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REzultatele CErcetărilor Noastre Tehnice

Industrial Engineering Journal

Transilvania University of Brasov, Romania

Vol. 14 (2013), No. 4(40) **ISSN 1582 - 0246**

ICEEMS 2013
7th International Conference on Economic Engineering and Manufacturing Systems

- selected papers -

iceems

40

November 2013

CONTENTS

Vol. 14, no. 4(40), November, 2013

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STOCHASTIC MODELLING APPLIED FOR INVENTORY OPTIMIZATION IN ADVANCED PRODUCTION SYSTEMS

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Abstract. Production systems have been lately and still are submitted to a profound changing process, with ascendant dynamics. In the conditions of the development and implementation of modern principles of organization of advanced manufacturing systems, the decisive role of inventory management is demonstrated that ensure continuity in production. Inventory management activity is regarded as a complex process with a large area of application, covering the management problems, dimensioning, optimization and inventory control. Taking into account the influence of the storage process it is necessary to find models and methods for the formation of some inventories, which by volume and structure, should ensure normal performance of the economic activity, but under the minimum necessary storage conditions and expenses as low as possible. This paper aims to develop and implement a methodology to improve the efficiency of production process and presents a stochastic model applied for inventory optimization to the manufacturing process of cylindrical parts.

Keywords: production systems, management, mathematical modelling

1. Introduction

By implementing production management methods, advantage is clear: reduce by half the length of human effort in production systems, reduce by half the final product defects, reduce by half the manufacturing space, reducing to one third of the time preparation of production, reduce inventory, reduce to a tenth or less of work in progress. Each manufacturer has increased its product quality and production moved to Flexible Manufacturing Systems (FMS) diversified, in small batches and to keep competitive costs and better satisfy customers. Integrated Logistics corresponds to the period characterized by increasing the supply that reaches or exceeds demand. During this period one of the ways to reduce the overall cost focused on reducing inventories. Small stocks, the zero limits, imposed manufacturing supply "just in time". To reduce logistics costs, and to finally get customer satisfaction, logistics managers are trying to take advantage of this environment for data integration. This led to the development of mathematical models for example to determine the optimal amount of products given the constraints of data centres where production and storage / distribution.

Global optimization is done so within the organization and not a series of local optimizations, [4]. Coordinating activity of inventory management and related information has special economic implications, resulting from providing production or material consumption continuity. Inventories represent those existing quantities of materials in spaces meant for depositing, storage, during certain periods and with a certain consuming destination. During the above mentioned periods, although available, inventories are not used, being inactive and considered as resources reserves.

Theory of inventories is appeared because of the need to provide a rhythmic supply rate and minimum raw materials costs during the production process, or of finished goods and consumer goods stocks in the business of selling goods. Stocks are designed to provide safety and guarantees that production will take place at predetermined time while the products will reach at time to the beneficiary. Specialists in logistics name stocks as regulator of the company’s activity and a timing element of consumer applications and moments of providing resources. The goal of an optimal inventory system is to minimize costs associated with managing stocks, which are actually subject to operation under conditions of economic efficiency. Storage process treatment as an "objectively necessary" process should be imposed, not only because of its economic nature, but also because his achievement attracts considerable expense, resulting in significant influence to storage-keeping facilities, transport-storage equipment, financial funds, etc.

There are many questions to ask when talking about stocks. Stocks are an important real estate for industrial enterprises. Indeed, if the customers debts and suppliers credits are offset, stocks represent on average 20 to 80% of the total assets of industrial enterprises, [2]. They come immediately after the investment on land, buildings, equipment and materials. Increase in stocks should be subject to a rigorous management: too often, stocks are unduly exaggerated, without avoiding for this interruptions, for certain items. To manage stocks is to decide their level, to decide how and when to acquire each product. As a complex economic process, inventory management has a broad scope, covering both the management problems, sizing, optimizing stocks placement in the field, sharing them on keepers, their training and registration and reception problems, warehousing and storage, tracking and control, redistribution and method of use [3].

2. Economic model of stock management

Economic model based on *Wilson model*, is the best known model of stock management. This model has been much analyzed and criticized within the specialty literature, [1, 2, 4]. It is based on a set of simplifying assumptions.

2.1. Model assumption

Physical data:

a) requirement is known, uniform, with a constant norm;
b) regeneration is instantaneous;
c) re-supplying period from the supplier is fixed;
d) stock discontinuation is not allowed.

Economic data: unit costs are fixed, independent of time and the quantity supplied and managed independent of other articles.

Supply Strategy:

a) corresponds to the (*Q*, *S*) strategy - fixed quantity and point of control;
b) economic evaluation of supply policy is based on the time unit management cost;
c) seeking an optimal strategy - corresponds to the search for a compromise between the costs of launch transmission, which increase with frequency of supply and cost of storage, which decreases when the number of supplies increases.

