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A Comparative Analysis of Spare Parts Management in Land-Based and Maritime CMMS

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ABSTRACT: The organization of maintenance means the organization of the workforce (with tools and knowledge) required for maintenance and the provision of the consumables and spare parts required for this maintenance. Therefore, the organization of maintenance is a complex process where it is necessary to use modern tools such as Computerized Maintenance Management Systems to make it as simple and successful as possible. Many industries have developed special systems that meet their specific requirements and needs. The maritime industry has its own peculiarities and differs in its rules and regulations from the land-based industry, and it is to be expected that the Computerized Maintenance Management Systems intended for it will differ from the systems used in the land-based industry. In order to determine the differences between the design of the system in the maritime and land-based industries, four different systems were analyzed in this paper, two for the maritime industry and two for the land-based industry. As no significant conceptual differences were found between the systems, the actual use of the system was analyzed to determine what should be done in the maritime industry within Computerized Maintenance Management Systems to comply with rules and regulations.

1 INTRODUCTION

The maritime industry has many characteristics that distinguish it from other industries in the world. It has mobile assets that often operate on unpredictable routes, travel far around the world and dock in some remote ports… All these characteristics make the management activities in the maritime industry more complicated and complex than in the land-based industry. Accordingly, the organization of good maintenance in the maritime industry is also more complex than in the land-based industry. By definition, good maintenance is the only means of improving reliability "*during the stage of usage of the system*" [1]. Successful maintenance requires that a sufficient quantity of spare parts is made available prior to maintenance, or in other words, spare parts and maintenance are "*closely related logistics activities where maintenance generates the need for spare parts*" [2,3]. Similar to the land-based industry, the cost of purchasing and storing spare parts is an important item in a company's budget in the maritime industry. Therefore, monitoring and managing spare parts is of paramount importance in any serious business, including the maritime sector. Nowadays, the monitoring, management and supervision of spare parts is a detailed organized process where Computerized Maintenance Management Systems (CMMS) [4,5] are used for the organization. These systems allow constant monitoring of all segments of the spare parts system, provided that personnel regularly update quantities and enter all necessary data.

Numerous CMMS are in use today, some of which have been developed specifically for the maritime industry. Previous research in the field of inventory policies [6] has shown that the characteristics of inventory policies in the maritime industry differ from normal land-based inventory policies and that current rules and regulations [7-10] in the maritime industry support this distinction. Following this logic, it is to be expected that the spare parts management in the CMMS for the maritime industry is different from the setup for the land-based industry, i.e. that the system logic and configuration is different. To verify this assertion, four programs are analyzed, two programs for the land-based industry and two for the maritime industry.

The first program created as a universal program is SAP ERP (Enterprise Resource Planning), one of the best known programs for resource planning in the land-based industry. The description on the official website defines ERP as an integrated system created to efficiently manage the financial side of operations, human resources, spare parts, services, purchasing, maintenance and all other processes related to the management of the company. The second program analyzed is also a general purpose ERP program used in the industry: IBM Maximo Asset Management. Two programs developed for the maritime industry that are compared to SAP and MAXIMO are AMOS BS and BAASnet. Both programs are competitive and widely used in the maritime market, and their features are common in the industry.

In the land-based industry, it is common practice to constantly monitor the stock of spare parts and order parts when needed. The time of ordering is not taken into account and the quantity ordered is often always the same. In the land-based industry, as mentioned above, a variable period, variable quantity or variable period, fixed quantity ordering policy is applied. On board a ship (in the maritime industry) the conditions for ordering are different. The ship sails all over the world and it is not possible to guarantee the delivery of spare parts everywhere. In addition, the long distance over which the parts are delivered requires precise delivery planning in order to reduce costs. For these reasons, the fixed period and variable quantity ordering policy is the most commonly used policy for ships in maritime trade [6].

