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Optimization of Inventory Management in the Supply Chain

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Abstract: Supply chain management (SCM)models incorporate effective technologies to reduce costs, improve the quality of products received, deliver goods and manage after-sales service allowing to minimize operating costs, increase the production throughput and the quality of products and services, which, ultimately, provides a competitive advantage in the market. Increasing globalization process requires permanent transformation in the supply chain management to meet present-day challenges and improve competitiveness of the local economy. Following from the above- stated, the complexity supply chain increases [1]. Therefore, an objective need for logistics audit and diagnostics is emerged focusing on innovative integrated technologies and mathematical models.The determining factor of supply efficiency from the perspective of procurement and logistics is the uninterrupted supply of raw materials and semi-finished goods that depends on the selection of a reliable supplier, as well as the continuous improvement of the quality of materials and the reliability of the customer-supplier relationship [2]. The most important precondition for line balancing is its modern and complete provision with the necessary technological, labor, material and financial resources. In the industry, logistics support primarily means supplying raw materials, semi-manufactured articles, assembly materials and products stored either in central production warehouses or those of the main enterprise. Thus, manufacturing inventories are hereinafter referred to as material resources stocks.

Keywords: Optimization, management, inventory, SCM, ERM.

1. Introduction

There are several objective factors compelling thematerial and technical supply services in manufacturing to createa manufacturing inventory.

Such factors include, first of all, the nonconformity between the line balances for delivery of material resources of production and for their consumption. For example, in an ideal case, when the consumption of goods is continuous and the supplyof goods is regular at a fixed volume, the quantity of inventoryinitially (*while receiving a supply*) is relatively large and then decreases to zero according to the size of the items ordered. Second, random fluctuations, as well as other coincidental factors occur in demand, during the time interval while supplying.

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2. Solution Methodology

In this case, the problem of ensuring the line balancing becomes stochastic and, subsequently, the reliability of production directly depends on the volume of manufacturing inventory.

Third, the factors that take into account the seasonality of demand and articles of consumption are of paramount importance when selecting manufacturing inventory.

Additionally, a number of no less serious circumstances that lead to an aspiration to reduce the inventory of material resources. These include: taxes on the creation and storage of inventories; economic loss due to the limited working assets; quantitative and qualitative loss of material resources, including moral depreciation, etc. [3].

Thus, the problem of selecting the necessary stock of manufacturing resources is of an alternative nature, which should be resolved by optimization methods, namely, the ones related to the systems analysis and management. Therefore, inventory management represents one of the most important parts of the operations research theory.

Our research was conducted in an enterprise, wheredifferent types m of reserve materials(glasswork of different compositions)are required and insufficiency of any of them is also inadmissible for a set period of time. The enterprise receives materials in batches. The costs of each batch entry (*creation*) do not depend on the amount of materials in a batch and equal α_i for an i-type one, while — for the storage of a single i-type material — amount to β_i per unit time.

The total demand for i-type materials for the specified time period Tequals m_i.

Inventories are replenished at constant βintervals;n_i material of i-type (*abatch contains* n_i *material*) arrives at the enterprise ateach interval.

Inventories are consumed evenly over time, therefore, the average amount of i-type materials within the specified period of timeτwill be $\frac{1}{2}n_i$. The average costs for storing i-type materials during the same period will be $\frac{1}{2}n_i\beta_i\tau$.

Thus, the total cost for one batch of i-type materials is as follows:

$$\alpha_i + \frac{1}{2}n_i\beta_i\tau \qquad (1)$$

Sincematerials m_i of i-type arrives at the enterprise during the specified period of time T and one batch contains material n_i of this type, for this reason, the number of the batches arrived totals $\frac{m_i}{n_i}$ and, at the same time, this value is equal to $\frac{T}{\tau}$. Consequently, the average cost for i-type inventories within the specified period of time T is as follows:

$$c_i(n_i) = \left(\alpha_i + \frac{1}{2}n_i\beta_i\tau\right)\frac{m_i}{n_i} = \frac{m_i\alpha_i}{n_i} + \frac{1}{2}m_i\beta_i\tau = \frac{m_i\alpha_i}{n_i} + \frac{1}{2}T\beta_i n_i \qquad (2)$$