Notation of variables: *Q* – launched quantity, T – period of restocking in time unit; *d* – demand of the unit time unit, C_L – launching cost command transmission in money unit (regardless of quantity); C_u – unit cost of the item (purchase price); *r* – coefficient of ownership in % per unit of time, C_S – storage cost equal to $C_u$multiplied by *r*. Relations between variables are:

$$Q = d \cdot x \cdot T \tag{1}$$

$$C_S = C_u \cdot x \cdot r \tag{2}$$

Storage cost depends on the unit supply cost of the item valuated by the coefficient of ownership which corresponds to the immobile capital's opportunity cost.

The stock passes from the maximum *Q* level to level 0. It is then to find the value of *Q* that minimizes the total management cost by unit of time, Figure 1.

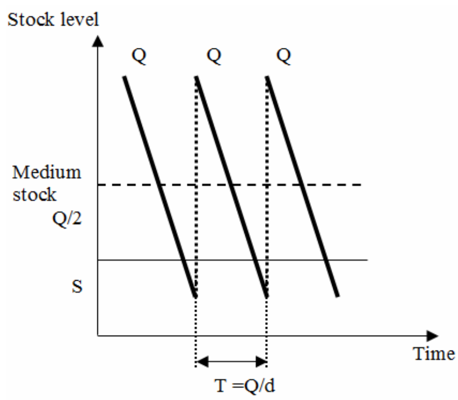

Figure 1. The basic model

In a period *T*, the cost consists of launching cost (C_L) and average storage cost (C_S) associated to the stock medium *Q*/2, equal to $C_S \cdot Q/(2T)$.

T is interval betweentwo deliveries

For a given strategy (*Q*, *T*) and a period *T*, the cost of storage is:

$$C_S \cdot \frac{Q}{2T} = C_S \cdot \frac{Q^2}{2d} \tag{3}$$

For a given range $Q = n \cdot T$, the cost of storage is expressed mathematically as to the relationship:

$$n \cdot C_S \cdot \frac{Q^2}{2d} = \theta \cdot T \cdot C_S \cdot \frac{Q^2}{2d} = \theta \cdot C_S \cdot \frac{Q}{2} \tag{4}$$

The launching cost (C_L) is:

$$n \cdot C_L = \theta \cdot T \cdot C_L = \frac{\theta \cdot d}{Q \cdot C_L} \tag{5}$$

Resulting total cost (C_T):

$$C_T = \theta \cdot \left[\frac{d \cdot C_L}{Q} + C_S \cdot \frac{Q}{2} \right] \tag{6}$$

This function is therefore minimized as compared with *Q*. The total cost is so minimal for:

$$Q^* = \sqrt{2d \frac{C_L}{C_S}} \tag{7}$$

By substituting Q^* into the total cost expression, results:

$$C(Q^*) = \sqrt{2d \cdot C_L \cdot C_S} \tag{8}$$

Figure 2 represents the evolution of total cost and of the two components according to the evolution of quantity.

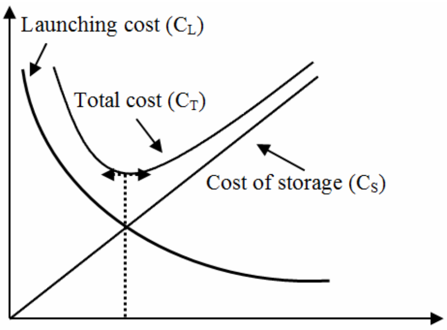

Figure 2. Evolution of total cost

3. Stochastic model of inventory management

Inventory management is very important for any company engaged in the manufacture, storage, shipment and sale of products and goods. Therefore, operational research is involved in solving the stock management through the development of mathematical algorithms and economic models.

Stochastic model to be solved takes into account the random nature of product demand, often encountered in practice. Model objective is to minimize costs related to stock management (storage process) and transportation and distribution costs of goods to consumers, which is actually subject to operation under conditions of economic efficiency.

Stochastic problem will be solved in two stages of decision [3]:

1. Determine the optimal distribution, rational use of resources or products to be stored in certain warehouses with known storage capacity.
2. The transport of products to customers in an optimal way, having in view the random nature demand.

3.1. Mathematical model

Mathematical model will be developed is a complex problem of the production, storage and transport [5]. In the inventory management models, the following main elements appear:

- size of demand for the period considered;
- optimum size of the order of supply;
- total cost of supply for the time considered;
- maximum level of inventories;
- average level of inventory;
- amount of time advance;
- number of supply orders in the period considered;
- size of the supply cycle.

