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Elements of installed base information value

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Abstract— Installed base information (IBI) is used in industrial service operations, but currently there are challenges with maintaining and utilizing this information to its full potential. The purpose of this paper is to aid in improving the realized value of IBI. We conducted two case studies of IBI collection and utilization with two industrial product-service system suppliers. From this material, we identified four elements contributing to the value of IBI and constructed a framework for managing this value. Furthermore, we identified the sources of the difference between the potential value and the realized value of IBI. The elements contributing to the value of IBI are its management, scope, utilization and quality. These elements form interconnected leaves in the proposed value clover framework. Each element potentially contributes to the difference between the theoretical maximum value and the realized value of IBI. Future research should look into the different elements and their relationships in more detail. Our framework helps managers in identifying shortcomings in the different elements of IBI value and in deciding on investments in this area. Previous literature has recognized the need for IBI, but not analyzed the different elements affecting its value. Our research offers industrial service operations a novel framework of IBI value.

Keywords— Industrial product service systems, installed base information, information value, asset management

I. INTRODUCTION

The literature on industrial services has well recognized the trend of equipment manufacturers needing to provide services for their customers (e.g., [1, 2, 3]). The notion of product-service combinations aimed to fit customer needs has gained increased popularity both with scholars and practitioners [4, 5]. For the manufacturer, the life-cycle perspective presents opportunities to create more profits by offering services to operate, support, maintain and upgrade the customer's equipment in use [6, 7]. However, the customer point of view is that there are several alternative sources to the manufacturers of the equipment for obtaining these services. Delivering products and product-related services requires a wider set of capabilities from the industrial suppliers [5].

Dekker et al. [8] define *installed base* as “the whole set of systems/products for which an organization provides after sales

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services” (p. 537). This definition takes into account that the manufacturer is not necessarily the only after sales service provider. *Installed base information* (IBI) includes information on each product individual on a wide scope. Ala-Risku [9] considers information on *item* (e.g., product type and individual product structure), *location* (e.g., site, access information, contacts), and *event* (e.g., service actions). Seilonen et al. [10] add “information about the condition of equipment” (p.45). In our view, IBI also includes information about usage, environment and product's role in customer's processes.

Successful service operations require IBI. Currently, however, there are challenges with this information. Lehtonen et al. [11] found that 40 percent of failed service visits of a capital goods manufacturer's service network were caused by lack of information. In our experience, IBI is often still seen as support for sales and spare-part business. One of the most urgent problems in this respect is the supplier's lack of access to IBI once the product has been delivered [9, 12]. Even with access, companies are not able to form a comprehensive view of the installed base due to restricted interaction between separate support systems for customer relationship management, equipment deliveries, service operations, and product development [13]. On the one hand, remote monitoring data can cause information overload, as managers do not know what to do with all the data. On the other hand, the manual gathering and maintaining of IBI is expensive and laborious and thus often omitted, resulting in a shortage of usable information.

The practical motivation for this research stems from company needs to optimize the utilization of IBI. This need was identified in a large-scale research program (39.3 M€, 6 years, 19 companies, 9 research groups). One aim of the program is to find and solve bottlenecks and inefficiencies in processes in order to enable service business adoption and expansion. In this context, we study the use of IBI in two cases of industrial service operations. A major challenge for industrial suppliers is to understand what kind of IBI is needed in industrial service provision and what is its value for their service operations. As long as managers do not recognize the value potential of IBI, they do not allocate resources for developing its utilization.

Previous literature has recognized the need for IBI, but not analyzed the different elements affecting its value. We try to fill this gap by answering the research question: What are the elements that contribute to the value of IBI? The scientific contribution of this exploratory study is a conceptual framework of IBI value. We will also make managerial contributions by relating the framework to industry practice. In order to contribute to the literature on service provision, we take the service provider's point of view. Our approach offers maintenance service operations a novel framework that assists managers in understanding the elements of IBI value. This is important when improving the practices related to those elements in order to realize the full potential value of IBI.

The paper is structured as follows. In section 2, we analyze literature on different aspects of IBI, followed by our research design in section 3. The empirical findings are then presented in section 4, including the IBI value framework. In section 5, we discuss our findings in relation to the existing body of knowledge and present managerial implications, and limitations of the research. In the last section, we draw conclusions of the study.

II. INSTALLED BASE INFORMATION AND ITS VALUE

A. Value

Information value depends on the context of its use; the same piece of information can be extremely valuable in one context, but be totally useless – or even an obstacle – in another context. Birchler and Büttler [14] define information value as the increase in utility from receiving the information and from optimally reacting to it. As the use of a piece of information changes, its value changes according to the new context, even if the intrinsic quality of the information stays the same.

