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Requirements & Enabled Improvements Related to the Implementation of Advanced Preventive Maintenance Methods

Popular Scientific Summary
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These days many service providers experience an inefficiency in their delivery due to its time-based nature. This thesis explores different methods which instead are based on the analysis of IoT data. It hopes to serve as a guide for companies to understand their limitations and opportunities in the development and implementation of advanced preventive maintenance methods.

Well-established technology-based manufacturing companies that conduct service activities themselves provide their markets with innovative and reliable products. Despite this, these firms often find their service delivery process to be inefficient. This is because they, oftentimes, are based on a timely routine. Time-based maintenance methods lack efficiency in several aspects, they may lead to high downtimes or to extensive service visits, they are also difficult to fine-tune for optimal performance. Furthermore, the markets on these companies are currently experiencing a shortage of qualified service personnel and thus sees a need to optimize the existing service delivery process. With today's fast development of IoT and the rapid increase in connected devices, it is now possible to gather a large amount of data related to the machines' operational condition. The data can then be analyzed in order to provide insights into the underlying factors of machine breakdowns and used to implement other, more efficient, maintenance methods. This knowledge may also create new opportunities for companies in the form of novel revenue streams or extensions of their current offering.

This thesis investigates the requirements and possible effects related to the implementation of these types of maintenance methods. Preventive maintenance methods based on quantitative analysis of IoT data, where the data is gathered from connected units in an industry environment. It is a case study of the company ASSA ABLOY Entrance Systems located in Sweden. Two analyses were conducted in parallel. One organizational analysis, focusing on the company, its market, and the possible implementation of outline advanced preventive methods. The second analysis focused on the quantitative IoT data, and centralizes on exploring advanced preventive maintenance through established data analysis methods.

The organizational analysis of the case company's possibilities of implementing more advanced maintenance methods started with an introductory market analysis of the after sales service market for entrance systems. Which established that order winning parameters centralizes around unique skills and expertise while order qualifying parameters focus on price and non-value adding attributes. The analysis continued by identifying the best suited maintenance approach for its given situation, which utilized an analytical hierarchy process of the identified maintenance approaches. Three seminars were held together with employees affected by the decision and concluded that predictive maintenance is the best suited approach for the case company's current situation.

From the thesis's initial literature study it became clear that an IoT-based service offer will change the business model of a conventional service offer. Hence, an IoT-centric business model was implemented. The business model contains four elements, *What*, *Who*, *How* and *Value*. The what-dimension is summarized as offering predictive maintenance as a service, while the who dimension consists of the customers affected by the offering. The most central aspects of the framework is the How and Value elements. Where the How aspect refers to the processes and activities related to developing and offering the predictive algorithm, which is summarized through two key activities. The activities consist of; finish the development process of the predictive algorithm, during which the order winning parameters should

be prioritized. Developing an intuitive application interface for the product, so customers easily can interact with and understand the product. Lastly, the Value dimension explains why the offering is financially viable. This is summarized through three characteristic traits of the service offering. Firstly, predictive maintenance has the potential of significantly reducing reactive service visits, a benchmark study established that predictive maintenance has the ability of reducing reactive visits up to 66%. This entails that the fleet of educated service technicians can be reduced through this offering, and enables the case company of reducing its total personnel costs in the range of 14%-37%. However, to gain the full financial benefits of the offering a transformation of the conventional pricing system is required. Where instead of charging fixed prices for services the price should be based on delivered performance, preferably delivered up time.

Lastly the organizational analysis was finalized through applying applying focusing on the current service delivery process. From which it became clear that through offering predictive maintenance as a service the service delivery process will see a significant increase in its technological dependence. Where connected devices, gathered IoT data, labeled historical service data, and complementary data will become a central part of the service infrastructure. Additionally, the service related infrastructure will assist the service delivery process in its continuous improvement of the prediction model.

The analysis of IoT data was done with an exploratory approach. This included searching for relationships between different types of data and devices, identifying normal and abnormal patterns or machine behaviors, and examining the impact maintenance work had on these behaviors. The data was divided into five types: *Cycle data* (counters of operating cycles), *Sensor data* (temperature and current), *Other parameters* (settings and software versions), *Event data* (log messages describing happenings and machine states), *Error data* (log messages indicating something wrong).

The aim of this analysis was to gain sufficient knowledge to be able to construct prediction models for machine breakdowns. Even through earlier studies have shown successful results in this regard it was concluded that this would not be possible in this study. Therefore, the focus were shifted towards understanding the requirements and finding the missing pieces. The most notable was the lack of complementary data to the IoT logs, such as maintenance history and data describing the devices and their characteristics. Secondly, the data used in this study ranged over six months. However, it became apparent that this period was shorter than the average time between breakdowns. A longer timespan is therefore assumed to provide a better understanding of device behavior and if/how it changes over time, something that the study failed to demonstrate. A larger set of devices would also be beneficial, both in learning the "normal" operations and in observing the deviating situations. A third issue that was identified was the high variance among measurements. Both between devices, which seem to have a low level of standardization, and within the measurements for individual doors. This lead to it being difficult to find strong relationships between the different features.

As for future research, the thesis lacks generalizability since large portions of the analysis are solely based on data collected from the case company, both in the organizational and the quantitative IoT analysis. To broaden the view it would be beneficial to include comparisons with other companies, both within and outside the own sector, in similar situations with resembling business models as the chosen case company. This could give insights into what issues are unique and which are more commonly occurring. An important realization in order to optimize the strategic path forward

Furthermore, the analysis of IoT data from the case company should preferably be extended. An extended analysis should include several of the denoted "missing pieces", such as complementary data and a longer timespan, in order to evaluate the possibilities of producing prediction models.