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Framework for Spare Inventory Management

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***Abstract*—**Spare parts inventory management is one of the major areas of inventory research. Analysis of recent literature showed that an approach integrating spare parts classification, demand forecasting, and stock control policies is essential; however, adapting this integrated approach is limited. This work presents an integrated framework for spare part inventory management and an Excel based application developed for the implementation of the proposed framework. A multi-criteria analysis has been used for spare classification. Forecasting of spare parts' intermittent demand has been incorporated into the application using three different forecasting models; namely, normal distribution, exponential smoothing, and Croston method. The application is also capable of running with different inventory control policies. To illustrate the performance of the proposed framework and the developed application; the framework is applied to different items at a service organization. The results achieved are presented and possible areas for future work are highlighted.

***Keywords*—**Demand forecasting, intermittent demand, inventory management, integrated approach, spare parts, spare part classification

I. Introduction

IN maintenance engineering, the cost of spare parts are tremendous expenditure, and spare parts are very important for equipment availability, they are significant resources in equipment maintenance [1]. The principal objective of any inventory management system is to achieve sufficient service level with minimum inventory investment and administrative costs [2]. Accordingly, the trade-off is clear: on one hand a large number of spare parts ties up a large amount of capital; while, on the other hand too little inventory may result in poor customer service or extremely costly emergency actions [3].

In addition, spare part inventory management is a special case of general inventory management with some special characteristics, spare parts are considered as very slow-moving parts with highly stochastic and erratic demands [1], derived by the different scheduled and unscheduled maintenance operations.

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Thus, they are different from work-in-process (WIP) and finished product inventories in inventory function and governing policies [4].

These and other unusual aspects of spare parts inventories have led the authors to focus on the following work objective, which is to develop a general framework for spare inventory management, develop an Excel based application to support this framework application, and to illustrate its effectiveness and practicality using a real-life case study.

The remainder of this paper is organized as follows. Section 2 includes a brief review of relevant literature; in Sections 3 and 4 the proposed framework of spare inventory management is introduced along with the developed Excel based application. In section 5, the application of the proposed framework to a real case study is presented and the implementation results are discussed. Finally, conclusions are drawn and areas for future research are suggested.

II. Related Review

The variety of research in management of maintenance inventories is very broad in scope [4]. To effectively manage inventories, three steps are needed; Spare Parts Classification, Demand Forecasting and Inventory Control. Some authors reviewed previous literature on spare inventory management such as [4] and [5].

The following sections present the review of the literature related to the three requirements of an effective spare part inventory management: Spare Parts Classification, Demand Forecasting and Inventory Control. Two approaches are detectable in the literature: considering each of the three requirements separately and the study of integrating these requirements. Both approaches are covered in the review.

A. Spare Parts Classification Review

Large number of spare parts inventories makes the management of inventory items difficult. As a result, parts are commonly grouped and special stock control policies are applied to each group. The most commonly used approach to classify inventory items is the ABC analysis. Traditionally, the importance of a stock item is evaluated in terms of a single criterion, the annual dollar usage of stock keeping units.

However, other criteria may also play a significant role in classifying stock keeping units such as lead time, criticality, stock out consequences, demand rate, etc. In that case multiple criteria ABC analysis for spare parts inventory is used. This has been addressed by different researchers [6]-[8] and various models have been developed to solve multiple criteria ABC analysis as in [8]-[13].

It should be noted that special attention has also been given to critical class of spare parts; where, demand for spare parts can sometimes be classified into critical and non-critical demand depending on the criticality of the equipment for production [14]. In addition, failure modes, effects and criticality analysis (FMECA) has been used for evaluating spare criticality [15].

B. Demand Forecasting and Inventory Control Review

As mentioned earlier, spare parts are characterized by highly stochastic and erratic demands, which are derived by the different scheduled and unscheduled maintenance operations. This type of demand is generally referred to as intermittent demand and makes forecasting especially difficult.

Traditional time series methods, such as moving average or single exponential smoothing are still the most commonly used in business practice [5]. Exponential smoothing places more weight on the most recent data, resulting, in the case of intermittent demand, in a series of estimates that are highest just after a demand occurrence and lowest just before demand occurs again [16].

