IMPROVEMENT OF THE WAREHOUSE OPERATION IN THE FURNITURE COMPANY ON THE BASIS OF THE SIMULATION STUDY

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ABSTRACT

The paper highlights the problem of computer simulation usage aimed at the warehouse operation improvement in the furniture company. Attention is paid mainly to the processes of receipt of parts in the warehouse. The simulation study ties together the project of the controlled warehouse implemented by the company. The goal of the simulation study is to verify whether workers are able to complete the intake of all parts within standard working hours. Subsequently, experiments with the use of the proposed model help to formulate recommendations which are to increase the productivity of processes and put down the time needed for the intake process into the warehouse. The Witness simulation environment is used for modelling and the subsequent simulation process. The simulation experiments are evaluated according to the total time needed for the intake of all parts, productivity of workers and the amount of overtime work. Finally, the proposed simulation experiments and evaluation of achieved results are described in detail.

Keywords: warehouse, warehouse operation optimization, modelling, simulation, computer simulation, Witness

1. INTRODUCTION

The right decision-making approach is unavoidable in each complex manufacturing system. Manufacturing companies are currently facing very strong pressure in terms of cost, quality, flexibility, customisation and a product delivery time to the defined market. Production and warehouse systems of these companies have to be flexible and able to react to changing production capacity requirements (Modrak and Pandian 2012). One of the ways to achieve efficiency is through the use of automated manufacturing, implementation available combinations of either manufacturing or replacement strategies (Chramcov, Bucki and Suchánek 2015) or improvement of the warehouse operation.

Warehouse operations efficiency is the key to the success of any company that processes inventories. When efficiency lags, products may not arrive at customer destinations on time, orders can get lost, and low inventory levels can result in stock-outs.

Operational optimization seeks to improve efficiency and effectiveness of a warehouse process. Despite the implementation of new philosophies in e-commerce, supply chain integration, quick response, just-in-time delivery and efficient consumer response that aim at shortening the supply chain by connecting the manufacturer with the end customers and hence gears towards eliminating the existence of a warehouse, many organization are yet able to implement these philosophies successfully (Tompkins and Smith 1998). Warehouses are still a common and central feature in most supply chains due to the partial implementation of lean and agile philosophies. Organizations need to find ways to effectively manage and perform operations inside a warehouse with much efficiency and in turn reduce the storage time and costs involved in the storage. These targets cannot be achieved by blindly adapting and deploying new trends and technologies. There is a need to optimize the technology, operation and manpower in order to get good results and high efficiency (Kare et al. 2009). An overview related to warehouse optimization problems is presented in (Karasek 2013). The author shows the current state of the art in optimization in three groups of interest in logistic warehouses and distribution centres.

Gill (Gill 2006) observes that warehouse management and inventory control are the areas within the supply chain with the greatest potential savings when it comes to optimization of the supply chain. Therefore, by properly managing inventory of an organization and warehouse operations by means of the best practices, management will provide the largest impact on a company’s bottom line than virtually any other functional area. Recent investigations also reveal that about 33 per cent of logistic costs can be attributed to the costs arising in inventory management and therefore, a proper investigation of savings that might be achieved within this part of supply chain is necessary and is, in many cases, profitable (Raidl and Pferschy 2010). Warehouse operation optimization generally focuses on how well the warehouse utilizes the existing storage capacity, measuring the impact of our choices of material handling equipment, labour, methods, procedures, and support systems. An extensive review on warehouse operation planning problems is presented in (Gu, Goetschalckx and McGinnis 2007). This paper provides a detailed discussion on warehouse operation-planning methods together with warehouse design, computational systems, and case studies. A recent survey on the overall warehouse design and operation problems is emphasized in (Rowenhorst et al. 2000). Moreover, in the work (Baker and Canessa 2009), the current literature on the overall methodology of warehouse design is explored, together with the tools and techniques used for specific areas of analysis. The output is a general framework of steps, with specific tools and techniques that can be used for each step. This is intended to be of value to practitioners and to assist further research into the development of a more comprehensive methodology for warehouse design.

