E-LOCUÇÃO | REVISTA CIENTÍFICA DA FAEX
EDIÇÃO 16 - ANO 8 - 2019 ISSN 2238-1899

A QUALITATIVE VARIABLE TO SAFETY STOCK PARAMETER DEFINITION APPROACH

PEDRO PAPANDREA[1]
ANDERSON PAULO DE PAIVA[2]
RAFAEL CORADI LEME[3]
JOÃO ÉDERSON CORRÊA[4]

ABSTRACT

The material requirement planning is normally calculated according to some parameters of inventory, such as safety stock, resupply point, maximum stock, and lead-time. Those parameters come from equations based on the historical data of demand. This paper proposes the incorporation of a qualitative variable based on the key-users knowledge of the process, to improve robustness in the safety stock calculation. The focus is directed to the maintenance items because their demand are harder to predict. The result is the decreasing of the risk of stock out and a better definition of the parameters by using the qualitative variable grouped in the standard equation for calculating safety stock. A full factorial design of experiment concept has been used to perform questions to the users what generate the qualitative variable. A real case application has demonstrated a significant decrease of the stock-out risk. Otherwise, this reduction does not has increased significantly the total monetary value of that safety stock.

[1] Institute of Industrial Engineering and Management, Federal University of Itajuba, Brazil.
[2] Institute of Industrial Engineering and Management, Federal University of Itajuba, Brazil.
[3] Institute of Industrial Engineering and Management, Federal University of Itajuba, Brazil.
[4] Institute of Industrial Engineering and Management, Federal University of Itajuba, Brazil.

facebook.com/faculdadedeextrema/ @faexoficial www.faex.edu.br (35) 3435-3988

1. Introduction

There are many studies that describe various types of calculating safety stocks and other parameters of inventory control in the literature, as seem in the works of Inderfurth & Minner (1998); Nenni et al. (2005); Ho et al. (2007); Inderfurth & Vogelgesang (2013); van Donselaar & Broekmeulen (2013). These methods may be impracticable since the equations are complex and in the most cases, it is necessary a special program to address them.

The knowledge of the user is a key element that can provide the basics principles to the relationship between the human factor and the engineering theory can be understood Kantowitz & Sorkin (1983). The key-users participation in projects like software developments, corporative culture research is already largest used Huang (2012), it is also used in new products development; e.g. vehicles gadgets Yao et al. (2012). The key-user is, at the most case, considered as a passive object of the study instead of an active font of knowledge McNeese et al. (1995).

The present work considers the knowledge of the key-users to dene the criticality parameters. Other gain detected was the interaction of different areas inside the company. Indirectly improving of the communication between those areas. It has permitted a responsibility's share between the department of supply chain and its customers. It also makes possible a better definition of the critical factors and the correct parameterizing of them in the enterprise resource planning system (ERP). The historical demand is not the only way to calculate the material resource planning (MRP) parameters anymore. It will be one more factor added important information came from the key-users. The big goal is make the parameters of MRP more robust when it is looked of the eye of planning and cost. The MRP is part of a methodology more expansive called supply chain management system (SCM), a lot of companies are using SCM to improve its efficiency and the level of management between factories in additional to increase the value of this operation and the values on the new supply chain projects Mathieu & Pal (2011).

One important factor of the MRP calculus is the safety stock. It is the initial point used to the calculus of the other parameters such as maximum stock, resupply point and so far. This work has concentrated the efforts on the main factor over the maintenance, repair and operations (MRO) materials, using its equations to investigate how the critical model can improve the inventory management and its costs. The goal was the improvement of the level of service thought the knowledge of the real use of the material. A case study in an automotive industry was performed to corroborate the applicability of this propose. The results of this work have been positive and have demonstrated the applicability in other types of materials beyond MRO.

The planning and control of production risk factor is high necessary if there is low level of confidence in the production resources and this important factor cannot be neglected. It refers as well to the variation of the demand as production to stock. Even though all efforts in quality control and quality programs to continuous improvement, the low levels of confidence in the production resources still is a reality in the companies and it turns to considerable financial lost Inderfurth (2006).

One important consideration was made for Will M. Bertrand & Fransoo (2002), before the 1970’s the operational research did not consider the material requirements planning (MRP) to be any importance. The MRP system was adopted as a way of working. It has changed when the companies’ starts to calculate all its costs, including inventory costs.

