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TECHNOLOGY, COMMUNICATION AND TRANSPORT

DYNAMIC SPARE PARTS RECOMMENDATION IN A GLOBAL MINING COMPANY

Case Normet Group Oy

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Abstract

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Abstract

The thesis introduces the reader to the basic concept of spare part recommendations for industrial machinery. This thesis project was scoped to be carried out for Normet Group Oy, a Finnish company that offers different solutions for mining and tunneling processes. Some key drivers to be mentioned are safety and sustainability.

The topic is well known at the case company Normet but there has not been one workable solution or process to handle spare part recommendations. The main goal of the thesis was to list the findings that the author has been facing during his period of working around the topic and to find solutions and ways how these challenges could be rectified. Findings have been recorded and the solutions are introduced to the reader.

In the outcome of the thesis it is described how the new dynamic spare part recommendation could be gathered using different sources and what information it could include. Also, different use cases for the introduced file are presented to the reader.

Keywords

Mining, tunnelling, spare parts, demand, forecast, maintenance, service, aftermarket

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ABBREVIATIONS

SPR = Spare Part Recommendation

PDM = Product Data Management

ERP = Enterprise Resource Planning

OEM = Original Equipment Manufacturer

DOS = Days of Supply

EOQ = Economic Order Quantity

SKU = Stock Keeping Unit

BOM = Bill of Material

IB = Installed Base

PM = Periodic Maintenance

IOT = Internet of Things, in this thesis it refers to equipment that is connected to a network and is able to send usage data

1 INTRODUCTION

In the time of authoring this thesis the services business line's turnover was higher compared to the equipment business line and currently this is the direction where many companies are heading. The importance of a well working and organized service structure cannot be emphasized enough, and it is a key factor in the growing mining industry and also a condition of continuity. Normet Group Oy (later Normet) being a market leader in its business and its production capacity growing also the importance of after sales increases. Spare parts recommendations are vital assets that are valuable to the customer and have the possibility to increase the aftermarket sales of Normet.

1.1 Background, Spare part recommendations

A spare parts recommendation (later SPR) is a list of spare parts for some certain machine and period of time. The mentioned items are the ones that are needed to keep the equipment maintained and working as well as the process running. Most of the spare parts have a certain change interval, which predicts and determines the lifetime of a spare part. This affects straight the number of spare parts needed for each hour level, meaning that a spare part recommendation for 1000 hours of operation recommends 4 pieces of a spare part that has a change interval 250 hours. These lists may vary for several reasons, e.g., location and conditions of the operating site or the age of the equipment.

There are also many reasons why these SPRs are requested, created, and used. The owners of the equipment do want to avoid prolonged periods of machine down situations in which the machine is not able to operate and the owner loses the opportunity to earn. With the predetermined service tasks and preventive maintenance the possibility to breakdowns and downtimes can be minimized and the equipment operates more continuously.

As important as maintaining the machine and having the spare parts available, is the availability of items that have a long delivery time and/or have a tremendous impact on the operation of the machine compared to the cost of the spare part itself. As an example, the price of this kind of spare part might be only a few percent of the cost of the machine having to wait for the part to be delivered. Because of this reason it might be better to buy it even though it might not ever be needed as the costs keeping a spare part available is much less compares of having a machine that cannot be operated and might even be stopping the whole mining process.

Besides having the right number of right items on hand the end user might also use the recommendation for spare parts cost estimation for some certain period of use e.g., first 1000 hours of use.

The manufacturer of the equipment is the most trustworthy to provide and create the recommendations as they have the knowledge and data. Normet has big fleets around the world in vastly different conditions. Data of spare parts usage is recorded, and this can be used as base for the data to determine for example different hour intervals for different items.