It is considered necessary to organize the process of optimal storage products / resources (r), in a certainrange oftypes and size; $r = \overline{1,...,n}$, determined by the items I_1,..., I_r,..., I_k, in warehouses.

Over the n-months must be made the items - Ir, in a production volume environment, $\overline{Q_i}$, $i = \overline{1, ..., n}$ in during a normal working regime.

It provides an additional production of: $\overline{Q_i'}$ $i = \overline{1, ..., n}$, units per month.

The unit costs of production are C_{PQ_i} and C'_{PQ_i} per month for the previous cases. Unit cost of storage per month is C_S.

To determine the amountof production $\overline{Q_i}$, $\overline{Q_i'}$, respectively stock quantities S_i and with minimal production costs of storage that is proposed the following mathematical model:

$$\sum_{k=1}^{n}\left(Q_k + Q_k'\right) - S_{i+1} = \sum_{k=1}^{i} I_k , 1 \le i \le n-1$$
$$0 \le Q_i \le \overline{Q_i}, 1 \le i \le n; \quad (9)$$
$$0 \le \overline{Q_i}, 1 \le i \le n;$$
$$S_i \ge 0, 1 \le i \le n;$$

Minimize storage costs to obtain the equation:

$$\min\left\{\sum_{i=2}^{n}\left(C_{P_i} Q_i + C'_{P_i} Q_i' + C_S S_i\right) + C_{P_1} x_1 + C'_{P_1}\right\} \quad (10)$$

After applying the mathematical model, on a flexible manufacturing line type cylindrical parts, resulting of dynamic evolution chartof stocks, shown in Figure 3, in order to management processing production.

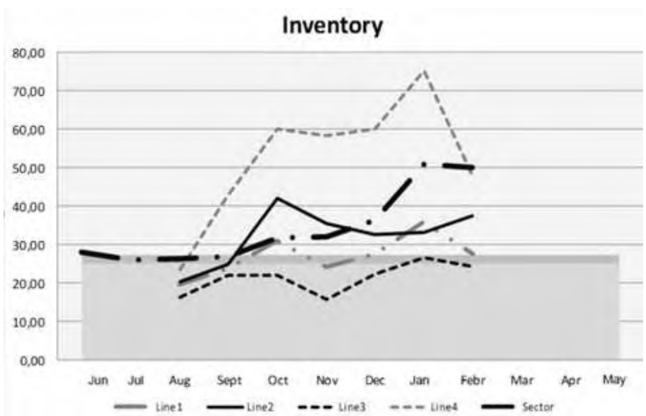

Figure 3. Calculation and representation of inventory

The next stage is the problem of organizing the transport of these resources to consumers, under optimal conditions with minimal cost.

It is assumed that the production centres n must distribute a product to consumption centres m. Are considered: X_i - availability of production centres i, $i=\overline{1,...,n}$, Y_j - consumer demand centre j, $j=\overline{1,...,m}$, and C_{ij} - unit transportation cost of product at the production and consumption centre j.

The aim is to optimize the transport plan, determining the unknown Q_{ij}, respectively determining the quantity of goods to be transported from the centre of production and consumption centre j, so transport costs are minimal.

Economic and mathematical model consist in optimizing (minimizing) the objective-function value that expresses the total average costs, subject to the processes of storage and transport to consumers [3].

Based on linear programming methods [5], the solution is given by the mathematical model:

$$\min\left\{\sum_{i-1}^{n}\sum_{j=1}^{m}C_{ij}Q_{ij}\right\}$$

$$\sum_{j=1}^{m}Q_{ij}=X_i,\ i=\overline{1...n}$$

$$\sum_{i=1}^{n}Q_{ij}=Y_j,\ i=\overline{1...m} \tag{11}$$

$$Q_{ij}\geq 0,\ i=\overline{1...n},\ j=\overline{1...m}$$

using initial conditions:

$$\sum_{i=1}^{n}X_i=\sum_{j=1}^{m}Y_j,\ \ X_{ij}\geq 0,\ \ Y_{ij}\geq 0,\ \ Q_{ij}\geq 0\,. \tag{12}$$

4. Conclusion

The storage appears as a regulator of uninterrupted supplies and production and the stock is the "inevitable buffer” that provides synchronization for consumer applications at times of supply of material resources. Flexible Manufacturing Systems (FMS) offers many strategic operational benefits over conventional manufacturing systems; its efficient management requires solution to complex process planning problems with multiple objectives and constraints. Mathematical modeling of optimizing problems offers the opportunity to find the optimal solutions, with immediate consequences for the system’s economic efficiency increasing. The researches will be also extended in the field of FMS management and control in real environment.

The implementing of a FMS in anintegrated manufacturing system represents an important result, which leads to the optimization of the entire material and informational flux of the enterprise.

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