The inventory control in supply chain is important to guarantee the level of service and satisfaction of the internal and external customers. The customer’s requirement need to be attended at the right time, right quantity and right cost, all of it with an efficient cost control Dolgui & Prodhon (2007). The inventory is a representative part of the industrial costs and in what the MRO items are included. This kind of items are the most hard to be planning because its demand does not follows predictable models. Its use is at most non-programmed or random. More than that, the area available to stocks is an expensive factor to be considered in the MRP, never forgetting about the “first in first out” (FIFO) methodology and obsolescence level. All of it to remark the importance of an efficient planning and control of materials and inventory.

When regarding about service level or level of care, it is important to understand that it is a percent of the total number of solicited service over the service that was attended. It can be extended to quantity of items needs over the quantity available of it. The inventory control are largest studied, Harris (1913) has proposed the economical lot buy equation. The optimization of the material flow is so important to the organization because it is a large part of the total operation cost of the supply chain

facebook.com/faculdadedeextrema/ @faexoficial www.faex.edu.br (35) 3435-3988

and logistical department. Because of that, the rhythm of the production cannot be broken. The cost of maintenance inventory is an expressive part of capital what may not be used to other ends.

The market requires that the companies have the correct use of all its resources. Stocks require a high cost, but they are essential to maintain the level of production and maintenance of the equipment. This work is intended also to develop a method that will improve how the criticality of the materials is designed, changing the equation that is commonly used for the calculation of the parameters of MRP, combining it with a spreadsheet with issues that the key-user will answer. Considering the demand for materials is under a normal distribution with a mean and standard deviation, we can apply the theorem central limit of the normal distribution to calculate the risk of stock.

This article is organized as follow: section 2, begins with the definitions of: MRP, including the definition of their parameters to reach the safety stock; cites the terms of literature and links it with the contributions of this work. The section 3 presents and describes the research methodology; section 4 provides the explanations of the proposal model. The section 5 presents the case study of the application in an industry of the automotive sector and compares the standard equations defined in the literature with this proposal. The results are shown in section 6 and finally the section 7 presents the conclusions and discuss about future resources.

2. Literature support

Material requirement planning system, MRP, is a computerized information system for the management of inventories, dependent scheduling of inventory and orders of resupply. The main objective of the MRP is receiving the right parts in certain quantities and in certain deadlines Ho et al. (2007). MRP determines the quantity and timing of the acquisition of dependent demand items needed to satisfy the master schedule requirements. One of its main objectives is to keep the due date equal to the need date, eliminating material shortages and excess stocks Ghobbar & Friend (2004).

Cox & Clark (1978) describes it as a technique of control designed to minimize the investments in inventory. He also demonstrate that the MRP is one important tool to maximize production and operational efficiency and improve customer service on program management. Furthermore, that program includes a detailed list of necessary quantities of each part and proper to start their purchase orders and work orders for each item, subject to its cycle time. That list is based on the B.O.M., build of materials on demand based on dependent items. There are two kinds of material requirements planning: based on the concept of dependent demand, materials that are used to manufacture the final product, such as raw materials, components, and sub-assemblies; demand based on non-dependent. Materials used for maintenance, security and office are some examples of this type of item.

Planning for dependent demand materials is based on the production schedule. In this case, the three primary inputs required by most MRP systems are: one master production schedule, the build of materials (BOM) of an archive of products and quantity available in stock Cox & Clark (1978), it’s a future view. Moreover, the design of non-dependent demand materials is based on historical consumption; it is vision in the past. The MRP has a significant history of implementation problems Cooper & Zmud (1989). Strategies for Purchasing and Supply an organization constitute a strategic factor of the business. The material planning is responsible for the management of materials, being an active part of inventory management. The requirements for good planning are the dates of the needs with the quantities of materials to be purchased and the required delivery dates for each of them. The table 1 shows the study lines in the supply chain field.

Table 1: Study line on the time

Study Line	Reference
Inventory management	Knoeppel (1920)
Mathematics in inventory control	Vazsonyi (1954)
Materials planning	Beckmann (1961)
Material requirement planning	Orlicky (1975)
Manufacturing resource planning	Wight (1984)
Enterprise resource planning	O'Brien James (1990)

An important factor for improving the manufacturing processes is production and inventory management, and a variety of production and inventory management information systems such as MRP have thus been developed Cooper & Zmud (1989).

The environment of the user that relates the knowledge of MRP, use and setting of the ERP enables multiple solutions in planning methods are used Jonsson (2008). The ERP can be understood as the system of information used by the organization to computerize and automate their processes. These multiple environments will be treated with the integration of key-users for the definition of the best parameters of MRP. Key users are those recognized by the structure of supplies as being holders of sufficient knowledge about the materials that they use to the point of being able to fill out the required data with reliability greater than 80%. Environment of the user is the operational environment that surrounds the planner of materials and that interferes in their everyday processes of planning Jonsson (2008).

