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Comparison of Inventory Models for Optimal Working Capital; Case of Aeronautics Company

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ABSTRACT

The goal of supply chain management is to provide products with best quality, low costs and shortest delay of delivery corresponding to customers' expectations. To ensure that, companies must be in continuous research for management methodologies which allows them the possibility to improve their financial results by decreasing costs and improving their process and thus customers satisfaction. Before searching for a metaheuristic function of the optimal solutions, this paper is presenting a basic research, conducted in aeronautic company to find out the better solution for raw material inventory management. These raw materials are obtained from the supply of imports and some local purchases. The aims of study are to present a comparison of inventory deterministic models, the economic order quantity, the Interval order quantity and the minimum maximum inventory. The first step is to collect data's containing 3896-part number with various suppliers, lead time, costs, consumption, holding cost and set up cost, the second step is calculating the order quantity with deterministic models and analyzing the results to choose the better solution. The third step is doing the ABC classification and comparing the amount of average stock between the three methods. The results show that the optimal deterministic solution is a combination of two of them.

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1. INTRODUCTION

The working capital is the money needed to finance the operating cycle, this money is mobilized permanently for the needs of the activity. Indeed, the activity requires financing in the short term a certain number of expenses, purchases be it goods or raw materials, and payment of other charges. However, customers of the company did not necessarily pay their bill, or the product is not sold yet. This gap between inflows and outflows creates a need for short-term financing: this is the need for working capital. This is the difference between the amount used to finance the inventory and the customer credit, and the resource from trade payables.

If the supplier payment is more than the total inventory value and commercial entrance, the need of working capital is less important. The working capital is calculated based on the balance sheet, receivables, inventories and liabilities in a certain time, improving the working capital requirement is to reduce it, or even turn it into a working capital surplus.

Here are ways to improve the working capital:

- Increasing the time for payment to suppliers
- Negotiate with suppliers
- Reducing the time taken to pay customers

This requires combating delays in payments and unpaid payments, the stock reduction is also a solution for working capital maximization.

The optimization means minimizing risks with a best return or having a maximum of return without risk. Therefore, From Figure 1, we can deduce that the keys of optimization are the working capital and risk.

For the working capital, the liquidity and the profitability have a negative relationship with the recovery delay and stock turnover [1]. For the optimization of inventory, to maximize the working capital, firms group products by lots and decide for the best lot size to order to meet the lowest costs [2].

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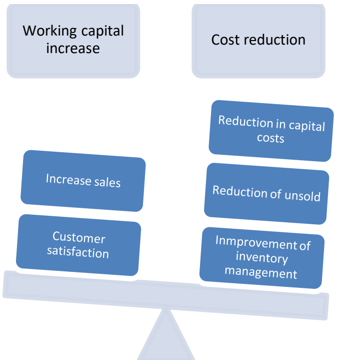

Figure 1. The role of optimized stock management in working capital

To simplify the meaning of inventory optimization, it's the balance between customer demand and supplier[3].

The way to conserve and satisfy a customer; the company tacked the risk to have an excess stock.

But after the economic crises, it was difficult to maintain this situation; there is also a risk for obsolescence, of space consumption, product damaged [4].

The stock is taking in general between 10 and 40% of the working capital [5]; for the case we have studied, the stock is taking 50% of the working capital.

To maximize the working capital, the inventory must be minimized, the economic order quality can be used in this case, and that's taking in consideration the minimum of ordering cost and minimum carrying cost [6].

For the company studied in this paper, it's a aeronautic company. The majorities of their suppliers are not in the same country, so there is more risk of variable costs and lead time.

The aims of study are to present a comparison of inventory deterministic models, the economic order quantity, the interval order quantity and the minimum maximum inventory. The first step is to collect data's containing 3896-part number with various suppliers, lead time, costs, consumption, holding cost and set up cost. The second step is calculating the order quantity with deterministic models and analyzing the results to choose the best solution. The third step is doing the ABC classification and comparing the amount of average stock between the three methods. The results showed that the optimal deterministic solution is a combination of two of them.

2. LITERATURE REVIEW

It's difficult to maintain or increase the external financing with continues economic crisis. For this reason, firms must follow more their operation cycle, with time gain to ensure business continuity under cash flow generation [5].