Other methods have been developed specifically for forecasting intermittent demand such as the one proposed by Croston, which forecast intermittent demand taking into account both demand size and the interval between demand incidences. However, Croston method has been reported to exhibit certain limitations and has been modified to improve its accuracy of forecasts [16]. Furthermore, a modified bootstrap method has been developed in order to take into account autocorrelation, which proved to be an even better method than Croston for forecasting spare parts' intermittent demand [17].

Finally, different approaches have been reportedly used to forecast spare parts demand with the objective of accurate determination of stock levels and taking into consideration the desired service level. These have been applied to real case studies and showed that better forecasting of lead time demand can result in reduction of stocking cost and stock out probability [3], [18] and [19].

C. Integrated Approach Review

In order to create an effective inventory model for managing spare parts, an integrated approach considering all requirements for this effective inventory management can be used. This approach should cover parts classification, demand forecasting, and inventory control policies.

An effective method to manage spare part inventory, over three phases, has been introduced and implemented on a case study of an Italian pasta producer [1]. Where, in the first phase, a FMECA analysis was performed to classify all items based on items criticality. Then, ABC method was used to evaluate spare parts consumption rate. Finally, a comparison between demand modeling techniques; Normal, Poisson, and Gamma distributions, was carried out.

Moreover, an effective spare parts inventory control methodology motivated by a case study at a large oil refinery has been presented [20]. The methodology starts with parts classification based on parts criticality, consumption rate, price, and lead time; followed by, demand forecasting using different forecasting methods. Finally, an inventory model has been used as well as an optimization of the system based on service level.

Finally, the integrated approach to spare parts inventory management has also been addressed from a theoretical point of view with no application to a real case study [21]. Again, different methods of parts categorization have been presented and an inventory model has been introduced for optimization of stocking levels.

This brief review of literature showed that few studies introduced the integrated approach for managing spare inventories; hence, an integration of spare classification and demand forecasting with stock control policies is needed. Furthermore, practical application of methods to real cases of spare management is often missing resulting in a gap between research and practice.

III. Framework Development

A general framework for planning and managing spare parts inventory is proposed with an objective of minimizing total inventory cost and maximizing equipment availability taking into consideration the desired level of safety. This framework can be used for spare part inventory management for both manufacturing and service organizations.

The proposed framework presents an inventory control mechanism by integrating three steps. It starts with classification of spare parts into groups, followed by spare parts demand forecasting and; finally, for each item class the suitable ordering policy is defined based on the forecasted demand. Each of these steps has a significant role for the determination of the stock control method.

A. Spare Parts Classification

A multi-criteria approach is adopted in the proposed framework for spare classification. Where, items are classified based on the following three criteria: criticality, consumption rate, and inventory cost. These criteria are selected to address the proposed framework main objectives; safety, equipment availability, and total inventory cost.

1) Criticality Classes

Maintenance work focuses on ensuring the continuous operation of equipment and maximum work efficiency. To ensure this, spare parts are needed. Yet, the priority of having different spare parts may vary. The lack of some spare parts may cause equipment shutdown and other significant consequences. The spare part is defined as a critical one as it critical for equipment operation, expensive with a significant variation in demand and long lead times. Accordingly, availability of critical spare parts stock needs to be ensured through an effective management method.

A systematic technique is used here to evaluate spare part criticality based on structuring the evaluation process into a three-level hierarchy. At level 1, we define failure consequences of spare parts, i.e. the most reasonable consequences resulting from spare part failure or malfunction; what could happen if the spare part is not available in stock, how it will affect the major concerns of the organization. The definition of failure consequences is shown in Table I.

TABLE I
DEFINITION OF FAILURE CONSEQUENCES

Organization Concerns	Failure Consequences
Safety	A risk on people and environment safety; parts failure may result in death, disability or environmental damage that violates law or regulations
Equipment Operation	The effect on equipment operation consecutively equipment availability; when a part fails it may cause total or partial equipment shutdown which result in less equipment availability.
Equipment Downtime Cost	A loss in money is always associated with equipment unavailability and maintenance work.
Products Quality (if applicable)	For industrial and manufacturer organizations, equipment is used to produce a product and if one of this equipment is not working properly, this may affect products final quality.
Customer Satisfaction (if applicable)	In service organizations, customers' satisfaction is the organization main goal and concern. Unavailability of some equipment may affect directly the customer needs.