The MRP works very well in deterministic environments. To adapt the method in uncertain environments, some parameters must be set. They are: safety stock, one used to absorb any problems of excess demand unplanned delay of suppliers, quality problems not previously detected, etc.; planning horizon or future planning time; reorder point, when the purchase orders, replenishment or production should be generated so that the items are available at the right time; within planned and safety lead time Dolgui & Prodhon (2007).

The safety stock or materials capacity buffer Plenert (1999) are needed to hedge against demand not planned and supplier lead-time uncertainty or delayed. As a means to avoid stock-outs, safety stocks (Figure 1) hence play an important role in achieving customer satisfaction and retention Nenni et al. (2005). All stock parameters get started on the safety stock (SS).

The SS is calculated using the Equation (1): (adapted from Nenni et al. (2005)

$$SS = \left(\sqrt{\sigma^2_{D_n} \cdot LT + \mu^2_{D_n}}\right) * k \tag{1}$$

Where:
SS is the Safety Stock (buffer)
σ^2_{Dn} is the variance of the demand in a time period (month, year)
μ^2_{Dn} is the mean of demand in a time period (month, year)

facebook.com/faculdadedeextrema/ @faexoficial www.faex.edu.br (35) 3435-3988

k is a constant of the standard normal distribution (Table 2)
LT is the resupply lead-time. The time between the purchase and the arrived of the items.

Scientific contributions that deals with theory-based determination of control parameters originate from research in the field of stochastic inventory control problems Inderfurth & Vogelgesang (2013).

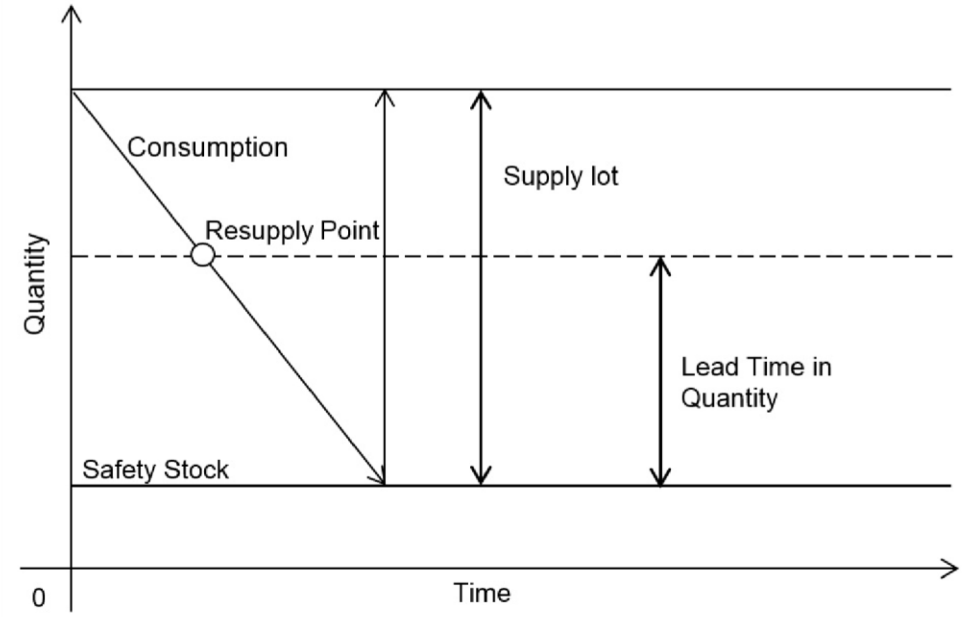

Figure 1: Consumption and resupply chart Slack et al. (2010), adapted by the author

Table 2: Standard distribution of risk

Stock out risk	Service level:	k
50%	50%	0.000
40%	60%	0.253
30%	70%	0.524
20%	80%	0.842
10%	90%	1.282
5%	95%	1.645

To understand k, first, is necessary to understand the normal distribution and the z-score. Normal distribution is also called de Moivre distribution, Gaussian distribution, and Gauss-Laplace distribution, due to the work of Abraham de Moivre, Johann Carl Friedrich Gauss, and Pierre-Simon Laplace in the eighteenth century. The Normal Distribution represents a family of continuous probability distributions, applicable in many fields. It may be defined by two parameters, location and scale: the mean (average, μ) and variance (variability, σ2), respectively. To indicate that, a real-valued random variable X is normally distributed with mean μ and variances σ2 (≥ 0), it is written as: X ~ N (μ,σ2). The normal distribution is given by the function of Equation (2) Burt (1963):

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} exp\left(\frac{-(x-\mu)^2}{2\sigma^2}\right), x \in \Re \tag{2}$$

Burt (1963) also describes that we can standardize X to obtain z-scores when $z = \frac{X-\mu}{\sigma}$. The distribution of the z-scores is the standard normal distribution, that is, the normal distribution with mean equal to Zero and standard deviation equal of one. Hence, if X ~ N (μ,σ), then z ~ N (0,1). Calculating the inverse of the normal distribution, we can take the z-value showed in Figure 2, linking with stock out risk k and detailed in the Table 2.

