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A MODEL FOR TECHNICAL OPTIMISATION OF THE DISTRIBUTION CENTRE

ABSTRACT:
One of the largest companies in Slovenia has been confronted with the dilemma of building a new storage distribution centre (SDC) or to find additional capacity by optimizing the exiting one. The company initiated a project with a goal to describe and analyze operation of the existing SDC and to propose measures for operation improvements. The research methodology and the results are based on a simulation model of SDC that allows more detailed analysis of the system operation, obtaining technical efficiency under different constraints, identifying the potentials for optimization and verifying effectiveness and justification of the proposed improving measures.

KEYWORDS:
logistic system, storage and distribution centre, optimization, efficiency, discrete simulation

INTRODUCTION

Distribution centres represent one of the main subfields of today's logistics and an important part of local or global supply chain. They remain an essential part of goods flow from suppliers to consumers, although, according to lean principles, the supply chain management tends to operate without or with minimal warehousing. Therefore the efficient management and optimization of distribution centres are indispensable tools for operations improvement with the aim of reducing handling and operating costs, increasing distribution accuracy and delivering the goods to customers faster. One of the largest companies in Slovenia that initiated a project for optimisation of the logistic system (L7-0242 – A Model for Technical and Economic Optimization of a Logistics System financed by Slovenian Research Agency ARRS) is aware of this issue.

The presented research work is a part of this project. Its goal is to describe and analyze the logistic processes, technologies, equipment, labour resources and inventory (goods) in the observed storage and distribution centre, and to propose measures for operation improvements.

The project started with an initial analysis aiming to obtain basic data about a structure, processes and also a dynamic behaviour of the system. The data were collected and processed from the available technological documentation, interviews with employees, a snap-shot of the existing processes, equipment and workers in the SDC as well as from the WMS database with recorded transactions of the material flow and order operations. On the basis of the collected data different analyses were accomplished focused on the basic performance indicators of the existent processes, equipment and the warehouse management system. Due to the results and conclusions from the initial analyses a simulation model of the SDC was built, which allows more detailed analysis of the system operation, obtaining technical efficiency under different constraints, identification of the potentials for optimization and verifying effectiveness and justification of the proposed improving measures.

INITIAL CONSIDERATIONS AND THEORETICAL BACKGROUNDS

The main issue of the presented research work can be defined from three different points of view. The first one refers to the development of an appropriate model for simultaneous optimization of the logistic system by technological and economic criteria. Optimization of the two purpose-made functions with different marginal conditions is dealt with. The first purpose-made function is essentially a production function that explains a relation between the actual volume of the realized logistic services on one side and the volume of the used inputs on the other. The second purpose-made function, which is basically derived from the first one with introduction of factor prices, is the cost function. Economic theory clearly proves and explains that there is a systematic inverse relation between production and cost functions. However, production functions are usually written as polynomials of degree two or three, for which an analytical search of inverse function is infeasible. A possible solution in this case is to introduce a discrete analysis instead of the continuous one.

The second point of view of the problem, which is the object of research, is linked to the fact that in the most practical cases analytical mathematical procedures are not enough for sufficiently exact calculation or estimation of consequences caused by a certain decision. For this reason a discrete simulation is used more frequently. From the theoretical point of view realizing this simulation is not a special problem for which science would not have an answer. However, there is a much bigger problem in application of this simulation. A discrete simulation is defined as a general program solution that is designed to form a dynamic computer or digital model of the complex system with a purpose of collecting data of dynamic behaviour of the system and optimization of its operation. For this purpose a user with a lot of special knowledge is needed, who digress the practical use of the discrete simulation. It's important to point out that the described discrete simulation considers only technological optimization of a logistics system.

The third point of view is an interdisciplinary approach. In economic reality there is a strong need to upgrade the technological point of view with the economic point of view. Only an interdisciplinary team of experts with the specific knowledge in mathematics, logistic and economy can take up such tasks.

DISCRETE SIMULATION

Very important aspect of the research project is modelling and simulation of discrete systems, which is a systematic and highly organized method for development of dynamic computer i.e. digital model of a complex system, gathering data of its dynamic behaviour and optimization of its operation. Digital model is a mapping, based on analysis and synthesis of an observed system into a computer form that allows user to perform experiments in digital environment with the aim to verify hypothesis and what-if scenarios, statistically analyze and present structural and dynamic characteristics of the observed system and compare properties, facts and distinctions of different systems without disturbing the real system or on the stage of developing a new one (Fig. 1).