The costs incurred on all types of inventories within the same period of time will be as specified below:

$$C(n_1, n_2, .., n_m) = \sum_{i=1}^{m} C_i(n_i) \sum_{i=1}^{m}\left(\frac{m_i\alpha_i}{n_i} + \frac{1}{2}T\beta_i n_i\right) \qquad (3)$$

It is a function of a variable m (n_1, n_2,…, n_m) and it is one of the most important mathematical problems included in the inventory management theory to research it.

Namely, we need to consider the function (3) as an objective one in accordance with the management theory and set an integer programming problem as defined here: we can select such values of variables n_i in order an objective function (3) to get the least value as defined below:

$$C(n_1, n_2, .., n_m) = \sum \qquad \to \min \qquad (4)$$

Simultaneously, stemming from the specific form of the function (3), the given problem can be considered to minimize the function of many continuous variables and then it may be relatively easy to find the solution to the original integer programming problem. Indeed, (3) is the sum of the functions of the amount m, each of which represents a function of one variable (n_i); consequently, while searching for stationary points of (3), if we use it to each variable and equate them to zero, we'll get the equation of the amount m; they are independent from each other.

On the other hand, this means that the minimum value of the function (3) is obtained, when each function $C_i(n_i)$ receives the minimum value.

Based on the above-mentioned, we can conduct the following investigation into the given problem for m = 1. In this case, the total cost function will be of this kind:

$$C_1(n_1) = C_{11}(n_1) + C_{12}(n_2) = \frac{m_1\alpha_1}{n_1} + \frac{1}{2}T\beta_1 n_1 \qquad (5)$$

Respectively, an optimization problem is formulated as follows: we can select n_1 (*the amount of* *materials in each batch)* so that the function (5) obtains the least value.

We can prove the following simple theorem in order to investigate the function (5): if the product of two positive variables $x_1$and x_2 is constant (a), then their sum is minimal, when these values are equal to each other.

For example, if the expression $x_1 + x_2 = a$ is given and its product is considered, we'll obtain the formulation as defined below:

$$x_1 \cdot x_2 = x_1(a - x_1) = ax_1 - x_1^2 = -\left(x_1 - \frac{1}{2}a\right)^2 + \frac{1}{4}a^2 \qquad (6)$$

It is easy to understand thatthe lesser value for the function (6) is obtained, when $x_1 = \frac{1}{2}a$, which means thatx_2 is also equal to $\frac{1}{2}a$ and the theorem is proved.

Therefore, the minimum value of the function (5) is obtained, if:

$$\frac{m_1\alpha_1}{n_1} = \frac{1}{2}T\beta_1 n_1,$$

or

$$n_1^* = \sqrt{\frac{2m_1\alpha_1}{T\beta_1}} \qquad (7)$$

If were present $C_{11}(n_1)$, $C_{12}(n_1)$ and $C_1(n_1)$ graphically, the Fig. 1a can be obtained.

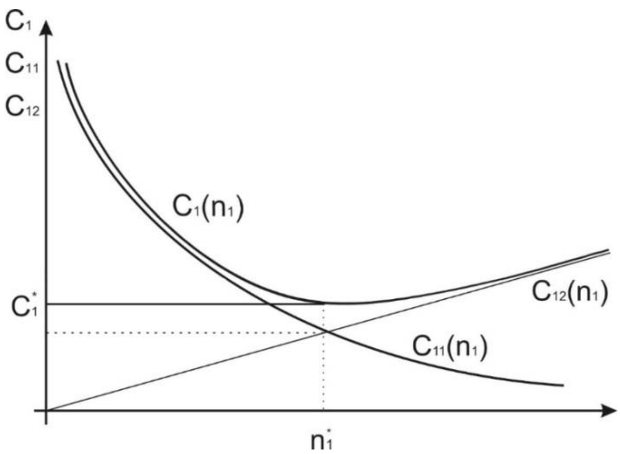

Fig. 1a.