The lack of raw material or input changes the entire production planning, causing more setups and lack of control in coordinating the productive capacity, besides the fact that it takes the finished products to rupture Slack et al. (2010). The increase in the number of companies involved in the supply chain caused by vertical structures of materials, in which the companies focus on their core competences, and transferring to other parts the activities that were being carried out internally makes the purchasing market more embracing along with the quantity of suppliers. It is common to have purchases from different companies usually with minimum lots, deliveries conditions and lead times for a gain in inventory costs.

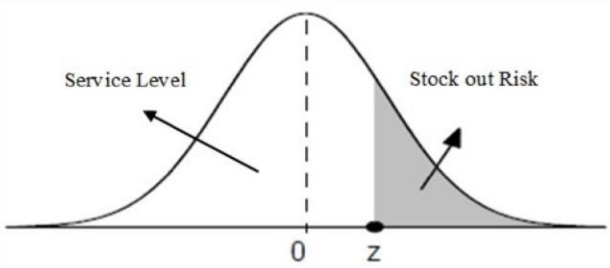

Figure 2: Standard Normal Distribution

Plenert (1999) has identified, in his works, that the lead-time has already been thoroughly demonstrated in the research that the majority of the total lead-time, over 95%, is non-productive time. Lead-time includes elements like queue time, waiting time, transfer time, etc., all of them which are much larger than the actual production time. In additional more than that, as stated earlier, is the loss of the inventory efficiency in order to gain labor efficiency. In the inventory replenishment process, the supplier can also offer a second means to supply items with a faster shipment at higher cost. This is referred to the emergency replenishments. Bijvank & Vis (2011). The safety stock levels are then used to provide a buffer and ensure the supply even in uncertainty of demands. Maintenance of safety stock levels is not the goals of planning Jonsson (2008).

Besides the problems described above, it is clear to mention the problem created by lack of space in the storage. The storage does not represent only the union or selection of loads where a systematization of insufficient storage places constitute one of the basic causes of a wide range of disadvantages, such as: traffic congestion, difficulty in materials rotation, excessive movements and displacements, poor use of resources and human resources. In other size, ABC analysis, also known as Pareto principle or management by exception tool, has long been used in industries for various applications, e.g. quality control, cost reduction, work measurement, method improvement, inventory management, etc. Chu & Chu (1987), and will be considered to choice the initial k- value.

3. Research methodology

The research has been conducted in an exploratory manner for data collection and case study applying the proposed methodology and analyzing the results. We can compare our method with Will M. Bertrand & Fransoo (2002) who has termed the empirical model-based quantitative research. It is the performed quantitative theoretical research in real-life operation process and analyzing the results.

The system used by the company, the object of this study, was initiated in 2005 when all the parameters were loaded. It was identified that, these parameters were calculated following a specific methodology, based on the experience of the planner materials without complex calculations. These data have not undergone modifications prior to this proposal.

3.1. The original data

The ERP system used by the company is the SAP R/3^{TM}. In the Master of the Materials (MM) module you can view all of MRP's parameters, including maximum stock, reorder point (or point of resupply), resupply time, safety stock. This last one is the objective of this work. All the data, codes and description of the materials are real, including the demands. The codes and descriptions of the items were coded in order to maintain and ensure the privacy of the company.

Of all of them, 1,173 different items were classified as MRO and then we have selected five materials. Its data are summarized in Table 4 to be used as an example. These five items were chosen randomly. Possession of the historical, the processes were followed: 1 - Organization of data; 2 - Calculation of risk levels as system data; 3 - Implementation of standard calculation models of SS and data analysis; 4 Calculation of risk levels with the standard equation; 5 - Comparison between the three previous models.

4. Criticality model

The model is based on the knowledge of the customer, called key-user, of each kind of material. This key-user needs to answer some questions, as many as necessary to the planner to have a good comprehension of that material or groups of materials. Here were used just six main questions to prove the power of the proposal. The Appendix shows these questions and possible answers, used to found the risk level, which one is not for fill of the customer. Those variables are classified as categorical variable, which are what produce responses that belong to groups or categories Newbold et al. (2012).

