Model of production resource management for manufacturing enterprise

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Abstract. The article discusses the construction of a simulation-dynamic model of inventory management for production. The model is built taking into account the following factors: production, shipping, desired demand, desired productivity, labor and others using Powersim Studio. A model management interface was created, which includes an input interface through which input of initial data is carried out, as well as an output interface that allows seeing the difference between demand and production, the actual and desired workforce, as well as the current and desired inventory. On the basis of the experiments, conclusions were drawn regarding the available data, and a comparison of the results of the experiments was carried out, as well as illustrating how the model visualizes changes in the process of inventory management.

1. Introduction

Inventory management is an important area of managerial activity at enterprises of various industries, both in the production of goods and in the provision of services.

In a market economy, in order to increase the efficiency of the material and technical supply of the enterprise itself and the marketing of finished products manufactured by it, issues of rational and efficient organization of management and control processes for the movement of material and financial flows in the enterprise become especially relevant. All this is necessary to optimize the level of stocks and their effective use, reduce their level, as well as minimize the working capital invested in these stocks.

The lack of inventories at the enterprise can lead to a disruption in the rhythm of its production, a decrease in labor productivity, overspending of material resources due to forced irrational replacements and an increase in the cost of production. At the same time, the presence of unused reserves slows down the turnover of working capital, diverts material resources from circulation and it reduces the rate of reproduction and leads to high costs for the maintenance of the reserves themselves. All this leads to increased costs, i.e., depreciation due to the creation of additional storage facilities for storing excess inventory, salary costs for increased accounting and warehouse personnel, increased utility bills for lighting, heating of additional storage facilities. Additional costs increase the
cost of finished products manufactured by an industrial enterprise and reduce its competitiveness in the goods market.

The task of inventory management appears when there is a need to create a stock of any material resources in order to meet demand for the considered time interval. Since the costs associated with inventory management are controversial, inventory management becomes the procedure for finding the optimum between insufficient and excess stocks in order to obtain minimal costs. There are many formal methods of inventory management. One of such modern and widely used methods today is simulation-dynamic modeling, the method of system dynamics. It is presented how and how the company plans its production, taking into account the demand [1, 2].

2. Resource management efficiency calculation model
A graphic diagram of a simulation-dynamic model for calculating the level of inventory management efficiency is presented in Figure 1. The model includes one level (drive), i.e., components of the products necessary for the production. The diagram also shows two streams, production, and shipment.

![Diagram of flows and levels of calculating the level of inventory management efficiency](image)

Figure 1. Diagram of flows and levels of calculating the level of inventory management efficiency.
The auxiliary variables are present in the diagram in addition to the listed flows and levels. The interpretation of the variables shown in the diagram is presented in Table 1 [3 - 5].

**Table 1. Variables used in the flow chart and calculation levels of inventory management**

| №   | Name                        | Documentation                                                                 |
|-----|-----------------------------|-------------------------------------------------------------------------------|
| 1   | Expected demand             | The number of goods that are considered sold every week                        |
| 2   | Workforce                   | Company workforce                                                             |
| 3   | Order cost                  | Orders shipped to customers from inventory                                     |
| 4   | Desired workforce           | Desired workforce                                                             |
| 5   | Change in expected demand   | Change in expected demand every week                                          |
| 6   | Productivity                | Workforce productivity                                                        |
| 7   | Time to change expectations | How long does it take to adjust demand expectations to predict demand         |

The following logical step will be to describe the available variables since all the basic elements have been added. It is necessary to maintain values and units of measure for the content for that.

A description of the variables is presented in Table 2.