Spare Part Group	Spare Part ID	Spare Part Description	Qty per EQ	Qty 1000h	Price	Total
Service parts engine	100048353	AIR CLEANER ELEMENT, KIT	1	4	- €	- €
	100172172	FUEL FILTER	1	1	- €	- €
	100172145	FILTER	1	1	- €	- €
	100021343	ENGINE OIL FILTER	1	3	- €	- €
	100172115	POLY V-BELT	1	1	- €	- €
Service parts transmission	100018677	TRANSMISSION OIL FILTER	1	3	- €	- €
	57412510	BREATHER ELEMENT	1	3	- €	- €
Service parts hydraulics	57624780	RETURN OIL FILTER	1	3	- €	- €
	100013076	PRESSURE OIL FILTER ELEMENT	1	3	- €	- €
Service parts compressor	57822298	OIL FILTER	1	3	- €	- €
	100122937	OIL SEPARATOR	2	2	- €	- €
	100025945	FILTER MAT	1	2	- €	- €
Service parts boom	45330925	LOCKING PIN	1	1	- €	- €
	45331055	PIN	1	2	- €	- €
	100036080	PLATE	2	2	- €	- €
	100036094	PLATE	2	2	- €	- €
	100036079	PLATE	1	2	- €	- €
	45938580	SLIDING PART	4	8	- €	- €
	45396730	SLIDING PART	6	12	- €	- €
	45396740	FLEXIBLE PLATE	2	4	- €	- €
	45936040	SETTING PART	6	6	- €	- €
	100044391	SLIDING PART	1	2	- €	- €

FIGURE 1 Part of a SPR

1.2 Case company, Normet Group Oy

Normet was established in 1962 in Iisalmi back then known as Peltosalmen Konepaja. It is still located in Iisalmi even though the manufacturing facilities have been renewed and extended several times. Normet manufactures machinery for underground mining and tunneling and besides those Normet offers also e.g., chemicals related to mining and tunneling. Currently Normet employs globally more than 1600 professionals in various locations and offices. With having delivered more than 14000 machines Normet is one of the market leaders in the world.

The current machine offering covers processes as concrete spraying, explosives charging, scaling, underground logistics and there is also offering for chemicals for example for water control. Depending on the requirements and wishes of the customer the machinery can be bought with conventional diesel engines or as battery electric vehicles.

The cornerstones of Normet way of working are strongly related to safety and sustainability. This can be seen in the equipment offering, which aims to a safer working environment at the working site, but also during the manufacturing phase.

FIGURE 2 Normet SmartDrive battery electric vehicles

1.3 Objectives

The objective of this thesis was to figure out the current challenges faced when creating a spare parts recommendation and how these should be dealt with in the future. For being able to deliver a high quality SPR these challenges must be known and taken into account. It is also known that the creation of the recommendation requires in its current state a lot of manual work and thus also time. The aim, a dynamic spare parts recommendation, would mean that the creation of the report would not anymore require manual labor and it could be created all around the world automatically, quickly, and with reliable content.

1.4 Scope of the thesis

The scope of this thesis was limited to spare parts recommendations and more precisely in explaining different challenges that have been encountered when working around the topic. The thesis introduces the reader to the topic in a way that the person gets an idea why these recommendations are needed and what is the purpose and benefit of them. The outcome of the thesis is a detailed expression of what a dynamic spare part recommendation could and should be.

1.5 Structure of the thesis

This thesis consists of four main chapters. The thesis begins with the introduction part opening the topic to the reader and introducing the case company. The second main chapter continues with the

theoretical background of the thesis that explains some of the theories used e.g. in determining different aspects and values needed when thinking of best possible ways of creating the spare part recommendations. The third chapter consists of various problems that have been encountered and also solutions to solve them. This chapter includes the most valuable information of the thesis that can be used in the future when having similar issues around the same topic. Even though the focus has been on the problems occurring when creating spare part recommendations, it is still highly likely that new problems can be found and identified. The fourth and last chapter of the thesis consists of the final vision, how and what a spare part recommendation should include, how it can be done, what are the benefits and different use cases for the report. The conclusion of the thesis reveals the future ideas and requirements related to the SPR.

2 THEORETICAL BACKGROUND AND RESEARCH

The work was conducted in accordance with field research by using the means of a qualitative research. Qualitative research fits well for this thesis because it combines work learned practical knowledge through theory. Most of the information has been gathered from discussion with various people in the company in different fields and positions and from the author's own work experience.

Spare part recommendations relate to the aftermarket business and that in turn is related to the creation of demand for spare parts. For that reason, the theoretical part of this thesis explains the connection between the factors mentioned earlier. Spare parts business in general is an exceptional field where demand is extremely hard to predict as the need of spare parts can come by surprise without any warning and it does not follow any usual laws of demand.

2.1 Uneven demand and forecasting

In the field of inventory management forecasting means the ability of being able to predict the demand and sales of a certain item. It is used as a guidance to help when planning inventories and warehouses the same way as weather forecasts help people to select the right clothing when going outside. The circumstances of a misleading forecast would be wrong clothing, or in this case a warehouse full of wrong items that are not going to be sold as planned.

