence purposes (Ives & Vitale, 1988). Considering the different purposes a company has, a scope of relevant information can be defined (Borchers & Karandikar, 2006) and collecting information outside of this scope might not be beneficial (Goh & McMahon, 2009). Thus, setting the targets and strategy for information collection, and in-

deed, the accessibility of information, is one aspect that will affect the usability of the information for different purposes.

Depending on the intended use of the collected information, both the timespan over which the information is collected and the frequency with which the information is collected can be crucial (Miles & Wastling, 2003; Miles & Andrews, 2008). Further, different levels of detail (also referred to as granularity) of information is required for different purposes (Miles & Andrews, 2008). Examples of granularity-related issues were encountered in service district design (Baker, Clayton, & Aggarwal, 1990), product improvement (Fleischer et al., 2006), customised solutions (Cohen, Kamesam, Kleindorfer, Lee, & Tekerian, 1990; van der Feltz, Lamers, Priem, & Melief, 2003), condition monitoring (Ahmad & Kamaruddin, 2012), warranties (Wu & Meeker, 2002) and failure information(Fleischer et al., 2006). Further, Wu & Meeker (2002) note that when the data is used for statistical analysis, there is a trade-off between the detail of the analysis and the statistical reliability. Finally, considering the costs associated with collecting information, we note that even small changes in inspection frequency (or detail) have a large financial impact when projected over a large service base.

However, even if the targets and required quality for information collection are set, data availability might still be an issue as the suppliers tend to assume that the data is easily available (Colen & Lambrecht, 2013; Romeijnders, Teunter, & van Jaarsveld, 2012). Even very basic information can be missing. Vijayaraghavan (2006) provides an example of serial numbers that fail to be properly recorded for most subsystems and, thus, are unavailable. This leads to the fact that software packages cannot be traced for their release levels. Some measures can be used to ensure improved data availability and make data quality explicit. Data structuring can be used to improve quality, and assigning uncertainties to each asset model can be used to make quality explicit (Ugarelli, Venkatesh, Brattebø, Di Federico, & Sægrov, 2010).

Some of the difficulties with data accessibility stem from the lack of co-operation between suppliers, service operators, subcontractors and customers. Direct competition between services supply chain parties may be a reason to refrain from sharing critical information on an installed base, inventories and demand. One way to secure data quality and accessibility for further utilisation is through contractual obligations (D'Agata, 2003). In this respect, an important source of IBI are the customer interactions (Kowalkowski et al., 2009). There are many contact points to the customer, but these interactions should also be seen as opportunities to collect IBI. The customers' willingness and ability to share information determines the type of service that can and, perhaps, should be offered (Ahonen et al., 2008; Holmström et al., 2010), and thus the usability.

Information about the installed base and spare parts demand has direct value for service development and operations (Dekker et al., 2013). Service operations by a third party make service information and knowledge less visible or inaccessible to the OEMs (Goh & McMahon, 2009).

Understanding the context of operations and the business environment is crucial for designing strategies as well as ways of managing service operations that yield the best results. The same also applies to IBI: the data acquisition and usage environment should be identified and understood for yielding the maximum gain (Jalil, 2011).

Examples of IBI utilisation in the literature

In this chapter, we will address some of the core contexts we found in the reviewed literature: preventive maintenance – related issues, spare parts management and development, and development and design of services. These categories emerged during the analysis phase as having the greatest correlation with the IBI utilisation topic; that is IBI seemed to offer clear benefits in these areas. These categories will be further addressed in the Discussion chapter.

Preventive maintenance

Preventive maintenance schedules can be optimised and planned based on IBI. In their study of an aerospace case company, Johnson and Mena (2008) show that by using real-time data monitoring the assets in use, the company was able to predict with 95% accuracy in a two-year horizon time the timing for a required repair or an overhaul. It enabled scheduling time slots for the work and placing orders for parts just in time.