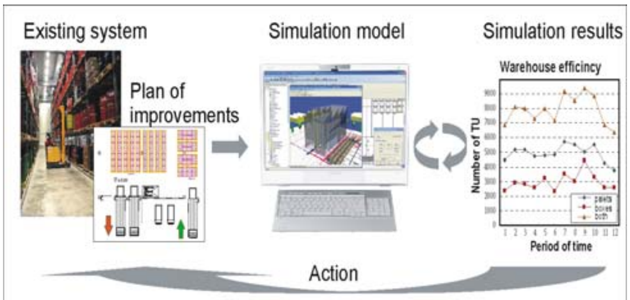

Figure 1- Planning, analyzing and optimizing a logistic system with the discrete simulation

The discrete simulation is designed for planning, analyzing and optimizing logistic systems. In spite of its provable applicability and profitability it is only now pawing the way from basic scientific research projects to real application projects for the industry. The first significant reason for that is a complexity of modern logistic processes and systems that demands an engineer professional knowledge about organizational, technological and technical properties of processes, procedures and equipment in a logistic system as well as an expert knowledge about the discrete simulation. The second reason is usually a detached observation of technological and economical aspects of logistic systems, which doesn't allow the holistic consideration of logistic problems.

THEORETICAL BACKGROUNDS

The scientific field of the discrete simulation for planning, analyzing, and optimizing logistic systems' operation and can be divided into two parts. The fist part is dealing with the discrete simulation [1] for production logistics with the emphasis on material flow simulation and layout optimization of manufacturing and assembly systems, lines and cells. The goal of the research studies of such systems is to obtain the key performance indicators, for example productivity, throughput, availability and reliability, and more complex indicators like overall equipment effectiveness and overall factory efficiency [2]. Beside estimation of the technological effectiveness of the observed system, from the first applications with the discrete simulation onwards there has been a demand for cost estimation. Unfortunately evaluation of costs cannot give applicable results, unless the holistic approach is used in production or a logistic system consideration. In the development phase an estimation of a certain production system effectiveness using a method of total costs of ownership is also possible, but only on the basis of a complete model of the observed system and the discrete simulation [3]. the second part of the simulation for the merchandise logistic systems is dealing with the internal logistic that ranges from a store and warehouse systems, distribution centres and the transportation to material and information flow between companies in a supply chain [4][5]. In spite of that the research studies using the discrete simulation are here more focused on the management and a control view of logistic systems [6] and they have usually not surpassed an estimation of technological properties of the observed systems.

DESCRIPTION OF THE SDC

In the particular case the logistic system is composed of a storage and distribution centre (SDC). SDC is a warehouse which is stocked with bulk products (goods) that need to be re-distributed to the internal (approximately 400 own shops) and external customers (retailers).

The SDC has been set up with the aim of properly organizing the supply network and cutting down the supply costs for the internal customers. The company has gradually becoming a wholesaler, as well, and so it also distributes goods to the other retailers. The processes for fulfilment of internal or external customers' orders are identical. The difference between them is more or less in predictability of the content, in the quantity of merchandise orders and in *time of delivery. The main challenge is to manage the influence of variation in type and quantity of goods (seasonal, monthly, weekly, daily) on operation efficiency of the SDC. The operation of the SDC is supported by the warehouse management system (WMS) with the primarily aim to control the movement and storage of goods within the warehouse and process the associated transactions including shipping, receiving, replenishment and picking to order.*

The distribution centre consist of space, equipment, labour resources and inventory (goods). It has three main areas: the receiving dock, the storage area and the shipping dock (Fig. 2). Goods (products) arrive and are stored in the distribution centre in various types of storage locations and containers suitable for the product characteristics and the amount of a product to be transported or stored. The pallets are the basic means (transport unit TU) for transportation and storage of the goods. Pallets are stored in a pallet rack and some of them also on the floor (block location). a particular pallet contains just one stock-keeping unit (SKU). Smaller goods are stored on shelves, in cartons (boxes).

The material flow processes in the distribution centre are supported by the warehouse management system (WMS). The primarily aim of the WMS is to control movement and storage of goods within the warehouse and process the associated transactions, including shipping, receiving, replenishment and picking to order. The WMS also directs and optimizes a stock put away based on real-time information about the status of the bin utilization.

