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Abstract

Manual data gathering and data quality in industrial context have been, to some extent, discussed in the existing literature. The focus has been on companies' own staff as data collectors. In the case of industrial companies, own staff might often be the only resource that can be harnessed to data gathering. However, this does not always hold true, and hence exploring also other alternatives is worthwhile. We have identified four data collector groups that can possibly be involved in the manual data gathering process, namely own staff, customers, equipment users and other parties. This paper explores the characteristics of the identified groups as potential data gatherers and provides our insights on how manual installed base information gathering utilizing multiple data collector groups could be approached.

1. Introduction

The role of accurate information is constantly growing in business operations. Different types of data repositories and analyses based on that data offer important sources for business development. Different sources and types of data are needed as well as ascertaining that the data are of high quality.

Installed base information (IBI) plays an essential role in the optimization of industrial services. IBI is utilized in making decisions of correct and accurate preventive maintenance plans and in targeting the sales of modernization packages, for example.

Sensors provide technical data via remote monitoring, but some data have to be collected manually. This manually collected data typically include operational and cost related data from service operations, such as hours spent at the site and spare parts used. Thus, manually collected IBI has a significant role when managing industrial services from business perspective.

Manual collection of IBI has been studied to some extent (e.g., [1,2]), but we argue that there are several unexplored data collector groups that can provide IBI for optimizing industrial services. Our paper explores manual IBI gathering as a process in which several different groups of people may potentially be involved. Based on our research, we feel that it is essential to approach manual data gathering in this broader sense. Companies should consider all the possible channels for obtaining good quality IBI in order to maximize the potential benefits.

This paper is structured as follows. We first briefly explore the concept of installed base information and how it is utilized. Then, we summarize previous literature on manual data collection. Thirdly, we present our classification of potential data collector groups that could be utilized in IBI gathering, and reflect our experiences from industrial studies. Finally, we end our paper to conclusions and discussion.

1.1. Methodology

The research projects that have provided the material for this paper have involved two globally operating Finnish equipment manufacturers that also provide maintenance and operation services to the sold equipment. The other one of

companies also services competitors' equipment in addition to its own equipment.

During our research, material has been collected through interviews, contextual inquiry and group discussions with representatives from the involved companies. Our primary research interests steering the material collection were current workflows and work environment of maintenance workers, motivational factors in manual data gathering, customers as data gatherers as well as involvement of ordinary citizens in manual installed base information gathering.

2. Installed base information

IBI includes information about the installed item, its location and events involving it, such as maintenance or repairs [3]. It can be derived from various information systems (manufacture, sales, etc.) or it can be collected automatically through sensors (remote monitoring). However, there are data that have to be collected manually. Examples include information about spare parts that were changed during maintenance or reasons behind an outage. This information can be reported by the customer or by the service provider. Currently, there are challenges with the accuracy and availability of this information.

By collecting, analyzing, and interpreting strategic product usage and process data suppliers can design and sell value-added services that enable customers to attain improvements in productivity and cost efficiency [4]. Based on the observations and findings we have made during our research projects we state that IBI plays an essential role in a number of functions. Firstly, this information can serve as a key source for making correct and accurate preventive maintenance plans. Furthermore, sales personnel may utilize up-to-date IBI as they make decisions on where to sell modernization packages or new substitutive equipment. Correct and timely information can also be invaluable in order to provide customers with the best possible service level. For instance, one of the companies involved in our research uses IBI to optimize the operation of equipment installed in their customers' site. This has resulted in improved performance and savings for the customer.

Although remote monitoring can often be utilized in IBI collection to some extent, observations from our research projects clearly indicate that usually a number of information pieces require manual acquisition. In some cases, manual data gathering can even be the only option, as the possibility to automatically receive data does not exist. In these cases, the quality of manually acquired data plays an especially crucial role.

In certain service business domains, equipment turnover in the service base can cause problems with keeping IBI up-to-date. When a service contract is lost to a competitor, the visibility to the equipment is lost. During that time the competitor may make changes to the equipment, and when the service contract is at some point won back the IBI at hand may be outdated. Therefore, trying to find means for keeping the IBI up-to-date is of great importance.