The risk is calculated by using the probability density function (PDF) of the normal distribution, given in the Equation (3).

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(x-\mu)^2/2\sigma^2} for - \infty < x < \infty$$	(3)

Where μ and σ are any numbers such that $-\infty < \mu < \infty$ and $0 < \sigma^2 < \infty$ and where e and π are physical constants, e = 2.8182... In addition, π = 3.14159... Newbold et al. (2012). In addition, the normal probability distribution represents a large family of distributions, each with a unique specification for parameters μ and σ^2. These parameters have a very convenient interpretation.

The history of consumption could turn not feasible to use Equation (1), for that reason it is proposed that the Equations (4) and (5). In this case, k is an inverse of the normal standard distribution (2) of the service level (Table 3) and was chosen according ABC curve applied on the unitary cost of the items.

Table 3: Service levels

ABC Curve	Service level	k
A	90%	1.282
B	70%	0.524
C	60%	0.253

If the materials are for scheduled maintenance and the stock out risk is low, the safety stock is setup in Zero; If the materials are of low criticality i.e. has substitutes, the risk factor is low and the SS is calculated in the Equation (4).

$$SS_{low} = \left[\left(\sqrt{\sigma^2_{D_n} \cdot LT + \mu^2_{D_n}}\right) * k\right] * \Phi \quad (4)$$
$$SS_{modhig} = \left(\sqrt{\sigma^2_{D_n} \cdot LT + \mu^2_{D_n}}\right) * (k + \Phi) \quad (5)$$

Where:
SS_{low} is the safety stock to low critical
SS_{modhig} is the safety stock to moderate and high critical
Φ is the parameter of the survey
If it is of moderate or high critical, the safety stock will be calculated in the Equation (5). To calculate the risk of each material, the key-users of maintenance area needs to answer some questions summarized in this work as:

- Is the Material of scheduled maintenance?
- Has the Material a substitute (other brand)?
- If the Material is stock out, is the production stopped?
- Is the Material from other country?
- Is the Material of personal safety?

- Is the Material cost more than $1,000.00?

The answers are categorized in Yes or No and will be the parameters to choose the Φ value in the Appendix.

5. Application in a real case

The proposal work was applied to a Brazilian automotive company. They were not being able to equalize the purchasing because the lack of consumptions that joins the conventional formulas of MRP. The company has the flowchart for purchase of materials following on Figure (3).

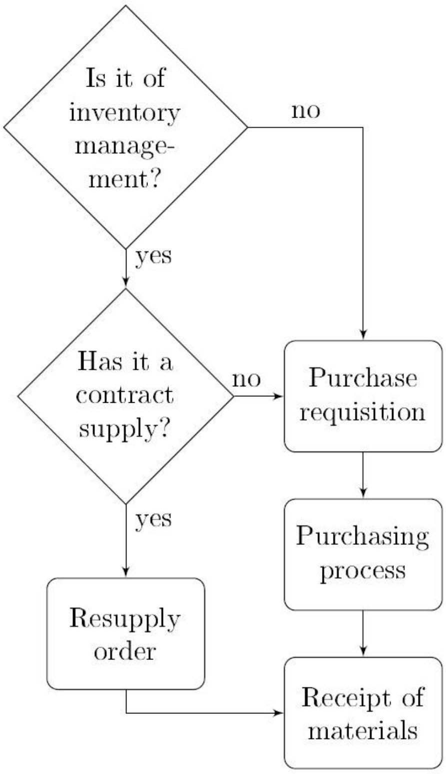

Figure 3: Flow Chart

The processes highlighted are the most impacted by the parameters of MRP enrolled in ERP. There are 1,173 materials classified as MRO. There are standard deviations of monthly consumption ranging from 6,800 to Zero, in 12 months, which demonstrate great variability on these consumptions. There were considered materials that it consumed one part throughout the year. Resulting in:

- 153 materials with stock equal to Zero;

facebook.com/faculdadedeextrema/ @faexoficial www.faex.edu.br (35) 3435-3988

- 886 materials above the stock maximum (1.5× the average monthly consumption, i.e., 1.5 months of consumption, disregarding the ABC curve);
- 134 materials with stock below the safety stock and greater than zero.

The data used in this paper has been collected from the ERP. Were collected five materials of them and the data can be summarized in the Table 4, as example. Those five items were chosen randomly.

The safety stocks were downloaded from the system and, have been loaded when the system startup in the year of 2005 without any calculation method, based only on knowledge of the materials planner.

