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USE OF SIMULATIONS IN THE WORKFORCE ALLOCATION IN THE WAREHOUSE

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Abstract:
The article deals with the use of simulations in optimizing the number and allocation of manpower in the warehouse. The simulation model is used to verify the need to secure workplaces by the workforce so that orders are ready for export at the required time and that there is no uneven burden on workers at picking and packing workplaces. The simulations are performed in the Tecnomatix Plant Simulation program. The simulation assesses proposals for the minimum and optimal amount of manpower, its allocation, time to meet requirements and occupancy of workplaces.

Key words:
simulation, Tecnomatix Plant Simulation, workforce utilisation

INTRODUCTION

The efficiency of distribution warehouse activities depends on several factors. The most important factors include the organization of storage facilities, the deployment of shelves and the management of the workforce and workflow. The entire process of securing the shipment, from receiving the order, determining its priority, packaging to picking, must be managed in the required time. Delays at any stage may result in non-compliance with the delivery deadline. The issue of warehouse optimization is addressed in scientific works from different angles.

The authors [1] compiled a systematic review of the literature to highlight the need to address bottlenecks in supporting activities. They presented new trends and approaches to the issue of personnel scheduling, also focused on work in the distribution warehouse. For example, the bottleneck in the distribution warehouse is addressed by the authors [2-3] using experiments on a simulation model created in ExtendSim program for fast delivery to customers. They are looking for the optimal assignment of employees to individual workplaces of the warehouse. Rasmi et al. [4] deal with the optimization of order picking time to speed up the delivery of the order to the customer and reduce warehouse costs. In order to shorten the order picking time, the authors Jiang et al [5] proposed a new strategy that first divides the orders and then allocates the sub-orders to different pickers. Authors Bahrami et. al [6] examine the performance in stock for different order picking methods. They measure performance in terms of total distance traveled, the number of collisions between operators (congestion) and order delivery times.The authors [7] deal with the problem of picking orders in a rectangular warehouse, which contains transitions only at the ends of alleys. They present an algorithm that allows order picking in a minimum of time. The authors [8] have compiled models that monitor the impact of workforce capacity on the level of selected performance indicators such as truck processing time and labor hours per truck. Manpower capacity for different demand scenarios is determined by target utilization levels, Square Root Staffing rule, and optimization. In the article [9], the logistic problem of inventory routing is solved using a heuristic approach.Robotic handling systems are increasingly implemented in distribution warehouses. They require little space, provide flexibility in managing different demand requirements and are able to work 24 hours a day, 7 days a week. This makes them particularly suitable for e-commerce operations. The authors [10] and [11] draw attention to the new integrated robotic warehouse systems and the need to reconsider the design logic of such warehouses, including the entire order handling process. The authors [12] have developed an algorithm that aims to minimize the number of storage aisles with capacity constraints - throughput and storage space.The aim of the article is to present the use of simulations in Tecnomatix Plant Simulation in optimizing the number and allocation of manpower in the e-shop warehouse. The simulation model is created on the basis of data obtained by observations and measurements in real operation and is the basis for the realization of experiments. The simulation assesses the proposals for the minimum and optimal amount of manpower, its allocation, time to meet the requirements and occupancy of workplaces.

1 MATERIALS AND METHODS

The distribution warehouse of the online store is operated as an e-shop without brick-and-mortar stores. It focuses on the sale of nutritional supplements, which customers order through the company's website. Picking starts at 6:00 and ends at 18:00. The work shift lasts 12 hours. Data on received orders were obtained by observation during a period of 1 week. Tab. 1 presents the average number of received orders in individual time windows.