IBI value has been explored in several studies. Auramo and Ala-Risku [15] studied the demand and supply network management of industrial services. Their results reveal that IBI is especially important with sophisticated maintenance service contracts, where various performance improvements are continuously supplied for the installed base. Dekker et al. [8] studied the use of IBI in forecasting spare parts demand and return, and conclude that these forecasts can be made timelier and more accurate using IBI, compared to using only historical demand. Jalil et al. [16] analyzed the value of installed base data in spare parts planning. They report cost savings of 1% to 58% using machine location data to derive transportation costs, travel times, and demand forecasts. These savings are due to lower stock requirements and reduction in transportation costs. Sacconi et al. [17] applied a decision-analysis-tree approach to evaluate the value of IBI in an underwater system in a cruise vessel.

B. Scope

As means, such as remote monitoring, for collecting vast amounts of information are becoming readily available, the challenge is to define what information should be gathered: what information can be obtained at a quality where its use brings more value than what is put into acquiring and maintaining it. This calls for focus on developing creative ways

to use the potential information and expanding the information scope in a way that is most useful for decision-making. Lehtonen et al. [11] found the type of the equipment as the most important piece of IBI in field service operations, and they also found advance information on the type of the failure helpful when preparing for a service call.

C. Management

IBI management consists of an array of practices that companies adopt to gather, analyze, use and share data regarding installed products and their usage. Ulaga & Reinartz [5] found that the strategic value of IBI is still widely unrecognized, and the importance of investments on proper technologies to gather data systematically is oftentimes overlooked.

Unsworth et al. [18] have studied the manual collection of IBI and the psychological factors that lay behind data collection. They conclude that a goal hierarchy approach supports customized interventions to improve the quality of collected information. Molina et al. [19] found that pressure from the supervisors to collect high quality data only increases the performance of some operators, whereas for motivated operators it had the opposite effect. Dekker et al. [8] give examples that show the difficulty of managing IBI: if the customer changes the location of the equipment without notice; missing information about the usage of the system (built environment vs. desert, for example); and a third party maintenance provider not always sharing the updated IBI with the manufacturer. These examples can all have a negative impact on things such as service delivery efficiency, and thus support the importance of properly handled IBI management.

D. Quality

Data quality has different characteristics, such as accuracy, accessibility, relevance, completeness and timeliness, and the required quality characteristics depend on the task at hand, changing over time as work requirements change [20]. Typical operational impacts of poor data quality include customer dissatisfaction, increased costs and lowered employee job satisfaction [21].

Jalil et al. [16] studied the effect of data quality in spare parts planning. They observed that the gains of using IBI deteriorated because of systematic data errors: all installed base items reported at the headquarters location or at the primary stock location due to incomplete or missing location data, and data communication error due to mismatch in communication with the vendor of the installed base items. Dekker et al. [8] observed deterioration of IBI quality due to the following factors: the size of the installed base, autonomous changes of product configurations, heterogeneity of products and customers, aged IBI scattered in legacy systems and difficulties in the acquisition of the data.

E. Utilization

There is a multitude of studies using the concept of IBI in different contexts related to improving the performance of service delivery and operations management. It is seen of importance for manufacturers' service delivery process, for the

performance measurement, and the development of user's operations [6]. The relevance of IBI is reported for the forecasting of spare parts demand [16, 22]. Equipment location information can be utilized for optimizing the traveling routes of field engineers [9, 16]. In the planning and management of material and human resources, knowing the likely job contents and being able to match the expected job with a suitable service engineer and materials is essential for good service quality [9, 23]. Product usage and customer process data can be used for developing industrial services, such as improving customer's business process, achieving productivity gains, and services to perform processes on behalf of the customers [5].

In addition to improving current operations, IBI is an important enabler of new services and performance-based contracts [24]. Internet of Things (IoT) relies mostly on systems processing real-time sensor data, but combining such data with manually collected maintenance information can lead to more effective and product-centric decisions [25]. Simulation of product life cycles can be used in pricing new services, but it requires good quality IBI [26].

III. RESEARCH APPROACH

We conducted two exploratory and descriptive case studies to reach a detailed understanding of the phenomenon of interest in its natural context [27]. We used an iterative approach for data collection, coding, and analysis, as recommended in [28].