A standard return of investment can be a result for having excess of current assets. However, firms may have shortages and difficulties for managing operations if they have a few current assets [1]. The management of the working capital is the essential part, companies demand to maintain its liquidity in functioning from day to day to assure smooth running and respect its obligation. However, it is not simple task because the administrators have to arrange companies operation is in the course of execution in an effective and profitable way [4]. The operations of working capital requirement includes all operations with financial need beginning with the reception of orders, procurement, manufacturing, product inventory and finally distribution. The solution for many firms is to produce just what they forecast to sell and assign all the assets to optimize supply chain. But, as the customer demand is not stable the firm must follow that demand [6].

Otherwise, the customer is not searching just for price and advertisement but the delivery time and service level following his demand [7]. that is why, the partnership between customer and supplier allows the possibility to make decision for the inventory policy [8]. Also, the integrated relation between customer and supplier, is way for each customer to maintain a level of stock [9], and the customer demand depend on the quantity on stock [10]. The payment delay, the lot sizing cycle is a way for a high level of working capital [2, 3, 11]. Therefore, optimization of inventory with the working capital is needed.

There are lot of researches including inventory management, taking in consideration the variability of quality of product, service level and manufacturing constraints for the management performance improvement. The subject of these researches is finding new formulas to propose in real situation and giving applicable solutions meeting the industrials needs.

But, there is a lack in specific industries of testing and measuring the models and methods [12].

The economic order quantity with the calculation of total cost, optimizing the holding cost and order cost was introduced by Harris [13].

The application of economic order quantity (EOQ) to maximize cash flow can be an appropriate solution [14, 15]. But without comparison with the other methodologies, we cannot decide if it's the optimal solution. With the comparison for some items without taking in consideration the impact for the cash flow, we can decide for a procurement methodology [16].

In this paper we analyze the classical inventory methods, Economic Order Quantity, Interval order quantity and Minimum- Maximum Inventory. We measure and test the applicability in aeronautic company and search for the best solution for the cash flow.

Since 1900s the EOQ was the method to define the quantity to order, with a balance of minimum order cost and minimum inventory holding cost. Apparently, the economic order quantity is the optimal method that can be used for this case, if we compare it with the interval order quantity which covers the lead time, and the min-max method taking in consideration both of lead time, carrying and ordering cost.

But after ranking the parts with ABC classification, which take in consideration the price and consumption of product, by these models, we search to minimize shortages and reduce the average value of stock. By the application of these methods the risk is minimum for shortages, we must add the safety stock to cover other risks. For the inventory average value is minimum using both of economic order quantity and economical order interval, one for each ABC category.

3. METHODOLOGIES OF THE STUDY

Companies may decrease occupation of capital by reducing procurement costs [17], that's why they must create a balance between the investment of inventory and the other costs [18]. The formula of working capital can be written as follow:

WCR = Inventory + Payment received from customer
- Payment to supplier

The excess stock is defined as accumulating stock to prevent the uncertain supply by ordering more than the quantity needed [19].

We can describe the solution for the theory of inventory as follow: How can we define the order point? What's the quantity to order? [20]

For this, they must choose the economic method for inventory management.

There are three classical methods:

3. 1. Economic Order Quantity

To hold stock there are many advantages and disadvantages and this approach can create a balance between them [16].

One of the classical models used is economic order quantity: EOQ; it's used when the demand is considered constant. In this case the history of sales and consumption, are influenced by the level of stock [17]. For a total profit, this methodology is used, to receive the order just in the time needed [18].

To minimize the total costs of procuring items, we must look for the cost of holding items in stock (*C*h) and the cost of placing order (*C*).

The holding cost is including the working capital, the storage costs and the risk of obsolescence costs.

Otherwise, when the company is placing order, the expense for this is not only for product but also for the forwarding costs.

The costs of storage and placing order can be calculated as follows [5]:

Total costs of storage = storage costs/unit × average inventory= Ch × Q/2

Ordering costs = ordering cost × number of orders per period= C × D/Q

So, total cost Ct = Ch × Q/2 + C × D/Q

Figure 2 demonstrates the inverse relationship between storage cost and order cost. The optimal order is corresponding to the intersection of the minimum of storage cost and ordering cost:

Ch × Q/2 = C × D/Q

Resulting the economic order quantity to order :

$Q = \sqrt{(2 \times C \times D / Ch)}$

3. 2. Interval Order Quantity

The interval order quantity is a basic and classical method fixing the periodicity of orders. At every order time, the order is launched with fixed quantity covering the consumption of the product during the supplier lead time and a safety stock for riskiness of delay of delivery or not predictable overconsumption, to restore the stock based on periodic cycle of order.