Tab. 1 *The orders received for individual transport companies*

Time	Courier company /Number of orders						
	Courier 1	**Courier 2**	**Courier 3**	**Courier 4**	**Courier 5**	**Courier 6**	**Courier 7**
6:00	250	50	75	70	105	90	77
7:00	10	8	15	8	14	11	9
8:00	37	12	22	15	20	15	11
9:00	55	10	20	25	30	14	17
10:00	67	22	30	31	41	35	28
11:00	75	27	45	40	45	42	35
12:00	90	41	52	52	60	33	48
13:00	15	5	50	60	62	49	62
14:00					70	54	50
15:00					31	37	58
16:00					8	25	15
17:00						6	18
Total	599	175	309	301	486	411	428

The store delivers the goods within 24 hours, if the order is submitted within the specified time limit. If the order is submitted after the time limit, the shipment is delivered within 2 days. The average number of orders received is 2,600 to 2,800 per day.

Picking up the goods in the warehouse is done manually using human force. Orders are packed according to priority. Orders that belong to the shipping company that leaves the warehouse first have the highest priority. The company uses the services of seven transport companies for transportation. Transport companies and their departure times from the warehouse are listed in Tab. 2.

Tab. 2 *Departure times for individual transport companies*

Transport company	Deadline for picking all packages
Courier 1	13:30
Courier 2	13:45
Courier 3	14:00
Courier 4	14:20
Courier 5	16:45
Courier 6	17:15
Courier 7	17:45

Observations have shown that the number of staff and their allocation to the picking and packing department is not optimal. It happens that the packing workers do not manage to carry out their activities on time, orders accumulate on the conveyor and the picking workers have to wait until the conveyor is released. The intention of creating a simulation model is to experimentally verify by simulation the need to ensure the activities of the workforce and the division of the workforce into workplaces.

2 SIMULATION MODEL CREATION

The simulation model is created based on the analysis of data obtained by observing the order handling process. The process and its individual activities are shown in the diagram in Fig. 1. The duration of the operations was determined by measurement. The time of picking and packing operations is not constant, it depends on the size of the order. A triangular distribution was used to determine the variability of the time quantity. On average, picking has a shorter duration than packing but a higher variance. Picking time is a quantity with more uncertainty. These facts were taken into account in determining the parameters of the triangular distribution. The transport time of orders by the packing conveyor is constant and lasts 15 seconds. In Tab. 3 are time and capacity data for the simulation model. The daily number of orders within hourly intervals was determined by observation and measurement for one week and in Tab. 1 are shown the average numbers of these orders.

Fig.1 *The scheme of order processing*

***Tab. 3** Input data for the simulation model*

Workplace	Time of process [min] (triangle distribution)			Conveyor capacity (crates)
	Likeliest	**Min.**	**Max.**	
Picking	3:00	2:30	5:00	
Transport		0:15		20
Packing	3:30	3:00	4:30	

The simulation model is created on the basis of the scheme and data obtained by measurement. Since the duration of one shift is 12 hours, the simulation run time was also set for 12 hours. The model consists of 10 blocks and their function in the simulation model is as follows (Fig. 2):