Therefore, the first two programs analyzed are expected to be set up for the variable period ordering policy with variable order quantity or the variable period ordering policy with fixed order quantity, while the fixed period ordering policy with variable order quantity is expected in the maritime industry.

Since the first part of the research presented in Chapter 2 did not produce the expected results, the second part of the research is carried out, i.e. an analysis of the use of these systems is performed, focusing on the fact that rules and regulations in force in the maritime industry must be followed [7-10]. This analysis is presented in Chapter 3. The use of the two CMMS developed for the land-based industry is analysed first, then the same approach is used for CMMS in the maritime industry. In the Discussion, the identified facts are compared and a Conclusion follows on how the systems are built and what the crew in the maritime industry does (have to do) to fulfil the requirements.

2 PROGRAMS SETUP

As mentioned earlier, previous research in the maritime industry [6] found that the fixed period (period R is fixed, in the analyzed databases it is set to 3-12 times per year) and variable quantity ordering policy is the most commonly applied policy for vessels in the maritime industry. It was also found that various maritime rules and regulations [7-10] prescribe the use of safety-critical spare parts, i.e. the quantity that should always be on the ship to ensure that the ship arrives safely at the nearest port in case of an unforeseen event (Figure 1.).

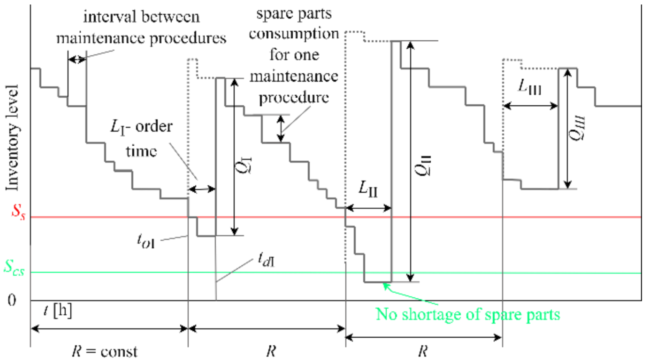

Figure 1. Spare parts policy for the maritime industry [6]

This quantity may not be used in any other situation and is essentially a zero quantity when considering the normal process of ordering spare parts. It is therefore assumed that this is reflected in the appearance and use of the CMMS, i.e. that the systems at sea are different from those on land.

2.1 *System 1, SAP ERP setup*

SAP ERP is enterprise resource planning software developed by SAP SE [11]. It is the largest company on the ERP market (in the land-based industry) with the largest number of customers (according to the available information, there are more than 433,000 customers using SAP ERP) and it is not limited to the ERP segment, there are many customers using other modules, for example accounting modules. As the market leader, the solutions applied in the program are copied in many other programs. SAP is also widely used in the maritime industry, but is limited to the accounting modules, the ERP module is not used in the maritime sector to the knowledge of the authors of this paper (or at least we have not come across it).

The structure of SAP ERP spare parts is shown in Figure 2.

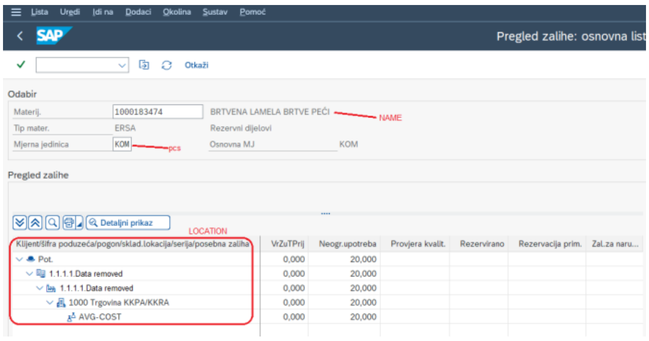

Figure 2. SAP ERP main spare parts page [11]

Although the program was originally created for operation in English, it can be seen that in this case the program has been adapted to the local language.

It shows the main page of the spare parts with the spare part number and the unit of measurement (piece). There are further details and a detailed description of the stock location. On the same page there is a log with the details of the quantities.