Extensive research has taken place particularly in the context of water and sewer pipe works, 25 of which are included in this review. Fenner and Saward (2002) provided a study which deemed that IBI could support effective sewer maintenance: service actions, scheduling, and optimizing of economics. They showed that case-based reasoning and knowledge-based systems can be used to develop a performance assessment methodology for sewers. In such a system, future management actions can be based on data collected from previous similar situations. In a decision support system for renewal planning of sewer networks, it was stated that critical IBI for sewers are condition and risk indices. Based on these, a list of sewers is prioritised according to their urgency of intervention (Halfawy, Dridi, & Baker, 2008).

Preparing for the site visits is critical because it directly affects service performance. From this point of view, IBI, to which service engineers have access, is crucial (Lehtonen et al., 2012). Ala-Risku (2009) proposed that in field service operations, one should maintain systematic IBI to support the identification of prerequisites for successful service deliveries to achieve required service quality, and to improve and expedite decisions in the service delivery process to achieve high service efficiency.

IBI is also used for predicting and forecasting equipment performance. Forecasting service life or the condition of equipment is of interest for many purposes, such as planning maintenance times, scheduling personnel

and managing service logistics (Schwenke et al., 2011). Reliability analysis of machinery can be performed to gain insight into the effect of maintenance actions on the probability of failure; in addition, this information can be used to improve the maintenance policy (Colen & Lambrecht, 2013). Warranty databases can be a good source of IBI for early detection of reliability problems (Wu & Meeker, 2002). Another use of IBI for forecasting is to predict or simulate the effect of operations. For example, in the context of sewer networks, it was proposed that a system for analysing risk for sediment build-up could also be used to test the effect of remedial action (Gérard & Chocat, 1999).

Spare part management

Spare part management is one context where IBI is frequently applied, for example: spare part demand and inventory management of an OEM; machine user's own inventory management and acquisition; identifying and arranging spare parts for a specific service task. Spare part inventory management is an extensively researched topic with most researchers agreeing that it can be optimised by applying IBI (Cohen et al., 1990; Colen & Lambrecht, 2013; Wagner & Lindemann, 2008).

Using IBI facilitates improved stock positioning in the network (Holmström et al., 2010; Jalil, 2011). This can result in considerable savings by reducing the requisite transportation needs (Jalil, 2011). With reliable demand forecasts, spare part demand can be anticipated and inventory allocation and replenishment adapted (Jin & Tian, 2012). For instance, machine location and machine type data can be used to derive transportation costs, travel times, and demand forecasts, even at the customer's postal code level to optimise spare part stock level planning by stock location (Jalil, 2011).

In addition to demand forecasting, other benefits of applying IBI in spare part management include improved forecasts of spare part returns (Dekker et al., 2013; Krikke, van Nunen, Zuidwijk, & Kuik, 2003), eliminating having obsolete stock at the end of the product life cycle (Wagner & Lindemann, 2008), and the ability to derive other input parameters, such as transportation costs and possible delivery options for spare parts inventory planning (Dekker et al., 2013). The logistics of returns benefit from knowing the location and condition in advance, which may be provided by tracking and tracing (Krikke et al., 2003).

Service design and development

The importance of access to IBI to support services offering development and service design has been clearly recognised (Ala-Risku, 2009; Colen & Lambrecht, 2013; Coyne, 2011). For example, new services become possible because of information (IBI) visibility enabled by smart products (Coyne, 2011). IBI enables integrated product and service offerings, where the main business benefits are increased customer value, a long-term improved return on investment, and a more stable cash flow (Isaksson et al., 2009). When the manufacturer provides and guarantees function instead of product, the equipment ownership stays with the manufacturer, and maintenance and repair cost have to be optimised. Good use of IBI brings mutual benefits.