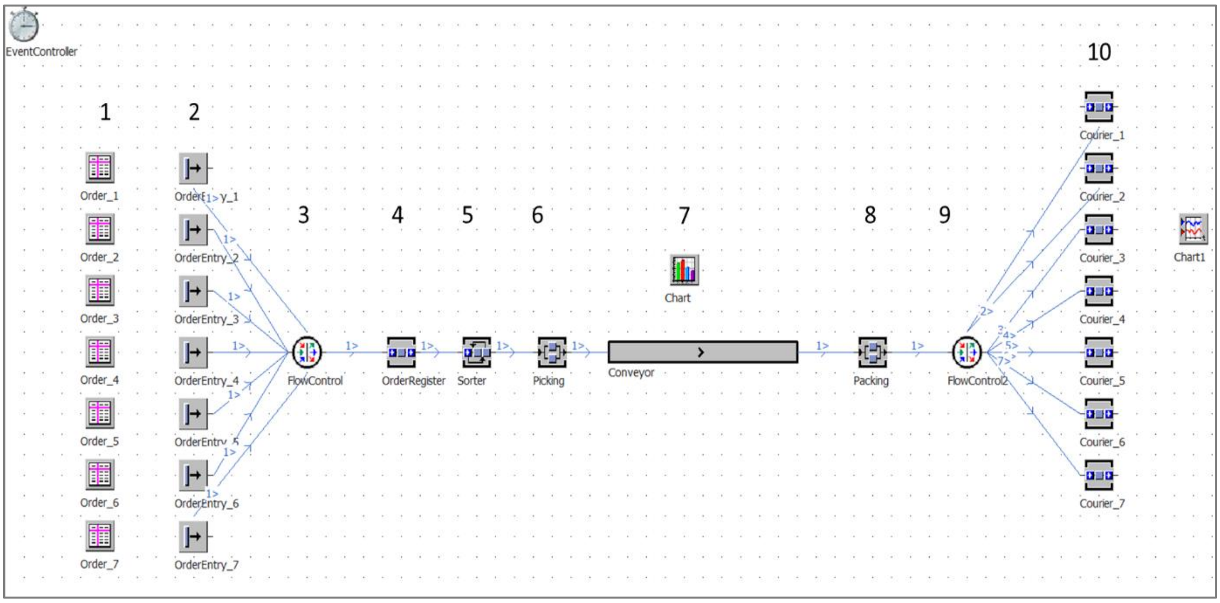

***Fig. 2** Simulation model*

1. Tables with data on time, quantity and attributes (priority and name of the carrier) of generated orders for individual carriers. Source data are in Tab. 1.
2. The „Source” block generates orders according to the data in Tab. 1.
3. The „FlowControl” block controls the composition of the flow of incoming requests so that they are drawn evenly from all sources.
4. The „Order Register” block represents the computer where the requests are collected.
5. The „Sorter” block controls the flow of orders to advance to the „Picking” activity according to their priority.
6. The „ParalellStation" block represents the „Picking" activity, in which goods are picked up from the warehouse according to priority. The operation is performed in parallel according to the number of employees. The times of this operation are in Tab. 3.
7. The „Conveyor" block represents the conveyor by which the orders placed in the boxes are moved to the packaging. The times of this operation and the conveyor parameter are in Tab. 3.

8. The next block „ParalellStation" represents the packaging of orders, i.e „Packing". The operation is performed in parallel according to the number of employees. Operation times are in Tab. 3.
9. The „FlowControl" block controls the order flow output. It divides and directs the flow of orders based on attributes so that they are directed to the right carrier.
10. The „Buffer" block represents a buffer where orders for individual carriers are collected.

3 SIMULATION RESULTS

The simulation model was used to verify the need to secure workplaces by the workforce so that orders are ready for export at the required time and that there is no uneven burden on workers at picking and packing workplaces.

Blocks for parallel activity were used in the simulation model to perform picking and packing activities, and different numbers of employees were set in individual experiments. The utilization of workplaces was monitored, as well as the time required to pick up all orders. It was important that the last order was ready for export before the departure time of the carrier. Regular departure times were given in Tab. 3.

Experiments have verified that the minimum number of workers in the warehouse is 30, while their distribution is 15 for picking and 15 for packing. With this number, it is possible at first achieve the readiness of all shipments within the set time limit. Whereby the workload is almost even (Fig. 3, Fig. 4). It is 97 % for picking and 98 % for packing. Workplaces were not blocked by other activities and idle time was only due to waiting (3 % and 2 %).