Figure 3. shows spare parts page with quantity details.

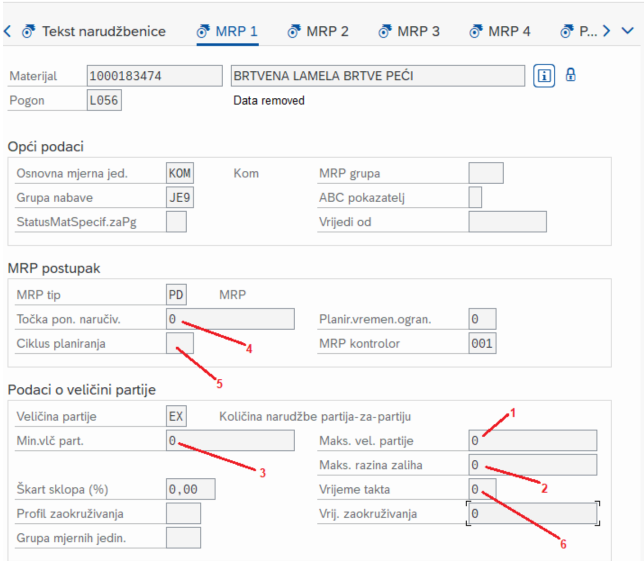

Figure 3. SAP ERP quantity details [11]

The quantities can be easily adjusted by adding the number in the field. Maximum order quantity is marked with number 1, maximal spare parts stock is marked with number 2 while minimal order quantity is marked with number 3. Reorder quantity or reorder level is marked with number 4 and order lead time is indicated with 6. The field marked with 5 is order cycle duration, a field which determines duration of the cycle.

This system structure enables (and requires) constant monitoring of the spare parts quantity and updating of the quantities consumed and received. When the quantity drops to the reorder level, there are no protective measures, i.e. operation continues without the operator recognizing this condition if no additional protective measures are in operation (which is a normal addition to the system). This inventory policy can be described as a constant review, fixed order quantity inventory policy where the order period can be adjusted (labeled 5), but this measure requires extensive additional programming and a tremendous amount of effort to implement this practice. According to the information gathered, there is no example of this practice in companies in the area. Without this customization and expansion, the setup is a constant review inventory policy with variable order quantities.

2.2 *System 2, MAXIMO setup*

Maximo is asset management software created for land-based industry, and initially released in 1985. In 2006, the program is purchased by IBM, and it was named IBM Maximo Asset Management. Today, there are more than 3,923 companies that use IBM Maximo [12] as their main help in organizing their operations.

Maximo spare parts setup is created as a list of inventory items (red arrow on Figure 4.) with the description of the stored item and the description of the storage (encircled in red). On other subpages there are more details like where the spare part is used, units of measure, etc.

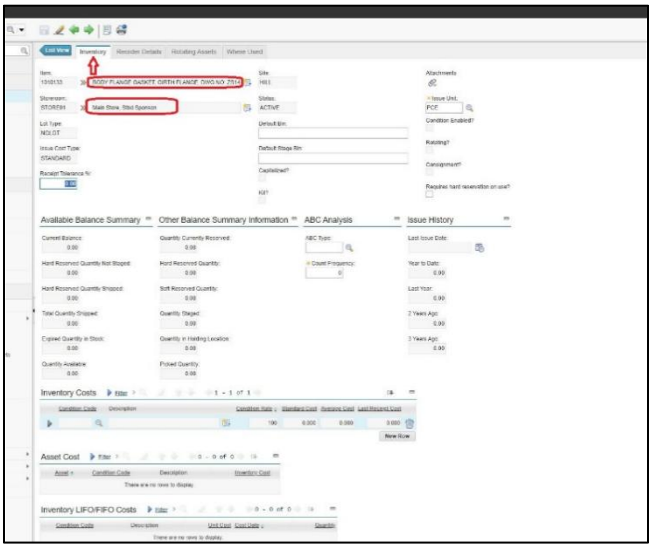

Figure 4. Maximo main spare parts page [12]

The part on the screen is Body Flange gasket, girth flange which can be found (if stored) in the Main store, Stbd Sponson. On the next subpage, which is visible on Figure 5., details about spare parts quantities are shown. This item has a reorder point, safety stock and Economic Order Quantity (EOC) adjusted accordingly, while maximum is left to 0.

