

IMPLEMENTATION OF OPTIMIZATION METHODS IN THE SELECTED AREAS OF PRODUCTION LOGISTICS

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Abstract

The contemporary business environment is constantly putting pressure on increasing efficiency in all areas of modern society. One of the key areas is undoubtedly production which is affected mainly by the dynamic development of modern technologies. However, it must be emphasized that production issues are not treated as a set of individual machines but as a system which is affected by the number of elements exerting both positive and negative influences on its course. These elements can be placed in the area of production logistics along with assigned production equipment, the human factor, methods of manipulation with materials and intermediates, storage, etc. Production logistics should be treated as a complex integrated system consisting of the predefined subsystems containing sets of related activities which are strictly categorized. Defining control rules of the individual subsystems appropriately results in increased efficiency of the entire system. In order to achieve the maximum possible efficiency of the entire system it is always necessary to optimize each subsystem which operates within its framework. Currently, simulation is used increasingly to support the optimization tasks and processes in all types of systems. The efficiency increases significantly when simulation tools become an inseparable layer parallel to the implemented control system.

Key words: logistics, production logistics, optimization, minimizing losses, modeling, simulation, ecological logistics.

Introduction

The success of business in today's local and global business environment primarily depends on its capacity to meet the growing needs of quality as well as customer expectations. Today's customers are interested in new, technologically developed products, and they assume that these products will be available in the near future. They also want to gain sufficient knowledge about these products and obtain a sufficient number of distribution channels with which they can purchase these products in the shortest possible time, as cheaply as possible and using a predetermined method (PPDT 1996).

For this reason, the companies are required to be able to produce the maximum number of products of required quality using minimal investment and raw materials, which corresponds to the so-called concept of lean company. Meeting these requirements becomes possible by defining both internal and external processes in enterprises and conducting effectiveness measurement. If irregularities are found in the operation of production systems, adequate procedures should be implemented to improve key processes that occur in them. Now a relatively wide range of offers supporting all logistics processes is available virtually. In particular, it relates to IT support that enables us to monitor logistic processes, modeling and simulation of logistic systems which ultimately leads to support their control and successive optimizing of their functioning. The discussed theme is mainly related to production logistic issues. Presented issues relate to problem areas and indicate which methods and what action are focused on optimization whereby a simulation is presented as a leading method.

1. Logistics and its contemporary state

It can be assumed that logistics is involved in the flow of products, semi-finished products, raw materials, financial resources and information between a supplier and a customer as well as within individual companies including different ways of storing resources (Christopher 2011). The task of the entire logistic department is optimization of flows in order to minimize costs associated with the operation of the entire company. Logistic companies are divided into trade logistics, logistic services and a logistic industry. Trade logistics is focused on chain stores and connected with them financial-information chains associated with the network warehouses. In other words, the logistic trade shows relationships associated with the company and its surroundings. Logistic services include activities related to the acquisition of spare parts, the human factor, providing warranty services and non-warranty ones, etc. The industrial logistic category comprises supply logistics, production logistics and logistics of sales of finished products.

This category includes steps involved in the process of transformation (from the start of production until the moment of its completing in the form of ready products), supply, delivery of final products to the end user, etc. It should also be emphasized that this categorization of logistics is important from the point of view of the necessity to describe and define activities within the various departments of the company (subsystems of logistics) wherein logistic in the company is treated as a complex system demanding full integration with all the previously mentioned subsystems. In the last two decades logistics in companies has been subject to distinct transformations from the point of view of its impact however, at present there are no significant restrictions relating to the geographical location of the recipient and provider therefore the whole problem is discussed as global logistics or logistics of global systems. Production logistics is constantly supported by new technologies. As an example, we can put IT support for production lines consisting of high-tech automated workstations which are equipped with conventional devices or robots. As it has already been stated in the introduction, one of the conditions for the success of modern enterprises is the proper definition and control of internal logistical processes and the adequate selection and integration with external logistic chains. While monitoring the current state of development of logistics, it is possible to statistically determine the most problematic areas of business practice in the enterprise (Table 1).

Table 1. Statistically the most important logistic areas in the company's business practice

Category problem	Characteristic
Transportation and allocation	Optimizing location of distribution warehouses, usage optimization of production and storage resources, optimization of manipulation, etc.
Assignment	Assignment of "man - technology" and "man - work task"
Queuing	Optimization of the number and use of means of transport and reloading, the priority issue of orders and services, optimization of warehouse operations (loading, unloading), etc.
Optimal resource utilization	Planning distribution cycles, investment decisions, solving multi-step problems, etc.

Source: EuroEkonom.sk.