At the second level, our main target is to specify how the whole system works and the relation between spare parts and equipment. Hence, we develop an equipment breakdown structure and maintenance plan structure. The criticality level is defined first as combined level then using priority level we can define a critical class of each item.

Finally, at level three, we provide a qualitative measure for spare part criticality based on expert judgment. The number of criticality levels should be established depending on the size of the system being considered to reflect the level of concern.

We propose two categories of criticality levels; "High, Medium and Low" or "Catastrophic, High, Medium, Low and No effect". Accordingly, we first define a combined class for each spare part then we assign priority level for each criterion to evaluate the final critical class of the spare part.

2) Consumption Rate Classes

Consumption of spare parts is an important criterion for spare part classification. It is used to specify which spare parts are more frequently used. The classification scheme used is ABC classification according to Pareto principle; where, class A includes spare parts with the most utilization percentage, class B includes spare with less utilization, and class C includes spare with the least percentages of utilization.

3) Inventory Cost Classes

Inventory management major conflict results mainly from inventory total cost, usually we prefer to stock all needed spare parts however we face the problem of inventory costs. Total inventory cost consists of three main components; holding cost, ordering cost and shortage cost.

In this study shortage cost is ignored, since the shortage cost is already considered in the criticality classification. The classification scheme used is ABC classification according to Pareto principle.

4) Multi Criteria Classes

The consideration of a number of criteria in classification raises a significant problem of conflicting objectives; a spare part may be considered as a critical item with high inventory cost and low consumption rate, which may lead in conflicts while choosing the stock control method.

Therefore, a management tool for multi-criteria cases is needed. In this framework a matrix-based methodology is adopted, which is computationally simple, effective, and easy to use.

First, a set of consecutive matrices are created; where, the number of matrices depends on the number of criteria considered. In this paper 3 criteria are used as an example; inventory cost, consumption rate, and criticality class.

According to the bi-matrix shown in Table II, items are first managed on the basis of consumption rate and inventory cost regardless of the criticality level.

TABLE II
CONSUMPTION RATE AND INVENTORY COST BI-MATRIX

		Consumption Rate		
		A Class	B Class	C Class
Inventory Cost	A Class	AA	AB	AC
	B Class	BA	BB	BC
	C Class	CA	CB	CC

Then, as shown in Table III, the bi-matrix developed is combined with the criticality criteria. A combined class is now defined for each stock item that includes the three criteria. Accordingly, we can select an inventory policy which better suits the class characteristics as will be described in details in next section.

TABLE III
COMBINED CLASSES

		Criticality Level		
		High	Medium	Low
Inv. Cost/Consumption	AA	AAH	AAM	AAL
	AB	ABH	ABM	ABL
	AC	ACH	ACM	ACL
	BA	BAH	BAM	BAL
	BB	BBH	BBM	BBL

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BC	BCH	BCM	BCL
CA	CAH	CAM	CAL
CB	CBH	CBM	CBL
CC	CCH	CCM	CCL

The second step is assigning a priority level for each criterion, priority levels are chosen on system basis. In the present study we propose a general structure for priority levels; criticality has the highest priority level. The class including spare parts with high criticality level must be physically present at the warehouse and controlled using safety stocks; regardless of the other two criteria; due to the catastrophic effects that can happen if they were not available.

The rest of classes will be managed on class basis using the priority levels defined. For example if second priority after safety is the consumption rate, items that belong to combined class "ACL", i.e. having high inventory cost, low consumption, and low criticality level are managed using just-in-time policy. However, items in class "CAM", i.e. having low inventory cost, high consumption rate, and medium criticality are managed using continuous review inventory policy (safety stock policy).

B. Demand Forecasting and Inventory Control

After the definition of all combined classes and the selection of a suitable inventory policy for each class, we need to calculate the parameters of the selected inventory policy; such as, the reorder point and order quantity for each stock item to achieve a predefined service level.

Economic Order Quantity (EOQ) is usually used to determine the order quantity and is evaluated average forecasted annual demand. In contrast, calculating the reorder point requires estimates of the lead time demand (LTD). As mentioned earlier in the literature review section, different forecasting methods have been applied to determine the lead time demand. In this work, both probability distributions and forecast techniques are used, in order to arrive at a robust framework that can be implemented in many situations and real case studies.