This method can be applied for products of regular consumption with known annual consumption.

The quantity is the consumption covering the shipment delay and delay of interval (see Figure 3)[16].

Q = (LT+Pr) * D

Stock covering the lead time

LT: Lead time

Pr: Reorder period

D: Daily Demand

3. 3. Min Max

There are two parameters for Min Max, the reorder point is when the inventory level is in the minimum. The quantity is placed to have the inventory in the maximum level, and the reorder point is covering the demand during the lead time [15]. Figure 4 explains the calculation of the min-max.

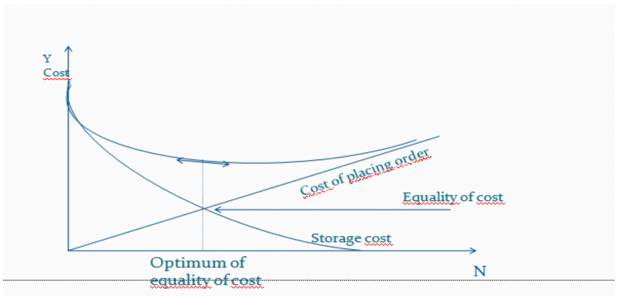

Figure 2. Graph for calculation of EOQ [23]

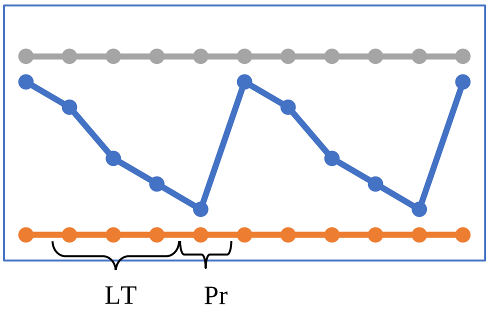

Figure 3. Graph of interval order quantity calculation

Stock min = LT * D + SS
Stock max = Qe + stock min
LT: Lead time
D: Daily Demand
SS: safety stock
Qe: economic order quantity

4. CASE STUDY

The company studied in this paper is an international aeronautic company. The companies of the aeronautical industrial sector have important stocks the value of which is a real lever. Indeed, very often these stocks arise from specific orders realized for a manufacturer, Engines of planes or rockets, spatial throwers, planes, helicopters, satellites and many others else. Even if this stock established constituted to honor several years of orders, the forecasts for raw materials are not exact, the change is rather frequent in references and in quantity besides the request for replacement part which are less predictable and which a shorter time of production is required. These spare parts must be supplied in time to avoid the incidents of type aircraft on ground. It's not just the request which is uncertain; the deadlines of supply are also.

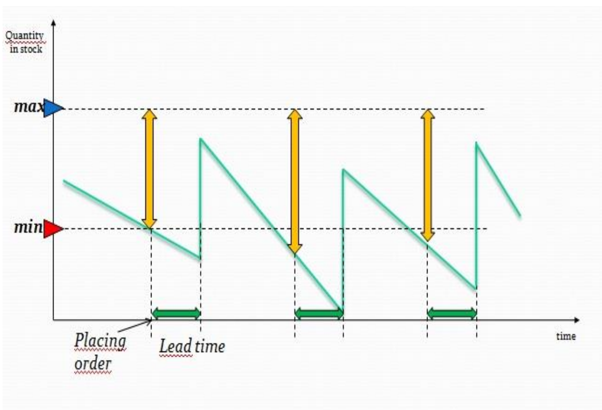

Figure 4. Graph for calculation of the min–max

Fast moving items do not involve that a single deadline of supply; it is necessary to take into account the whole chain, going of the change of component until the provision of material. The deadline of total supply includes numerous stages: administrative deadline, deadline of acquisition, deadline of transport, deadline of reception, deadline of handling of stocks, processing time in store. From the history of the orders, the data of the stock and the technical data a segmentation of the references was realized. This implies frequent shortages. Figure 5 shows the impact of shortages.