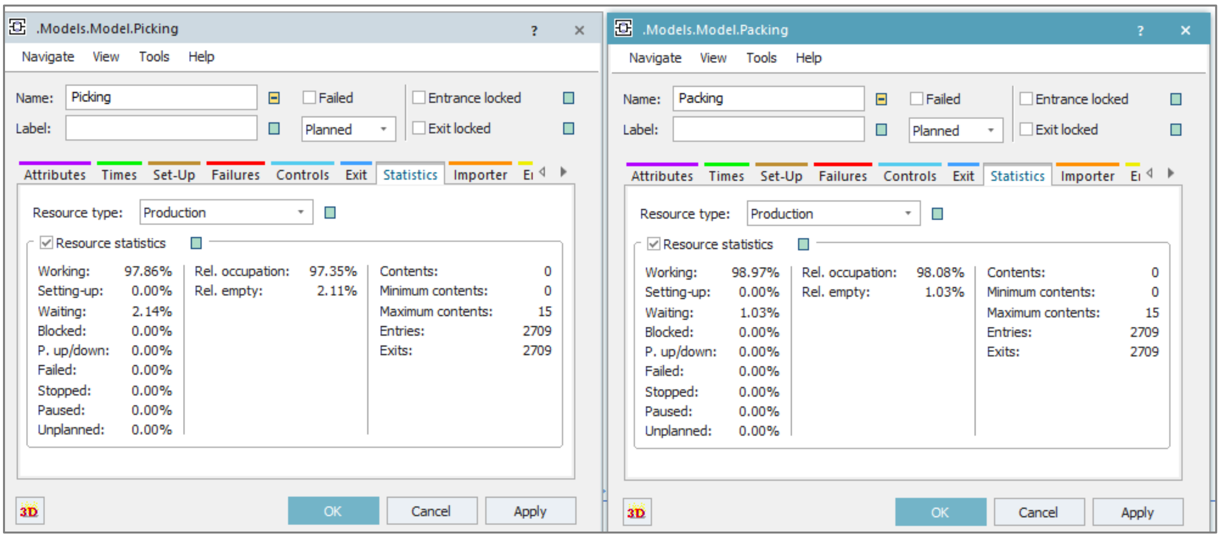

***Fig. 3** Utilization of picking and packing workplaces*

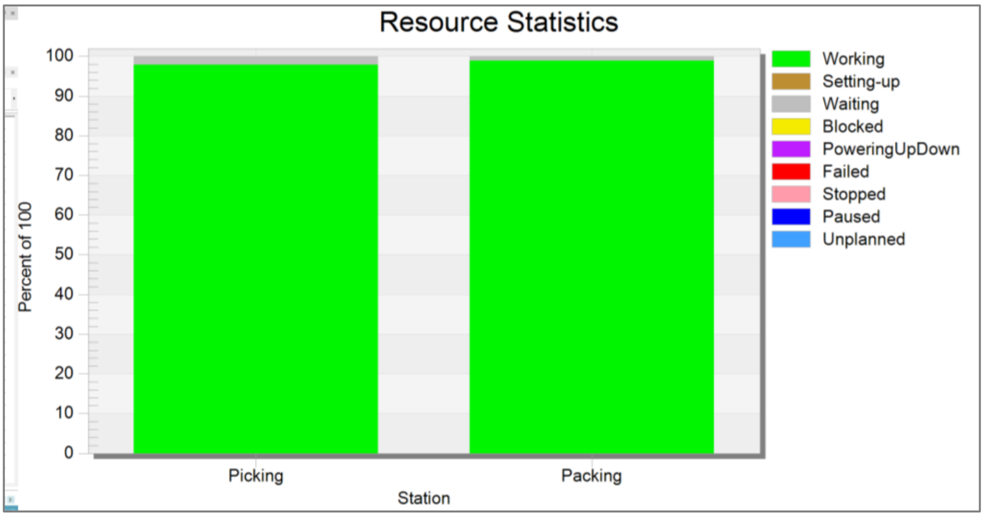

Fig. 4 *Percentage utilization of available picking and packing time*

The status of the order solution after the simulation also shows a 3D preview (Fig. 5), where we can see all orders ready for export in the bins on the left. There is no unfinished order at any workplace or conveyor. The orders were completed on time, but only a few minutes in advance before the carrier's departure.