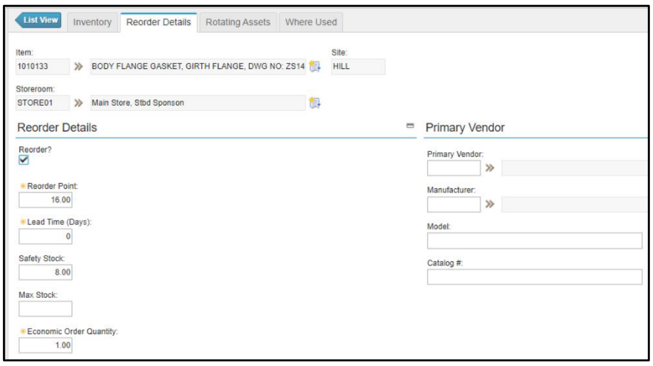

Figure 5. Maximo quantity details [12]

The system setting shown requires constant monitoring of the spare parts quantity and constant updating of the quantities consumed and received. If the quantity drops to the reorder level, there are no safety precautions, i.e. the process continues to run without a corresponding order, without this condition being recognized by the operator.

It can be seen that this setup does not have order cycle time, which was present in SAP ERP. This inventory policy can be described as a permanent review inventory policy with a fixed order quantity where the order period is not defined. The main problem of this system is the control of spare parts at the reorder point (or below), which depends only on appropriate actions by the operator.

2.3 *System 3, AMOS BS setup*

AMOS BS [13] is one of the oldest programs intended for maintenance planning and management of spare parts used in the maritime industry. It has been on the market for more than 30 years and many other programs are created following this design.

Despite being an old program, its features are still actual and it is still used by many shipping companies.

AMOS BS spare parts setup (for a randomly chosen equipment and part) is shown at the Figure 6.

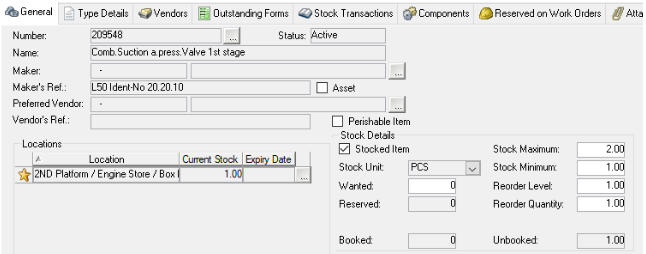

Figure 6. AMOS BS quantity details [13]

The description of the spare part is given on the general page, where the name of the article is given, together with the details about the article in the field Maker' ref. and details about storage location. At the same page there is a setup of minimum, maximum, reorder quantities and reorder level. The part on the screen is 1st stage valve for an emergency compressor L50, which can be found (if stored) in the Engine Store in the Box 11. It has a set maximum and minimum stock quantity, as well as the quantity when these parts should be ordered and the quantity that should be ordered. It also shows that at this moment, there is one spare valve on board and that this spare part should be ordered.

The system adjustment as shown requires constantly monitoring of spare parts quantity and constant update of the consumed and received quantities. When the quantity drops to Reorder Level the order should be created, but in this program, that function requires some additional programming and more efforts.

This inventory policy, as described above is permanent review inventory policy with fixed order quantity, with variable period order policy. Fixed order policy can be obtained by accumulating many spares at the reorder level and ordering them at the predetermined interval, in that case stock minimum and reorder level should be adjusted accordingly to prevent out of stock situations which are not recommended (allowed) in the maritime industry.

