Introduction

Optimization of the logistics processes is very difficult and complex problem, especially in case of warehousing processes. There are several important issues and factors which influence on warehouse performance. The goal of this study is to introduce a simulation as a tool which enables and facilitates analysis of these processes. Optimization may be understood in many different ways. The goal may be optimization of the facility throughput, quantity of resources or even cycle time. Model built as a purpose of this study enables user to determine his own goals. Friendly interface allows the user to easy and quick modifications of the created model as well as lets him simulate any process and optimize it in the way he wants to. Simulation model was created in purpose to analyze real distribution center performance and its most important processes. Analysis should give the answer how to adjust current facility to be able to cope with growing demand for the goods it is operating on. This study is also supposed to present actual information on warehousing issues and describe methods and trends in simulation study. The main reason of this study is to create a tool which enables user to analyze all processes in easy and quick way, as well as to allow him to determine optimal configuration of the distribution center resources. There are also some constraints like: space required to build another assembly section or add some new racks in the warehouse, and a number of orders that facility have to be able to fulfill. Model should enable user easy modifications in the resources structure and let him adjust the facility to any conditions. One time he may focus on achieving maximum number of orders fulfillment, otherwise may decide to optimize cycle time of each order. The user should have a possibility to simulate and compare different cases and different situations. Then, this tool would be a perfect assistance in decision making processes.

Distribution centers in general

Every distribution center has three main areas and may have additional specialized areas. The three main areas are: the receiving dock, the storage area and the shipping dock. In small organizations it is possible for the receiving and shipping functions to occur side by side, but in large centers, separation of these areas may substantially simplify the process.

Though warehousing is really important in logistics and supply chain management, it is still integrated with and to a large degree dependent on other logistics activities. In fact, warehousing is presented as the last of the five logistics activities (see figure 1) for a variety of reasons. First, good planning in the other four areas of logistics may eliminate the need for warehousing. Second, requirements in the other four areas of logistics may suggest that third-party warehousing firm should be retained to operate the warehouse.

The warehouse must be designed to meet all the requirements of the customer service policy spelled out in the customer response master plan, house all the inventory required by the inventory master plan, work to receive in quantities stipulated by the supply master plan, and serve a mission stipulated by the transportation master plan.

The tasks, or functions, are also indicated on a flow line in Figure 2 to make it easier to visualize them in actual operation.

Distribution centers are essential elements of supply chain. In terms of cost, they represent approximately 20 per cent of total logistics costs, whilst in terms of service they are critical to the achievement of customer service levels, particularly as distribution centers are often the final point in the supply chain for order assembly, value added services and dispatch to the customer. That’s why providing world class warehousing a company may substantially improve its profitability, flexibility and competitiveness. Warehousing is a broad area in which companies may gain a competitive advantage over their competitors. The warehousing systems have to be reliable and responsive in order to be competitive.

With the dynamic growth of warehouses importance in supply chain, several new solution have arisen in purpose to improve warehouses performance. One of the most important is automation. It is the application of computer software and/or automated machinery to improve the efficiency of logistics operations. This refers to operations within a warehouse or distribution center, with broader tasks undertaken by supply chain management systems and enterprise resource planning systems.

Logistics automation systems can powerfully complement the facilities provided by these higher level computer systems. The focus on an individual node within a wider logistics network allows systems to be highly tailored to the requirements of that node.

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2 Reviewed paper.
Automation in warehousing immediately conjures the image of a high-rise Automated Storage Retrieval System (AS/RS) [2]. It involves the use of high-rise racks with a storage machine operating within the aisle, serving both sides of the aisle. Loads are stored in the racks and retrieved either automatically or in a semi-automated fashion. The loads could either be unit loads that are palletized, or, in some cases, involve drawers and totes that are used to store smaller parts. The heights of AS/RS systems can vary, depending on the application. The highest systems are 100 feet high. Figure 3 shows an example of such warehouse.
AS/RS provides several benefits:
1. Bringing material to the operator cutting cycle time by eliminating wait, walk, and search time.
2. Provides real-time inventory control with instant reports. With near 100% accuracy and real time information about the inventory on hand.
3. Dramatically increases operator productivity. The “Part to Picker” model of order fulfillment is 3 to 5 times more productive that having the picker travel to the part to complete the fulfillment.
4. Reduces work-in-progress inventory. Better inventory accuracy and better responsiveness to need result in reduction or elimination of “safety stock” in the overall inventory model. This has the net effect of inventory reduction.
5. Improves product quality and productivity. Real time information, faster response to a need, physical protection, and traceability of material access all contribute to a better process where time can be spent on improving the quality of the process instead of on expediting material to a point of use.