Inadequate ways of solving problems listed in Table 1 are the cause of losses which are often reflected in inflated costs. It should be noted that the importance of the factors with a lower weight and which, at the same time, have a negative impact on the efficiency of the system with increasing coverage clearly increases in the discussed logistics of a company, especially in the area of production logistics.

2. Production logistics

The modern industry requires increased focus on both efficiency of the development cycle and the production efficiency. Current trends focus on the need to create a diversified offer which reacts to changing demands flexibly and quickly. This is due to the transition from the offer market to the demand market started in the nineties of the last century. Currently, the manufacturer is obliged to provide primarily what the customer wants. Because of it, the basic goals of the company are, among others, the need to shorten the order making time, shortening the time between preparations and setting manufacturing equipment, planning and control equipment life-time or their parts, reduction of extensive working processes, saving space in companies, etc. In practice, this applies to all kinds of serial production, production procedures, workshops and generally all manufacturing companies (Němec 2002). The importance of unit production as well as short time-series production on special request (not being a standard offer) constantly increases. The main objective of efficient production is making orders with minimal losses which in fact means, among others, minimizing waste and production expenditures. With regard to the data contained in Table 1, it should be noted that typical losses in the area of manufacturing logistics are generated during execution of non-productive activities taking place during unnecessary manipulation and storage. This is due to improper preparation of workstations for the production processes, forced awaiting for the fulfillment of the conditions necessary for the implementation of manufacturing operations (missing material, incomplete manufacturing documentation, incorrect setting of working tools, etc.). One of the causes which can be mentioned here is the necessity of removing the effects of manufacturing defective or out-of-tolerance products (repairing damages, manufacturing a new product, solving complaint problems at a client's location), wrong organization of the production processes or improper control of them (resulting from incomplete, outdated or inaccurate input data and without taking into account the actual capacity of the company or operational and production management based solely on the orders with threatened execution date) (Černý 2007).

2.1. The spatial dislocation of production

Spatial organization (layout) of workstations on the basic (base) area i.e. the total available working surface which is available during the deployment of individual workstations is an important part of production logistics. As the area of companies grows the losses can be bigger due to incorrect definition of the allocation of production equipment, its service and manipulation activities (material shifting, semi-finished products, tools, etc.).

For this reason, when defining the functions of production the whole range of different factors should be taken into account.

The most important principles that should be considered when creating production systems include:

- nature of production;
- laying the foundations for trouble-free and reliable functioning of production and maintenance;
- laying the foundations for the introduction of flexible changes;
- minimizing installation and re-installation costs;
- minimizing material flows and transport costs;
- optimization the internal transport network in accordance with the selected criterion;
- optimizing the deployment of workstations within the base surface;
- collision avoidance related to the movement of materials between workstations;
- conducting internal optimization within individual workstations.

As shown in (Miller 2009), the company's ability to compete is possible to achieve at the level of determining the costs of production, quality and delivery times. Lowering costs is achieved by minimizing operating costs. Their basic division includes the costs associated with handling and the production itself. The quality of products is achieved by means of minimizing the number of failures during manipulation and appropriate deployment of workstations. The date of delivery is affected by non-productive periods which include periods of manipulation with material at the workplace and between workstations.

2.2. Production logistics and production technologies

A significant impact on the achievement of the objective of minimizing coordination costs and shortening production time is the transition to the production process where there is a smaller number of manufacturing steps.

The basic ways to organize production with fewer steps are, inter alia:

- integration of technological operations at the manufacturing unit (in order to increase the number of operations carried out by one device);
- elimination of unnecessary production steps;
- replacing technological operations which require a larger number of devices;

In today's world there exists a rule according to which reducing the number of the so-called production levels is more efficient than the reduction of the number of operations in the whole technological process. The assignment of more stages of production to one even more complicated process

results in a greater working load of the machinery. However, it is important to emphasize that, from a logistical point of view, the option characterized by the lowest costs of production is not always the most convenient.

In addition, it is also necessary to take into account other circumstances such as:

- simplified handling of transport operations;
- effects arising after shortening fixed times and corrected supply capacities connected with them as well as guaranteed standby;
- reduced costs resulting from reducing the number of manufacturing steps;
- increased productivity, etc.

2.3.Storage

In the context of the production it is necessary to secure storage functions and therefore, the following points are generally formed:

- input warehouses (supply warehouses) – designed to ensure a smooth production process;
- warehouses for semi-finished products;
- warehouses for collecting semi-finished products and supplying production subsystems;
- warehouses for finished products;
- warehouses for finished goods of the company to handle orders according to customers' demand;

From a theoretical point of view there may be the same groups of activities in all types of warehouses (relating for example to the entry processes, locating, storage, commissioning, output of components and IT support).