2.4 *System 4, BASSNET setup*

BASS Company [14] is founded in 1997 in Norway. Their program BASSnet quickly become one of the leading programs for maintenance planning and management of spare parts used in the maritime industry. Today, its new variants are among top global programs for ERP in maritime industry as well as for rigs and floating productions, storage and offloading vessels (FPSOs), as well as offshore units.

BASSnet spare parts setup (for a randomly chosen equipment and part) is shown at the Figure 7. The analysed spare part is Handhole gasket as given in the field material name.

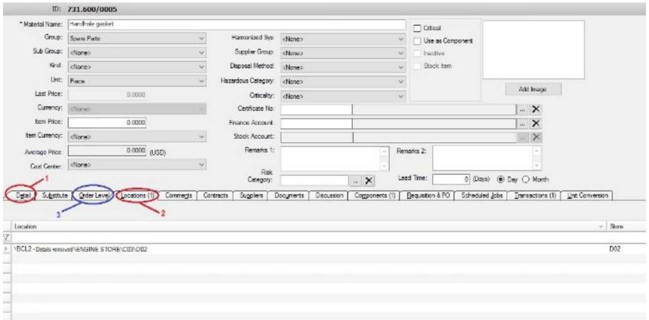

Figure 7. BASSnet main spare parts page [14]

The description of the spare part is given on the central part together with some main information. Manufacturers details are addressed in subpage details (marked with number 1 and encircled in red). Location setup (storage of this item) is visible on the subpage Locations (marked with number 2 and encircled in red), A setup of minimum, maximum, working, reorder quantities and levels is presented on Figure 8. and it is organized on another subpage (encircled blue and marked with number 3 on Figure 7.)

The system adjustment as shown requires constantly monitoring of spare parts quantity and constant update of the consumed and received quantities, same as all other analysed programs. When the quantity drops to Reorder Level there is a feature in the system which allows appropriate action, but which require additional adjustments and efforts and which analysed company did not use.

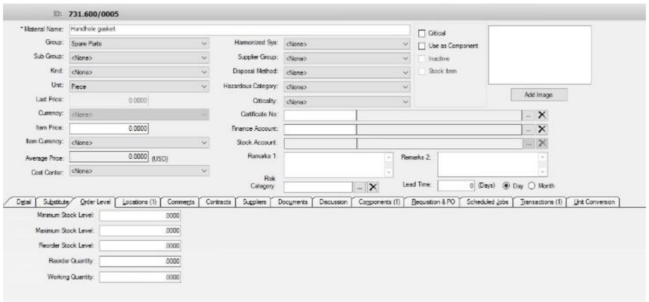

Figure 8. BASSnet quantity details [14]

Same as with AMOS, this inventory policy is permanent review inventory policy with fixed order quantity and variable period order policy. Fixed order policy can be obtained by accumulating many spares at the reorder level and ordering them at the predetermined interval, all of this has to be performed by operators without additional support from program.

2.5 *Setup comparison*

After examining four different CMMS, two of which are intended for use on land and two for the maritime industry, the results are not as expected. All the examples presented have exactly the same spare part design, i.e. despite their design, there is no fundamental difference between their spare part solutions. All CMMS have a setup of minimum, maximum, working and reorder points, albeit in slightly different forms. None of the programs examined has a safety-critical spare parts inventory.

All programs require (and support) constant monitoring of spare parts quantities and constant updating of quantities used and received. They also support the automatic ordering process, provided that minimum and reorder quantities are defined.

In all the programs studied, the system is designed to allow a permanent review inventory policy with a fixed order quantity and variable period ordering policy. The fixed period ordering policy is not an option in any of the systems examined; only SAP supports this, and only after extensive program setup.