3. Manual data gathering

Unsworth et al. [2] state that although a trend to replace humans with sensors as the diagnostic element has been widespread, certain elements of the failure diagnostic process cannot be easily handled without the presence of human actors. Sensors only provide discrete data regarding variables (e.g., temperature) that can indicate failures but human observation is needed to form a deeper understanding of the failure cause.

Literature recognizes motivation as an important factor affecting the success of manual data gathering (e.g., [2, 5]). Motivation can be further elaborated, and Ryan & Deci [6] divide motivation into two sub-types: intrinsic and extrinsic motivation. Intrinsic motivation is the need to be adequate and in control; doing something because it is interesting or enjoyable. Extrinsic motivation comes from pursuing an external outcome, such as a monetary reward. Unsworth et al. [2] approach the motivation towards manual data gathering through goal hierarchies. Their approach leans on the premise of goals being at the core of motivation. According to Vancouver et al. [7], people are motivated to act in pursuit of achieving their conscious or subconscious goals. The goal hierarchy as presented in [2] consists of four levels, namely task goals, personal projects, identity and values, and it illustrates the interrelations between goals steering people's behaviour. The bottom level, task goals, consists of goals related to daily tasks that are needed in order to achieve the higher-level goals. The level of abstraction increases when moving up in the hierarchy, all the way to the value level that contains abstract concepts such as happiness. Motivation plays a central role in achieving the goals. The more connections a low-level task goal has to upper level goals, the more likely this task will have high priority and the worker's motivation to carry out the task is likely to be high. On the other hand, if a task goal (e.g., gathering IBI) does not serve the achievement of higher-level goals, the motivation is likely to be lower. In regard to predicting the likelihood of good quality data input from workers, it is important to view the overall pattern of goals and their connections rather than concentrating on single elements [2].

Unsworth et al. [2] highlight a set of reasons why data collectors feel they are not collecting high quality data. Firstly, motivation towards data gathering is low if data collectors do not consider data gathering as being part of their job. Data collection can also be considered as additional paperwork, hence not being fascinating. Further, data collectors may feel incompetent what comes to data gathering, and therefore be unwilling to participate. Lastly, some workers may fear that the gathered data could somehow be used against them, which makes them reluctant to collect data. [2]

According to previous research many factors can potentially reduce the chances of getting high quality manually acquired data. Insufficient training and deficient data collection guidelines can negatively affect the quality of manual data gathering [8]. Problems can also occur due to people's manifold interpretations of complex equipment involved in the data collection [9]. Also, the important role of

education regarding the importance of good quality data has been highlighted [5]. Sandtorv et al. [9] bring out the challenges in getting people with adequate competences to collect the data. Regarding the potential effects of work environment and the nature of work tasks, it has been suggested that operator time pressures are likely to affect the quality of collected data [1].

The quality of manually gathered data can also be negatively affected by poor management structures that do not promote accuracy, completeness and timeliness of data reporting [8]. Tayi et al. [10] touch on the same subject by identifying inadequate specification of appropriate data quality level and lack of weight put on data quality as problem areas. Furthermore, Tee et al. [11] name management's commitment to data quality as well as data quality awareness as important factors in the pursuit of high-quality data. The importance of effective management and operator feedback as well as fluent communication amongst involved stakeholders has been brought up by multiple authors [1,5,11].

4. Potential data collector groups in IBI gathering

Literature on manual data gathering exists to some extent as presented in the preceding section. However, in the light of our exploration, the current literature seems to lack an examination regarding other possible sources of manually collectable IBI besides the companies' own staff. We argue that this subject needs elaboration in order to entirely understand and exploit the possibilities in manual data gathering. In our past and ongoing research projects we have identified four data collector groups that can be involved in the manual IBI gathering process. In this section, we explore each of these groups in more detail. The identified data collector groups are illustrated in Fig. 1 below. For the sake of understanding the overall picture, we have also included other sources of installed base information, namely remote monitoring and information systems, in the picture. However, these are not in the focus of this paper and therefore not discussed in detail.
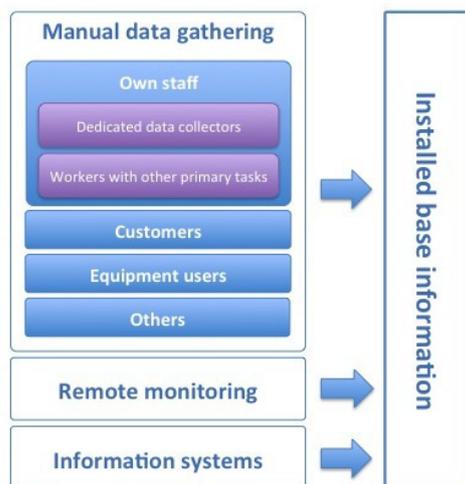

Fig. 1. Sources of installed base information.