**Table 2. Description of variables.**

| Name                        | Value                                                                 | Variable |
|-----------------------------|----------------------------------------------------------------------|----------|
| Production                  | Workforce * Productivity                                             | units/wk |
| Shipment                    | Order cost                                                           | units/wk |
| Order switch                | 1                                                                    | none     |
| Inventory coverage          | 4                                                                    | wk       |
| Desired inventory           | Expected demand * Inventory coverage                                 | units    |
| Desired performance         | Expected demand + (Desired inventory - Components required for production) / Time to change inventory | units/wk |
| Time to change inventory    | 6                                                                    | wk       |
| Constant cost               | [100<<units/wk>>+STEP(20<<units/wk>>; STARTTIME+20<<wk>>)]             | units/wk |
| Random cost                 | [100<<units/wk>>+RANDOM(-50<<units/wk>>; 50<<units/wk>>;0,3)]         | units/wk |
| Cyclic cost                 | [100<<units/wk>>+SINWAVE(20<<units/wk>>; 20<<wk>>)]                   | units/wk |
| Order cost                  | {Constant cost; Random cost; Cyclic cost}[INDEX(Order switch)]       | units/wk |
| Expected demand             | Order cost                                                           | units/wk |
| Change in expected demand   | (Order cost – Expected demand) / Time to change expectations          | units/wk²|
| Time to change expectations | 8                                                                    | wk       |
| Desired workforce           | Desired performance / Performance                                     | person   |
| Performance                 | 6                                                                    | units/person/ wk |
| Workforce                   | Desired workforce                                                   | person   |
| Recruitment                 | (Desired workforce – Workforce) / Time to adjust workforce + Exhaustion| person/wk|
| Exhaustion                  | Workforce / Time to leave                                           | person/wk|
| Time to leave               | 100                                                                  | wk       |
| Time to adjust workforce    | 36                                                                   | wk       |
The STEP function is generated at altitude the first time.
The STARTTIME function returns the start time of the simulation.
The RANDOM function generates a series of random numbers that are distributed according to a uniform distribution, with a minimum value of Min and a maximum value of Max.
The SINWAVE function creates a time-dependent sine wave, with amplitude as its amplitude and period as its period. The wave is biased by the bias time.
The INDEX function allows using A as an index variable when accessing an array element using the following syntax: Array [INDEX(A)].

3. Management interface simulation-dynamic model for calculating the level of effectiveness of inventory management
Figure 2 shows the “User interface”, which consists of a frame with a name, a graph, a slider, and a switch. It is an input interface where the user can independently change the data that he considers necessary for a more accurate display. In turn, the graphs represent the output interface.

![Graphs showing product components, workforce, and order cost](image)

Figure 2. Input interface.

4. Results
Experiment 1. During the experiment, a model was built that formalized the change in the process of inventory management. The input values for the calculation are presented in Figure 3.

It is possible to conclude that the cost of the order increases sharply to 120 units per week and remains unchanged throughout the simulation of the model. One can say the same about the expected demand.
Figure 3. The input data for the model run.

Figures 4 and 5 show the results of the run.

Figure 4. The result of the run of the output interface model.

The production throughout the course of the simulation grows, reaching 130 units per week, then falls below the expected demand to 112 units of the model, and then, during the course of the simulation, it fluctuates (it becomes 2-3 units higher than the expected demand, or 1 unit lower in week).

The bottom line is the quantity of goods produced is higher than what is required by demand, which can lead to overproduction, accordingly, a situation arises when it is necessary to reduce
production itself, as can be seen on the graph. As the model simulates with the expected constant demand, production tries to match. It will happen only in 5 years.

**Figure 5.** The result of the run of the input interface model.

When viewing the inventory and the desired inventory, one can see the following. The actual amount of inventory in the first stage drops sharply to 200 units. It is lower than the desired number by 260 units. Further, the actual amount of inventory increases sharply to 600 units. It is 140 units higher than the desired one. This is due to the fact that production itself is becoming larger, which means that more inventories is required. After a short period recession occurs. It is associated with a drop-in production itself, becoming lower than the desired amount of inventory by 60 units. At year 5, the desired and actual amount comes into balance.

The conclusion when viewing the actual and desired workforce is the desired amount of labor in the first stage grows to 23 people, then drops to 19 people, and then grows to 21 persons. The remaining time value does not exceed 20 persons. The desired workforce in the first stage is higher than the actual one in 7 persons, which is associated with a sharp jump in production. Further, there is a sharp decline, up to 15 persons, which is lower than the actual workforce by 8 people. It is also related to the nature of production. During the simulation, the desired workforce reaches its new peak of 23 persons, which are 4 people higher than the actual one. At year 5, the desired and true labor force comes into balance.

In accordance with the results, it is possible to say that the company spends a huge amount of resources at the first stage, which is not true, which means that such a strategy of behavior can negatively affect its condition [4].
Further, in order to correspond to the real state of affairs, a reduction can also negatively affect its condition. Only at the fifth year does the stabilization of the real and the desired occur, which is very long lasting. Accordingly, it is necessary to change: either the time for adjusting the labor force so that resources are not wasted in vain, or the strategy of the order value, or the time the inventory changes or its scope should be changed.

5. Conclusion
In this work, the model shown in the example was built, with the available input data. It was concluded that the stabilization process would take longer with the first input data; the stabilization process will be much faster at a faster rate of change in the correction time. However, it is necessary to have a sufficient amount of resources for these operations.

Despite the fact that the model itself is simple and not cumbersome, it helps to view more interactively the dynamics of changes in inventory, production and how all this is affected by demand. It is also worth considering that when running the model, the value of the order cost, which affects the expected demand, was not used.

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