Impacting an Organization by Reducing Cost of Spare Parts and Excess Inventory

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Abstract *— Excess inventory and the cost of replacement parts are found to be an area of opportunity within a maintenance department for a vessel terminal in San Juan, Puerto Rico. The quantitative model is the approach that was selected to describe the current inventory status management practices and to compare the information with the theoretical framework. It was confirmed that the demand for the consumption of spare parts was lumpy and intermittent. Results show that increasing stock fulfillment order cycle reduces the cost amount per invoice while higher order quantities of the supplies will lower the costs for an annualized period. Forecasting the consumption of the inventory was challenging to implement due random demand. The increase of safety stock levels by bulk ordering shows an increase in maintenance costs, although it was noted that it decreased the stock shortages and increased the equipment's uptime for the operation.*

Key Terms *— inventory management, preventive maintenance, proactive, safety stock level*

INTRODUCTION

On a vessel terminal operator organization in San Juan, Puerto Rico, excess inventory and the cost of replacement parts is found to be an area of opportunity as the operation keeps moving forward. The equipment maintenance department serves as the group that keeps the equipment operational and in a serviceable status for the operation of loading and unloading containers on a vessel. The various equipment the department maintains are divided into the following categories: reach stackers, forklifts, bombcarts and yard trucks. Each equipment mentioned has their own inventory stored in the maintenance shop segregated by these main categories. Although most of the equipment is of the same manufacturer and model within each category, they have their specific inventory requirement differences. It is also known that sometimes in these storages there are obsolete parts that have no use in the current environment.

It has been observed that the storage areas have spare parts with high levels of corrosion due to not having a temperature controlled safe space and high humidity levels. Most of the parts stored were observed to be with high levels of dust, indicating there's no need to consume the parts and parts have been occupying critical storage space for a long period of time. The consumable fluids for the equipment were also studied and were be limited to the following: hydraulic oil, coolant, and oil.

The objectives of this project are to:

- Forecast the consumption of the inventory by measuring parts order flow.
- Determine proper tracking of costs and documentation accompanying parts received.
- Determine optimal inventory levels for the application while ensuring stock availability.
- Determine the feasibility of bulk purchases to take advantage of lower shipping and order generation costs for the spare parts.

The area of opportunity at hand was evaluated by corroborating the inventory practices used on-site and compare them with the theoretical framework. The application and recommendations of inventory management practices has been moved forward by interviewing different department representatives, collecting data, and analyzing the data.

LITERATURE REVIEW

As part of the decision-making process of a manufacturing process to optimize spare parts optimization, it has been proposed that the

Condition Based Maintenance (CBM) model is preferable instead of using a time based model [2]. CBM incorporates "Detect- Predict- Decide- Act" model and the pro-active event-driven architecture model. They use a sensor technology for a real-time fast-moving application of a manufacturing process, but for this application it was used in a lower-scale slow-moving setting in which there is no reports from sensors within the mechanical units. There is concurrence in future actions to develop a computer system (hardware/software program) with sensor integrated to consider the context affecting the decision model [2]. In addition, maintenance and inventory management are strongly interconnected and should both be considered simultaneously when optimizing a company's operations [2].

On the other hand, it was noticed in multiple inventory management optimization issues that the demand for spare parts is assumed in most of the models to be lumpy and intermittent [1, 3]. Therefore, the forecasting aspect of the inventory replacement parts is complex and the safety stock level has to be modified accordingly. The Advance Order Policy (AOP) is preferable instead of the Temporary Order Policy (TOP) as the AOP is of a proactive nature and the TOP is of a reactive mindset. In addition to the variables already mentioned, the storage constraints, approximation on cost components and peculiarity of each item also can affect order quantities and reorder directives [1]. A relationship has been observed between the literature and the container terminal organization in which the use of the equipment is erratic and non-continuous but the equipment is strived to be in service 100% of the time. The proactive mindset using forecasting models and AOPs is preferable to be used to optimize the use of the storage space and lower the maintenance cost.

A relationship exists between the three major cost categories: purchasing, the holding cost associate and the shortage costs [4]. The increase of the safety threshold factor will decrease the probability of spare parts shortages but increase the storage space costs [4]. On the other hand, it was stated that bulk purchases will lower the purchasing cost [4]. Conjointly, if a container terminal increases the repair rate of the mechanical equipment used on the operation, then it can decrease the safety stock level and thus can minimize the expected cost of the overall organization [5]. Combining the knowledge gained, there a several options in which a container terminal organization can be impacted such as by lowering the amount of parts stored and focusing on the optimum level of the total cost function. Additional action can be taken in the future to measure the sensibility of the documented information and the impact on the organization's cost factors.

METHODOLOGY

The personnel responsible for keeping the inventory purchases and control was interviewed. The interview process was in part to confirm and focus on the inventory management theoretical framework and practices used on site which were as follow:

- Economic Order Quantity (EOQ)
- Minimum Order Quantity (MOQ)
- Safety Stock level
- First-In-First-Out (FIFO)
- Last-In-First-Out (LIFO)

These were the methods that correlated the most to the application.

Data collection took take place directly from the maintenance and finance department. The collected information was dissected from the Purchase Orders (POs) specific to the suppliers, quotes used to generate the POs, spare parts consumption from the Work Orders (WOs) and inventory level records. The cited methodologies aided in the determination of the optimal replacement rate of spare parts. One of the limitations found was that maintenance department was in transition of digitalizing the reports which in the past were handwritten and the accuracy of the data recorded was found to be skewed (i.e. incomplete, incorrect). The main assumption used during the data collection process is that the consumption of the spare parts needed to keep the equipment operation was lumpy and intermittent.