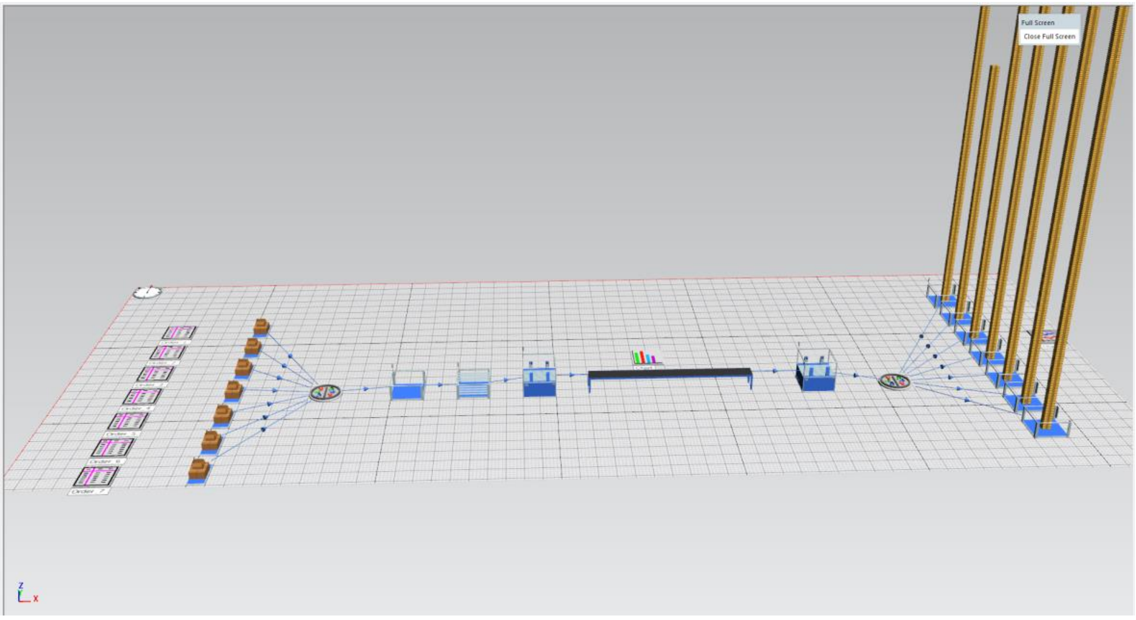

Fig. 5 *3D preview of the warehouse situation at the end of the simulation*

The smallest time reserve is for courier 6, only 7 minutes and for courier 1 only 15 minutes. Picking up other orders is prepared with approximately a 30-minute time reserve (Fig. 6, Tab. 4). Such operation of a warehouse is in a very tense mode and practically without any time reserve. In this case, any unexpected delays or sudden increases in orders means that all orders that should be exported on a given day have failed to prepare.