As mentioned earlier forecasting the demands in spare parts business perfectly is often impossible. Surely there are lots of items that are so called "smooth" and frequently sold items, but the challenge comes with expensive and highly sporadic items. Automated forecast tools of ERP software recognize slowly moving items and try to forecast the demand but fail often because there is not enough historical data or any recognizable demand profiles. For the moving items more known inventory management models and conventional forecasting methods as Economic order quantity (EOQ) or Days of Supply (DOS) can be used. These are commonly used in many fields of businesses but both of them are very sensitive to fluctuations in demand, which causes the supply to react too late to the actual demand. When the demand already turns into a growing phase the equation still indicates the demand decreasing, which causes a lack of items compared to the need and demand. This will eventually be fixed but only after a delay.

For the reasons mentioned above, this kind on traditional models might only be used for the frequently moving items. Spare parts are mentioned to be by a big part very stochastic/random by their demand and in some cases not even the customer knows in advance if, when and how many items they need. The main challenges according to Happonen, 2011, are large number of items, which prices vary significantly, the lead times from suppliers to warehouses differ much from each other, there are large differences in the quality of demand and also the cycles and frequency of it.

There are certain basic factors which cause these challenges. Spare parts are often needed in batches or series which creates a spike in the demand as it might be that they are ordered in large quantities. The spikes are often created by the companies ordering bigger amounts of items to avoid shortages to prevent any downtimes. In some fields of businesses there are also maintenance breaks which might again cause short periods of high demand.

The fluctuation of lead times is often caused by the supply chain model that is commonly used in the spare part business. The spare part might be in house design and assembled by the OEM but its subparts are bought from different vendors. Besides that, some OEM's keep items in their own stock, which can be used for production purposes but also for the aftermarket as spare parts.

$$EOQ = \sqrt{\frac{2DC_o}{C_h}}$$

D = demand, pcs. /year

C_o = ordering cost

C_h = holding costs = V * r

V = value

r = holding rate, %

FIGURE 3 Economic Order Quantity formula

$$DOS = \frac{T}{C}$$

T = on-hand inventory

C = avg. daily units sold

FIGURE 4 Days of Supply formula

2.2 Demand-based categorization

Items and in this case spare parts can be categorized for inventory management purposes in different categories based on their nature of demand. A combined table, shown in Figure 5, for deman-based categorization has been introduced by Syntesos & Boylan, Croston, where items can be classified in different classes as per their recognized type of demand. There are four different categories, which all contain a different type of description for different demand types. Smooth, Erratic, Lumpy and Intermittet. These classifications can be determined by the squared coefficient of variation of demand sizes (CV^2), which describes the amount of the demand. The X-axis on the other hand describes mean inter-demand interval (p), which is the time frame between the demands.