4.1. Own staff

The first of the data collector groups in our classification is own staff that consists of company's own employees. We further divide this group into two sub-groups, namely 1) dedicated data collectors and 2) workers with other primary tasks. By dedicated data collectors we mean persons whose primary task on a site is to collect IBI. However, they may also have other off-site work duties. The practices of having dedicated information gatherers may vary depending on, e.g., the country. The second sub-group, workers with other primary tasks, includes all workers that, in one way or another, perform work tasks with the installed base but whose primary work tasks do not include IBI gathering. In the context of our research, this group includes skilled technicians and the manufacturer's maintenance staff. These persons could collect IBI alongside their primary work tasks while they are at the site.

In our classification, own staff is the only data collector group that existing literature on manual data gathering and data quality seems to explicitly recognize. Challenges related to data collection in this kind of a setting were presented in the preceding section exploring manual data gathering. In addition, we refer to research on computer supported cooperative work (CSCW) by Grudin [12] as a relevant examination regarding division of work tasks in an organization and the resulting effects on worker motivation towards certain tasks. Grudin presented that people benefiting from the use of certain work-related applications are often not the same ones as the ones putting in the additional effort. This leads to failures of these applications [12]. This same problem applies also to the context of manual data gathering - the person gathering the information may not benefit from the use of that information which can result in a diminished motivation to collect data.

In the course of our research, we have observed factors that affect manual data gathering as a process and the quality of collected data. First and foremost, workers' motivation plays a crucial role. The data gatherer has to have a proper incentive in order to be motivated. According to our findings, the motivation for information gathering can be generated through at least three alternative ways. Firstly, direct monetary compensation or some other kind of reward (e.g., vouchers) can be used to whet workers' appetite for gathering information. Secondly, information gathering may bring intangible benefits for the information collector, which can positively affect attitude and motivation. An example of such benefits is something that eases the person's other tasks. The benefit can either result directly from the worker's actions regarding information gathering, or another party can grant the worker certain benefits as a reward. Lastly, the workers' motivation may be improved by promoting the meaningfulness of information gathering through effective communication, hence making workers feel themselves important. The most suitable motivational strategy may not be any single one of the aforementioned means but a combination.

In the case of the group of workers with other primary tasks, we have found out that integration with other work

tasks is crucial. Workers are not motivated to perform an additional task if it causes significant deviation to their current workflow. Moreover, our observations point out that usability of the tools used for entering information affects both the quality and quantity of provided information. We propose that solutions with weak usability hinder information-gathering process by causing inability to provide the information and decreasing workers' motivation to provide comprehensive and good quality information. Similar to the findings reported in the literature, we have noticed that lacking or insufficient training and guidelines on data gathering are likely to negatively affect data quality. Also, depending on the case, workers with varying competence levels may be involved in data gathering, which can result in data quality problems. Our observations suggest that elaborate, comprehensible and uniform data gathering training and guidelines should be provided to all workers that are or could be involved in the IBI gathering process. Similar to the literature, we have also made observations related to communication issues. According to our findings, maintenance workers have a great amount of precious knowledge regarding the installed base. However, this knowledge is not currently utilized due to lack of awareness and weak communication between field workers and the other stakeholders within the company. Lastly, our findings indicate culture as being one aspect potentially affecting the quality of manually gathered data. Besides the cultural differences in global scale, also organizational cultures vary possibly affecting manual data gathering.