The procurement management following the customer demand involves for the same item shortage, and if they order more than quantity demanded they risk the overstock as presented in the Figure 6.

To prevent losing the customer they can be more than stock for some parts and have shortages for a lot of others.

The over stock is impacting the liquidity of company, shortages impact customer service level. Figure 7 is allowing these conclusions.

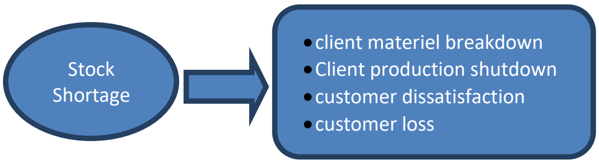

Figure 5. Results of shortages

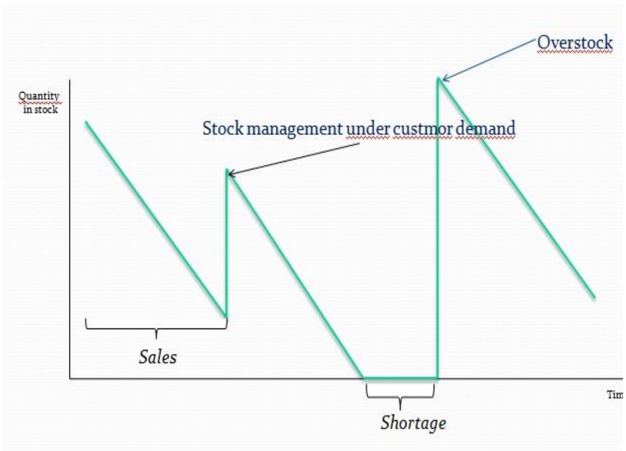

Figure 6. Graph of excess and shortages

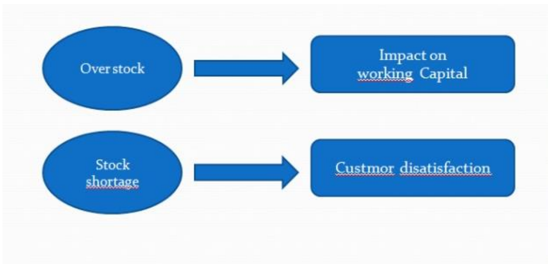

Figure 7. Over stock and shortage consequence

5. RESULTS AND DISCUSSION

We have calculated the average stock value per item using the three methods.

This calculation was done for 40056 sales lines to calculate the average annual demand for 3274-part number.

5. 1. Economic Order Quantity

TABLE 1. EOQ calculation for 10 items

Part	Valued Consumption	Ch	C	Q	EOQ Value
1900002032	419 411,05	0,12	400	5 835,00	271 842,95
1100025351	343 313,03	0,12	400	16,00	129 718,04
1000052185	339 058,76	0,12	400	25 286,00	221 000,13
1000052265	303 796,38	0,12	400	1 565,00	192 234,47
1100053305	254 307,78	0,12	400	6 622,00	164 536,63
1100053305	254 307,78	0,12	400	6 622,00	164 585,54
1100034606	228 389,70	0,12	400	125,00	122 639,87
1100116108	227 352,02	0,12	400	38,00	99 891,23
1100116101	220 698,62	0,12	400	38,00	95 934,00
1000061581	213 121,76	0,12	400	44 627,00	139 036,74

5. 2. Interval Order Quantity

TABLE 2. IOQ calculation for 10 items

Part	Consumption	Lead time	IOQ Lead time	IOQ	IOQ average value
1900002032	14633	60	5	36 582,50	56 894,79
1100025351	36	60	5	90,00	46 728,72
1000052185	57023	60	5	142 557,50	45 993,65
1000052265	3340	60	5	8 350,00	41 212,62
1100053305	12932	60	5	32 330,00	34 497,33
1100053305	12932	60	5	32 330,00	34 497,33
1100034606	231	60	5	577,50	31 020,46
1100116108	70	60	5	175,00	30 854,92
1100116101	68	60	5	170,00	30 021,50

5. 3. Min Max

Finally, the total stock average value is the sum of stock value per item.

The data below show that the Interval order quantity is giving the lowest value of the average annual stock.

The industry and service company must stock a lot of items, so they cannot address the same attention and make efforts for all items [21], that's why we classified the items with ABC technical.

