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Simulation Modeling of a Warehouse Logistics Department of a Medium-sized Company

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Abstract. The article gives a simulation model of a warehouse and logistics department of a medium-sized company. Based on the pre-specified workload, the following characteristics of the department are established, such as the load of the warehouses, the size of the queues for import / export of goods and the waiting time in them, the volume of the warehouse and the number of service personnel (warehouse workers). The model can be easily changed for various similar situations.

INTRODUCTION

The supply of raw materials to small and medium-sized industrial enterprises is carried out in certain quantities (shipments) at intervals. The company uses raw materials in its production process, i.e. their use is determined by the products produced as well as by their type and volume. For the same batch of products, the use of the supplied raw materials is subject to a certain rhythm. The optimization of deliveries according to the needs of the enterprise is a classic task of the logistics management, which is solved according to various factors, restrictive conditions and optimization criteria. In large enterprises producing large volumes of homogeneous products, this optimization can be achieved more easily. In small and medium-sized enterprises, the batches produced are not so strictly defined in time by volume and type of products. The latter is even more valid under the conditions of economic uncertainty in the event of a slowdown in economic growth or its decline.

A similar logistical task exists for commercial companies [1, 2]. And in commercial / retail companies there is a significant difference in solving this optimization task: depending on the size of the company and the type of customers (end customers or companies).

This logistics process is shown on Figure 1 as a part of the general logistics chain "manufacturer end customer".

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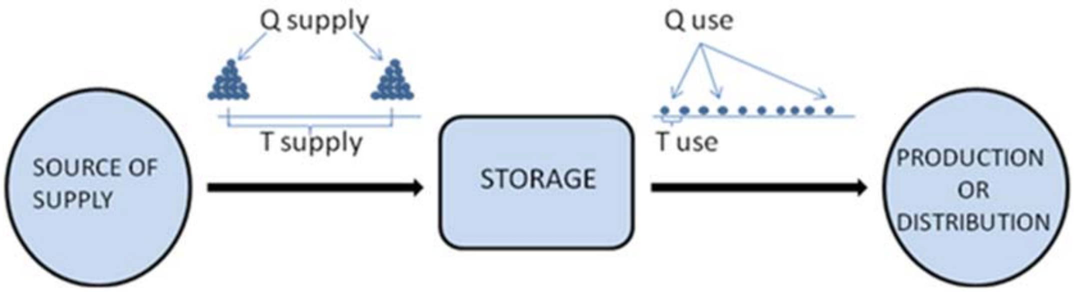

FIGURE 1. Scheme of planning the delivery and consumption of a particular good or raw material.

There are the following main issues:
1. Ensuring deliveries by type and quantity so that there is no shortage of them;
2. To ensure storage of the delivered quantity;
3. The process to be as cost-effective as possible according to a certain criterion / criteria

In order to have a balance of the purchased and used (or sold) quantity of goods, the following condition should be met:

$$\frac{Qs}{Ts} = \frac{Qu}{Tu} \tag{1}$$

where:
- Qs is the volume of delivery in the respective measurement unit characteristic for the goods (pcs., m, etc.);
- Qu is the volume of the quantity used in the production in the respective measurement unit characteristic for the goods (pcs., m, etc.);
- Ts is the period of time between two deliveries;
- Tu is the period of time in which the quantity of goods Qu is consumed.

If $\frac{Qs}{Ts} > \frac{Qu}{Tu}$, there are conditions to overflow the warehouse, and if $\frac{Qs}{Ts} < \frac{Qu}{Tu}$, there is a shortage of material for production.

The main problem in equation (1) is the existing in practice tolerance in the times and the quantity of delivery and use of the goods. The reasons can be of different nature:

- on the part of the source of supply, there may be problems with production and logistics, there may be an alternative source, there may be temporary promotions, etc. In order to avoid dependence on the supply of raw materials, certain storage reserves are needed, which in turn incur additional storage costs;
- by the manufacturer and / or distributor: problems with production, reduced or increased demand, production accidents, strikes, etc., which also affect the size of the warehouse and reflects on storage costs.

There are various classical ways to solve the problem of determining the volume of supplies. Wilson's formula giving Economic Order Quantity (EOQ) [3] is the most commonly used method for determining the volume of the order. At the same time, this method does not make possible to estimate stochastic fluctuations, which can have a significant effect.

Another important problem to determine is how many warehouse workers there should be. Although in theory they can be a variable over time, in the real case of a business unit it is appropriate to have staff appointed for a certain period of time. The salaries of this staff determine a significant part of the storage costs.