An initial conclusion on the terms used in the inventory management theory is as follows: the economic costs in the above-mentioned problem of the inventory management are minimal, when the costs forcreating and maintaining of stocks are equal to each other.

The expression (6) can easily provide the optimal value of the stock replenishment cycle as defined below:

$$\tau^* = \frac{T}{m}n_1^* \qquad (8)$$

The optimal cost value of the stock replenishment cycle can be expressed as follows:

$$C_1^* = C_1(n_1^*) = \sqrt{2mT\alpha_1\beta_1} \qquad (9)$$

The characteristsicof the change made to the function $C_1(n_1)$ is shown in Fig. 1a. This line gives us the sensitivity of thefunction $C_1(n_1)$ within a small area of the point n_1^*. Obviously, if β_1 is larger, then a small deviation of n_1 from n_1^* will result in a significant change to the total costs. This conclusion is an accountable factor in organizing the supply process.

3. Customer Interface

We developed a consumer interface for the software design of the obtained mathematical model. In VisualStudio.NET_2019work environment, we built a conceptual model in the form of ERM diagrams (Fig. 1**b**) depicting business processes included in the supply chain [4].

Based on the above-mentioned diagrams, we get the composition of SQL Server database and spreadsheet from the ERM schemeas a DDLfile in an automated mode.

In Visual Studio.Net environment we created a new Windows Form Application project matching it to the database designed in SQL Server.

After designing the supply chain database and implementing it in SQL Server 2016 with its DLL file, we developed a consumer interface in an integrated environment — Visual Studio.NET Framework 4.5 program— and used the programming technology — WPF Windows Presentation Foundation.

We designed a consumer interface (Fig. 1c).

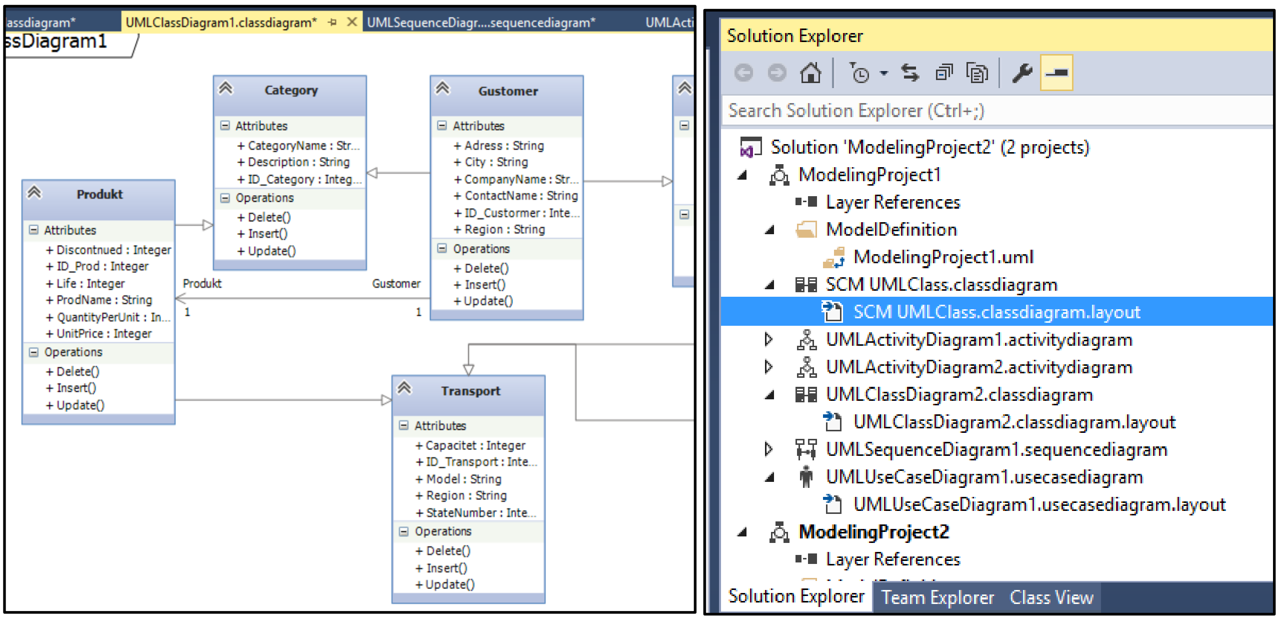

Fig. 1b.