This article focuses on a proposal to streamline warehouse operations of the furniture company. It results in the simulation study of the system. Several experiments were designed and subsequently simulated within this study case. The goal of the simulation study was to find a solution to the problem of completing the process of receiving and storing all varieties of pallets (coming within a day) throughout a standard work shift. Therefore, there was a need to suggest measures that would increase the productivity of processes and, at the same time, reduce the time needed for storing pallets which are to arrive on that certain day. Modeling and simulation were implemented in the simulation environment Witness. Validation and verification of the model was performed on the basis of comparison with real operational data and, in particular, on the basis of consultation with the warehouse staff.

2. DESCRIPTION OF THE SYSTEM

Individual processes and incoming stock pallets in the warehouse are schematically illustrated in Fig. 1. This diagram represents the basic elements and relationships of the discussed system and is the basis for the future computer model.

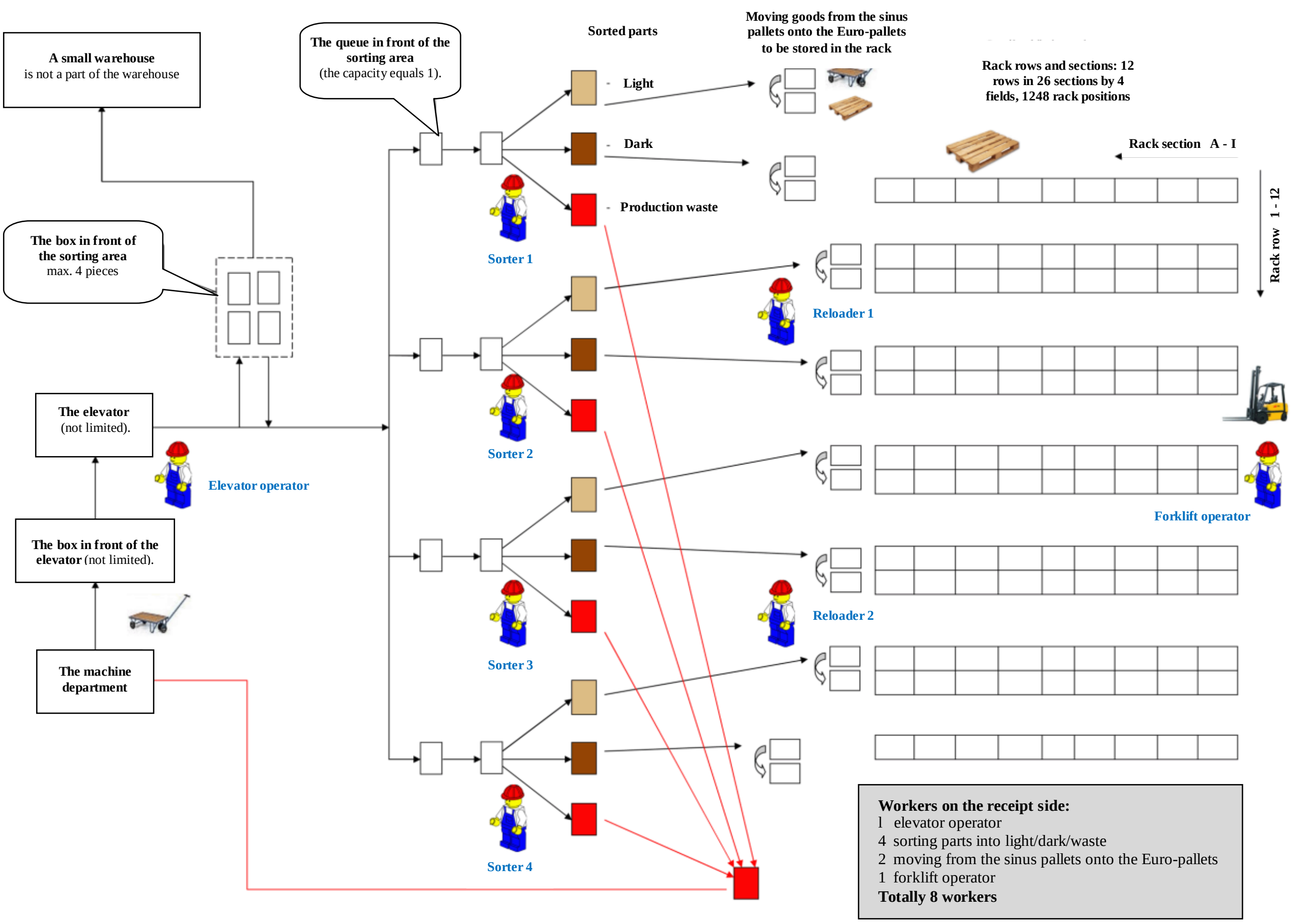

Fig. 1: The conceptual model

As it can be seen from the diagram in Fig. 1, eight workers are employed to secure functioning of the warehouse while receiving and storing. One worker handles operation of the elevator, four workers ensure the process of sorting the individual components to be stored, two workers put components on the rack pallets and one worker operates the forklift. The goal of the elevator service is to supply the workstation which sorts pallets with pallets intended only for sorting. One working cycle consists of several sub-steps. More detailed specification is outlined in Table 1. Some of the incoming pallets are designed for a small stock. This kind of warehouse is not considered in the simulation study. The pallets are put aside by the elevator operator after transporting them to the specified point and the operator of the small warehouse cares of them.

There are four sorting workplaces. Each of them is served by one worker only. Its main goal is to sort parts into light and dark pieces. The duty of the cycle sorting process depends on the specific type and quantity of pieces on a sorting pallet. After completing the sorting process, sorted pallets are moved to the sorting workplace.

Table 1: Description of the working activities of the warehouse employees.

Workplace	Work activities	Operation time
elevator service	elevator ride to the ground floor for loading pallets	40 s
	walk for a pallet	17 s
	transporting the pallet into the elevator (if there are more pallets in front of the elevator, this step is repeated until the elevator is filled with four pallets)	17 s
	elevator ride to the storing space	40 s
	removing the pallet from the elevator	17 s
	recording the arrival of each pallet by means of the electronic reader	12 s