This article aims to solve this classic problem using stochastic tools that are available to small and medium enterprises.

Thus, the article presents a stochastic approach, in which if the characteristics of the inflow and outflow are known, the two main parameters of the warehouse can be determined - capacity and service personnel.

MODEL PROPOSITION

The above optimization problem is reduced to solving the classic problem of a producer-consumer pair, organizing their work through a common buffer [4, 5], in this case it is a warehouse. By means of simulation, final values of the intensities of the incoming and outgoing flow of goods are set and thus the maximum size of the warehouse and the maximum number of warehouse staff (and equipment such as forklifts, electric trucks, etc.) are found.

After simulating determination of the maximum capacity of the warehouse, a reserve (about 10 %) is added and is converted to a real model of the warehouse, which is described in the scientific literature as data exchange between a producer-consumer pair (Fig.2.) of n elements [6].

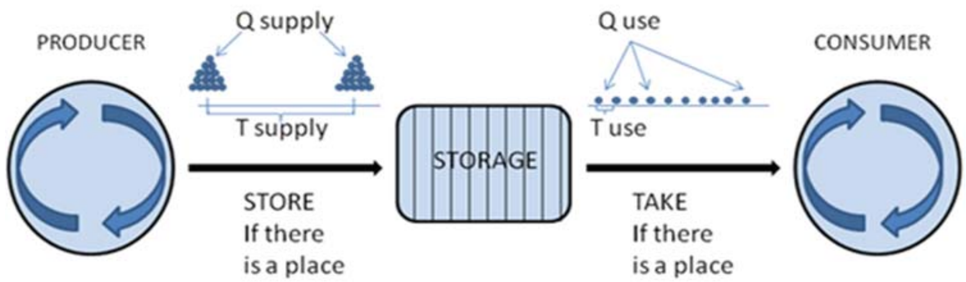

FIGURE 2. Presents the problem as a producer-user pair organizing their work through a limited buffer.

The following rules (synchronization requirements) are required for the warehouse to function [7]:

- the entry / exit of the goods in / out of the warehouse is performed by warehouse workers and specialized equipment (e.g. electric trucks). The following options are possible: the same workers to perform the work of import and export or to have a specialization related to the unloading of shipments and forwarding of warehouse products to customers;
- products cannot be put in a full warehouse;
- products cannot be exported out of an empty warehouse.

SIMULATION OF PROPOSED MODEL

To solve this problem, the so-called Queuing theory and its supporting GPSS discrete simulation environment [8] is chosen. The main advantage of the simulation modeling in comparison with the analytical models of CTM [9] consists in:

- significantly easier work with the GPSS simulation environment;
- easy change of the task;
- graphical output of the system, convenient for business analysis.

The use of a simulator greatly simplifies the work of determining the maximum capacity of the warehouse and the number of employees. By means of minimal changes in the program model of a producer-consumer pair, different circumstances can be investigated under the limitations described above.

The shown on Fig. 3 program model consists of two model segments - for each one of the processes producer and user. In this case, it is assumed that:

- deliveries in the warehouse are with a volume of 100 units and are made every 1000 minutes (about 16 hours 40 minutes), which requires 4 warehouse workers and it takes an average of 45 minutes;
- the export of goods has a single volume, it is carried out on average every 10 minutes, only one worker is needed and it is done in 15 minutes;
- much larger values are set for warehouse volume and number of workers in order to see their maximum values.

In this case, the tolerance is set as an even distribution (for the convenience of the reader), and changing it to Poisson's or exponential is a trivial task, as GPSS includes a wide range of ready-made distributions.

```
wrkr       storage   100       ; Number of workers
stor       storage   10000     ; Warehouse volume in conventional units
; ***  IMPORTING TO THE STORAGE ***
           generate  1000,500  ; Request to the warehouse for import
           queue     qwrkr
           enter     wrkr,4    ; Occupying fourth worker
           depart    qwrkr
advance    45,15               ; Import work
enter      stor,100            ; Occupying 100 units of warehouse volume
leave      wrkr,4              ; Leave 4 workers
           terminate           ; End of import work
; ***  EXPORTING FROM THE STORAGE ***
           generate  10,8      ; Request to the warehouse for import
advance    1000     ; Wait for first supply
queue      qwrkr
           enter     wrkr      ; Occupying an worker for export
           depart    qwrkr
           advance   15,10     ; Export work
           leave     wrkr      ; Release one worker
gate SNE   stor
leave      stor                ; Release of a unit from warehouse
           terminate
```

FIGURE 3. Main part of the GPSS model program

When changing the values of the parameters in this model program, this program can be used to determine two main parameters of the actual existing warehouse - capacity and service personnel.