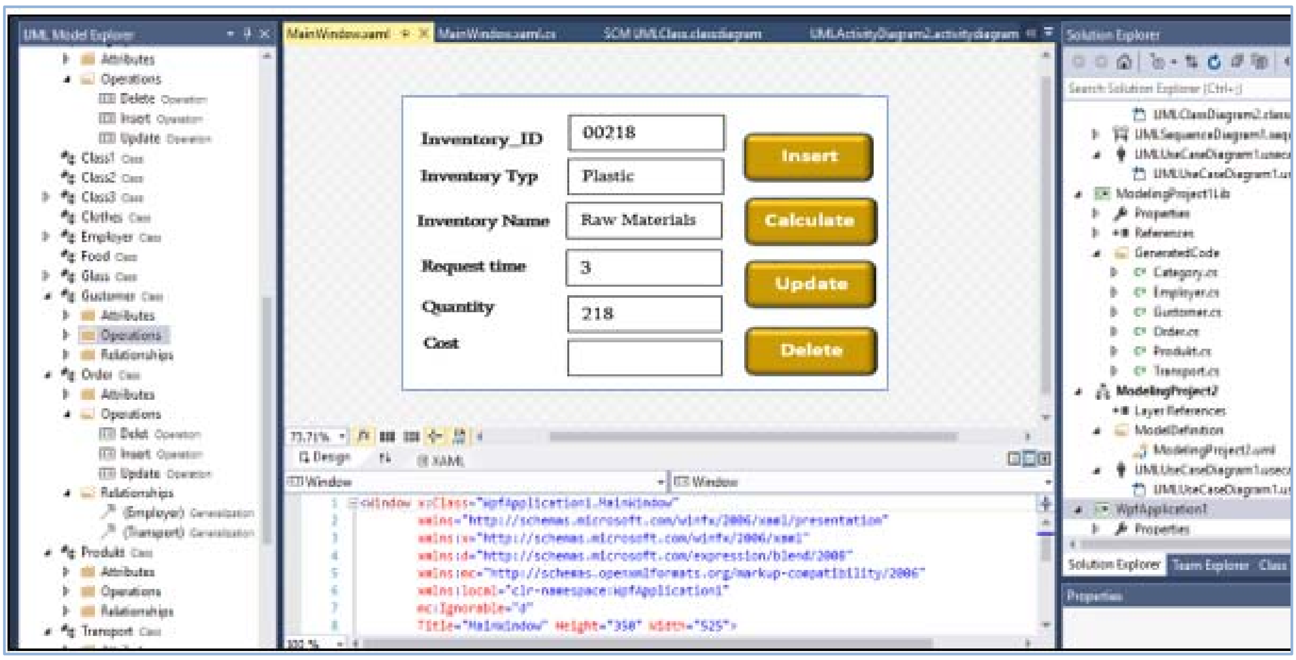

Fig. 1c.

As the description given above shows, WPF-technology allows its users to design a consumer interface through both Windows and other operating systems, as well as in the web environment; the web application will be placed in any internet browser.

We integrated the mathematical model adopted by us into a WPF environment and designed the consumer interfacefor the automated inventory management system, which enables its customers to receive information about inventories in unit of time, their value and relocation.

4. Conclusion

For optimal determination of the business processes, inventory management and product costs included in the supply chain,this paper covers the mathematical model and IT platform directly related to the product value formation and rational inventory management.

By using this model, it is possible to significantly reducecosts, determine accurate information aboutinventories in a short timeand observesafety standards.

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