A. Case companies

The research involves two globally operating equipment manufacturers who also provide maintenance and operation services. The focus of the cases has been on IBI usage, namely in preventive maintenance. The preventive maintenance context was chosen due to its established position in manufacturing research and its relatively unexplored position in field services. This situation provides an opportunity for comparisons and for building new theory through case research, potentially benefiting both areas of research [25].

Company A supplies electrical equipment for marine vessels and after-sales services such as maintenance and repair for the equipment. We selected case A to understand how remote monitoring is applied in service business.

Company B manufactures capital goods and provides also installation, modernization, and maintenance services. We selected company B because it efficiently manages a challenging operational environment: the installed equipment base has significant geographical variability due to, e.g., acquisitions and mergers as well as the long lifespan of the equipment. Besides servicing its own equipment, Company B also services competitors' equipment.

B. Data gathering and analysis

Altogether 24 interviews were conducted, of which 17 with representatives of company A. We also received 5 questionnaire responses from one of the customers of company A. With Company B, we carried out 7 interviews, 2 observations of maintenance workers, and a facilitated workshop, aimed at identifying the untapped potential of IBI

utilization. The interviews targeted a wide variety of job roles. We interviewed people in managerial roles, people creating IBI and conducting actual maintenance work, people responsible of IBI management and IT system development, and one customer representative. The main themes in the interviews were service products offered to customers, the equipment under maintenance, current IBI management, remote monitoring systems, and the usage of IBI in service operations. The customer questionnaire included the same themes supplemented by questions about service delivery from the customer point of view. The interviews lasted 2-3 hours and they were recorded and later transcribed.

Data analysis and synthesis had two phases. First, four researchers coded data individually so that relevant and important themes from the transcript were emphasized by each individual researcher. Second, in order to combine individual views and to remove individual bias, we used a brainstorming workshop where all the challenges related to IBI value that were identified from different cases were shared and discussed. This brainstorming was done with 8 researchers including also researchers who studied the same topic but did not participate in the interviews directly. All researches then grouped similar challenges individually. The groups were reviewed and modified together resulting in a conceptual model representing a common understanding about the groups of challenges found in the companies. An individual group of challenges represents one leaf in the value clover illustrated in Fig. 2, which represents the resulting conceptual model.

The value clover framework was validated by presenting it to representatives of the case companies. We organized a joint meeting where the representatives were asked to validate the interpretation of the situation from a practical viewpoint. These company participants agreed with the overall structure of our value clover. After constructing the framework we re-analyzed literature from the value clover's perspective to identify the existing knowledge and compared our findings with it.

IV. FINDINGS

A. Origins of installed base information

On the basis of the case analysis, we found IBI to originate from three sources: the manufacturer of the equipment, the customer, and the service provider. The manufacturer and the service provider can be the same entity, but this is not necessarily always the case. For example, both of our case companies offered maintenance services for their own equipment, but one of them did that also for similar types of equipment produced by competitors. Fig. 1 shows the identified origins of IBI. Manufacturer generated information includes, e.g., the type, structure, and specifications of the equipment. Customer may provide or enable access to information of equipment usage and location, for example. Service supplier generates information about performed maintenance activities, among others. The circles are partly overlapping as the roles are overlapping in some cases, and there may be alternative sources of some information. For example, a service provider may update information on product structure when it upgrades the product or uses substituting spare part types.

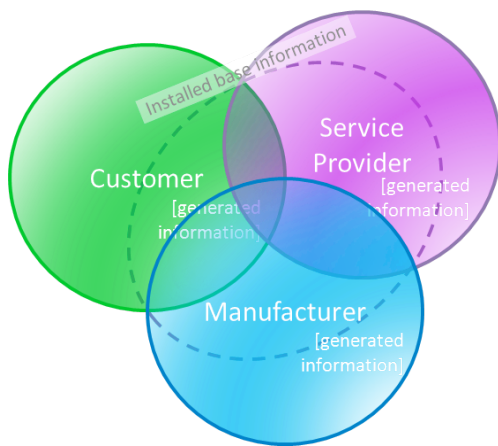


Fig. 1: Origins of installed base information

B. Value clover framework

In the following subsections, we structure our findings on IBI according to the five elements that emerged from our analysis of the data (pictured in Fig. 2): value, scope, management, quality, and utilization. These elements are presented with evidence from the case studies.

1) Value

IBI has value if it can be used in a business context where it lowers costs or increases revenue. Both of our case companies had profited from the use of IBI in lowering costs.