SIMULATION RESULTS

Based on the specified workload and system parameters after continuous simulation, the following results were obtained (Table 1):

- maximum used warehouse capacity - 225 units;
- maximum number of workers – 9.

TABLE 1. Results from first simulation

STORAGE	CAPACITY	REMAIN	MINIMAL	MAXIMAL	AVERAGE C.	UTILISATION
WRKR	100	97	0	9	1.667	0.017
STOR	1000	1000	0	225	16.326	0.02

An analysis of the results shows that it is extremely rare to use more than 6 workers (their load factor is 0.017), therefore the following parameters of the storage system are chosen - volume 250 units and service personnel of 6 people.

A second simulation has been performed with the newly adopted data and a study of the efficiency of the use of the resources of the warehouse has been made (Table 2).

TABLE 2. Results from the second simulation

STORAGE	CAPACITY	REMAIN	MINIMAL	MAXIMAL	AVERAGE C.	UTILISATION
WRKR	6	4	0	6	1.667	0.280
STOR	250	250	0	183	2.372	0.009

It is seen that again the WRKR workers are not sufficiently loaded (0.280), but the fact that they are used for simultaneous operations (import / export to / out of the warehouse) leads to a reduction in warehouse use. Also, with 250 units of warehouse size, an average of 2.37 is used, and the maximum filling is 183 units.

At the beginning the warehouse is empty and the next unit is waiting for its production, due to which it is used immediately (see Fig. 4.). Only at the ninth delivery we have a residual reserve in the warehouse. On the other hand, a shortage in the warehouse should not be allowed because it reflects the cessation of production, where the missing materials are used. Thus, it is very easy to determine what the delivery period should be until the warehouse is full or until the volume of the first delivery in order to avoid shortages.

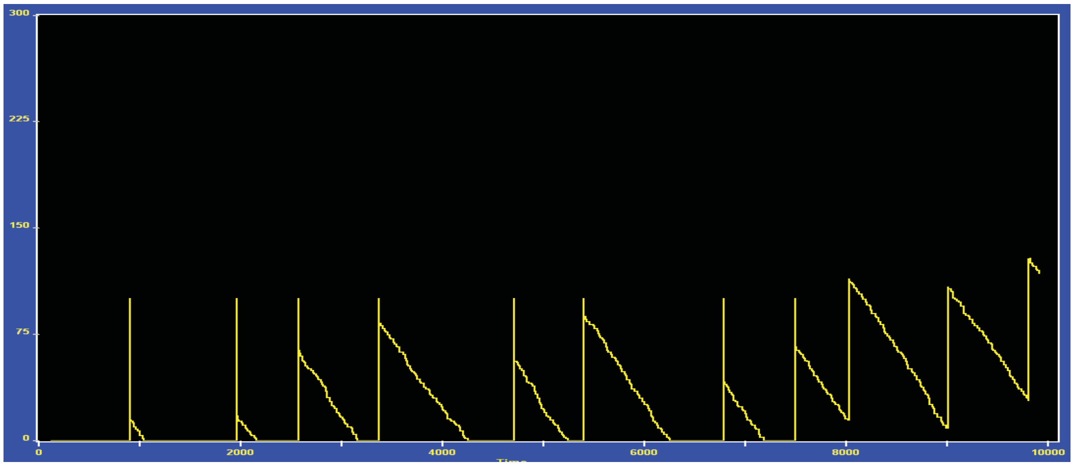

FIGURE 4. Initial loading of the warehouse

Fig. 5 shows the change in the quantity of stored units of goods in the warehouse. The fluctuations of the stored quantity of goods, caused by the tolerances in the supply and consumption, can be seen. The vertical lines of the diagram show the times of new deliveries, and the sloping lines show the consumption of the enterprise. At some times there are short-term shortages of stocks.