The workers in the first sub-group of own staff have no other tasks that would interfere with information gathering so they can fully concentrate on it and they have enough time to do the task well. What comes to motivation for collecting good quality information, it is likely to be naturally high because the evaluation of the worker performance is based on the quality of information gathering. The persons in the second sub-group have their primary work tasks that are handled as the first priority and information is gathered if there is time left for it. The nature of the site visit can be one factor affecting the time left for gathering IBI (e.g., regular maintenance visit versus fault visit). Because information gathering is not a primary work task based on which the performance of workers in second sub-group are measured, the natural motivation may not be as high as with the dedicated information gatherers.

4.2. Customers

Customers who either own the equipment, or buy services that are provided by using the equipment (e.g., power-by-the-hour engine services), form the second data collector group. The literature has recognized the need for IBI from the customers in the context of service innovation [13]. However, the data are also needed in service provision. The customer needs to gather and provide information, such as usage data, environment information and location data, to enable value-added services provided by the manufacturer or a third party service provider. The data collector group of customers encloses a variety of different people working for the customer, which means that people with varying job roles are

involved. Furthermore, people in different job roles can have varying incentives when it comes to gathering IBI, which brings additional flavor to the entirety.

Similar to company's own staff, we have noticed that also with customers as data collectors, usability of the tools utilized in providing the information has clear effect on the quality of manual data gathering. Bad usability causes confusion and leads to mistakes when providing information as well as leads to frustration and reduces motivation to provide data. Moreover, majority of the other affecting factors already mentioned with regard to companies own staff hold true with customers as data collector as well. These factors include provided training and guidelines, variability in the competence levels of data collectors, integrality with other tasks as well as culture and organizational conventions.

Like the second sub-group of own staff, the persons in this data collector group have other duties based on their role in the customer company, and information gathering is of a lower priority compared to the primary work tasks. The incentives for collecting information are likely to differ from those of company's own staff, and they may also vary between involved persons that work at different positions in the customer company. It can also be so that the benefits that the customer company gets in exchange for the gathered information are more likely to interest the executives of the company than lower level workers that may be the ones gathering the information.

4.3. Equipment users

As a third data collector group we have identified equipment users. By equipment users we refer to ordinary citizens who have no particular tie to the company at issue but who use the products or services provided by the company. Whether companies have users amongst ordinary citizens depends on the product and service offering of the company. Among industrial companies this is less common compared to companies providing consumer products and services, but these kinds of companies do exist. If an industrial company has users among ordinary citizens, these equipment users can, in practice, provide the company with IBI. In our research, we have used the term industrial crowdsourcing when discussing ordinary citizens as IBI gatherers. This brings a whole new dimension to the discussion around manual data gathering, which has not been touched in the previous research.

The term crowdsourcing was coined in 2006 jointly by Jeff Howe and Mark Robinson [14]. Howe defines crowdsourcing as *"the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call"*. The job can be performed either collaboratively by many people or by single individuals. Brabham [15] presents crowdsourcing as a web-based business model for distributed problem solving. Indeed, a number of remarkable examples of crowdsourcing are web services. Amazon's Mechanical Turk (AMT) [16] and applications based on the AMT platform are often highlighted examples of crowdsourcing services (e.g. [17,18,19,20]). AMT is an online marketplace where companies can find persons to perform

small tasks that would be challenging for computers to perform [17]. These micro-tasks requiring human intelligence may include things like identifying information pieces from photographs and finding relevant information [18]. The tasks in Mechanical Turk require little time and effort, and offer a small compensation [17,18]. Crowdsourcing is also utilized in other applications such as product design, stock photography and scientific problem solving. Besides the companies solely built around the crowdsourcing ideology, also companies with traditional business models have explored the possibilities of crowdsourcing, e.g., in their marketing activities and even in examining geologic data in pursuit of identifying new potential targets for finding gold [15]. In addition to business applications, prime examples of crowdsourcing are textual knowledge bases such as Wikipedia and Yahoo! Answers [19]. Furthermore, crowdsourcing has also been applied in the contexts of disaster relief and supporting people in developing countries, for instance [21]. Despite of the undeniable advantages and possibilities of crowdsourcing, it involves certain challenges that need to be considered, namely recruiting of contributors, determining what they can do, developing a good practice for combining contributions and dealing with the possible abuse [19].