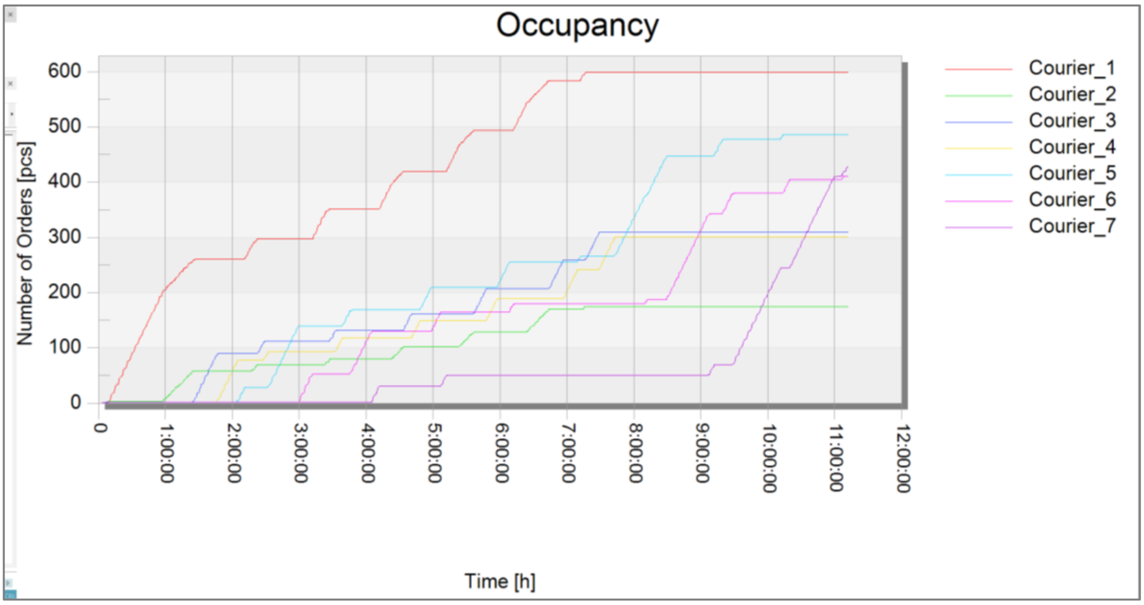

Fig. 6 *Chart of the order handling process*

Tab. 4 *Packaging times of the last package for individual couriers*

Company	Deadline for picking all packages	Packing time of the last order
Courier 1	13:30	13:15
Courier 2	13:45	13:18
Courier 3	14:00	13:25
Courier 4	14:20	13:40
Courier 5	16:45	16:16
Courier 6	17:15	17:08
Courier 7	17:45	17:12

To reduce the workload of workplaces and increase time reserves, it is necessary to increase the number of employees. It is optimal to reduce the workload below 90 %, which creates a sufficient capacity reserve for a sudden increase in orders, even in the event of an unexpected delay or failure. The simulation verified the effects of increasing the number of employees on the warehouse ability to meet the requirements and at the same time on the workload of workplaces. By increasing the number of employees to 16 for picking and 17 for packing, the workload was reduced to 90 %. Time reserves have only been increased for some carriers. The processing time of the last order depends on the time of receipt of this order, which is also in the late afternoon. Higher quantities of later received orders do not allow the completion of the preparation of the shipment in a more significant time advance. The process of order handling with the mentioned increased number of employees and the degree of workload of the workplaces is shown in Fig. 7 and Fig. 8.