These results raise an important question. If all of the programs studied are nearly identical and do not support the inventory policy prevalent in the maritime industry, how did the users of the programs studied solve this problem?

3 USE OF THE CMMS IN MARITIME INDUSTRY

The research of spare parts ordering policies in the maritime industry [6] found that the predominant method is the fixed period, variable quantity ordering policy. In that research it was found that the fixed period is usually determined by the company and varies between 3 and 4 months (in some cases even 2 months). The variable quantity is based on future maintenance needs (planned maintenance) and the quantity on board, and in all cases studied, the applicable rules and regulations [7-10] for safety-critical spare parts were implemented.

Comparing this fact with the conclusion from the first part of this research that all the programmes studied are designed to allow a permanent review inventory policy with a fixed order quantity and a variable period ordering policy, and that the fixed period ordering policy is not an option in any of the systems studied, a question arises. If the system is not configured to perform the intended fixed period, variable quantity ordering policy and crews (companies) actually use it, how do they do it? This second part of the research focuses on answering this question.

3.1 *System 3, AMOS BS usage*

The critical spare parts in the company using AMOS BS are properly labelled in the system. Although the system offers several options for labelling criticality (Figure 9), the company studied uses only one, namely "Critical".

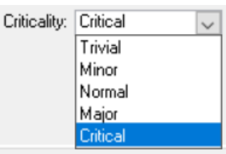

Figure 9. AMOS BS Criticality setup [13]

The company under investigation stated that all required Critical and Safety-critical spare parts are properly labelled and that the minimum quantities of these spare parts are entered into the system. The minimum corresponds to the sum of the Safety and Safety-critical spare parts. The actual labelling and quantities entered are verified by comparison with the Lloyds Register [8] list for Fuel injection pumps and Fuel injection piping (see Figure 10).

No. 26 (cont)	Item	Spare part	Number recommended
10.	Cylinder lubricators	Lubricator, complete, of the largest size, with its chain drive or gear wheels, or equivalent spare part kit	1
11.	Fuel injection pumps	Fuel pump complete or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc.), or equivalent high pressure fuel pump	1
12.	Fuel injection piping	High pressure double wall fuel pipe of each size and shape fitted, complete with couplings	1
13.	Scavenge blower (including turbo chargers)	Rotors, rotor shafts, bearings, nozzle rings and gear wheels or equivalent working parts if other types	1 set[2]
14.	Scavenging system	Suction and delivery valves for one pump of each type fitted	1 set
15.	Reduction and/or reverse gear	Complete bearing bush, of each size fitted in the gear case assembly	1 set
		Roller or ball race, of each size fitted in the gear case assembly	1 set

Figure 10. Part of Lloyds Register list [8]

The number of ME fuel injection pumps and fuel injection piping in stock is shown in Figures 11 and 12.

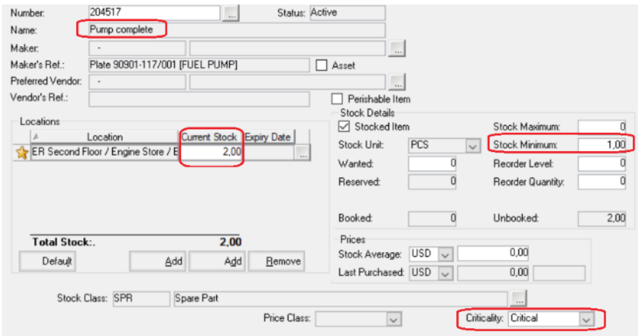

Figure 11. ME Fuel injection pump in the CMMS [8]

Figure 11 provides an insight into the ME injection pump complete (as a spare part). The pump is properly labeled as critical, a minimum stock level is set, and there is more than the minimum quantity on board.