	transporting pallets to the sorting workstation	19 s
	return to the elevator area	12 s
sorting	sorting process	according to the type and number of parts
	moving a pallet	24 s
reloading	reloading process	according to the type and number of parts
forklifts	finding where the required pallet is currently by means of a reading device	6 s
	ride for the rack pallet	36 s
	picking up the pallet from a rack position	25 s
	transporting the pallet to the sorting workplace	40 s
	stock performance of the new number of parts on a pallet by means of the reading device	20 s
	transporting a pallet to the rack	40 s
	putting a pallet to the rack position	30 s
	return to the sorting workplace for the new task	36 s

There are four sorting workplaces. Each of them is served by one worker only. Its main task is to sort parts for light and dark pieces. The duty cycle sorting process depends on the specific type and quantity of pieces on a sorting pallet. After completing the sorting process, sorted pallets are moved to the sorting workplace.

Until now, the so-called sinus pallets have been used to manipulate with the parts which are not suitable to be stored on the rack. The workhouse space includes 8 workplaces used for reloading operations. They are served by two employees moving between them. The time of placing parts on the Euro-rack pallet is given by a certain type and amount of pieces reloaded on the pallet.

The operator of the forklift delivers a rack pallet of the required type to the sorting place. After carrying out sorting operations, the operator secures restocking Euro-pallets to the appropriate rack. It is important to emphasize that there is only one worker in the warehouse. Table 1 presents individual tasks for this worker including duration. The total time of unloading a rack pallet equals 107s and putting it back into the rack position takes 126s. As seen from the above, it was necessary to collect a large amount of data to form a valid model. The data is analysed and evaluated subsequently.

There are nearly 1,150 kinds of parts stored in a large warehouse. They were divided according to their similarities into 46 type groups for the purposes of the simulation study. Each type group is characterized by four basic characteristics e.g. the ratio of dark and light pieces, sorting time, time of storing operations, belonging to the small or large warehouse.

Times of sorting and storing or manipulation operations as well as times of recording by the reading device were set on the basis of the measurement of direct observation in the workplace. The number of measurements varies according to the length of the working cycle.

Arrival times of the individual pallets in the system are obtained from the output information system of the company.

The warehouse operates in one shift of 8 hours. The shift starts at 6.00 am and ends at 2.00 pm. The lunch break lasts from 10.45 to 11.15 am.