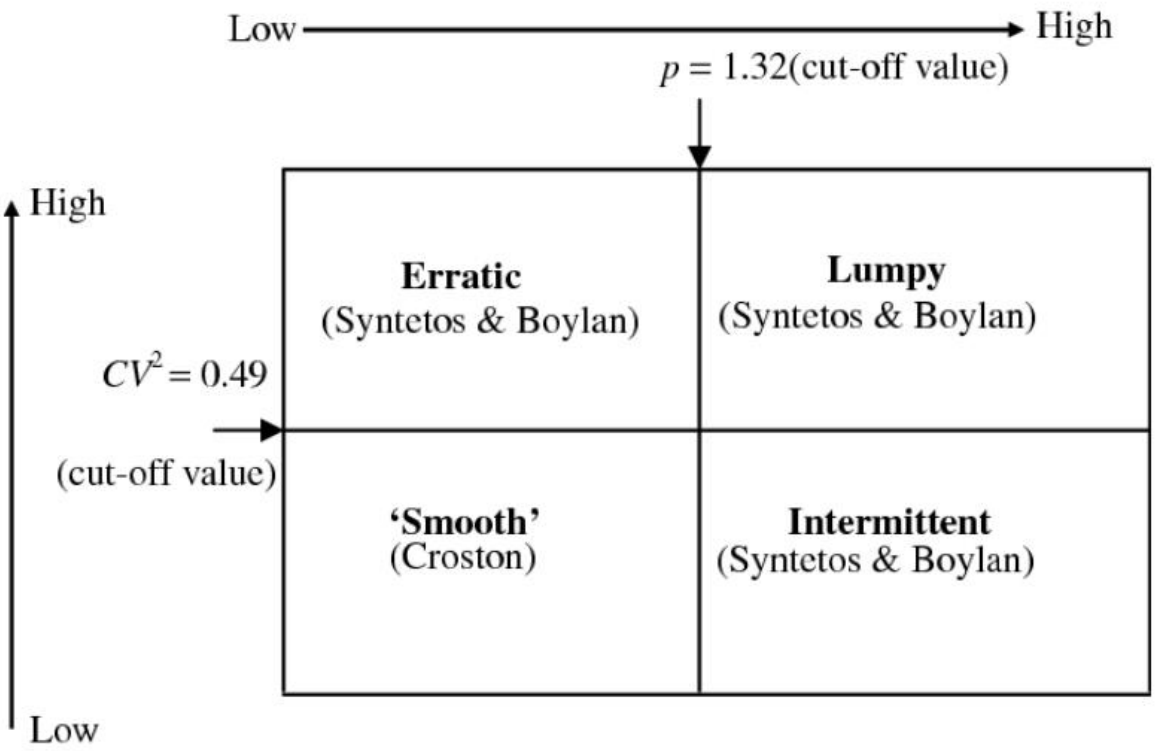

FIGURE 5 Demand-based categorization for forecasting

The definition of the alternative demand patterns resulted from a direct comparison between the theoretical MSE performances of Croston's method, simple exponential smoothing (SES) and the Syntetos and Boylan approximation (SBA). Both, the parameters and their break-point values were the outcome of this formal comparison, and the validity of the scheme was empirically tested and confirmed on 3000 SKU from the automotive industry. The contribution of this work lies in the identification of the CV^2 as an additional categorization parameter for demand forecasting purposes. (Syntetos, Boylan and Croston (2005)

There are multiple similar classification tables that do not differ too much from each other. Depending on the research and the authors the classes can be named differently but the meaning stays more or less the same. In some tables the limits might differ and the specification differ so that the content in each class can be different even though the names are the same. It is difficult to specify these classifications in a way that all of them would have exactly same parameters and specifications.

3 CHALLENGES

3.1 Challenges and difficulties found

In the following chapters under each heading is introduced one challenge or problem and after its possible solution or improvement for solving the problem. The nature of these findings differs a lot and some of them are easily resolved compared to some of them do not yet have any known solution. Most likely there are also a lot more problems that have not been recognized yet and would require a deeper understanding to be identified.

3.1.1 Spare part criticality

The spare parts have a predetermined criticality in the PDM system. Current levels are called Low, Medium, and High. This should indicate if the item is a critical one for keeping the machine running and if it would be able to stop the complete process when breaking down.

Unfortunately, the current ratings are very unreliable and not trustworthy. There are no clear instructions in determining a spare parts criticality and it does not inform whether the item is a safety or operational critical spare part. E.g., a hydraulic pump would be an operational critical part whereas work or driving lights are safety critical items. Besides these mentioned factors a spare part can become critical also by having poor availability or a long delivery time.

By creating clear guidelines for deciding levels of criticalities it would provide more reliable information that could be used also as one factor when creating a spare part recommendation. As mentioned, there should not be different levels of criticalities but different areas of criticality, operational criticality, safety criticality and availability or stocking criticality.

3.1.2 Change of main component

It might be that at some point of the machine's life cycle a main component of it is going to be changed for example due to a breakdown. It means that the engine, compressor or lifting boom will be changed to a new one. It might be possible that for example the original axle that has been installed on the machine at the factory during assembly is no longer available. In such a case the axle will be replaced with a never one that fits for the machine, but it has different spare parts compared to the original and also the change interval hours might differ.

When creating a SPR for a machine that has a changed main component there is a risk that they will eventually get wrong spare parts for it if parts for the old axle are ordered. Changes like in the above-mentioned example need to be recorded and the service structure, Installed Base, needs to be updated so that there will not be risk of inaccurate information to any direction. By keeping up the latest service structure of the machine and the correct components in the installed base bill of materials it can be verified that the spare part recommendation includes the correct spare parts.