**Modeling and simulation of complex production systems**

The methods of modeling and simulation is used when getting the solution analytical methods are too complicated or impossible and direct experimentation on the practical (physical) model is too laborious, dangerous and expensive. Modeling is also used when other methods do not provide the required level of assurance that the actual manufacturing system will behave according to the assumptions of the theoretical model (virtual). Modeling and simulation of manufacturing processes, allows them to analyze and investigate the operation of the selected object (position, surgery, treatment, operations, transport, storage condition, interference, etc.), sometimes lasting many years, in just a few minutes. Allows you to carry out verification of the assumptions prior to their use in practice, and identify anomalies that may occur during the operation, in particular the weak points of the proposed or implemented production system. Modeling and simulation of the production process is the formation of the virtual computer model of the actual manufacturing system, in which a number of experiments performed.

As a result of the simulation is obtained sets of reports, by which develops further action, for example, is used to choose the organizational form of production stations or the type and number of vehicles, including program changes that can be made in the existing system to get the intended effect, as for example, productivity, and shorten the production cycle. The tested model of the production system can be improved and the successive simulations for its various options and settings, such as different numbers of products, storage capacity between the positions, anticipated interruption and disruption associated with such maintenance and repairs of machinery and their failure rate, etc. In addition, the analysis can take into account the costs manufacturing or investments for selected variants of the system, which in turn allows for rapid analysis of economic efficiency. To develop a model of the production system is necessary to know and input data with a reasonable level of quality, form and quantity. This is a preliminary step for deriving a view to solve the problem, including information about new methods that can be applied to solve it. In addition, input data permits the development process model in sufficient detail the principles of the minimum number of facilities required to achieve the objectives of the project in a manner as simple as possible. For basic information about the built model may include [3]:

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**Fig. 3. Unit Load Automated Storage & Retrieval Systems (AR/RS) [2]**
information about objects of the system, such as the type and number of machines, means of transport and their plans for renovations, the organization of production positions,

- performance of the system, such as production planning, lot size,
- number and capacity of storage of input, output, and interoperable,
- sequence of production orders,
- the cost of materials, direct labor, bench, spreadsheets, etc.

In times of a dominant market competition and constant efforts of enterprises to reduce production costs, the use of computer modeling and simulation is one method of contributing to a much faster design new and verification of existing manufacturing systems. It allows you not only to shorten the development time of projects, but also allows you to simultaneously perform experiments on a number of variants of the virtual production process and track the impact of changes before taking a final decision. This reduces the risk of failure, which can be very expensive and also raises quality indicators, both being developed and used in future technologies allowing to choose the best option in terms of actual application. To accomplish the task of material flow simulator was used DOSIMIS-3.

**Structure model of an automated distribution center**

The study concerns a given distribution center which is designed to operate on liquid products that are carried in cans and barrels. It is specially created to be able to carry out this kind of goods. There are four basic product types that are operated in this facility:

<table>
<thead>
<tr>
<th>Name</th>
<th>Maximum quantity on single pallet</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>KA</td>
<td>16</td>
<td>Cans</td>
</tr>
<tr>
<td>FA</td>
<td>4</td>
<td>Mid barrels</td>
</tr>
<tr>
<td>IE</td>
<td>1</td>
<td>Barrels</td>
</tr>
<tr>
<td>EX</td>
<td>1</td>
<td>Barrels with a toxic liquid</td>
</tr>
</tbody>
</table>

*Source: design your own.*

In purpose of detailed description of the facility, it is divided into four basic sections. These sections are: Storage area, Transport system, Assembly sections and Shipping zones. Layout of discussed distribution center and its representation in DOSIMIS-3 are consecutively presented in Figure 4.

Fig. 4. Layout of the model made in DOSIMIS-3

*Source: design your own.*
Transport system is one of the most important elements of the whole system. Set of overhead trolleys is responsible for moving pallets through the distribution center. In created model these trolleys are represented by the vehicles which are moving through the tracks system. Speed, acceleration, capacity and all other parameters of trolleys are also mapped carefully. To build this section, loading and unloading stations are used as well. An essential importance in discussed DC (Distribution center) have assembly sections. Every single item which is destined for shipment has to be passed through one of them. These sections consist elements like: shuttle, workstation, crossing, accumulation conveyor, source and sink.