Another important thing is also the need to answer the question how many warehouses or places for storing are required and how big they are to be. The dimensions of the warehouse are defined in accordance with the warehouse space or in accordance with requirements relating to the storage space. While calculating the size of the warehouse the volume of production and the so-called clean production during various stages of the manufacturing process are usually taken into account. Storage sites between different workstations as part of the production are, in many cases, unavoidable. Another important issue is the problem of warehouses dedicated for input materials (charges) or semi-finished products and ready products. It is known that excessively prolonged storage of input materials intended for production generates a loss for the enterprise therefore, it can be stated that the warehouse should be the last element in the chain of production which is desired by the enterprise from the point of view of effective management. The reason for this is the cost of storage which is always added to the costs

and losses. The solution to this problem falls within the definition of lowering the level of supplies (Factory Magazine 1988) up to the zero level. One way is to use the approach Just-In-Time (Hirano 1988). For such a system to work, it is essential that each subsequent process must refer to the previous i.e. the output of the previous process must be received at the required time and amount. The preceding process must only produce a certain number of products and it is finished at the moment when the next process begins. Various methods may be used to define the production control system. Some of them are shown in Table 2.

Table 2. Systems for planning management of production

Systems for planning management of production	Characteristic
MRP I (Material Requirement Planning)	This topic concerns developing appropriate solutions for controlling inventory in the whole system responsible for controlling production. The disadvantage is that unlimited capacity with a predetermined cycle length and fixed manufacturing batches are taken into consideration.
MRP II (Manufacturing Resource Planning)	Widening and deepening the MRP (financial, marketing, purchasing and control aspects). It results not only in material plans but also in the performance. Implementation of MRP II leads to minimizing overtime, reducing the number of deliveries in the safe mode, reduces inventory and increases turnover.
KANBAN	This technology was first presented by Toyota Motors and was quickly implemented by manufacturing companies around the world. It is used in the engineering industry, particularly in the automotive industry (in bulk production where the sale is agreed). This technology consists in the fact that the supplier is responsible for quality, and the recipient is obliged to pick up the completed order. Performance abilities of suppliers and recipients are balanced and their activities are synchronized. Consumption of materials is uniform without major fluctuations and changes in assortment. Suppliers and recipients do not produce any stocks, there are the so-called self-steering circuits forming interconnected pairs (suppliers – recipients) on the basis of the so-called pull principle where the order is at the same time the load of one or more modes of transport means fully loaded with a fixed number of products and where material and information flows take place in the following stages: a receiver dispatches an empty means of transport with a label (the so-called. Japanese Kanban) – the production letter having the function of the order, after receiving the means of transport a supplier starts loading the required order, loading dedicated goods on the means of transport and sending it to the recipient (attaching labels - consignment note), the receiver takes over and controls the received products.
KAIZEN	The Japanese approach to improving the functioning in the area of quality and also to the issue of cost reduction.

OPT (Optimized Production Technology)	The emerging so-called bottlenecks have a significant impact on the course of production. The identification and optimal use of bottlenecks may lead to improving the average use all available means of production, shortening the production time and reducing the number of employees. The decisive factor in this matter is to present a production network chart after dividing it into the critical and non-critical areas.
BOA (Belastungsorientierte Auftragsfreigabe)	In the BOA approach, the production flow is considered from the point of view of its stochasticity. The control size is the level of inventory at workstations or the level of inventory in the context of production lines. The condition of using BOA is the same or a slightly different manufacturing time in single workstations.

2.4. Just-in-time production

One of the most important methods related to manufacturing resource planning is the method Just-in-time (JIT) which means a supply concept proposed by Toyota. As a result of its implementation inventory, which generates unnecessary costs and waste of resources, is minimized. JIT deliveries are based on the idea of controlling the production process using the natural law of supply and demand which means that parts are delivered to the production line at the precise moment when the process requires it, and moreover, in the quantities in which they are required. The basic principles of this method is planning and production on request, production in small amounts (each product is treated as an independent order), elimination of losses, continuous manufacturing flow, quality assurance, appropriate treatment of workers, elimination of excessive inventory and workforce, and maintaining a transparent and long-term strategic direction. Generally, the JIT method is treated as a continuous and flexible production system. Production takes place in small series; it becomes possible to shift the production of one type of product for production of another type in accordance with the order. From the viewpoint of the structure this method can be introduced into production systems consisting of autonomous production stations. It should also be mentioned that the method JIT is not a new issue and its characteristics can be found in earlier publications, i.e. Hay and Zonderman (1988), or Cheng and Podolsky (1993).