5.1. Implementation

The first step to the work were developed in several meetings with the manager of the maintenance area and with the key-user of each kind of MRO. The manager of the stock control was of great importance because he has provided time of his employees, and he is the boss of that area. In the other side the key-users has great responsibility and needs to understand the high importance of his answers. Is not just a survey, it is the setup of the most important MRP parameters and your correct application could provide big savings to the company and to the maintenance area. No project can be successful if all the players do not are completely involved.

The second step was the application of the questionnaire. Is the time to the answers, but the key-users did not knew the result, because if they knew, they could manipulate it to change the quantities of some items in the inventory by himself.

Third step was to remove from inventory the items with scheduled maintenance and low criticality, authorized by the maintenance manager.

The fourth step was the application of Equations (4) and (5) and finally the input on the ERP program. All the steps were presented to the maintenance and supply managers.

Table 4: Data of five materials

Month/Mat.	A	B	C	D	E
January	1,132.65	25.00	4.00	25,750.00	14.00
February	669.00	20.00	0.00	19,750.00	30.00
March	1,123.60	40.00	2.00	38,500.00	22.00
April	385.00	22.00	1.00	16,250.00	33.00
May	1,106.40	20.00	4.00	27,250.00	32.00
June	911.00	13.00	4.00	22,250.00	32.00
July	1,140.00	20.00	6.00	33,750.00	5.00
August	1,229.00	20.00	1.00	31,000.00	34.00
September	986.00	30.00	3.00	31,500.00	37.00
October	981.00	30.00	2.00	30,750.00	30.00
November	1,075.00	20.00	3.00	29,250.00	16.00
December	420.00	4.00	11.00	7,750.00	24.00
Total year	11,158.65	264.00	41.00	313,750.00	309.00
Low dem.	385.00	4.00	0.00	7,750.00	5.00
High dem.	1,229.00	40.00	11.00	38,500.00	37.00
Lead time	0.63	0.63	0.97	0.63	0.63
k for "B"	0.524	0.524	0.524	0.524	0.524
$/unit	1.15	64.00	3.93	0.25	3.09
$/year	12,832.45	16,896.00	161.13	78,437.50	954.81

Table 5: Results of the five materials

Result/Mat	A	B	C	D	E
Risk Level	Moderate 2.0	High 3.0	Moderate 2.0	Low 0.5	Low 0.5
SS proposal	2,410.00	81.00	11.00	7,054.00	7.00
SS std eq.	500.00	12.00	2.00	14,109.00	14.00
SS initial	300.00	8.00	1.00	7,000.00	12.00
$/SS proposal	2,771.50	5,184.00	43.23	1,763.50	21.63
$/SS std eq.	575.00	768.00	7.86	3,527.25	43.26
$/SS initial	345.00	512.00	3.93	1,750.00	37.08
Risk proposal	0.00%	0.00%	10.93%	74.36%	67.58%
Risk std eq.	23.11%	75.76%	97.76%	41.42%	38.40%
Risk initial	49.87%	87.78%	99.10%	74.57%	46.79%

6. Results

The key areas and their main users are in the process of calculation and related to the needs of maintaining a certain product stored. For example, materials for scheduled maintenance can be removed from the inventory if Phi also classifies as a low criticality. In this case, prompted by the maintenance area in advance and on time recorded in ERP. Table 5 shows that there were significant changes on the risk of materials, and there are cases that the increase in SS was small in relation to reducing the risk of failure of the item. Φ was delimited on three levels: For high critic it is equal

facebook.com/faculdadedeextrema/ @faexoficial www.faex.edu.br (35) 3435-3988

to 3.0, for moderate critic, it is equal to 2.0 and for low critic, it is equal 0.5. The author based on practical tests selected those levels of Φ.

On total, the proposal has dropped the risk by 87 % with an increase of the SS 6 % and 34 items have been removed from inventory but an important goal was not measurable involvement of other areas for configuring the model of criticality. Table (5) summarizes the main results.

Where: SSproposal are the results after application of the methodology and proposed equations. SSstdeq. are the values using the conventional Equation (1) and SSinicial are the values as were found in the ERP system.

7. Conclusion

Applying qualitative analysis, combined with the study of the historical consumption of materials of uncertain demand, is possible the optimization of the financial resources used in inventory without there being a loss in the level of service provided to internal customers. In addition, the involvement of area attends in definitions of materials is of fundamental importance for the correct sizing of safety stock. It was identified a culture of the maintenance area that they always want to increase the quantities of items in inventory. If it is that way, some mistakes of maintenance can be fixed without programming. The correct dimension of inventory force also the correct programming of the maintenance.