Equipment users can be considered as the least traditional one in our listing of the four potential data collector groups. When exploring this group it is important to notice that collecting IBI is not inherently interesting for most equipment users. It may also be challenging to get the users to see the potential benefits they could get from providing the information. According to our findings, building motivation amongst this group of data collectors is likely to require more of the extrinsic motivators such as direct monetary compensation, vouchers, movie tickets or free subscriptions to services. We also found that inclusion of game-like elements as well as social aspects may increase the interest towards information gathering by making it more engaging, even though other compensation was expected besides that. With right kinds of motivators people seem to be willing to participate in the data gathering process. Some of the important characteristics of the group of equipment users to be considered are the facts, that users may spend a very limited period of time with the equipment and there may be distracting factors that hinder information gathering.

One challenge when considering the group of equipment users as data gatherers is to determine the proper form and amount of compensation. On the one hand, equipment users seem to expect a reasonable monetary compensation, but on the other hand, the profitability from the company perspective may suffer from too high compensations. The company needs to make calculations on the value of information for the business and based on that determine the possibilities regarding the amount of compensation. Making the information gathering task convenient and as little time-consuming as possible enables the compensation to be lower. Our findings indicate that taking photographs is considered as a convenient way of gathering information, requiring only minimal effort. What comes to sending the photographs to the company, cross-platform mobile messaging apps such as WhatsApp Messenger were considered as good alternatives to

utilizing separate native apps or web pages for uploading the pictures. From the company perspective, receiving information in picture format complicates the direct use of information. However, there are solutions, such as utilizing crowdsourcing for extracting the desired information from photos in a similar manner as with Mechanical Turk. Also pattern recognition algorithms are constantly developing, which may, at some point, provide one viable option for extracting information out of pictures.

4.4. Others

In certain business domains, it is possible that external inspection agencies gather information regarding the installed equipment while they are making inspection reports. They may also have own databases where this equipment information is being stored. Hence, these authorities can be considered as one potential source of IBI. According to our company contacts, a representative from the own personnel can also sometimes be sent to accompany the person from the inspection agency, which provides an opportunity for gathering IBI.

Insurance companies collect IBI and use it in estimating risks. They also provide information to their customers when pointing out risks in customer operations. Vice versa, if customers can show that they manage their risks, for example, by collecting and analyzing IBI, insurance companies may be willing to lower insurance payments due to lower risk levels.

5. Conclusions and discussion

Manually gathered IBI is important for a number of business functions. However, our research findings indicate that the current flow and quality of manually acquired IBI does not live up to expectations. We claim that increasing the awareness of all potential sources of IBI is an important step towards maximizing the odds of getting all the needed manually acquired information.

In this paper, we have presented potential data collector groups for manual data gathering that we have identified in the course of our research. We do not claim that all of the listed groups are applicable in each case, but rather try to widen the perspective from solely looking at own staff as information gatherers.

With each specific case it is first necessary to identify the relevant data collector groups out of all of the possibilities. After that, the set of information that is truly needed needs to be defined. We claim that it is not reasonable to collect large amount of information just in case it might be utilized at some point - the true usefulness of most of it may end up being debatable. Smaller set of information also increases the likelihood of actually getting all of the needed information.

When planning the manual data gathering process, it needs to be considered that each data collector group has its own characteristics regarding incentives and preferred means to provide the information, for instance. Also, all of the involved groups may not be capable of providing every piece of information, and therefore the gathering of information may be divided between the groups. One crucial aspect to consider

with regard to all of the selected data collector groups is to identify the proper benefits and suitable baits that could be offered to people in order to motivate them to gather the information. Again, these are likely to vary between the different data collector groups. Finally, it is important to have a system that effectively integrates the information pieces received from the different data collector groups so that the information is easily utilizable in different business functions.

Our goal with this paper has been to open the discussion regarding all potential stakeholder groups that could be harnessed to manual data gathering. Based on the material we have been able to collect so far, we do not intend to give ready answers or detailed instructions, but rather widen the current perspective on manual data gathering and provide a basis on which further research can be built upon. Future research agenda could, for example, include in-depth case studies regarding the applicability of the different groups of data collectors in different situations, and further exploring incentive structures and suitability of the different motivators for the groups. This would provide a decent basis from which more elaborate suggestions for how data collection could be organized and implemented could be derived.

Acknowledgements

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