3. MODEL OF THE CURRENT STATE

The model of the current state of the warehouse was created on the basis of a detailed analysis of the system. The simulation environment *Witness* was used to create the model and carry out the subsequent simulation process.

Six experiments were carried out with the created model. Each experiment was based on various input data. These data correspond to 6 specific working days. These days were marked as average by warehouse employees without the occurrence of abnormal conditions and failures. The results of these experiments were compared with the facts and were also consulted with the staff of the warehouse.

One day was chosen on the basis of comparison of the resulting times required to store the last pallet on an individual day. This day was treated as the reference one while carrying out simulation experiments. The day characterized by the highest difficulty time was chosen. The combination of the number of pieces of each type placed on pallets as well as their sorting and reloading times are given.

A target function (evaluation criteria) of simulation experiments were set on the basis of consultation with warehouse workers.

Individual simulation experiments are evaluated by:

- the total time needed for storing all pallets (storing the last pallet);
- workload of individual workers;
- amount of overtime work;
- the number of workers needed for one shift.

3.1. Simulation results of the model of the current state

Simulation results of the current state are shown in Table 2 in the form of exact beginning and finishing times of working activities of individual workers during one day. Moreover, there are real work times and downtimes of individual workers. Workload of a worker is a ratio of the real working time to the total time which the worker spends at the workplace within one working day (i.e. till finishing the last working activity).

Table 2: Simulation results of the current state of the warehouse

Employee	Beginning of the shift	End of the shift	Real beginning of work	Real end of work	Waiting time (downtime)	Worktime	Workload	Overtime
Elevator operator	6:00:00	14:00:00	6:05:00	14:50:10	5:03:07	3:47:03	42.83%	0:50:10
Sorter 1	6:00:00	14:00:00	6:07:10	15:42:50	3:04:50	6:38:00	68.29%	1:42:50
Sorter 2	6:00:00	14:00:00	6:09:40	15:36:10	4:32:44	5:03:26	52.66%	1:36:10
Sorter 3	6:00:00	14:00:00	6:12:10	15:31:20	4:52:11	4:39:09	48.86%	1:31:20
Sorter 4	6:00:00	14:00:00	6:23:20	16:22:10	5:10:45	5:11:25	50.05%	2:22:10
Reloader 1	6:00:00	14:00:00	6:15:10	16:46:30	5:43:48	5:02:42	46.82%	2:46:30
Reloader 2	6:00:00	14:00:00	6:37:00	16:39:00	7:20:04	3:18:56	31.13%	2:39:00
Forklift operator	6:00:00	14:00:00	6:12:30	16:48:00	0:56:23	9:51:37	91.30%	2:48:00
Total	---	---	---	---	**36:43:53**	**43:32:17**	---	**16:16:10**
Average	---	---	---	---	**4:35:29**	**5:26:32**	**53.99%**	**2:02:01**

From the results it is evident that it was impossible to store the last pallet in the due time shift i.e. till 2 pm. The last pallet was stored more than two hours after the end of the shift. Knowing this fact, a need to employ workers overtime arises. This overtime equals more than 16 hours which gives more than 2 hours per worker on average. The total working time of employees equals 43.5 hours approximately and the waiting time during the work period for all workers equals approximately 36.7 hours. The downtime represents 45.8% of the time spent by workers at the workplace.

From the point of view of individual workers, it is obvious that servicing the forklift is the bottleneck of the system. Utilization of this worker equals more than 90 percent.

4. SIMULATION EXPERIMENTS

On the basis of the simulation results of the model representing the current state of the warehouse it became necessary to propose appropriate solutions to improve warehouse operations. The goal was to sort out and store all pallets in the shortest possible time while reducing and finally eliminating overtime work. Moreover, it was necessary to specify an appropriate number of staff at each work position of the warehouse.

The time-scaling of simulation experiments was carried out from two points of view. First of all, there was a need to increase the flow of the system i.e. to eliminate bottlenecks in the process of receiving and storing in the way which can enable us to minimize the total time of storing all pallets. Secondly, there was a need to minimize the waiting time of individual workers i.e. maximize their workload.