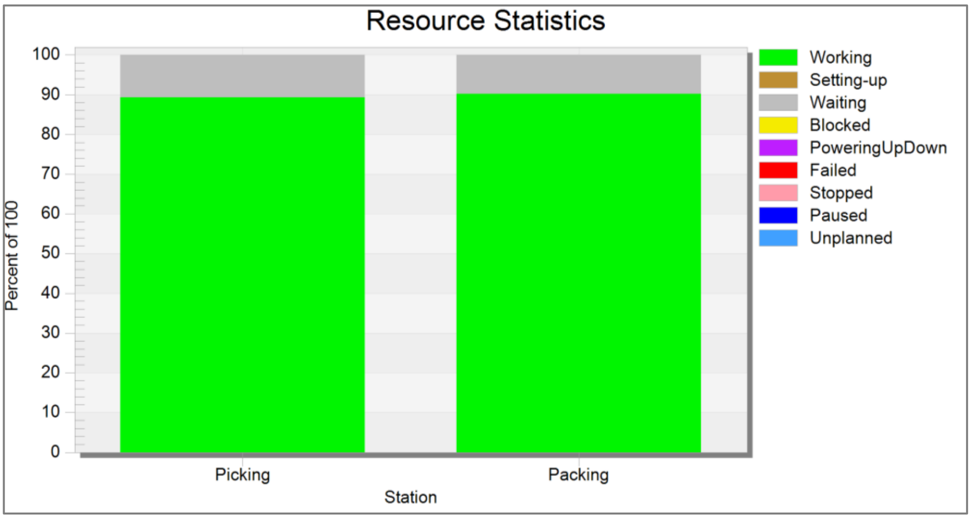

Fig. 7 *Workload of workplaces with an increased number of employees*

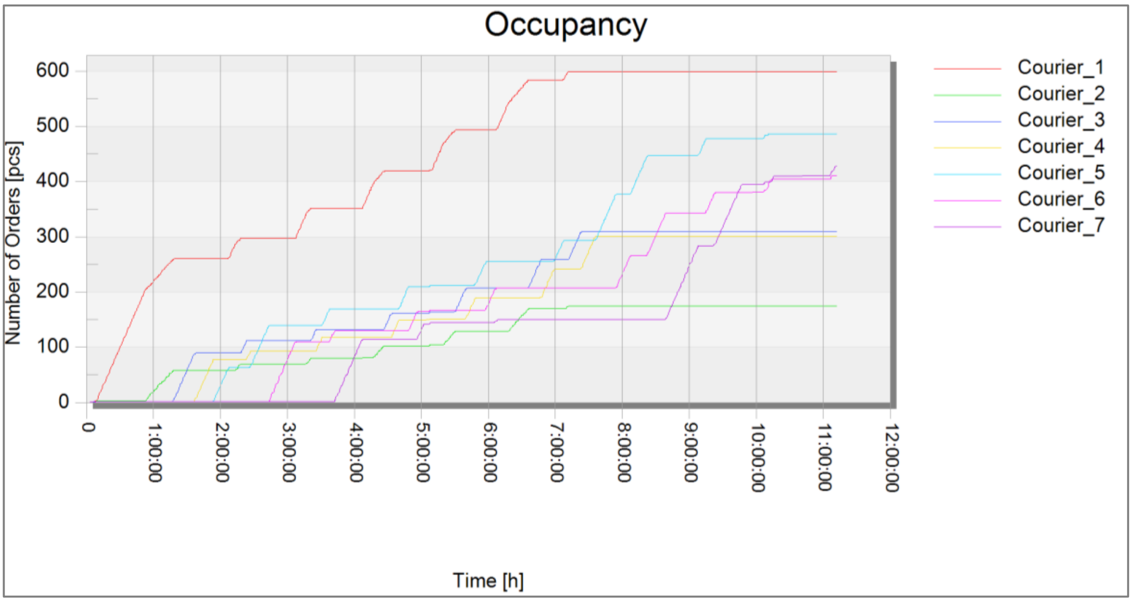

Fig. 8 *Graph of order processing with an increased number of employees*

4 CONCLUSIONS

The use of simulations has an irreplaceable place in solving the optimization of logistics processes. One of the problems solved by simulations is the optimal utilization of resources, allocation and solution of bottlenecks. The article dealt with the use of simulations in optimizing the number and allocation of workforce in the warehouse.

The simulations were performed in the Tecnomatix Plant Simulation program. The simulation model was created on the basis of data obtained by observation and measurement in real operation, formed the basis for the realization of experiments. The simulation assessed proposals for the minimum and optimal amount of manpower, its allocation, time to meet the requirements and occupancy of workplaces. Experiments have shown that the minimum security of picking and packing workplaces is 15 workers at each of the workplaces. This will ensure that the preparation of orders within the set time limit is completed. The minimum solution has almost no time reserves (reserves are less than 10 minutes) and the occupancy rate of workplaces was 97 %. Therefore, other layouts and manpower numbers were tested experimentally, which would mean a workload of workplaces no more than 90 %. Such an optimal occupancy of workplaces represents 16 workers for picking and 17 for packing. The simulation application speeds up decision-making and helps optimize processes. The advantage of the simulation model is its rapid adaptation to changed conditions, e.g. in the event of a change in working hours, departure times of vehicles, employment of part-time workers.

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