IBI utilisation helps in forming clear and modular service offerings customised according to heterogeneous customer needs (Korpi, 2008). Further, designing for reliability and maintainability can be supported by using IBI (Colen & Lambrecht, 2013). It is also possible to optimise the allocation of resources to design, manufacturing, and service logistics, in a way that the total costs (design, manufacturing, repairs, inventory costs, downtime costs) are minimised while the system performance goals are still met (Jin & Tian, 2012).

Discussion

Context of IBI utilisation in industrial firms' service business

We aimed to better understand the focus of the research on the utilisation of IBI. Therefore, we analysed the core contexts of the ar-

ticles through the lens of different perspectives presented in the academic discussions (see Figure 2). The four perspectives – servitised manufacturers, manufacturers, service providers and asset owners – emerged from the analysis of the literature. The perspective of the servitised manufacturer is the most frequently addressed one. This can be explained with the growing focus on the capital goods manufacturers shifting the focus from stand-alone products towards the provision of life cycle solutions that include services as an integral part (Baines et al., 2009; Mathieu, 2001; Oliva & Kallenberg, 2003). The literature does not always maintain a clear distinction between the concepts, for example, of servitised manufacturer and [pure] manufacturer or servitised manufacturer and [service] supplier. In this study, we do not analyse the differences between the different concepts used in the literature; rather, we present them as they were used in the articles we reviewed.

Figure 3 shows that IBI usage in the context of preventive maintenance is fairly well-covered from all perspectives. In this context, preventing value-destroying unexpected disruptions increases the importance of preventive maintenance compared to corrective maintenance. Thus, the topics of failure prediction, condition monitoring, forecasting of performance for both equipment and services, as well as planning for needed service operations, are widely discussed, especially from the perspectives of asset owner and servitised manufacturer as the examples of IBI utilisation show (see pp. 8–9).

Similarly, operations and maintenance management, asset management, condition monitoring and warranty received attention

FIGURE 3.
Core contexts addressed in the analysed articles from different perspectives (n = 114).

CORE CONTEXTS

NUMBER OF ARTICLES

Service provider   Manufacturers   Servitised manufacturer   Asset owner
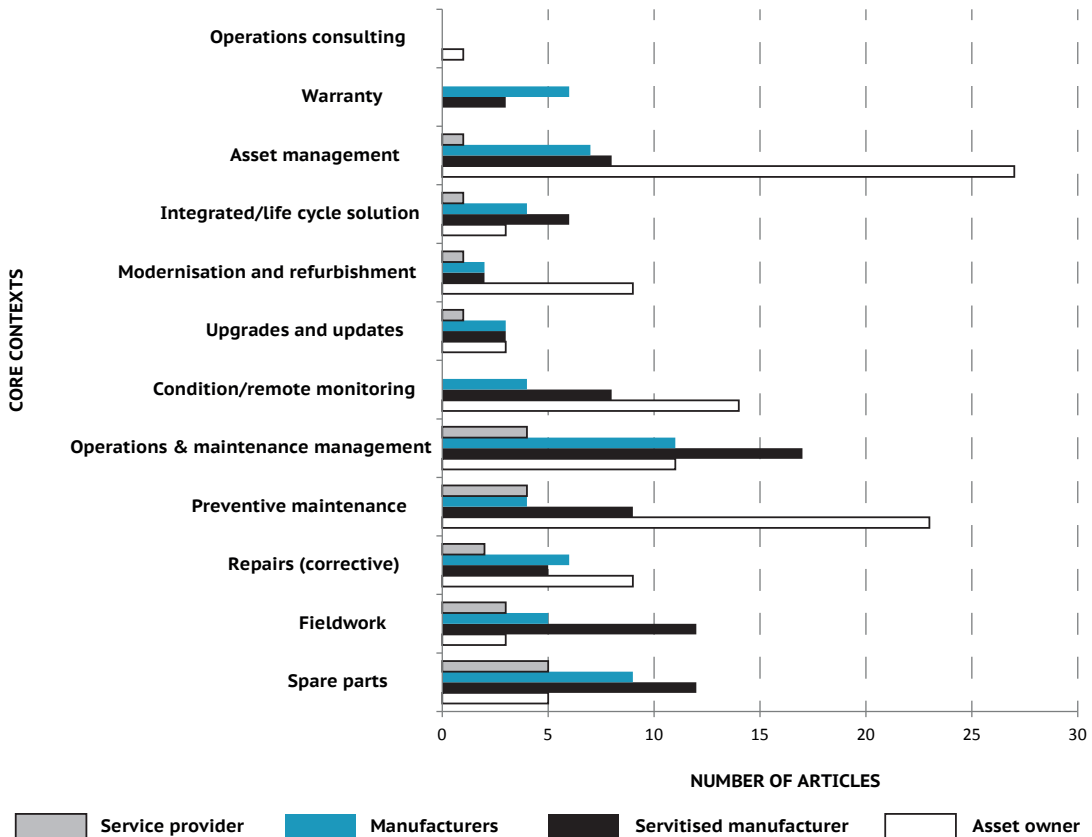
within all three perspectives. However, in this case, the asset owner perspective received the most attention. Naturally, asset performance is a prime concern from the asset owner point of view. It is equally important for the servitised manufacturers to address these issues to deliver value for the customers. Considering that these topics are also relevant and urgent for manufacturers and [pure] service suppliers, we found a lower number of articles addressing these perspectives to be an unexpected result.