Workstations represent places where pallets are waiting to be unloaded. After unloading an appropriate number of items, pallet is taken from the workstation by shuttle (forklift) and moved to one of the crossings (system of conveyors which direct empty pallets to the special section, and semi-loaded pallets back to the storage area). Items unloaded from pallets are moving through accumulation conveyor to the workstations which imitates pallets destined for shipment. When pallet is ready for shipment, it is moved through the system of conveyors to the shipping zone and loaded on the truck (sink).

Figure 5 shows the material flow in order fulfillment process. Whole process is getting started when system receives an order form the customer. It is a signal for warehouse to pick-up appropriate pallet from the rack.

Because there is a very high volume of loads being moved into and out of storage, this area is equipped with fully automated robotic system controlled by computers that enable all the operations, like: unloading goods from carrier, sorting, put-away, storage, order-picking, staging and loading of goods can be done by machines automatically. This solution is called Automated Storage and Retrieval System (AS/RS) and is widely used in distribution operations to hold and buffer the flow of material moving through the process to the ultimate end user. No human involvement in this process results in extremely high inventory accuracy. Further, picked-up pallets are moved by the system of conveyors to the loading stations where are waiting for transport vehicles which can forward them to appropriate assembly section. Here a decision is made where a specific order is going to be fulfilled. Next section is being used to convey pallets from storage area to the appropriate assembly zone. Instead of conventional forklifts it is supported overhead trolleys, which consist of a continuous loop of chain or cable that is suspended from a track. Carriers are attached periodically to carry the pallets. This kind of trolleys provides two significant advantages over other types of industrial conveyors. Subsequently pallets are unloaded from trolleys at the appropriate assembly section. Each unloading station has an unique destination code of station. Pallets may be unloaded from trolley only when its final destination and destination code of unloading station matches. Then, goods are moved to the section where are waiting for its turn in assembly process. From each pallet a given number of items are taken in purpose to fill an order. Using system of conveyors, items are moved to the section where are collected on the pallets destined for shipment. Each pallet has to contain a given number of items of specific type. It is determined at the beginning, when an order is generated. When the collection is completed, the pallet is moved to the shipping department and loaded on the truck. Next sections of this chapter provide detailed description of this facility virtual model, present certain optimization issues and the results of several simulation runs.
Simulation model is based on the specially prepared algorithm which describes ordering process in discussed warehouse [4]. First step in this algorithm is receiving an order from customer. Then instructions about it are forwarded to storage section where appropriate pallets are picked up. After that, there is necessity to make a decision where current order will be preparing for shipment. Algorithm chooses the assembly section with a present minimal occupation. Later pallets are loaded on trolleys and transported to the appropriate section. Next step is to unload pallets and put them on the first free place. Then, from each pallet a given number of items is taken and forwarded to the section where they are collected on the pallets destined for shipment. When all required items from the pallet are taken, it is released and directed to one of its final destinations. If this pallet is empty, then is stacked on other empty pallets. If it still contains some items, then is going back to storage area. Figure 6 shows how is it done step by step on the flowchart. The algorithm is finished when there is no more orders from customers. User receives set of results which can be carefully analyzed. When results are revised user can modify input data and run simulation again to adjust the processes to limited resources and distribution center necessities.

Built model consisted of about 500 elements (source, drain, conveyors, buffers, loading-unloading stations, trolleys, etc.) and 120 tables, making the implementation of the algorithms used to control the flow of cargo units. In order to reproduce the behavior of dynamic objects (different types of loading units, empty pallets, objects related to the flow of information) are assigned and coded 43 different types of objects.

Analysis of research results

One of the main objectives of the construction of the model of the test center and carry on the simulation studies was the need to review the assumptions on system performance [5].

Several optimization cases will be considered – referring to different situations model can be applied at. Analyzes include presentation of input data and solution tables as well as appropriate charts providing better overview and understanding of the computed results [6,7]. Each simulation run is made on the basis of the same set of orders. It is a historical data of orders gathered during real DC operations. Duration of each run is also constant, and is equal to one week (7 days). Model has been created – constant improvement in purpose to quickly adapt to changing situation what is one of the most common goals in supply chain management.
The tests are given two cases: the conditions of the actual companies and case improves the flow of material streams. Case 1 is based on the real data taken from the discussed DC. The purpose of this case is to show the model complexity and give an overall idea about the optimization issue. It is a basis for further analysis. Watching continuous animation of the processes (it is a tool provided by DOSIMIS-3) and analyzing simulation output data, weak links and bottlenecks of the system can be easily found. Assumptions of the model are: orders are generated from normal distribution with mean value equal to 80 sec. and standard deviation equal to 10 sec. In this case it is also going to be analyzed if one assembly section is capable of filling given number of orders. Transport system is equipped with 10 trolleys in this case.