Company A focused on quantifying customer value of information gained by remote monitoring of installed base. The purpose was to understand and quantify IBI customer value on certain customer segment. Depending on the criticality and capital intensiveness of the customer's operations, as well as the safety culture in the industry, the value can be significant.

[Q1] *So there must be some benefits that this system delivers. This [X MEs] somehow shows that there must be quite much actually with the remote monitoring that you can avoid [certain types of unexpected costs].” (Business development manager, Case A)*

At Company B, IBI added value mainly by increasing the productivity of service operations and by reducing over and under maintenance. Item and location information were used in preventive maintenance, leading to desired equipment availability or acceptable failure rate. Event data was used in controlling maintenance resource efficiency and thus reducing costs. Event data was also transformed to customer value through service and equipment awareness, and as a proof of regulatory compliance.

[Q2] *In some cases the customer has to be able to prove [to a third party] that the equipment has been maintained accordingly, in which case the [event data] comes in handy for the customer. (Regional service sales manager, Case B)*

2) Scope

The informants we interviewed in both case companies stated that they would benefit from an increase in the scope of the IBI that they have access to.

Company A had partially almost real-time information about the usage and status of their installed base at customer locations. However, they felt that they could use more information in order to make better analyses and decisions.

[Q3] *...of course we are in situations where we don't have the data we would like to have, we go by educated guesses... (Remote monitoring system responsible, Case A)*

[Q4] *The data we receive and store are reliable, and we trust that, but still in development we see that it is not collecting all the data we want, we don't know everything. (Remote monitoring system responsible, Case A)*

The interviewees at Company B identified situations where more accurate item information could be utilized. However, collecting this information was questioned in some situations, given the diversity of some main component types and the difficulty to identify the type.

[Q5] *No technician can tell the exact model of [a main component] by looking at it; the only way to know is if you find a sticker or something. They all have such a similar appearance, which raises the question whether the data can be collected at a level accurate enough for it to be useful. (Data analysis specialist, Case B)*

3) Management

IBI management includes the tools and processes for gathering and maintaining IBI, as well as giving access to IBI for those who need it.

The management of IBI at Company A could not focus only on information management tools, as some IBI was stored only in the heads of the service personnel. In addition, scattered IBI made it difficult to utilize it in fleet level analysis, covering the whole installed base.

[Q6] *...the knowledge is between the ears of three, four, five people so we have these people still working for us who have actually commissioned [the piece of equipment].” (Business development manager, Case A)*

[Q7] *...we have also tried to develop a process where all the data that has been collected on board [a vessel]...and we can actually store all the data in [product manufacturers database] ...so you could have all the information on hand to make fleet or group analysis (Senior technical advisor, Case A)*

Manual gathering of IBI was found problematic at Company B. There were differences between the national frontlines in the scope of collecting IBI. One of the reasons for this was that collecting information generated costs, and if the collector was not using the information, there was little reason to collect it. Furthermore, the technicians had little knowledge of how IBI was utilized and how it affected their work, which meant that they had little incentive to gather additional IBI.



Fig. 2: Value clover framework

[Q8] *Globally, we don't have any process utilizing this information, so the frontlines have no reason to collect the information. Gathering information, especially if it requires a site visit, generates expenses, and that is something that is to be avoided. (Data analysis specialist, Case B)*

One of the challenges with IBI management at Company B was the moment when a new equipment individual enters the service base. When the information required for the preventive maintenance plan was collected and the plan activated, there was no mechanism for measuring the suitability of the maintenance plan, especially considering the possible situation of over maintenance.

[Q9] *The operational environment is evaluated by a person, [...] this is a characteristic which is often misunderstood, as it is, instead of being determined as it should be, determined to be demanding if the usage intensity is demanding. (Solution manager, Case B)*

4) Quality

The most important information quality attribute in our case companies was accuracy.

According to our observations at Company B, information accuracy problems emerged more frequently in situations where the collector of information was not using it directly or whom it did not affect. Other problematic situations were when the person using the information could not confirm it.

[Q10] *If the technicians then understood that this is the data based on which the maintenance profiles are determined, it might serve as an incentive to keep that data up to date. (Data analysis specialist, Case B)*

Another challenge with information accuracy at Company B was caused by the heavy competition in the after-sales market, which led to frequent loss and reacquisition of service contracts. Every time the equipment exited Company B service base, the service history was cut off and visibility to the equipment was lost. When the equipment at some point re-entered their service base, there was no record of possible modernizations or part renewals, which meant that the old item data could not be trusted.