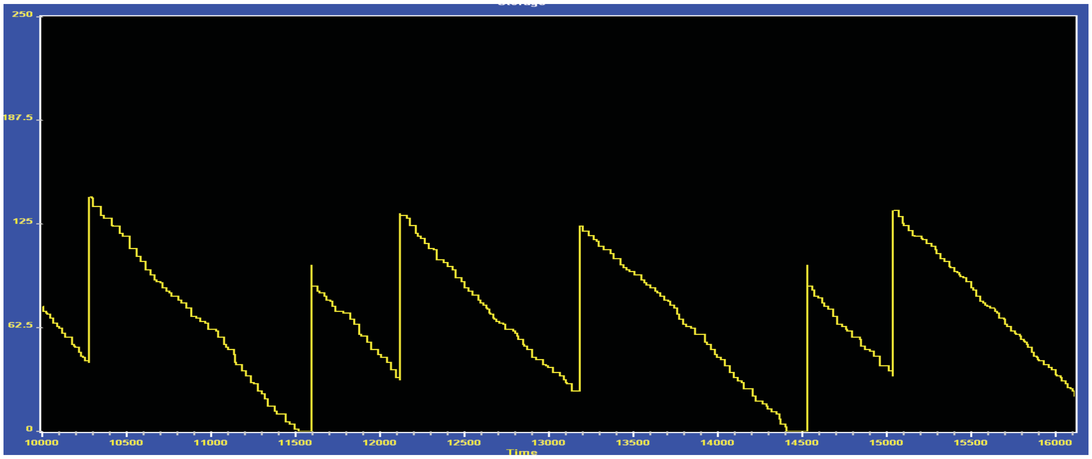

FIGURE 5. Stationary mode of operation of the warehouse

Fig. 6 shows the load and the number of workers (respectively forklifts, electric trucks). The difference in the workload of the warehouse staff over time is seen. Through this simulation, the business manager can decide to reduce the number of employees in the warehouse by finding a more cost-effective way to take on overtime work (e.g. overtime hours, paid extra).

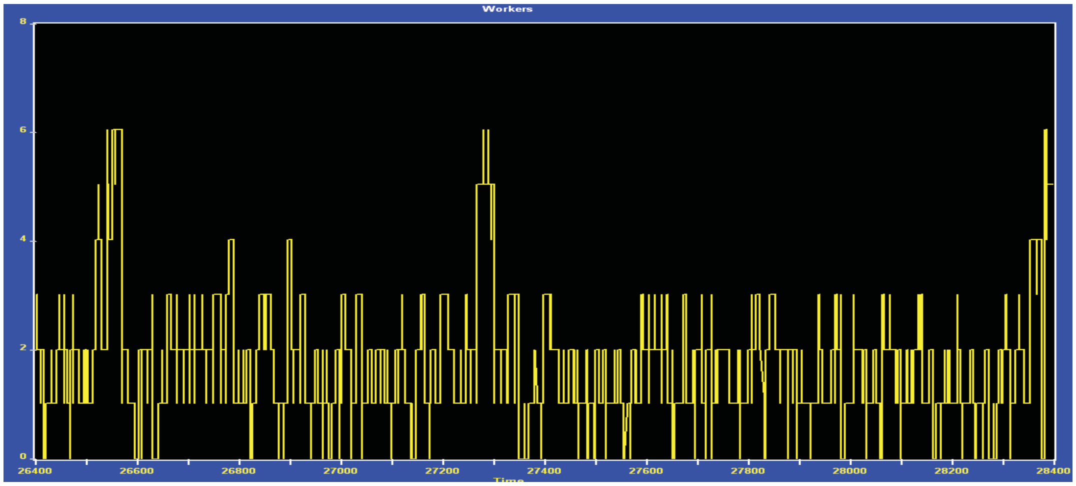

FIGURE 6. Diagram of workload of workers. The height indicates the number of simultaneously working warehouse workers.

In addition, 25 simulations are made with different tolerances with an even distribution of supplies and consumption in / out of the warehouse. 3 main parameters are studied: maximum size of the used storage area (Fig. 7), number of unserved orders for consumption of goods from the warehouse (due to lack – see Fig. 8) and aggregate costs, including the previous parameters – costs related to the value of the warehouse volume and lost benefits due to lack of stock.