3.1.3 Multiplicity of items in the bill of materials

The spare part recommendations always include the information of needed quantity of spare parts required for some certain level of hours, for example periodical maintenance parts needed for 2000 hours of operation. The bill of materials of machines is built in a way that the same items might be located in various different positions which causes errors when counting the total quantity of some certain item. For example, it might be that the machine's BOM has the diesel engine oil filter located in three different places in the BOM which on the spare part recommendation shows up as three pieces of the same filter. If this error is not noticed and someone orders the items with the announced quantity three times, too many will be received.

To avoid this kind of errors in the making of the spare part recommendation, the used data, in this case the equipment's bill of materials, needs to be made to an appropriate level so that it can be used for this purpose as well. Also, there are ways in data management tools to clean the data e.g., of duplicates to avoid certain mistakes.

3.1.4 Creation of a prospect SPR

Sometime SPR's are requested already in an early phase of the machine offering and at that point there is no certain structure or BOM out of which the recommendation could be done. These are needed sometimes in the early stages of the bidding because the SPR can be helpful when calculating the total costs of a new machine, also including the spare part consumption.

It would be beneficial to have SPR's for basic equipment already before the machine is going into the manufacturing stage. Also, the machine's modular structures can be utilized in a way that the spare part recommendation would be gathered of different parts of the machine and compiled in a different way than usual. Still there is no automated way to make a SPR for a machine that does not have an actual structure and BOM created in the system.

3.1.5 Data quality and accurate timing

The spare part data is the foundation for the whole spare part recommendation. The data is stored and maintained in the PDM and also other systems. There are certain processes that are needed to be followed when for example creating new spare parts in the system. If these rules are not followed it might be that the different details and attributes are not set up correctly which eventually will show up as an error of some form. The quality of the data has been improved during the latest years which makes it possible the design and implement automated reports like the spare part recommendation.

In some certain cases where the equipment and technologies have been new and implemented only moments ago it could be noticed that all the needed spare part data has not been available. This is challenging when the needed SPR's need to contain some certain component's spare parts that might not exist in the system yet.

Currently there are certain processes for new components so that the mentioned scenario does not happen anymore. Every new component that is installed in new machines during manufacturing is checked by various persons so that it will be ready also for the aftersales and spare parts business.

Data being the cornerstone of this report, no matter from what system it is fetched, it must be maintained and kept up to date. If the quality fails there is a high risk that the work done creating refined reports, views, and graphs out of it, will not be as valuable as possible.

3.1.6 Fleet spare part recommendation

Currently there is no certain way of taking into account the complete fleet of machines that might be located at the same site. Understandably there is a noticeable difference in the number of required spare parts when there are for example three pieces of the same machines located at one site. For example, it might be unreasonable to have an alternator for each machine reserved in the warehouse, but it would be good to have one piece to cover all three machines.

Many of Normet machines are built using the benefits of modular structure which means that many different machines share in the end many of the same components. Especially for this reason it is beneficial to create the spare part recommendation considering the whole fleet. The easiest way would be to multiply the items by the amount of equipment needing the item, but it might turn out that many of those items will remain unused in the warehouse for a long time and that is one of the main reasons why the content and quality of a spare part recommendation needs to be correct.

3.1.7 Fluctuating quality of SPR

During the past years there have been many different ways of doing spare part recommendations and not only one certain right way. People around the world have different kind of knowledge and also because of this the quality and content of the spare part recommendations vary quite a lot. A person who has been doing the recommendations for years might have better insights about the content than others. Because of the lack of instructions or guidelines and the process being very manual, the end result will be different every time.

By automating the process, the quality could be ensured, and the outcome would be always the same. It would be based on the spare part data that has been set up for the spare parts in the PDM system. The requirement for this to work is, as commonly in many solutions, that the basic spare part and equipment data has to be as well maintained and upkept as possible. This will be introduced further in the last chapter of the thesis.

3.1.8 Lack of follow-up

Currently the spare part recommendations are not followed up, meaning that they do not for example have any individual identification. If the cases would be identified and connected to some certain machines it would be avoided that one machine would get several spare part recommendations. Also, the tracking in sales would be easier and it would enable the chance to investigate how many SPR's actually will lead to a spare part sales.

The solution would be to give each SPR an individual code or reference that would be used to identify the recommendation. This way every recommendation could be connected to a spare part sale and there would be a possibility of gathering different data e.g. percentage of SPR's leading to an actual order and others.