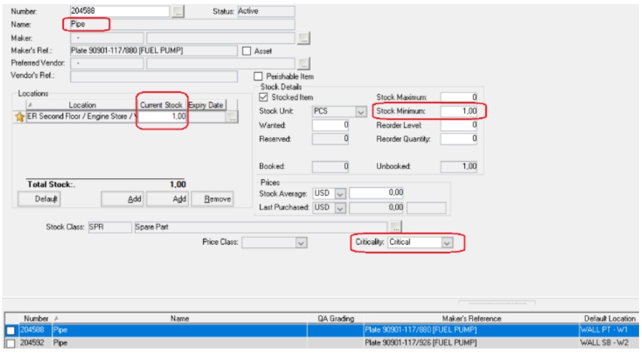

Figure 12. ME Fuel piping in the CMMS [8]

Figure 12 shows an insight into the ME injection piping, from which it can be seen that they are properly labeled as critical, a minimum stock level has been set and the minimum quantity is available on board. A further check showed that all safety critical items have been entered into the database, with the minimum quantity adjusted to match the Lloyds list [8].

Neither a reorder point nor a reorder quantity has been set for any of the items examined. The company believes that these quantities are not required and that the crew must check all quantities again before ordering. In this case, spare parts planning is based solely on the experience of the crew, the spare parts are not linked to the corresponding work orders, i.e. it is possible to call up all the work planned for the desired period in the system, but the spare parts (to be) consumed are not linked to any work.

From this insight it becomes clear that the ordering policy with fixed periods and variable quantities is made possible by human labour and extensive planning outside the CMMS. The system itself is not adapted to its full potential and crew (company) does not take full advantage of its benefits.

3.2 *System 4, BAASnet usage*

Similar to the company using AMOS BS, the critical spare parts in this system are properly set up (as indicated by an arrow in Figure 13).

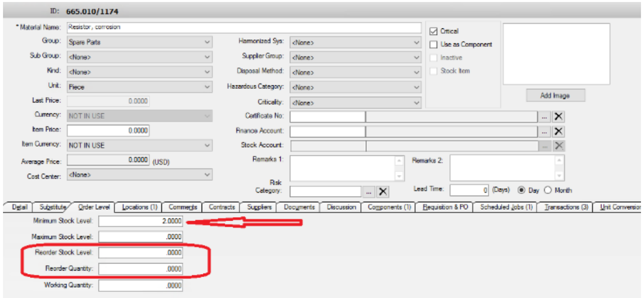

Figure 13. BASSnet order setup [14]

As for the safety-critical spare parts, in this examined case, as in the previous example, there is no difference between the labelling of critical and safety-critical spare parts, all are labelled as critical (Figure 14).

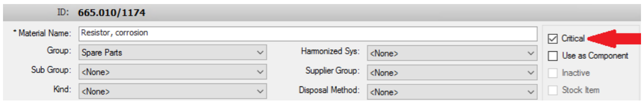

Figure 14. BASSnet critical spares tick [14]

The safety-critical spare parts listed in the Lloyds Register [8] are compared in this company with the quantities entered as Minimum stock levels. The verification showed that the Minimum stock levels in the CMMS are greater than the Lloyds Register list, which confirms the company's claim that the minimum stock level in the CMMS is the sum of safety critical and safety stock.

Comparing the quantity of safety critical spares in the Lloyds Register list [8] with the Minimum stock level, it is clear that the Minimum stock level is greater than the quantity required by the Lloyds Register [8].

From this, second insight, it also becomes clear that the ordering policy with fixed periods and variable quantities is made possible by human labour and extensive planning outside the CMMS. The system also is not adapted to its full potential and does not provide full advantage of its benefits.

3.3 *CMMS systems use comparison*

Two cases analyzed from the maritime industry show exactly the same results. Both companies comply with all the requirements laid down in the rules and regulations [7-10]. In both companies, the critical items are clearly labeled with the minimum quantity is adjusted as needed. The same logic is applied in both companies: Safety spares and Safety-critical spares are both labeled as critical.