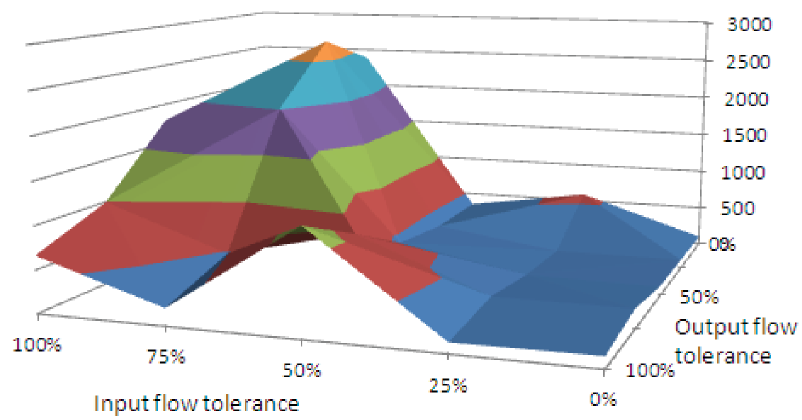

FIGURE 7. Size of the used storage units as a function of the tolerance of the deliveries and the consumption in/out of the warehouse

Fig.7 and Fig. 8 show the presence of the phenomenon interference in the realization of random variables, i.e. at some higher tolerance values it is possible to have less used storage and / or no stored products for the next production unit. It should be noted that in cases of lower utilization ratio of storage space, the opposite negative phenomenon is observed - lack of stored production output and vice versa. For this reason, the two phenomena are combined as a cost and a waste benefit with a weighting factor of 1 and the result is shown on Fig. 9.

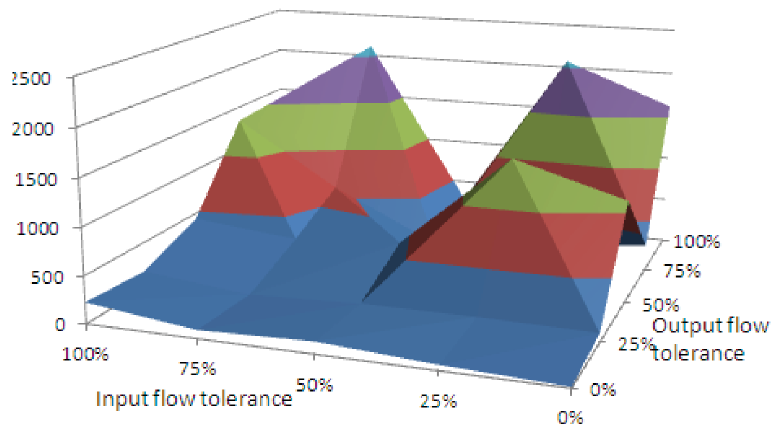

FIGURE 8. Number of unserved orders for consumption of goods from the warehouse as a function of the tolerance of deliveries and consumption in/out of the warehouse

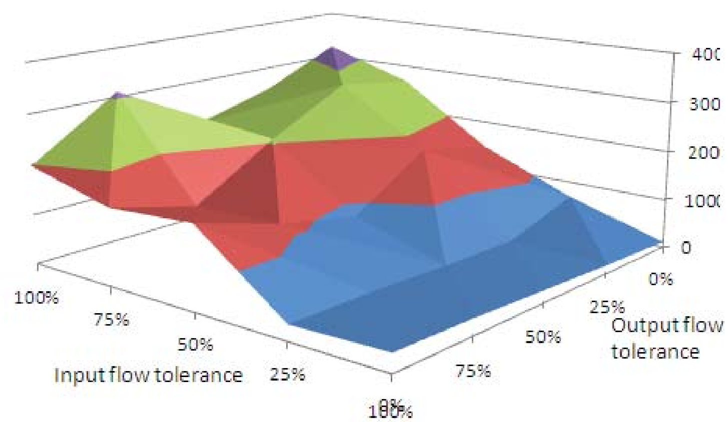

FIGURE 9. Reduced costs related to the value of the warehouse volume and lost benefits due to lack of stock (number of undesirable situations)

In all cases, it is valid that the tolerance of the inflow, 100 times longer delivery interval and correspondingly larger volume, has a significantly greater impact on the amount of the storage costs.

CONCLUSIONS

A stochastic simulation approach is proposed, which determines the two main parameters of the warehouse - capacity and service personnel. It is proved that on the basis of such models can be easily obtained results that can optimize the activity of the warehouses, production and trade enterprises. If an economic assessment is made of the following factors - cost of logistics, impact of the quantity of purchased goods and delivery price, warehousing costs, storage mechanization costs, staff costs, risk of delayed delivery and sale of goods, etc., an accurate analysis can be made and the economic efficiency of the enterprise can be increased.

Through small changes in the model code, it is possible to specify an input flow (workload), which is a superposition of several different Poisson flows. Such a statement models heterogeneous deliveries related to different: goods, delivery sources, delivery periods with their respective distribution (tolerance). The research carried out provides grounds for the advantages of the application of simulation models in solving such problems.

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