[Q11] *The tendering-cycle is quite short and big pools of equipment are in motion constantly. This means that the data either disappears or at least there are*

shortcomings as the equipment shift to competitors once in a while. (Regional service sales manager, Case B)

5) Utilization

IBI was utilized in both of our case companies. However, the utilization of IBI was still in its infancy and we expect to see major increase in this area.

Company A collected and utilized IBI mainly through remote monitoring. They analyzed the data to provide troubleshooting to their customers and to consult them about the scheduling of maintenance and repair operations.

We observed varied utilization of IBI at Company B's processes. In the supply chain process of spare parts, inventories were optimized through using IBI. In addition, service technician routes were optimized with IBI. The preventive maintenance plans were constructed using item and location information. Furthermore, event data was utilized in measuring the performance of the preventive maintenance resources. Company B had remote monitoring in place in some newer, Company B manufactured, equipment. However, at the point of observations the utilization of remote monitoring information was in its infancy, while it was expected to improve the predictability of operations in the future.

[Q12] *Based on the [item and location information], the [preventive maintenance allocation system] tells you how often you need to check or maintain your equipment, from a technical point of view, specified by product development. (Data analysis specialist, Case B)*

6) Tying the value clover elements together – the challenges in realizing the full value of IBI

The value of IBI is realized when the information is used in a business process. For example, the value of location data is realized when optimizing the travelling routes of field engineers. IBI can also enable new kinds of business processes. However, the realized value of IBI was observed to be often considerably less than its potential value. The potential value of IBI is the theoretical maximum value achievable with full scope, optimal utilization and perfect quality with minimal management costs.

In our cases, value was lost with the value clover elements, as depicted in Fig. 3. Our data analysis revealed four mechanisms reducing the realized value. First, all of the desired IBI was not accessible when needed, either because it was not updated in any IT system, or because the person who had the information was not present. For example, bearing health prognostics was performed based on remote monitoring data (vibrations) without full certainty whether the bearing was manufactured by an OEM or a third party ("pirate"). Second, IBI was not utilized in its full scope due to limited access to IT systems or poor user interfaces of the tools leading to only partial access to IBI. Third, the quality of IBI was often insufficient. In certain situations, IBI was not up-to-date and in others, a value was presented without contextual information making interpretation difficult; a temperature reading without related output power, for example. Fourth, IBI management costs, including all the labor, processes and tools reduced the realized net value of IBI.

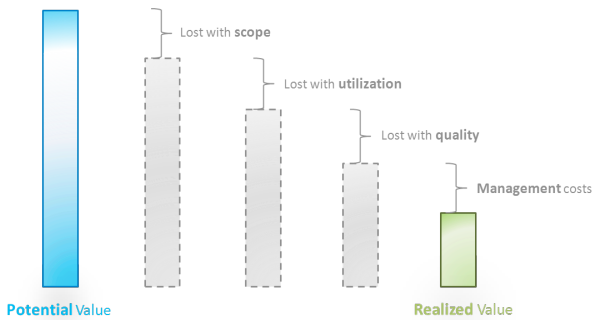


Fig. 3: Managerial aspects where value of IBI is lost.

V. DISCUSSION

It is impossible to define the correct scope of IBI irrespective of context in the diversity of today's service business. Instead, our framework describes what issues should be considered when defining the needed data in various service contexts. The dilemma in defining the right scope is that it is difficult to see the value of information before it is utilized. The challenge is to decide what information you need more, and what information is only confusing and thus hindering you from making right decisions. To maximize the value of IBI one needs to look at the value clover as a holistic system. We argue that many of the problems related to IBI can be expressed as originating from an uneven focus to the five elements of the value clover. As the structure and behavior of the interconnection are not seen, there is a tendency to select actions that are satisfying: sufficient instead of optimal.

Fig. 3 above is a static snapshot of the realized IBI value. In practice, the different elements, as well as the value, are interconnected and by making changes in one you inevitably affect another. Leaving some of the elements out when making decisions could potentially nullify the efforts made. Let us consider an example of a company attempting to increase the utilization of IBI and the value provided for the customer by extending the scope of collected information. The extended scope of IBI increases the amount of relevant information available for decision-making (i.e., more *utilization*). However, if data is collected manually, the extended scope may in fact hinder utilization if no effort is made to support the extra work of maintaining the data. As information quality would start to suffer from the lack in maintenance technicians' abilities or motivation to maintain additional data, decision makers would be less inclined to utilize the information (i.e. less *utilization*). In other words, the value creation through IBI is a complex, dynamic system.