As it can be easily noticed, looking on the figure 7, simulation has been disturbed. The model got stuck. Under these assumptions facility is not able to operate normally. There are several reasons why this situation occurs. First of them is that orders are generated too quickly, and facility cannot work so fast. Another problem is a wrong transport strategy. In this case, new orders were assigned to the trolleys according to the rule fcfs (first come – first served). It means that trolleys were picking up pallets which have been waiting for transportation the longest period of time. It caused a situation when orders were coming continuously, while assembly section wasn’t able to cope with such a big amount of goods. Trolleys picked up pallets from storage area in purpose to deliver them to assembly section; it means that couldn’t take care of another load. Simultaneously, assembly section was preparing goods for shipment. Some pallets were fully unloaded and stacked one on the other, while these semi-unloaded had to be sent back to the storage area. Here a problem occurs because all the trolleys available were occupied by pallets picked up in storage area. Main difficulty here is that there no possibility to prepare one order in two separate assembly sections. Some orders consist so many positions that even if a transport system and AS/RS machine are ready to work, they have to wait until assembly section will be able to accept next pallet. Therefore it is necessary to implement some changes in assumptions and run model the again.

In case 2 wrong assumptions from case 1 are going to be changed. It is also devoted to show possibility of quick model rebuilding. First of all a frequency of orders generation is being changed. It is still made from normal distribution but the mean value has been changed to 220 sec. Standard deviation remains the same (10 sec.). Also transport strategy is different. To avoid situation that occurs in Case 1, the highest priority have loading stations with semi-unloaded pallets from assembly sections. It will set assembly sections free of unnecessary pallets, and ensure transport system the possibility to unload carried pallet in the place of its final destination.

In this case simulation has been completed successfully. A set of results has been computed, but to check if these results are optimal ones it is necessary to run simulation model several times using different resources configurations. This time, during whole week discussed DC was able to dispatch 1673 pallets, it means that mean time required to prepare single pallet for shipment is equal to 8,23 min. Significantly reducing the cycle time compare to the actual conditions of an average of 1 min.
Looking on Table 2 it can be easily noticed that there are some priorities in transport system. The highest priority has pallets which should be transported from assembly sections to storage area.

Last step in transport system analysis is control of used trolleys efficiency. Transport system is equipped with 10 trolleys. Each of them one-time may carry only one single pallet.
Figure 9 shows that most of their time trolleys are waiting for new orders. They devote for deliveries only 1.5% of total available time. It means that it is necessary to check possibility of trolleys number reduction, in order to reduce production costs.

Table 3 shows utilization statistics of the first assembly section – in this case only this one was used. These parameters are relatively low.

Based on the results can say that the greatest system performance can be achieved using 8 vehicles at selected vehicle control set priorities of broadcasting. A simulation shows that most of the time did not differ significantly for different cars, which may indicate the accuracy adopted in the experiment, both the parameters and assumptions and control algorithms. As a result of the simulation, it was found that the load of the production unit is 94%. Occupancy rate also increased Wheelchair transporting food commodities. Comparing the simulation without taking into account the time to provide the tools you will notice the enhancement of the effective time of the production unit from the initial 73.2% to 87.6%.

Built model can be the basis for the development of the logistics enterprise system: system comprising: the flow of goods, information and costs, and the flow of decisions.

Summary and conclusions

Model created for the purposes of this study can be directly used in the analyzed company. If modifications may be made model and the correction of flow control strategies implemented loads without a fundamental change in the structure of the model.

The simulations showed that the applied control the flow of materials and information enable the realization of its objectives. Also indicated the elements of the system, which can be a potential bottleneck in the system. Main advantage of this model is that it may be applied to review almost every kind distribution center. his model is able to check analyzed facility capabilities, shows possibilities for further development and points out company constraints. It may be applied in almost every kind of material flow system.

Abstract

Development concerns the problem of modeling and simulation of complex logistics processes taking place in enterprises. The methodology used in the study of modeling based on the mechanisms of discrete event-driven systems. The study has been subjected to one of the automated distribution center products manufacturer in the food industry. The main objective of this approach is to support the decision in determining the workload of warehouse processes and the execution of experiments, including the variable load of the system. The presented results demonstrate the usefulness of the proposed models as tools to support decision-making processes at the level of the enterprise.
REFERENCES


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