3.1.9 Communication differences

Often the requests are received from all around the world and due to different communication habits, the name of the requested document differs from spare part recommendation to critical spare part list or stocking list. These are all partly related to each other but in the current state neither one of these can be provided directly.

Also the channels from where the requests are sent and received differ a lot from each other and there is not only one way how the request can be received.

The requesting of spare part recommendations should be centralized and only one channel should be used. In this way it could be followed up easier and the amount of request could be monitored in an efficient way.

As mentioned earlier, by taking into use new criticalities for items, the list of critical parts could be created easily. Also, the stocking recommendation could be done using different parameters that could be filtered down from the master file, which will be further introduced in the next chapter. All information related to one certain machine would be available in one list and based on different views and setups it could fulfil different purposes.

4 CURRENT STATUS AND VISION

In this chapter the vision of the future spare part recommendation report is described in a more detailed level. It includes an introduction in different fields of the actual report and from where this information is received. Also, the benefits and possibilities of different ways of using the report are explained and opened up. As the thesis project has been ongoing for quite a long time some of the visions and plans for the future have already been taken in use. Still all the ideas and visions that have been coming up during this work are introduced in the following part.

4.1 Spare part recommendation report

The spare part recommendation report is created by a PowerBI enquiry that fetches the data from the PDM systems Installed Base, the service structure of Normet machinery. Each machine is separated by its own serial number, e.g. GE205 or DJ143, and the master file can be created by selecting a machine that is needed for a certain case. It gathers all the spare parts that are needed for service tasks, have a change interval as 2000 hours of operation, or correct spare part classifications. After the PowerBI enquiry is complete from the PDM side additional information is fetched from the ERP. This populates the existing spare part list with information like lead time, availability information as warehouse balances, prices, and movability classes. After all of the mentioned information is available and gathered you would have the so called "master file" that would be used as the base when creating the final spare part recommendation.