The first experiment tries to remove the bottleneck of the system. According to the simulation of the current state (see Table 2) a forklift operator seems to be the bottleneck. For this reason, the option including adding the second forklift operator was added in order to improve the flow of the system.
Results of this simulation experiment are clearly shown in Table 3. By means of adding another operator of the forklift the average workload of the discussed workers went down to 52%. The bottleneck was moved to the sorting area where workers are characterized by their 62% average workload. A possibility of increasing the number of sorting places cannot be taken into account due to the dimensions as well as physical layout of the warehouse.

Table 3: Simulation results including adding one more operator of the forklift

Employee	Beginning of the shift	End of the shift	Real beginning of work	Real end of work	Waiting time (downtime)	Worktime	Workload	Overtime
Elevator operator	6:00:00	14:00:00	6:05:00	13:57:40	4:15:21	3:42:19	46.54%	0:00:00
Sorter 1	6:00:00	14:00:00	6:07:10	15:17:50	2:13:27	7:04:23	76.08%	1:17:50
Sorter 2	6:00:00	14:00:00	6:09:40	14:19:40	2:56:11	5:23:29	64.74%	0:19:40
Sorter 3	6:00:00	14:00:00	6:12:10	14:37:20	3:24:00	5:13:20	60.57%	0:37:20
Sorter 4	6:00:00	14:00:00	6:23:20	14:17:20	4:26:13	3:51:07	46.47%	0:17:20
Reloader 1	6:00:00	14:00:00	6:14:30	15:24:40	4:53:19	4:31:21	48.05%	1:24:40
Reloader 2	6:00:00	14:00:00	6:15:00	15:24:10	5:33:44	3:50:26	40.84%	1:24:10
Forklift operator 1	6:00:00	14:00:00	6:12:30	15:26:30	3:57:22	5:29:08	58.10%	1:26:30
Forklift operator 2	6:00:00	14:00:00	6:13:10	15:26:50	5:02:54	4:23:56	46.56%	1:26:50
Total	---	---	---	---	**12:42:30**	**19:29:30**	---	**8:14:20**
Average	---	---	---	---	**4:04:43**	**4:49:57**	**54.22%**	**0:54:56**

Increasing forklift service by one operator leads to accelerating storing all pallets nearly by 1.5 hours. The total utilization of all workers remained very similar to the current state. The amount of overtime fell by 8 hours. Therefore, it is worth considering to what extent the reduction of storing time of all pallets is the key issue for the company. Moreover, it is important to find out whether it is worth investing in another forklift and a trained employee.
A more detailed analysis of the workload of individual workers revealed that workers are busier in the afternoon hours than before the midday. This is due to a higher number of incoming pallets to be stored in the afternoon hours. For this reason, several experiments were designed and carried out. They solve the problem of moving the working shift of individual workers. Table 4 presents the results of the simulation where the beginning of the working shift of one reloading worker was moved to 11.15 am. This time corresponds to the time of return from the lunch break.

Table 4: Results of the simulation experiments including moving the working shift of the reloading worker

Employee	Beginning of the shift	End of the shift	Real beginning of work	Real end of work	Waiting time (downtime)	Worktime	Workload	Overtime
Elevator operator	6:00:00	14:00:00	6:05:00	14:45:50	5:00:16	3:45:34	42.90%	0:45:50
Sorter 1	6:00:00	14:00:00	6:07:10	15:34:50	2:56:52	6:37:58	69.23%	1:34:50
Sorter 2	6:00:00	14:00:00	6:09:40	15:43:40	4:58:27	4:45:13	48.87%	1:43:40
Sorter 3	6:00:00	14:00:00	6:12:10	16:11:40	5:08:48	5:02:52	49.52%	2:11:40
Sorter 4	6:00:00	14:00:00	6:23:20	15:28:10	4:22:01	5:06:09	53.89%	1:28:10
Reloader 1	6:00:00	14:00:00	6:14:30	16:44:50	5:07:05	5:37:45	52.38%	2:44:50
Reloader 2	11:15:00	15:15:00	11:15:00	16:47:20	2:48:28	2:43:52	49.31%	1:32:20
Forklift operator	6:00:00	14:00:00	6:12:30	16:49:30	1:03:16	9:46:14	90.26%	2:49:30
Total	---	---	---	---	**7:25:12**	**19:25:38**	---	**14:50:50**
Average	---	---	---	---	**3:55:39**	**5:25:42**	**57.04%**	**1:51:21**