The normal distribution is selected for modeling spare parts demand as a probability distribution, since it performs better in business practice, provides more accurate results, and is simpler to use. In addition, exponential smoothing and Croston method are selected as two competing forecasting methods.

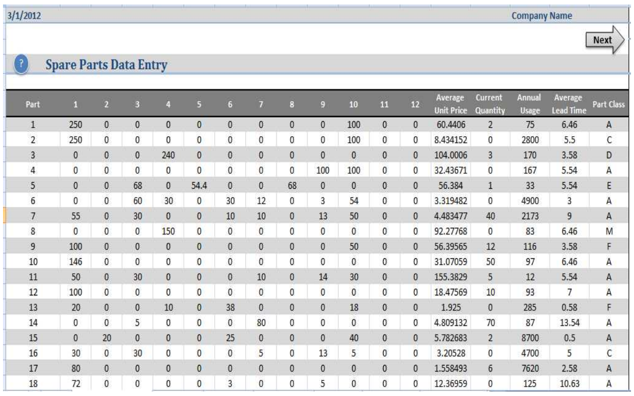
IV. Computer Model Development

An Excel based application for spare part inventory management has been developed. It provides an effective and user friendly tool for applying the proposed framework for small sized organizations. The main components of the application are a startup screen for data input and three main modules for basic operations; spare part classification, inventory management, and reporting module.

The output of these modules is the ordering policy of each spare part. Furthermore, it can be easily configured by users to match their current business processes and requirements. This section presents a step by step guide through the developed computer model showing its main and special features of its constituting modules.

A. Initial Data Setup

Users start using this application by adding the initial data required as shown in Fig. 1.


3/1/2012 Company Name
Next
Spare Parts Data Entry

Part	1	2	3	4	5	6	7	8	9	10	11	12	Average Unit Price	Current Quantity	Annual Usage	Average Lead Time	Part Class
1	250	0	0	0	0	0	0	0	0	100	0	0	60.4406	2	75	6.46	A
2	250	0	0	0	0	0	0	0	0	100	0	0	8.434152	0	2800	5.5	C
3	0	0	0	240	0	0	0	0	0	0	0	0	104.0006	3	170	3.58	D
4	0	0	0	0	0	0	0	0	100	100	0	0	32.43671	0	167	5.54	A
5	0	0	68	0	54.4	0	0	68	0	0	0	0	56.384	1	33	5.54	E
6	0	0	60	30	0	30	12	0	3	54	0	0	3.319482	0	4900	3	A
7	55	0	30	0	0	10	10	0	13	50	0	0	4.483477	40	2173	9	A
8	0	0	0	150	0	0	0	0	0	0	0	0	92.27768	0	83	6.46	M
9	100	0	0	0	0	0	0	0	0	50	0	0	56.39565	12	116	3.58	F
10	146	0	0	0	0	0	0	0	0	0	0	0	31.07059	50	97	6.46	A
11	50	0	30	0	0	0	10	0	14	30	0	0	155.3829	5	12	5.54	A
12	100	0	0	0	0	0	0	0	0	0	0	0	18.47569	10	93	7	A
13	20	0	0	10	0	38	0	0	0	18	0	0	1.925	0	285	0.58	F
14	0	0	5	0	0	0	80	0	0	0	0	0	4.809132	70	87	13.54	A
15	0	20	0	0	0	25	0	0	0	40	0	0	5.782683	2	8700	0.5	A
16	30	0	30	0	0	0	5	0	13	5	0	0	3.20528	0	4700	5	C
17	80	0	0	0	0	0	0	0	0	0	0	0	1.558493	6	7620	2.58	A
18	72	0	0	0	0	3	0	0	5	0	0	0	12.36959	0	125	10.63	A

Fig. 1 Initial spare parts data entry screen

After setting initial data, users can define what criteria and methods are to be used, as shown in Fig. 2. First they select the classification scheme, whether single or multi-criteria and the type of criteria considered. Then they select the method for forecasting demand of spare parts. Three methods are available; normal distribution, single exponential smoothing and Croston method. Finally, they can specify which reports are needed.