It is impossible to put the value clover's leaves in the order of importance. If there are deficiencies in scope and the data needed in decision-making is missing, it will not help if the available data is of good quality. If the scope is defined to include all needed data, but the managers fail to motivate data collectors to collect the data there will still be deficiencies. Similarly, if good quality data exists, but is not utilized in decision-making, the investments in data collection are lost. Finally, if the costs of data collection are higher than its value in decision-making, there is no point in collecting the data.

A. Scientific contribution

This paper contributes to the current research on IBI in multiple ways. First, it gives a coherent overview of IBI, its elements, and relevance for service operations. A clear definition of IBI does not exist yet and the attempts to create one are influenced by the contexts of the studies. In some cases, even though the authors operate with the term IBI or its synonyms, it is not clear what the concept entails in the authors' interpretation. We add the lacking holistic picture on IBI and its value to service operations to the current body of knowledge.

Second, we classify the three sources of IBI: manufacturer, service supplier and customer – and connect them with Ala-Risku's [9] systematization on types of IBI: item, location and event. We identified that, typically, item information originates from the manufacturer, location information from the customer, and event information from the service supplier.

Third, our framework provides a holistic view of IBI value. Our study supports the claim of Ulaga and Reinartz [5] about the criticality of product usage and process data as a resource in providing hybrid offerings. We extend the works of Jalil et al. [16] on the potential value of IBI for spare parts logistics and Dekker et al. [8] on forecasting spare parts demand by discussing the value of IBI in industrial services in general and by identifying the elements of its value.

B. Managerial implications

We synthesized challenges found in our case studies in a conceptual framework. It helps managers in identifying and balancing the different elements of IBI value and for justifying investments in this area. One of the managerial challenges with IBI is the lack of communication and information sharing over company boundaries. For instance, after changing the service provider for the equipment, its service history is effectively lost, as the new service provider does not have access to the information. If the information was sold or the equipment owner would also own the information it could be transferred with the service contract. Transferring IBI ownership to the owner of the equipment could improve the quality of IBI, as the owner of the information would stay the same, making it possible to keep the information up to date.

Although our case companies currently had most value from IBI in lowering costs, we recommend planning its collection and use as an enabler for new products and services. The value of IBI could be significantly higher in increasing revenue. The possibility of new services means that it should be easy to change the scope of collected IBI according to the needs of changing business contexts. Manual gathering of IBI requires motivating maintenance technicians for maintenance reporting and other manual IBI gathering. IBI quality should be measured and root causes behind poor IBI quality analyzed in order to focus improvement actions to where the gains are largest. IBI should be seen as a resource and enabler for various uses, including IoT applications. Identifying possible utilization, the needed data analysis efforts and evaluating the value that is possible to gain with the collection and utilization of IBI should guide future developments into maximizing the realized value of IBI.

C. Limitations of our study

The primary limitation of the research is a consequence of the chosen method. While case studies enabled us to gather detailed understanding on the value of IBI in the studied context, at the same time we have to avoid direct generalizations to other contexts [27, 28]. It is the task of future research to evaluate whether our findings apply to other contexts, which could best be done using methods for increasing the external validity, such as surveys or other quantitative methods. We used multiple sources of evidence to increase the construct validity as proposed by Yin [27]. These sources included documentation, interviews and observations. The study was compared with similar literature to sharpen its generalizability [28]. However, due to the exploratory nature of the study, care must be taken in generalizing the results. Furthermore, our research was conducted in one country with two industrial companies participating in a joint research project. Although the companies have international operations, it would be beneficial to conduct additional studies in other countries to gain a better understanding of other possible factors, such as cultural aspects.

VI. CONCLUSIONS

Our main findings indicate that both industrial suppliers and their customers have difficulties in realizing the full value potential of IBI in industrial service operations. Previous literature has recognized the need for IBI, but not analyzed the different elements affecting its value. We have identified the elements of IBI value in the context of industrial services. These elements are the scope, management, quality, and utilization of the information. The elements are interconnected and making changes in one of them affects the others. Therefore, managers should balance the different elements in order to maximize the value of IBI. Our approach offers maintenance service operations a novel framework of IBI.

More extensive empirical enquiry is needed to define the value of IBI from the customer perspective; especially the ways suppliers can get a better understanding or even influence customer value experience to develop better offerings. Future research should look into the different elements and their relationships in more detail. Another avenue for future research would be to make a systematic overview of strategies companies take to cope with maximizing IBI value, taking into account context and situationally dependent factors.

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