There is strong reluctance of the maintenance industry to remove materials from stock. It may be noted a strong tendency for inclusion of items in stock without a real need, just to transfer responsibility for the programming industry supplies. This culture was also identified in other sectors outside maintenance. An interesting proposal, which was not explored in this study, would be to introduce a planner for each user area, one trained in planning tools that could assist the sectors on your schedule, without increasing the amount of items in stock person. This planner would be responsible for scheduling purchases of materials that do not have continuous use and are used sporadically in their areas. Thus, there would be a reduction in the fear of lack of material and non-stock inventory could relieve to keep items with very little use.

facebook.com/faculdadedeextrema/ @faexoficial www.faex.edu.br (35) 3435-3988

The company under study considers very little use, items without consuming more than twenty-four months, two years.

The efforts for better scaling of inventory is part of a cultural change in the organization, the advance planning is the main factor of these changes, and the user can share the responsibility for their own care index. The involvement of all enables the optimization and makes this work a great possibility of gains for the organization studied. Can also be applied to any organizations that follow the predetermined criteria, being that the amount of questions is not limited.

The participation of key-users can be more explored in other fields of supply chain and in the warehouse management. It can be used for sizing of packages, local delivery of requests, schedules of deliveries of orders, etc. as well. It was possible to confirm that the knowledge could be the main gain of MRP studies and his application could be the key to improve the supply chain as a whole.

facebook.com/faculdadedeextrema/ @faexoficial www.faex.edu.br (35) 3435-3988

REFERENCES

Beckmann, Martin. 1961. An inventory model for arbitrary interval and quantity distributions of demand. Management Science, 8(1), 3557.

Bijvank, Marco, & Vis, Iris FA. 2011. Lost-sales inventory theory: A review. European Journal of Operational Research, 215(1), 113.

Burt, Cyril. 1963. Is intelligence distributed normally? British Journal of Statistical Psychology, 16(2), 175190.

Chu, Chao-Hsien, & Chu, Ying-Chan. 1987. Computerized ABC analysis: The basis for inventory management. Computers & Industrial Engineering, 13(1), 6670.

Cooper, Randolph B, & Zmud, Robert W. 1989. Material requirements planning system infusion. Omega, 17(5), 471481.

Cox, James F, & Clark, Steven J. 1978. Material requirement planning systems development. Computers & Industrial Engineering, 2(3), 123139.

Dolgui, Alexandre, & Prodhon, Caroline. 2007. Supply planning under uncertainties in MRP environments: A state of the art. Annual Reviews in Control, 31(2), 269279.

Ghobbar, Adel A, & Friend, Chris H. 2004. The material requirements planning system for aircraft maintenance and inventory control: a note. Journal of Air Transport Management, 10(3), 217221.

Harris, FW. 1913. How much stock to keep on hand. Factory, the Magazine of Management, 10, 240241.

Ho, Johnny C, Solis, Adriano O, & Chang, Yih-Long. 2007. An evaluation of lot-sizing heuristics for deteriorating inventory in material requirements planning systems. Computers & operations research, 34(9), 25622575.

Huang, Manhui. 2012. Key user knowledge, attitude and IT performance: The moderating effect of organizational culture. Procedia Engineering, 29, 18241829.

Inderfurth, Karl. 2006. Risk and safety stock management in production planning and inventory control with stochastic demand and yield. Springer.

Inderfurth, Karl, & Minner, Stefan. 1998. Safety stocks in multi-stage inventory systems under different service measures. European Journal of Operational Research, 106(1), 5773.

Inderfurth, Karl, & Vogelgesang, Stephanie. 2013. Concepts for safety stock determination under stochastic demand and different types of random production yield. European Journal of Operational Research, 224(2), 293301.

Jonsson, Patrik. 2008. Exploring problems related to the materials planning user environment. International Journal of Production Economics, 113(1), 383400.

Kantowitz, Barry H, & Sorkin, Robert D. 1983. Human factors: Understanding people-system relationships. Wiley New York.

Knoeppel, Charles Edward. 1920. Graphic production control. Engineering magazine Company.

Mathieu, Richard G, & Pal, Raktim. 2011. The selection of supply chain management projects: A case study approach. Operations Management Research, 4(3-4), 164181.

McNeese, Michael D, Za, Brian S, Citera, Maryalice, Brown, Cliord E, & Whitaker, Randall. 1995. AKADAM: Eliciting user knowledge to support participatory ergonomics. International Journal of Industrial Ergonomics, 15(5), 345363.