Much of the discussion on IBI use in the industrial context is concentrated around spare parts forecasting for industrial products. For example, Dekker et al. (2013) state that forecasting the demand and return of spare parts can be considerably more accurate and timely using IBI, compared to forecasts only based on historic demand. Somewhat interestingly, the topic of spare parts is significantly addressed in the literature from the servitised manufacturer perspective, while one would expect it to be more connected to pure manufacturers. However, for servitised manufacturers, the issue of spare parts remains highly relevant as many of them seem to focus on life cycle support and services where spare part supplies is one of the core activities. Another explanation potentially lies in how different researchers in the field defined services and servitised manufacturers in the reviewed literature.

Research topics in IBI utilisation

The research on IBI seems to be concentrated on particular topics when it comes to the utilisation of the information (see Figure 4). As the literature review shows, much of the discussion is around information collection for the purposes of service scheduling and planning. This is also true for service resource management as it is connected to the scheduling and planning topic. One important context within the service planning topic is condition monitoring and the utilisation of IBI for forecasting asset performance, especially spare parts needs and potential failures as traditional manufacturing issues. IBI uti-

lisation for the purposes of condition monitoring and asset performance forecasting is especially well-addressed by the researchers focusing on infrastructure, particularly water and sewer pipe networks and less so for industries.

Service design and development- and service offering-related research are dominated by the perspective of the servitised manufacturer, while few papers are related to these issues from the asset owner perspective. Although the servitised manufacturers in designing services and co-creating life cycle solutions between them and their customers (asset owners) is gaining attention, it seems that the research covering the customer – asset owner perspective is scarce and concentrated on particular issues. Also notable is the relative lack of IBI utilisation-related research on the topics of service sales, service development and service contracts from all perspectives. As integrated service and product offerings become more common, we expect more research in these areas.

Conclusions

In sum, the reviewed literature deems IBI useful and relevant for industrial service operations. However, it is evident that there is a shortage of empirical studies and further investigations that show concrete applications of IBI in different service activities. The existing research is somewhat concentrated on particular contexts, such as preventive maintenance and asset management. Many other contexts are not significantly addressed. Furthermore, attention devoted to servitised manufacturers compared to the asset owner (or customer) perspective in many of the reviewed topics (see Figures 2 and 3) is lacking in the literature. The use of IBI for service offering, service contracts and service sales is rarely discussed in the literature. These are potentially the avenues for the researchers to explore in greater detail.