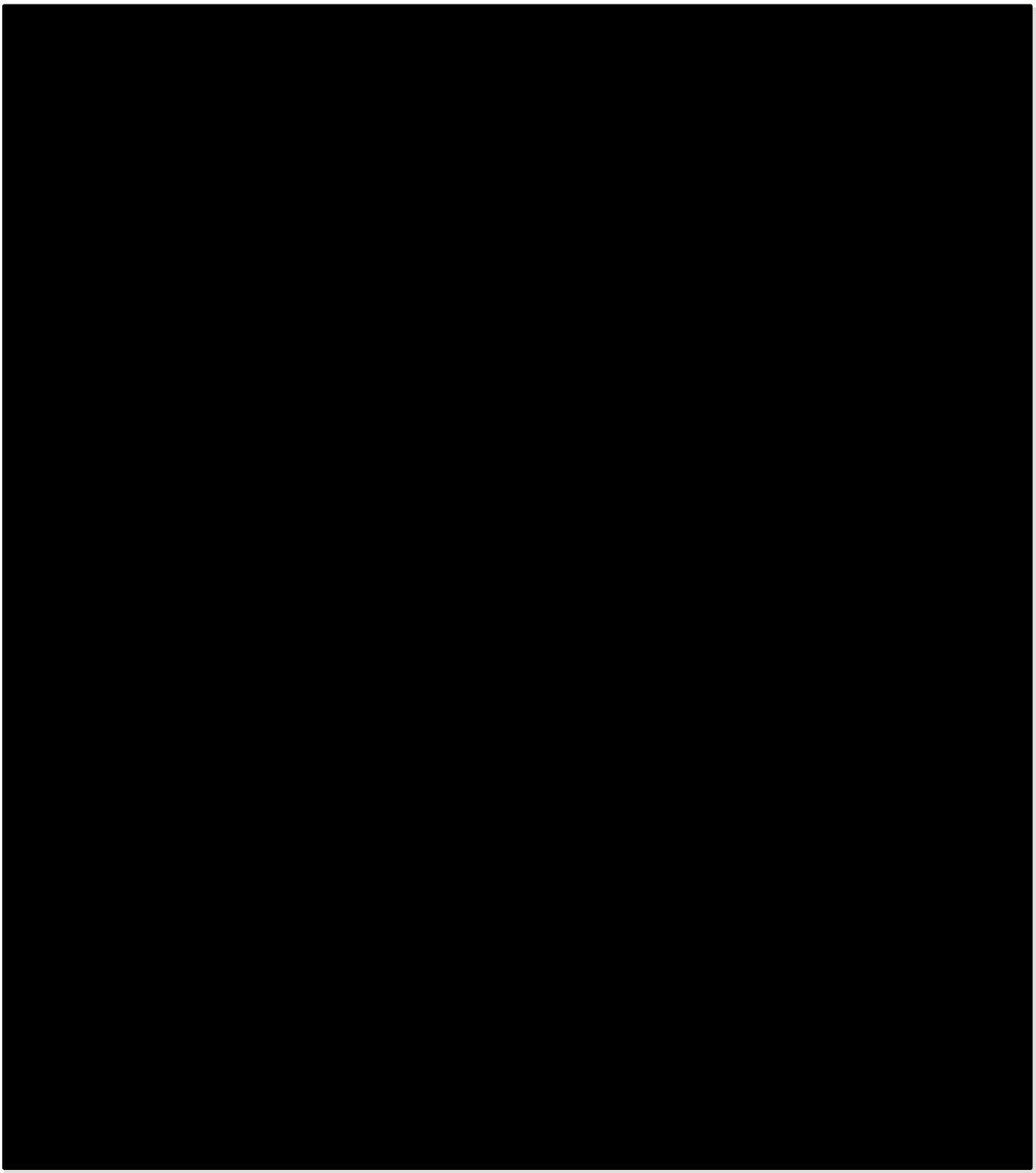

FIGURE 6 Example of PowerBI datamodel

Besides only using the data from the PDM and ERP also other sources should be utilized. The machine fleet information contains information of the assets service history, owner and location. This information is stored and maintained in a field service business application. It is also possible to extract some actual spare part usage data out of it, which can be used in improving the quality of spare part data in general. If this information were utilized, the information in a spare part recommendation would be more fact based and data driven.

Another improvement regarding the visibility to the actual condition of the customers machines can be achieved by IoT. Equipment that is connected to a network and sends usage data which can be seen and analysed remotely. The benefits for the creation of a SPR would be gained by possible alerts caused by improperly working components and the actual operating hours of the machine. With the help of these the content of a spare part recommendation can be focused in a more precise way.

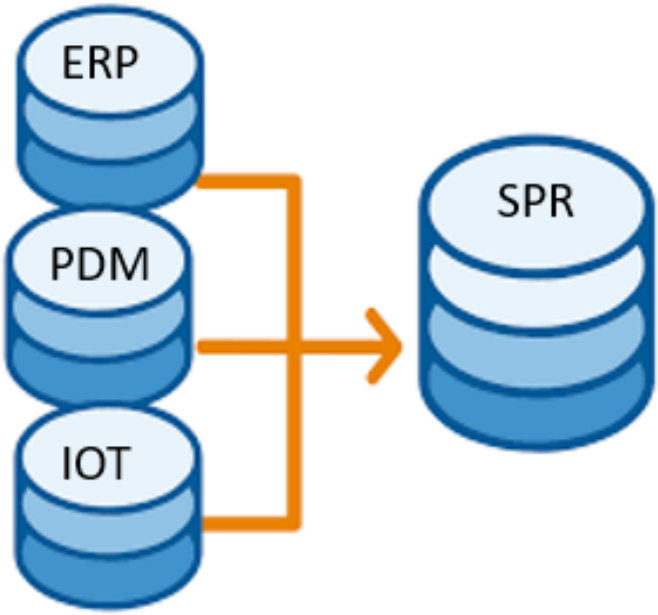

FIGURE 7 A spare part recommendation combines information from different data sources

The dynamicity in this is that the master file can be edited with little effort based on the local needs. This means that a spare part recommendation for a machine located in India might be partly different compared to a machine working in Central Europe. This is mainly the consequence of the location as the customer can rely more on a main warehouse located in Europe compared to machines far away of it. Also, environmental differences affect, as some sites might be very dusty whereas some can be moist and wet. This would for example increase the usage of air filters and also accelerate the corrosion of the machine. The content, number of spare parts and information in general, of the dynamic spare part recommendation is so rich that it will fulfil the needs globally no matter what the conditions are.

4.2 Benefits

The benefits that a customer can experience of an accurate spare part recommendation are for example improvements in the net working capital by optimizing inventories as unnecessary spare parts are not bought. This way working capital is not in inventories and usable for other improvements or investments.