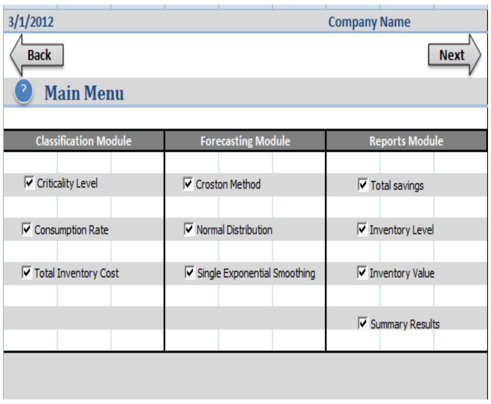


Fig. 2 Main screen

B. Spare Parts Classification Module

1) Criticality Evaluation

We built this evaluation process based on five questions concerning the effect of spare unavailability on safety, system operation, downtime cost, products' quality, and customer satisfaction; as shown in Fig. 3.

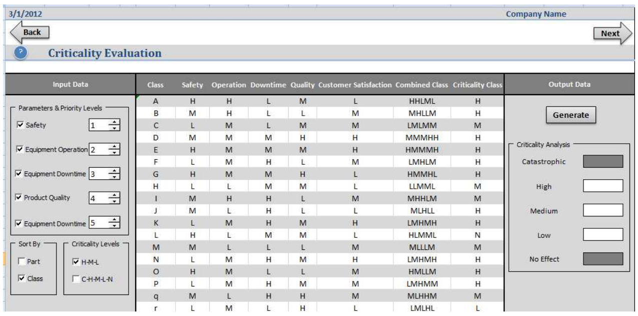


Fig. 3 Criticality evaluation screen

This module allows users to:

a) Select which questions are applicable. For example a product quality may be inapplicable in a service organization. Furthermore, if the available questions are inconvenient, the user can add/replace available ones (a maximum of five questions can be used).

b) Assign priority levels for questions. Users can set the priority levels according to their needs.

c) Choose the criticality level category. The user can choose between "High, Medium, and Low" or "Catastrophic, High, Medium, Low, and No effect".

d) Select if criticality will be evaluated for each part or for each class of parts if needed.

e) Evaluate for each part the combined criticality class; consequently, the module will determine its criticality class using the defined priority levels.

f) Generate a summary report of the number of stock items in each class and its percentage out of the total number of stock items.

2) Consumption Rate and Total Inventory Cost Calculations

The consumption rate and total inventory cost modules are carried out in a similar way, using ABC method as shown in Fig. 4.

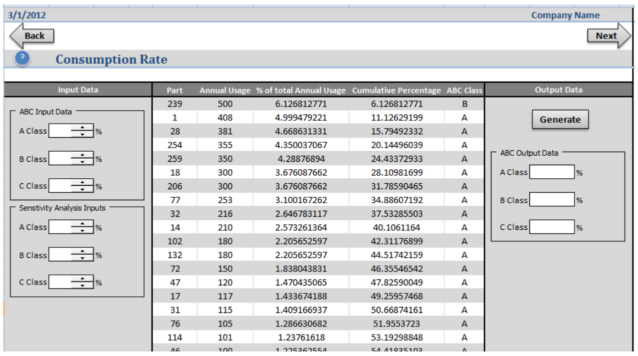


Fig. 4 Consumption rate calculation screen

However, sometimes the results from the ABC method can be inconvenient for some users; therefore, we added a sensitivity analysis capability, which will update the results according to an acceptable range, defined by users, for each class. Same as criticality process, the user can generate a summary report of the number of stock items in each class and its percentage out of the total number of stock items.

3) Multi-Criteria Analysis

The multi-criteria analysis module shown in Fig. 5 is responsible of assigning priority levels for each criterion through any of the following alternatives:

a) Users can customize priority level for each criterion based on maintenance requirements and objectives.

b) Users can use the system default settings, which is criticality, consumption rate, then total inventory cost.

Using the defined priority levels the module will calculate the combined class and consequently the final class.