Nenni, ME, Schiraldi, MM, & Van de Velde, SL. 2005. Determining safety stock with backlogging and delivery spare time. In: International conference on production research. Universit di Salerno.

Newbold, Paul, Carlson, William, & Thorne, Betty. 2012. Statistics for Business and Economics. Pearson Higher Ed.

O’Brien James, A. 1990. Management information systems. Galgotia Publications.

Orlicky, JA. 1975. Material Requirement Planning: the new way of life in production and inventory management. McGrawHill: New York.

Plenert, Gerhard. 1999. Focusing material requirements planning (MRP) towards performance. European Journal of Operational Research, 119(1), 9199.

Slack, Nigel, Chambers, Stuart, & Johnston, Robert. 2010. Operations management. Pearson Education.

van Donselaar, Karel H, & Broekmeulen, Rob ACM. 2013. Determination of safety stocks in a lost sales inventory system with periodic review, positive lead-time, lot-sizing and a target fill rate. International Journal of Production Economics, 143(2), 440448.

Vazsonyi, Andrew. 1954. The use of mathematics in production and inventory control. Management Science, 1(1), 7085.

Wight, Oliver W. 1984. Manufacturing Resource Planning: MRP II. Oliver Wight.

Will M. Bertrand, J, & Fransoo, Jan C. 2002. Operations management research methodologies using quantitative modeling. International Journal of Operations & Production Management, 22(2), 241 264.

Yao, Xiang, Hu, Hong-yan, & Li, Jia. 2012. User Knowledge Acquisition in Automobile Engineering Styling Design. Systems Engineering Procedia, 3, 139145.

APPENDIX

Questions and part of the possible Answers

Is the Material scheduled mainten.?	Has the Material subs- titute	If the Material is stock out, prod stopped?	Is the Material from other country?	Is the Material of personal safety?	Is the Material cost >than $1,000.00?	Risk Level	
No	No	No	No	No	No	0.5	Low
Yes	No	No	No	No	No	3.0	High
No	Yes	No	No	No	No	0.5	Low
Yes	Yes	No	No	No	No	0.5	Low
No	No	Yes	No	No	No	2.0	Moderate
Yes	No	Yes	No	No	No	0.5	Low
No	Yes	Yes	No	No	No	2.0	Moderate
Yes	Yes	Yes	No	No	No	0.5	Low
No	No	No	Yes	No	No	2.0	Moderate
Yes	No	No	Yes	No	No	0.5	Low
No	Yes	No	Yes	No	No	2.0	Moderate
Yes	Yes	No	Yes	No	No	0.5	Low
No	No	Yes	Yes	No	No	3.0	High
Yes	No	Yes	Yes	No	No	0.5	Low
No	Yes	Yes	Yes	No	No	2.0	Moderate
Yes	Yes	Yes	Yes	No	No	0.5	Low
No	No	No	No	No	Yes	0.5	Low
Yes	No	No	No	No	Yes	0.5	Low
No	Yes	No	No	No	Yes	0.5	Low
Yes	Yes	No	No	No	Yes	0.5	Low
No	No	Yes	No	No	Yes	2.0	Moderate
Yes	No	Yes	No	No	Yes	0.5	Low
No	Yes	Yes	No	No	Yes	0.5	Low
Yes	Yes	Yes	No	No	Yes	0.5	Low
No	No	No	Yes	No	Yes	2.0	Moderate
Yes	No	No	Yes	No	Yes	0.5	Low
No	Yes	No	Yes	No	Yes	2.0	Moderate
Yes	Yes	No	Yes	No	Yes	0.5	Low
No	No	Yes	Yes	No	Yes	3.0	High
Yes	No	Yes	Yes	No	Yes	0.5	Low
No	Yes	Yes	Yes	No	Yes	2.0	Moderate
Yes	Yes	Yes	Yes	No	Yes	0.5	Low
No	No	No	No	Yes	No	3.0	High
Yes	No	No	No	Yes	No	0.5	Low
No	Yes	No	No	Yes	No	0.5	Low
Yes	Yes	No	No	Yes	No	0.5	Low
No	No	Yes	No	Yes	No	3.0	High
Yes	No	Yes	No	Yes	No	0.5	Low
No	Yes	Yes	No	Yes	No	0.5	Low
Yes	Yes	Yes	No	Yes	No	0.5	Low
No	No	No	Yes	Yes	No	3.0	High
Yes	No	No	Yes	Yes	No	0.5	Low

facebook.com/faculdadedeextrema/ @faexoficial www.faex.edu.br (35) 3435-3988