This method helps the company to allocate for each category the proper management [22]. Effectively the result was not the same for all items.

Table 5 demonstrates the method with the minimal average stock, for A is the economic order quantity, for the category B, the interval order quantity, and for category C the best one is interval order quantity.

The economic order quantity is giving best results for parts with higher costs and consumption. But for the parts less expensive of less demanded, it's not necessary to search for the reduction of carrying cost and ordering costs because the value is already reduced in this case. It's better to cover the lead time to not have shortages with known interval of orders using the interval order quantity model.

TABLE 3. Min Max calculation for 10 items

part	D	Q	Min Max value	min	max
1900002032	14633	5 835,00	17 670,12	6 495,00	12 330,00
1100025351	36	16,00	15 735,18	17,00	33,00
1000052185	57023	25 286,00	15 041,30	25 307,00	50 593,00
1000052265	3340	1 565,00	13 861,85	1 483,00	3 048,00
1100053305	12932	6 622,00	12 154,94	5 740,00	12 362,00
1100053305	12932	6 622,00	12 154,94	5 740,00	12 362,00
1100034606	231	125,00	11 320,62	104,00	229,00
1100116108	70	38,00	11 367,60	32,00	70,00
1100116101	68	38,00	11 197,21	31,00	69,00

TABLE 4. Min Max calculation for 10 items

	EOQ	IOQ	Min-Max
Average of Total Value	**32 000 575,00**	35 950 901,00	62 623 901,00

TABLE 5. Min Max calculation for 10 items

	EOQ	IOQ	Min-Max
Average total value	**32 000 575,00**	35 950 901,00	62 623 901,00
Catg. A Average value	**17 736 206,00**	28 707 703,00	42 148 888,00
Catg. B Average value	8 046 352,00	**5 406 596,00**	12 683 949,00
Catg. C Average value	6 218 015,00	**1 837 001,00**	7 791 064,00

6. CONCLUSION

In this paper three classical inventory models are compared, the economic order quantity, the Interval order quantity and the minimum maximum inventory, considering many parameters, uncertain demand, costs, variable delay of delivery. A numerical example in aeronautic company is considered to apply these models. The comparison showed that the economic order quantity is giving best results for fast moving items; but for the slow-moving parts it's better to cover the lead time to not have a shortage with known interval of orders using the interval order quantity model. That costs decrease with the firefly algorithm. Even if the inventory problem is a classical issue always existing but the application for slow moving and fast moving raw materials it's an advantage especially if the implementation was done with real data for industrial companies impacted by this issue. The proposed solution can help inventory practitioners to face the working capital issue having as target of decision maker to set the customer service level. The limitation of this paper is on stochastic demand and other variables. This work is an opportunity to apply this issue with metaheuristics to optimize inventory and compare it to find the best solution and also propose a model taking into consideration in the environmental impact to be optimized with these algorithms.

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چکیده

هدف از مدیریت فروشگاههای زنجیره‌ای مهیا نمودن فرآورده‌ها با بهترین کیفیت و هزینه پائین در کوتاهترین مدت تحویل طبق خواست مشتریان است. براین اساس جهت جلب رضایت مشتریان شرکت باتکنولوژی مدیریت می‌تواند عملکرد مالی را بهبود بخشد و هزینه‌ها را کاهش دهد. قبل از دستیابی به حل مطلوب این مقاله مبانی تحقیق برای بهترین راه حل برای مدیریت مواد اولیه را بررسی می‌نماید. این مواد اولیه از شرکتهای تدارکاتی یا پشتیبانی خریداری می‌شوند. هدف از این تحقیق ارائه الگوها برای سفارشات کمی است بر حسب حداقل و حداکثر سفارشات است. در اولین گام داده‌ها از 3896 شماره قطعه با شرکتهای تدارکاتی متفاوت، زمان، هزینه، مصرفی، زمان نگهداری و هزینه نمایش جمع آوری گردید. در گام دوم محاسبات کمیت سفارش طبق الگو تعیین شده و انالیز نتایج برای انتخاب بهترین گزینه بعمل می‌آید. در سومین گام طبقه بندی الفبایی و مقایسه مقدار میانگین ذخیره در میان سه روش اجرا می‌گردد. نتایج نشان می‌دهد که بهترین راه حل در دو روش ترکیبی بدست می‌آید.

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