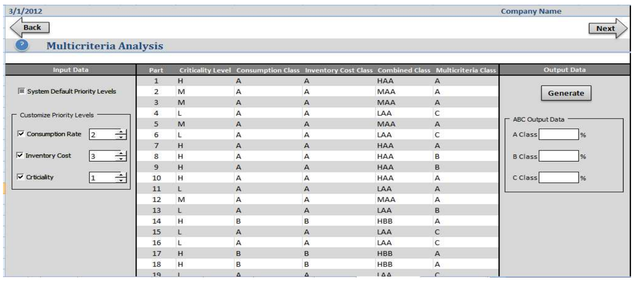


Fig. 5 Multi-criteria analysis module

C. Inventory Management and Demand Forecasting Module

In this module, the inventory policy is selected and the reorder point, EOQ, and safety stock level are calculated.

1) Inventory Policy Selection

Inventory policy can be selected either automatically or manually. Based on the classes defined for each item in previous step, the model can automatically select the inventory policy; class A and B are managed using continuous review inventory policy; however, for class C, just-in-time policy is applied. Furthermore, users can select the inventory policy according to their own judgment regardless of the item class.

2) Forecasting Demand and LTD Modeling

This module is responsible of forecasting demand, modeling LTD, and consequently determining the parameters of the inventory policy; reorder point and order quantity for each item. Of course these values are determined at a specific service level as shown in Fig. 6.

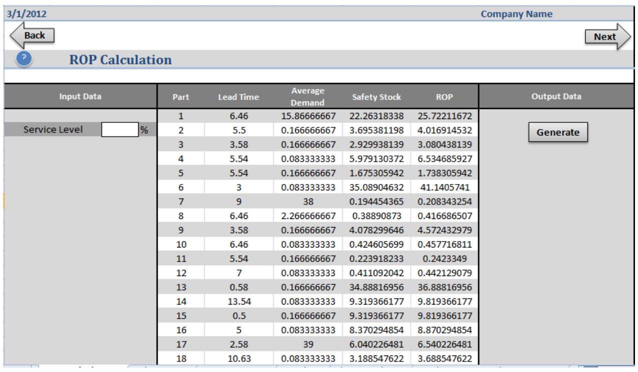


Fig. 6 ROP calculation screen

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A. Reporting Module

This module summarizes all results obtained from the other modules. Moreover, this module provides a mean to evaluate the difference between the three methods used for demand forecasting by calculating average inventory level and the average inventory value for each item.

The average inventory level is calculated based on the average minimum and maximum level of inventory. The aspired minimum level is the safety stock; while, the aspired maximum level is the sum of the safety stock and the EOQ.

The same calculation applies to the inventory values as shown in Fig. 7.

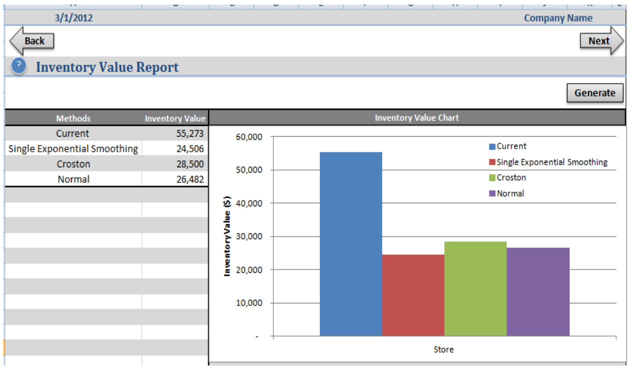

Fig. 7 Inventory value report screen

Furthermore, the reporting module calculates total savings achieved using the proposed methods in comparison to current inventory value as shown in Fig. 8.

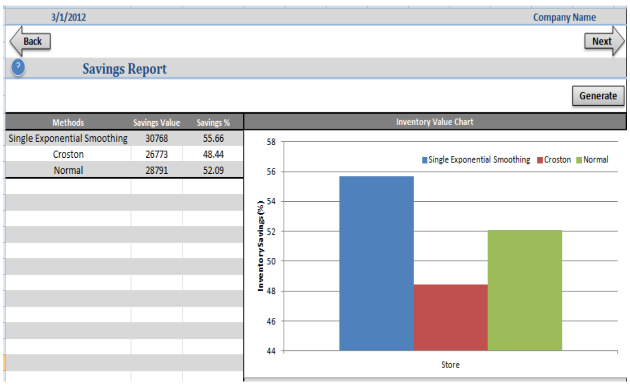

Fig. 8 Savings report screen

V. CASE STUDY

A. Problem Definition and Data Collection

In order to evaluate how the framework can be taken into practice, test the developed computer model, and illustrate its performance; the proposed framework is applied to a case study at a service organization. We investigate the inventory management system of this service organization, gather historical demand data and their corresponding facility maintenance information then use these data in the implementation of the proposed framework using the developed spread sheet based application.