Results of the experiment indicate that the work time of the reloading worker was shortened by 4 hours (moving the beginning of the shift to 11.15 am and the ending of the shift to 15.15 pm) however; this measure did not have a major impact on prolonging the period of storing all pallets. This period was extended only by 90 seconds. Thus fewer resources were required to store all pallets (fewer man-hours). At the same time there was an increase in the average workload of staff of the whole process of receiving and storing by 3% and the amount of overtime fell by 1.5 hours.

Based on the results of previous experiments, several new experiments were designed and carried out. These experiments remove the bottleneck of the forklift operator and at the same time purposefully move the working shift of individual workers.

Table 5 presents results of one of the best experiments which comprises the aforementioned conditions.

The bottleneck (the forklift operator) was supported by another operator beginning with 11.15 am. This worker is employed part-time in the process (half shift). This measure covers the bottleneck of the storing process which is caused by the increased intake of pallets in the second half of the work shift. The beginning of the working shift of all warehouse employees was moved unlike the current state (see Table 5). Additionally, the length of one reloading worker's shift was shortened to its half.

Table 5: The results of the simulation experiment concerning adding one more operator of the forklift and moving the working shift of individual worker

Employee	Beginning of the shift	End of the shift	Real beginning of work	Real end of work	Waiting time (downtime)	Worktime	Workload	Overtime
Elevator operator	6:30:00	14:30:00	6:30:00	14:08:10	4:00:28	3:37:42	47.52%	0:00:00
Sorter 1	6:30:00	14:30:00	6:32:20	14:13:10	2:01:18	5:41:52	73.81%	0:00:00
Sorter 2	6:30:00	14:30:00	6:36:00	15:14:30	2:42:45	6:01:45	68.97%	0:44:30
Sorter 3	7:00:00	15:00:00	7:00:00	14:30:10	2:47:15	4:42:55	62.85%	0:00:00
Sorter 4	7:00:00	15:00:00	7:00:00	14:29:00	2:24:46	5:04:14	67.76%	0:00:00
Reloader 1	6:30:00	14:30:00	6:39:30	15:25:00	3:05:59	5:49:01	65.24%	0:55:00
Reloader 2	11:15:00	15:15:00	11:15:00	15:17:00	1:29:23	2:32:37	63.06%	0:02:00
Forklift operator 1	6:30:00	14:30:00	6:37:30	15:24:30	1:39:11	7:15:19	81.44%	0:54:30
Forklift operator 2	11:15:00	15:15:00	11:15:00	15:27:00	1:38:59	2:33:01	60.72%	0:12:00
Total	---	---	---	---	**21:50:05**	**19:18:25**	---	**2:48:00**
Average	---	---	---	---	**2:25:34**	**4:48:43**	**65.71%**	**0:18:40**

Introduced measures shortened the time of storing all pallets by 17% i.e. 8 hours 57 minutes. This means loading the last pallet during 15 hours 27 minutes. Moreover, average utilization of the warehouse employees was also increased in comparison with the reference day by 11.7 %. At the same time the amount of overtime work was reduced by 83%. A forklift operator was added to the process of storing pallets employed for half of the work shift. Additionally, the shift of the worker responsible for reloading pallets was shortened to a half. In this case, the number of man-hours remained unchanged.