The availability rate of the machines increases also as spare parts for planned maintenance are bought in advance, uptime increases and downtime decreases. This way unnecessary waiting and downtimes can be at least minimized or even avoided.

Within the company a working report saves a lot of time in many stages, as global sales companies do not have to contact the sales support every time a recommendation is required somewhere in the world. The biggest savings are done by having the earlier required manual labour more or less completely automated.

One of the biggest benefits for the company would be the possible increase in the spare parts sales. By having spare part consumption data-based information available it can be shown and justified to the owner of the machine that they will be needing the mentioned spare parts to successfully operate the machine.

4.3 Diverse ways of usage

The dynamic SPR can be used in different varieties and used for different purposes. The different documents can be created by selecting different values and settings from the master file. In the following chapters some of the use cases are introduced.

4.3.1 SPR for different hour levels

The basic SPR would be the list including all spare part items that have a change interval on that certain machine. Besides that, also a certain hour level could be selected, e.g. 2000 hours, so that the report shows and counts the quantities needed for the first 2000 operating hours. The same would be applicable also for different hour levels.

4.3.2 SPR for new equipment

Once the report would be working flawlessly and it would be relatively quick to generate a list of spare parts needed for the first operating year, it would be a good standard practice to generate for every manufactured machine. To work properly this requires that all of the spare part data is accurate and up to date. This would create a standard operating process and the spare part lists for new machines would not be any more dependable of the equipment salesperson.

4.3.3 Market analysis

Once the content of the spare part recommendation is accurate and based on consumption data, the SPR can be used to forecast, at least for periodical maintenance spare parts, what the machine should consume on average. This way it would be possible to notice if some new equipment is not consuming the parts as predicted. This could indicate that the machine owner purchases spare parts from another source besides the OEM. After it were noticed, it could be investigated and some corrective actions could be done.

4.4 The upkeep in future

Information and data have already been gathered for a relatively long period of time and the amount of it is vast. In the future there will be a focus on making use of this for being able to perform better in every part of the business. Data management tools are evolving and there are multiple ways of processing data from various sources and combining these. By analyzing this combined data new aspects can be found and thus service can be targeted more precisely ensuring that the customers would get the most out of their assets and equipment.

As the aim is to proceed towards more and more data driven and automated ways of working, especially regarding the spare part recommendations, there will be a lot of work to be done in gathering and improving the quality of the used data sources.

FIGURE 8 Factors affecting the data quality

The upkeep of the foundation for the spare part recommendation needs to be maintained and updated frequently. The information is going to be gathered from various locations which means that multiple persons need to make sure that the basic requirement of the information is on an appropriate level. Eventually the updates are going to be automated but the validation part needs to be done manually until there is a way to ensure that the requirements are fulfilled automatically.

5 CONCLUSION

Spare part recommendations are a well-known but challenging topic at Normet. Different spare part listings have been done during the years in several different ways manually relying on the knowledge of individuals. There has not been only one determined process to handle the requests concerning different requirements of spare part lists, recommendations, or any of the earlier mentioned documents.

The scope of this thesis was to gather the findings that the author has encountered during his work with spare part recommendations and from that point of view this project can be considered as successful. This kind of work around this certain topic has not been conducted earlier in the company and that makes the gathered information also valuable for the company. It is likely that the information will be utilized in the company and some of the development work towards solutions introduced in this report have already been started. Data has already been gathered and created for a long time and now it is the time to start utilizing it. By understanding and recognizing the exact needs the data sources can be specified more accurately. Knowing which areas of the sources need more improvement and by improving the data quality even more the spare part recommendation will evolve all the time to a more accurate tool.

The schedule of the completion of the thesis changed multiple times and eventually it took much longer to get the work completed. On the other hand, it was beneficial as the knowledge of the author around the topic got deeper than it would have been if the thesis would have been completed following the original schedule.

In general, it can be said that the project was challenging even though the topic was familiar from the related work at the case company. The topic itself can be spread to multiple different areas such as inventory planning, maintenance, or even spare part marketing. There is not only one way how to do a spare part recommendation correctly as there are many different factors affecting to it, as mentioned in the report. This report has gathered some of the main challenges and possible solutions in it and it introduces the content of a future spare part recommendation. By gradually working and moving towards the introduced SPR it can be noticed that a working solution is not unreachable.

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APPENDIX 1: EXAMPLE OF OLD SPR