In regards ordering policy, both companies are using fixed periods and variable quantities ordering policies. Both companies have not set a reorder point or reorder quantity, but rely on the crew to check everything necessary when ordering. Maintenance planning is well established in both cases, but in both cases the spare parts required for maintenance are not linked to the planned work. Therefore, the spare parts planning capability is neglected in both examples, resulting in a much more difficult ordering process.

The spare parts planning functionality requires an additional modification of the CMMS data, i.e. checking each individual work order in the system and linking the corresponding spare parts. This additional modification cannot be done by an ordinary data entry person, but requires a person who is well versed with the CMMS and engineering technology, preferably a senior Marine Engineer. This measure is therefore very time consuming and costs more than a complete CMMS with a standard database. In view of these facts, it therefore makes sense to dispense with spare parts planning.

4 FIXED PERIOD, VARIABLE QUANTITY ORDERING IN CMMS

Of the four systems analyzed, only SAP supports the fixed period ordering policy. To gain insight into the main reason why this ordering method is not set in CMMS, inquiries were sent to the companies that own the above programs and do not have this option available. Two out of three companies responded to the inquiry that such a request has never been made and the programs can be changed relatively easily and quickly if needed.

When asked whether it was possible to add an additional field to the program with the designation "safety-critical spare part", all companies replied that this was a simple and easy procedure and could be done in a very short time, both for new programs and for those already in use.

The other issue is the price of implementing the ordering policy with a fixed period and a variable quantity. The process must start with entering the critical spare parts quantity into the CMMS. Then the safety critical spares, the minimum stock level and the reorder point must be added. This part of the database change requires a lot of work, but no technical knowledge, just adherence to company practises and policies set out in the Safety Management System (SMS).

The last item to be entered into the CMMS is the determination of the required quantity of spare parts to be used for each individual work order. This part of the process requires a highly qualified person and a lot of time, considering that there are more than 30,000 spare parts in the mentioned databases that need to be linked to more than 500 work orders. An additional problem with all of this is the possibility of human error (about

3-4% of the data entered [15]), which ultimately makes the end result questionable (who wants to order unnecessary or incorrect parts).

The latest information about the introduction of a fixed period, variable quantity ordering policy came after a query about the cost of this facility. There are many manufacturers of maritime CMMS databases, and the authors contacted several to find out how much it would cost to create this facility. Only one company responded that they had the ability and time to participate in the project. Although they did not give an exact figure, they estimated that two technicians would be needed for a period of three to four months. The cost of this can be estimated knowing that a CMMS database can be completed within two weeks and costs approximately $8,000 - $10,000.

5 CONCLUSION

It has already been mentioned that at the beginning of this research it was assumed that spare parts management in the CMMS for the maritime industry is different from the setup for the land-based industry, i.e. that the system logic and configuration is different.

While this assumption was not confirmed during the research, the results confirmed a very different fact. Two programs intended for use on land were compared with two programs intended for maritime use and the analysis showed that their basic concept is largely identical. This conclusion is not (and cannot be) affected by the minor differences.

Having established that the system settings are the same, an analysis of the ordering method was carried out, as the ordering methods in the shipping industry differ from the CMMS settings. Namely, the two companies studied from the maritime industry use a fixed period, variable quantity ordering policy, although the system is set to a constant monitoring, variable quantity ordering policy.

It was found that the fixed period and variable quantity ordering policy is made possible by human labor and extensive planning outside the CMMS, where the spare parts planning function is not possible due to the high cost.

In conclusion, there are no differences in the ordering policy between land and sea CMMS. The only difference is the personnel and their ordering practices.

Parallel studies have shown that it is possible to introduce an automated ordering policy with a fixed period and variable quantity. This comes at a significant cost, which is not welcome in today's competitive maritime industry. Another problem is the possibility of human error, which would result in the wrong parts being ordered. Both problems are difficult to solve with existing CMMS. Future systems must be able to learn (to order parts that were consumed during the last maintenance), but also to make independent conclusions and predictions.

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