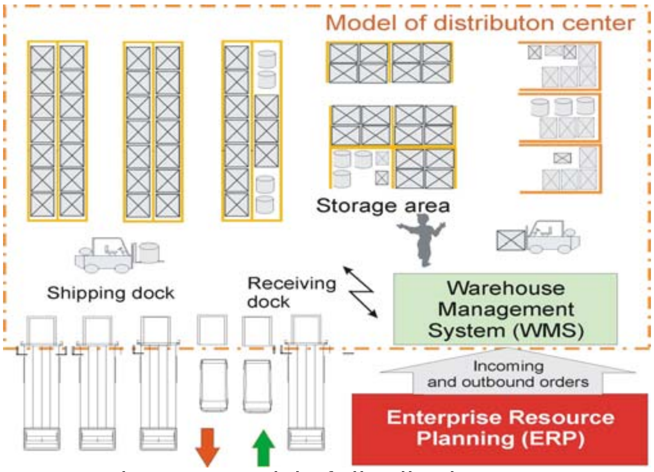

Figure 2 - Model of distribution centre

The WMS provides a set of the computerized procedures for handling the receipt of the stock and the returns into the warehouse facility, modelling and managing the logical representation of the physical storage facilities (racks and shelves), managing the stock within the facility and for enabling a link to order's processing in order to pick, packing and shipping goods from the facility according to the customers' demands and organizing deliveries of goods to customers.

Figure 3 - Information flow in the supply network

The warehouse management system is a stand alone program application that communicates with the enterprise resource planning system (ERP). Orders from external as well as internal customers are always inputted in the ERP system and then sent to the WMS system in the distribution centre for processing (Fig. 3.). After the order is accomplished, the WMS sends a confirmation to the ERP system. The same is with the incoming goods. Without receiving order from the ERP no goods from the incoming shipment can be properly received (tagged and stored) into the distribution centre.

INITIAL ANALYSIS AND OBSERVATIONS

The aim of the initial analyses was to obtain the basic data of a structure, processes and also a dynamic behaviour of the system. The data for the initial analyses were collected and processed from available technological documentation of the logistic system, interviews with employees in the distribution centre and from a snap-shot of the existing processes, equipment and workers in the distribution centre. Very important and useful source of information about operations and inventory in the distribution centre is the warehouse management system. The database in the WMS contains data of the inventory in the distribution centre at the moment of storing the database and a complete history of processing the shipping and receiving orders in a certain period.

Different analyses were accomplished on the basis of the collected data and they focused on the basic performance indicators of existent processes, equipment and warehouse management system. Some significant observations can be summarized from the results of the initial analyses, as follows:

- *The WMS provides the necessary IT support for more organized operation of the SDC including the automated storage allocation, automated replenishment, optimisation of the picking to order procedure, and automated data collection.*
- *The implementation of the WMS along with the automated data collection significantly increases accuracy of the fulfilled orders (more than 99 % of the orders are fulfilled correctly).*
- *Expectations of the inventory reduction and the increased storage capacity are not less likely, because the predominant factors that control the inventory levels are lot sizing, lead times and demand variability. The WMS has no significant impact on any of these factors.*

- *In spite of the WMS decisions about grouping orders to shipments, a delivery schedule, transportation paths and a pattern for the storage allocations of goods are still in the domain of human operators (dispatchers, supervisors and warehouse managers).*
- *The WMS tracks and logs a location of goods and notes also the transactions of processes and events (except when picking to order)*
- *The WMS is a foundation for further improvements of a operational performance of the SDC (even more accurate data and tracking of all operational events).*
- *The WMS needs to provide more key performance indicators then just a stock turnover.*

DIGITAL MODEL OF THE SDC

Due to the results and conclusions from the initial analyses a simulation model of the SDC was built, which allows more detailed analysis of the system operation, obtaining a technical efficiency under different constraints, identifying the potentials for optimization, and verifying effectiveness and justification of the proposed improving measures. The aim of the simulation model is to obtain and compare the key performance indicators of the observed system under different organizational changes, control algorithms, operational decisions and business models without disturbing the operation of the real SDC.

The formal description of the SDC is mostly based upon data from the available technological documentation supplemented with interviews with employees and the snap-shot of the existing processes, equipment and workers in the SDC. The recorded transactions of the material flow in the WMS database helped us to complete the detailed description with the specific data of duration of handling operations. The digital model considers different aspects of the SDC as a detailed layout with a spatial relationship of locations and transport paths, size and type of locations (receiving and shipping platforms, selective pallet storage racks, bulk locations, locations on shelves), transport equipment (number, type and velocity of forklifts, detailed operation procedure), work procedure for receiving, put away, replenishment, order picking and shipping, informational support (the warehouse management system, RF terminals, barcodes, data acquisition and record, data capture), human resources (work procedures, number and skills of workers), transport units (size and SSCC of pallets, content of pallets) and logistic data of the articles (code of SKU, weight and size, packing).

For example, the forklift operation in the digital model is a detailed emulation of the forklift operation in the real system. The real forklifts are equipped with the RF terminals and the drivers communicate over terminals with the WMS. The drivers can select a job and a task and have to confirm the accomplishment of a job or task. In the model, the driver can select one of the tree basic jobs (putaway, replenishment and pick to order), then he gets the task, executes the task and has to confirm it's accomplishment (Fig. 4) like the real drivers do in everyday work in the SDC.