The data collection includes general information about the organization, equipment function and hierarchy, maintenance operations, stock items (number of warehouses, demand, prices, lead time, and current quantities), inventory management methods, and processes. Interviews with responsible persons are conducted to gather this information.

The service organization under study consists of a large complex that includes a considerable number of assets and systems used to operate all aspects of the building. This organization has one main warehouse with 6343 items; including all materials and spare parts needed for maintenance and repair. This warehouse is divided into 6 storage areas according to maintenance systems, e.g. mechanical stock, heat ventilation and air conditioning (HVAC) stock, electrical supplies…etc. Currently, an enterprise asset management system (EAM), a management system for maintenance and spare parts, is used. It provides the tool to manage equipment maintenance and to keep track of warehouses main data (transactions, current quantities, reservations...etc.) but it is not specific for inventory control. Therefore, available stores are managed based on expert judgment whether for spare part classifications or demand forecasting.

In addition, parts needed are ordered on demand, i.e. no inventory policy is applied which results in high stock levels and thus high inventory cost. Accordingly, the main objective of this study is to define how much stock is needed for each item taking into consideration different criteria such as item criticality, price, demand rate...etc. to ensure low stock levels associated with high level of equipment operation.

Demand information is collected on monthly basis for 1 year (from January 2011 to January 2012) so a total of 12 periods is available. Demand set is not specified whether it is due to preventive or corrective maintenance. We exclude parts with negative or zero annual demand. We classify stock items in two demand categories, spare parts and consumables. Spare parts are needed for maintenance or repair therefore they are characterized with an intermittent demand with a large proportion of zero values. While consumables are used more frequently to maintain a high level of equipment operation which resulted in a more regular demand with less proportion of zero values. In the present study, both spare parts and consumables are considered while forecasting demand.

According to prices, parts with average price zero are not owned by the maintenance department. Therefore, they are not associated with any holding cost, consequently these items are not considered while evaluating the inventory model.

Interviews are conducted with maintenance engineers, inventory specialists and top management to define their main concerns, goals and available resources. We find out that safety and equipment operation are the major two concerns of the organization. They give first priority to safety and require a service level of 95% for equipment operation. Additional interviews are also organized with responsible maintenance engineers to determine the criticality level of stock items.

They choose a criticality level category of "High, Medium and Low".

B. Findings Summary

Using the collected data and the developed computer model, spare classification processes and demand forecasting are carried out; consequently, we calculate the reorder point and EOQ for each stock item.

However, we still cannot judge the overall effectiveness of the proposed framework. According to decision makers, they still do not have a clear picture on which forecasting method is better. Hence, performance measurement is carried out using the reporting module. For each store we calculate optimum inventory level and its value. Furthermore, total savings achieved from the adoption of the proposed framework are calculated.

Fig. 9 shows that using the exponential smoothing method results in minimum inventory value in comparison to Croston method and Normal distribution except for store 2.

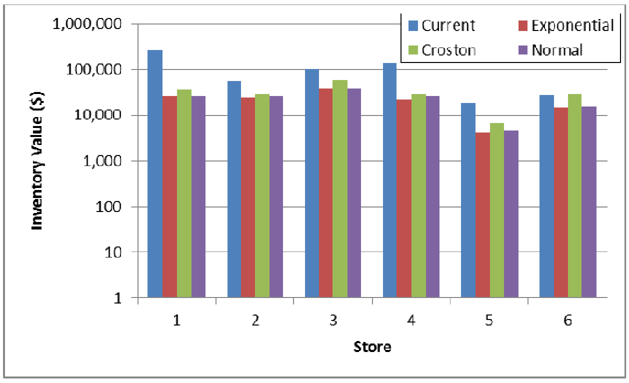

Fig. 9 Stores Inventory Value

On the other hand, Fig. 10 shows that for almost all stores, Normal distribution provided the least inventory level. Furthermore, we observe that the majority of stores have current inventory levels less than the forecasted levels, however their inventory value is much greater, this is resulting from stocking non critical and expensive spare parts. This result reflects the existing gap between spare part classification process and inventory control. Therefore, we conclude that using the integrated perspective stresses the relation between spare part classification and inventory management, resulting in less inventory value for the same service level.