The quantitative model is the approach that has been selected to describe the current inventory status and shows the possibility of re-organizing the equipment's inventory. The total costs to keep the equipment running include the following variables: equipment maintenance labor hours, shop supplies, spare parts, fuel, and labor during the operational hours. Obtaining cost information of the maintenance labor hours and operational hours of the equipment was a limitation but the study was carried out with the variables specific to the inventory's area of opportunities already cited.

Inventory management approaches and techniques were applied to analyze the possibility of cost reduction efforts specifically intended for spare parts ordering and consumption. On the other hand, the reduction of excess inventory was addressed by understanding the need of optimizing the organization's limited resources while maximizing the use of the storage space and increasing the accountability of spare parts.

RESULTS & DISCUSSION

It was confirmed during the interview process that the demand for the consumption of spare parts was indeed lumpy and intermittent for the entire maintenance department. This includes the shop consumables inventory and the spare part inventory for the forklifts, reach stackers and bombcarts. The yard trucks and bombcarts were confirmed to be in a contract in which they are leased. This means that the minor spare parts and their respective consumables do not cost extra for regular maintenance and repair as stated within the contract agreement. It does cost additional if a major repair is required. Therefore, this equipment has been discarded from the analysis as the equipment owner runs a lean inventory directly supplied by them. Safety stock level was determined to be the theoretical base for the current inventory management practice.

During the process of the data collection, documentation was verified regarding a certain shop supplies contractor. The invoice document dates aided in understanding the replenishing cycle of the shop supplies both timewise and order quantity-wise. Figure 1 shows a gap in order dates pertaining to the maintenance shop supplies inventory. The major grid for the horizontal axis of Figure 1 was set to a fixed 30-day period to better appreciate the stock cycle period and dates.

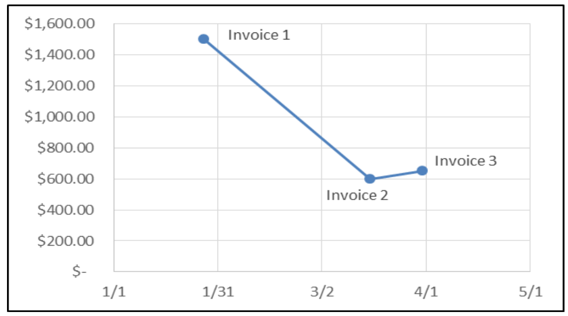

Figure 1
Shop Supplies Inventory Fulfillment Cycle

Throughout the inspection of the invoices, it was noticed that the gap is explained by the stocking up to the highest accepted level of inventory (i.e., orders items and parts quantity) for those specific shop supplies during the ending of the month of January 2022. Although this period was prior to the selected dates for the scope of the analysis, Invoice 1 was needed to understand the lumpy and intermittent stock requests and replenishment of the shop supplies inventory. The remaining invoices show a shorter-term shop supplies resupply but lower invoice dollar amount.

These results show that increasing stock fulfillment order cycle reduces the cost amount per invoice. On the other hand, Invoice 1 proves that higher order quantities of the supplies will lower the costs in the long run (i.e. annual period) due to a minimized need for transportation fees (i.e. freight, shipping costs) as the order stock-up cycle is reduced. The reach stackers' replacement part inventory showed the same behavior as for the study of the consumables replacement for the bulk purchases analysis. Bulk purchases will lower the need to generate orders while small orders will, in general, represent the need to make more frequent orders.

There were a few limitations encountered as there was an information overload as the organization uses many suppliers to cover the maintenance department needs. This problem was solved by the application of the ABC Method applied specifically to the suppliers and resulted in the reduction of suppliers to mainly one on the consumables supplies and three for the reach stacker and forklifts' spare parts suppliers. The literature reviewed provided many complex mathematical equations which needed software programming integration non-linear equations and integrals equations. As the study was focused on a more simplified application, the formulas were simplified to the address the micro scale aspect of the inventory optimization and the reduction of the cost of the spare parts for an annualized period.

Conclusion

During the beginning of the selection of the project objectives, it was determined that there were too many objectives to be achieved during a short period of time. The objective to "ensure a safe storage space area" of the replacement parts was discarded since the initial weeks of the study due to the time factor. It was rapidly noted that it was going to take longer (i.e., approximately 6 months) than the period enclosed for this course. In addition, objectives were consolidated as the determination of the inventory optimization impact on the organization was able to be addressed from the inventory management perspective using previous work from multiple proactive maintenance efforts and studies [2, 3, 5].

However, forecasting the consumption of the inventory was confirmed to be challenging to implement due to the lumpy and intermittent random demand of replacement parts used for the equipment maintenance efforts. Furthermore, the proper tracking of costs and documentation accompanying parts received was noted to be showing promising results due to the implementation and transition into a new digital inventory management program during the period studied eliminating the need of handwritten reports prone to human errors. Finally, even though the increase of safety stock levels by bulk ordering and proactive maintenance mindset shows an increase in maintenance costs of the equipment, it was noted that it lowered the stock shortages and consequently increased the equipment's up time for the operation and customer satisfaction levels. This also lowered overall costs of the operation as the equipment was in optimum condition and ensured an increase in the efficiency of the organization's resources. Primarily, this was found to be important during the Covid-19 supply chain and logistic problems encountered during the past years resulting in stock shortages.

Future monitoring of the new inventory management program will need to be considered for proper determination of the program success (or failure). Moreover, the digitalization of the inventory management program may be evaluated to be aided with the placement of new controls and sensorial gadgets that minimize the human errors on data entry and to automate the inventory consumption and fulfillment processes.

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