The forklift's operation on the location is also modelled in detail. For example, the movements of a forklift (lifts the fork on a level of a particular rack, loads and unloads the pallet) and operation of a driver (scans a code of the location or a SSCC code, types the data in the RF terminal, confirms the task) are modelled with all particular movements (velocity of moving forks up and down), spatial characteristics (elevation of the rack) and operational data (time for scanning and confirming the task).

The digital model of the SDC (Fig. 4) offers a good platform for experimenting with a different number of forklifts to optimize the equipment efficiency and throughput, experimenting with different allocations of goods in racks for minimisation of path and time for picking to order, studying the possibility of shipping dock enlargement with the aim to increase the throughput, studying the possibility of storing different SKUs on the same location (rack) with the aim to enlarge the capacity of the SDC.

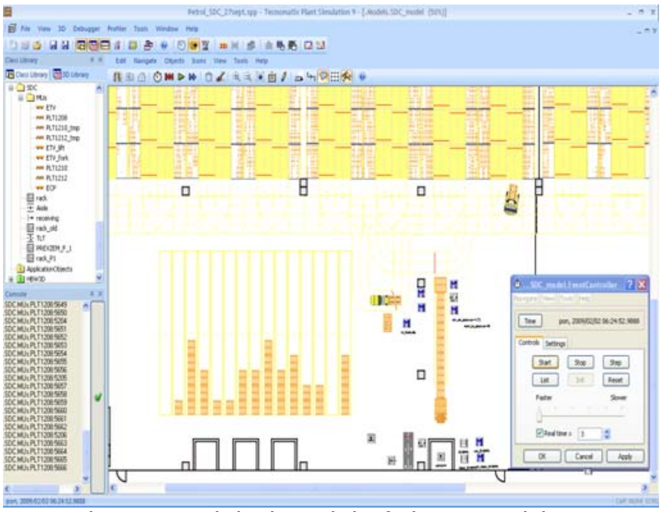

Figure 4 - Digital model of the SDC with 2D representation

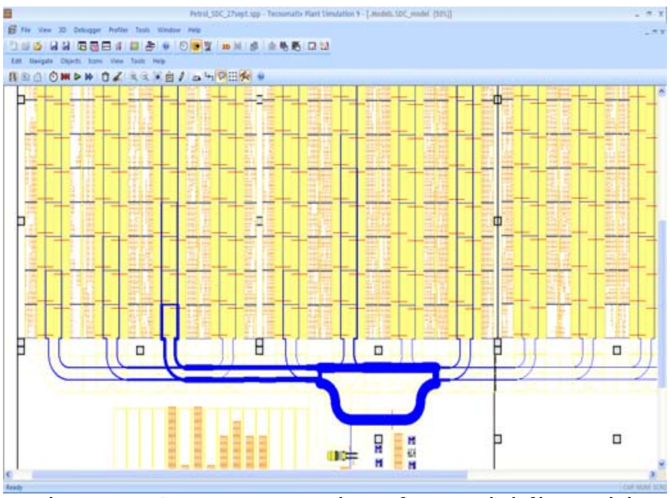

Figure 5 – 2D representation of material flow with Sankey diagram

One of the main advantages of using a digital model for experimentation is the graphical representation of the results. For example the representation of the material flow with Sankey diagram (Fig. 5) can be very useful for optimisation of allocations of goods in racks and for minimisation of path and time for picking to order or for replenishment.

CONCLUSION

Further work of the project goes in tree directions [7]. The first direction is to establish a mathematical model of the logistic system, which will allow a more detailed statistical analysis. The second direction is to complete a digital model of the SDC, to conclude the experiments and to propose a direction of the practical solution. The third direction is optimization of the distribution paths. Given a set of goods, a transportation network with delivery locations and a fleet of transportation vehicles the goal is to carry out deliveries from the SDC to all customers incurring minimal costs and subject to certain additional constraints [8]. In the final stage the digital model of the SDC and the model for optimisation of distribution paths will work together in an integrated and complete digital environment that will offer an efficient platform for overall operation optimisation of storage and distribution centres.

The research work on the project pointed the reasons why there are not more practical examples of modelling and simulation in the practise. The first reasons are the skills and great effort needed to build an adequate digital model. The second and also very important reason is the recognition of the benefits of testing and experimenting in digital environment instead of using findings from successful case studies.

It is also very important to understand that for the effective implementation of simulation of the well defined goals and the specified key performance indicators are of great importance.

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