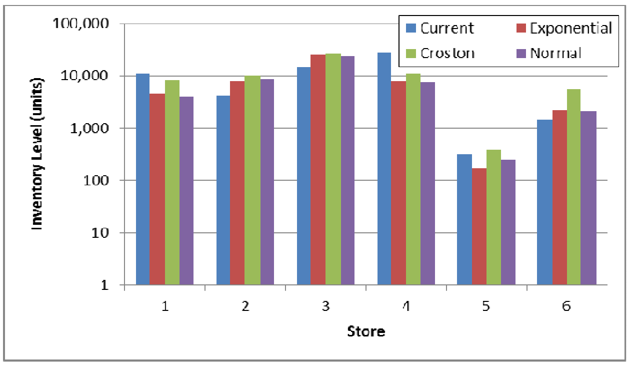

Fig. 10 Stores Inventory Level

The results are compared to the current inventory value and total savings are calculated for each store. Fig. 11 clearly shows that all proposed methods provide better results than the current system. Expect for, using Croston method in store 6, which does not result in any savings; however, on the contrary negative results are achieved.

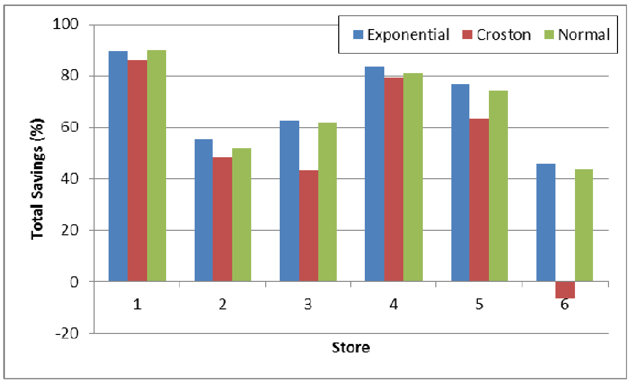

Fig. 11 Total savings

Further investigation of the results obtained for store 6 shows that it contains more consumables than spare parts. In other words, it has a more stable demand than that of the remaining stores. This is why we obtain the least savings when using the exponential smoothing method and even obtained negative results when using the Croston method. This proves that the proposed framework is more suitable to use for managing spare parts inventory having lumpy demand.

Furthermore, single exponential smoothing method provides the least inventory value as well as the highest cost savings with respect to other methods. Savings vary from 46% for store 6 to approximately 90% for store 1.

Finally, Croston method, despite its ability to provide more estimates of demand per period, has performed the worst of all methods, the inventory level was overestimated and the inventory value is the highest among the models used.

VI. Conclusion

Spare part inventory management is a vivid field of research due to the importance of the items under control, their influence on the operations and the difference in demand structure from other stocking items. From the conducted literature review it can be concluded that an integrated approach is effective for managing inventory of spare parts. Few works have been presented in this subject area and practical case studies are hardly presented. The objective of the current work is to fill in this gap by proposing an integrated framework for spare part inventory management and providing a real life case study implementation.

The proposed framework comprises spare part classification, demand forecasting and inventory management. In order to facilitate and automate the implementation of the proposed framework, we develop a spread sheet based application for spare part inventory management.

It provides an easy to use tool for inventory control; our main target development is to create a generic application suitable for a wide range of case studies.

In order to verify and validate the proposed framework, it is applied to a case study at a service organization using real historical data of 6343 items; including all materials and spare needed for maintenance and repair. The conclusion drawn from the implementation results is that an integrated approach leads to lower inventory levels for the required service level. In addition we may conclude that Exponential Smoothing technique for demand forecasting performs better than the other two methods; normal distribution and Croston method.

This present study and other integrated approaches presented in literature, did not take into consideration the type of maintenance policy applied whether it is scheduled or unscheduled. Furthermore, integration between spare part management and maintenance intervals may be studied. Since maintenance operations directly affect spare parts inventory management, further study is needed in this field and an attention to maintenance intervals while implementing spare part classification, demand forecasting and inventory control is needed.

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