4.1. Evaluation of experiments and recommendations

The goal of the simulation study was to find the effective number of the warehouse workers, increase the productivity of the process of receiving and storing pallets however, the most important is the need to decrease the time needed to store all the pallets. While looking for a satisfactory solution the whole range of simulation experiments was carried out. Some of them are described in the paper above. Their results show that making processes in the warehouse more effective consists in moving individual workers‘ shift and supporting the working position of the forklift operator in the period between 11.15 am and the end of the shift. This assumption is proven by the results of the last experiment. The comparison of the results of chosen experiments including results of the simulation of the reference day is given in Table 6. From the above comparison it can be stated that under the terms of the last experiment all pallets can be stored in less than 9 hours which means reducing a storing time compared to the reference day representing the current state by nearly two hours. In this case, there is a need to add one extra worker to operate the forklift in the process of receiving and storing pallets. Therefore, the effective number of employees in the warehouse equals 9 but one person for the reloading position and one forklift operator are required for this process for only 4 hours a day. The number of man-hours per shift is therefore unchanged in comparison with the current state. Due to this fact, there was also an increase in the average utilization of warehouse employees and especially for steady usage of these workers It was impossible to remove the overtime work. However, reducing the amount of overtime work by 83% can be considered a very good result. Thanks to a more detailed analysis of individual overtime jobs it is further possible to reduce the amount of overtime work namely by means of a better distribution of the workforce at the end of the work shift. It depends on a suitable approach to solving this kind of problem and especially team behaviour of workers (mutual assistance) at the end of the work shift.

Table 6: Comparison of simulation experiments

Target function	Reference day	Experiment 1	Experiment 2	Experiment 3
Time for storing the last pallet	10:48:00	9:26:50	10:49:30	8:57:00
Real time of storing the last pallet	16:48:00	15:26:50	16:49:30	15:27:00
Average utilization of warehouse employees	53.99%	54.22%	57.04%	65.71%
Amount of overtime	16:16:10	8:14:20	14:50:50	2:48:00
Average overtime of warehouse employees	2:02:01	0:54:56	1:51:21	0:18:40
Number of workers needed for one shift	8	9	8	9
Number of man-hours	8	9	7.5	8

5. CONCLUSIONS

The simulation study of the furniture company warehouse continues the warehouse management project. After starting the warehouse operation, the company was facing the problem of effective staff utilization within one working shift and a long sorting and storing time of all parts made by the preceding manufacturing process. The simulation study shows the possibilities of more effective staff utilization with newly organized processes so that the workers are able to complete storing of all components within the standard working time with the minimal number of overtime hours. The proposed simple measures clearly lead to a significant reduction in the time needed for storing all parts, reduction in overtime and balancing the workload of individual workers.

The paper presents the possibilities afforded by using computer simulation for the design and identification of reserves in warehouse systems. Using concrete examples, it is demonstrated that the use of the Witness simulation environment - not only for the initial creation and design but also in suggestions designed to increase the affectivity of existing warehouses is valid and effective.

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REFERENCES

Baker P., Canessa M., 2009. Warehouse design: A structured approach. European Journal of Operational Research, 193(2), 425-436.

Banks J., Carson J.S., Nelson B.L., Nicol D.M., 2005. Discrete-Event System Simulation. Fourth Edition, New Jersey : Prentice Hall.

Bucki R., Chramcov B., Suchánek P., 2015. Heuristic algorithms for manufacturing and replacement strategies of the production system. Journal of Universal Computer Science, 21(4), pp. 503–525.

Gill R., 2006. Fast methods for warehouse optimization. Progressive Distributor Journal. November/December issue. Ohio USA.

Gu J., Goetschalckx M., McGinnis L.F., 2007. Research on warehouse operation: A comprehensive review. European Journal of Operational Research 177 (1), 1-21.

Karasek J., 2013. An Overview of Warehouse Optimization. International Journal Of Advances In Telecommunications, Electrotechnics, Signals And Systems, 2(3), 111-117.

Kare S., Veeramachaneni R.,Rajuldevi M K., 2009. Warehousing in theory and practice. University College of Boras dissertation. Sweden.

Modrák V., Pandian R.S., 2012. Operations Management Research and Cellular Manufacturing Systems: Innovative Methods and Approaches. IGI Global.

Raidl G., Pferschy U., 2010. Hybrid Optimization Methods for Warehouse Logistics and the Reconstruction of Destroyed Paper Documents. Dissertation paper. Vienna University Of Technology. Austria.

Rowenhorst B., Reuter B., Stockrahm V., Houtum G.J., Mantel R.J., Zijm W.H.M., 2000. Warehouse design and control: Framework and literature review. European Journal of Operational Research, 122 (2000), pp. 515–533.

Tompkins A.J., Smith J.D., 1998. The warehouse management handbook. Thompkins press, 2nd edition.