From the practitioner's perspective, the literature indicates that many companies are lacking a holistic approach to IBI manage-

FIGURE 4.
Core topics addressed in the analysed articles from different perspectives (n = 114).
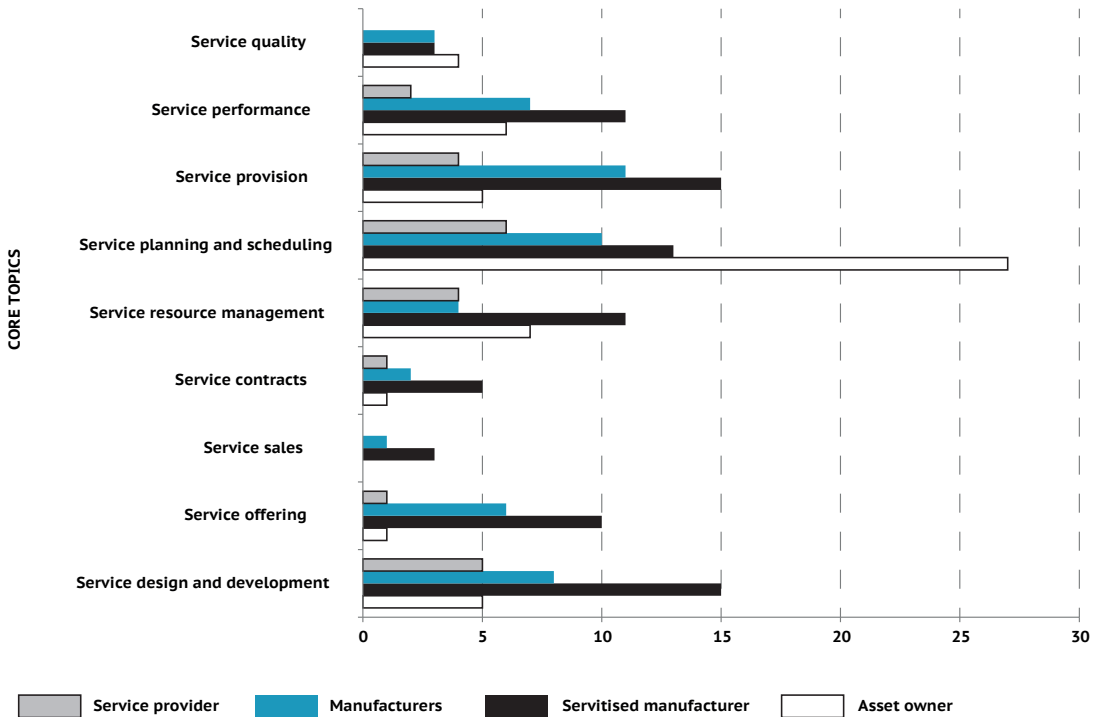
ment, in general, and utilisation as part of it. It is not uncommon for companies to build information databases of considerable size. However, an understanding of which data is crucial for different aspects of service operations, as well as how to present and analyse it in an effective way, is lacking. This leads to similar or even repetitive data, which differ only in the way they are presented in the database, being collected in abundance (see, e.g., Ugarelli et al., 2010). The interrelationship between pieces of information is then lost, the analysis is difficult and the results are inaccurate.

The use of information is, to a large extent, dependent on whether it is easily available in a needed form, or whether the service supplier is dependent on the other actors to obtain it. For example, it is not always possible for a service provider or servitised manufacturer to make the customer share the needed in-

formation via the contract terms or based on trust. If the parties having access to the installed base do not wish to share the information, effectiveness in service provision might be hindered.

Even though we reviewed only a specific segment of publications and scientific works due to the methodological criteria of the study, we can conclude that the current research has already outlined practitioner problems and defined potential remedies well in terms of IBI utilisation. The next step for researchers in the field of industrial services is to address these problems by focusing on the development and testing of tools and processes that support IBI utilisation in industrial service operations to help practitioners overcome the gaps. This should be done considering the roles and perspectives of multiple actors involved in service operations.

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