2.5. Production and the human factor

We can sometimes forget about the appropriate allocation of machines to operators in automated production systems. On the one hand it depends on the qualifications of the personnel, on the other, on the development of new production machines. Machines should be focused on the human factor (PPDT 1996) i.e. they should be tailored to the people who service them. As Němec (2002) claims, if it comes to producing an inadequate or completely defective product, the machine should automatically stop. The Japanese

name for this approach is Jidoka which means automation however, this is not mere automation, but equipping machinery with certain intelligence. Therefore, there is translation which prefers the term automation with a human face. Machines which have some human characteristics stop automatically in case of a certain non-standard event. This means that in the case of the normal operation of the machinery there is not any need to implement a human factor. The operator intervenes when a machine is damaged or has just produced a product which is inconsistent with the quality requirements. This allows one employee to manage and operate several machines. A non-standard situation is generally signaled visually and intervention of the human factor occurs at the time of manufacturing defects and other unusual situations. Such a system becomes effective mainly from the standpoint of minimizing costs. On the other hand, from the point of view of their own employees it becomes necessary to analyze the problems of their motivation and qualifications.

2.6. Environmental logistics

The increasing emphasis on improving the quality of the environment is reflected in the increasing demands on productive activities. From this point of view, logistics in a company should have the desire to synchronize coordinates and optimize the flow of information and materials to meet the needs of customers at reasonable (the lowest) costs assuming the negative impact of business activities on the environment is minimized. The direction of development of logistics oriented to the impact of economic activity on the environment (e.g. the relationship between transport modes with the level of environmental pollution, striving to reduce material and energy requirements of logistic activities, relationship with certification to ISO 14000) referred to as green logistics, ecological logistics or environmental logistics (Škapa 2002). According to Olšovská and Butorová (2008), the basic problem which is mentioned due to ecologization of production concerns the possibility of reducing the negative impact of functioning of enterprises on the environment while increasing efficiency. In many cases this problem can be solved by the so-called environmental management systems (EMS).

According to Olšovská and Butorová (2008), the benefits of introduction of the EMS and certification according to ISO 14001 can be summarized as follows:

- achieving full compliance with applicable legislation and all applicable environmental requirements;
- reducing operating costs (e.g. savings in the use of raw materials, energy and minimizing the costs associated with the disposal operations, including savings in fees for environmental pollution);

- reducing the risk of accidents having an impact on the environment;
- savings consisting in avoiding fines and other penalties for environmental pollution;
- elimination or reduction of costs due to an unclear organizational structure and clearer definition of investment projects and business plans;
- improving relations with the society, government institutions and other environmental organizations;
- increasing business credibility for investors, banks and insurance companies (a lower interest rate, insurance);
- increasing export opportunities in the field of export and in the area of state orders and supporting business activities;
- improving the image of an organization.

Companies should also take into account the circumstances described by Červeňan and Sakál (2002) emphasizing the importance of environmental logistics which plays a very important role in the competitiveness of the company. It is assumed that the lack of environmental policy of the company is reflected in a negative impact on its financial results and perhaps it will also result in a gradual rejection of its products on the market, both for retail customers and especially by clients at the level of other enterprises unwilling to cooperate with the company which will be said to prefer bad environmental policy and has a low level of support for sustainable development.

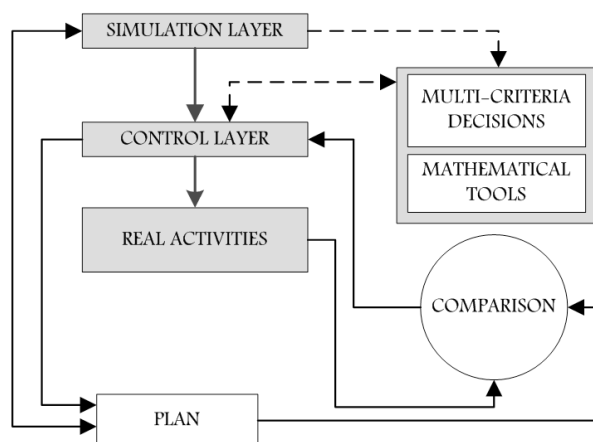
3. Simulation as a modern optimization method of production logistics

Factors influencing production logistics have different weights and the main management goal remains a constant need to optimize the whole system in a way enabling us to meet the predefined criteria. Simulation seems to be one of the contemporary methods supporting system optimization. Its results enable managers to make a decision at the operational and strategic levels. A vital issue is making a decision which simulation method can be implemented and how to adjust it to the complex control system of the company.

For the purpose of the simulation process it is required to adopt basic assumptions which creates adequate models (Chramcov, Balate 2009) using, for example, the process-oriented approach (Řepa 2006), (Šperka et al. 2013), the value-oriented approach (Shapiro 2006; Vymětal 2009), the multi-agent approach (Wooldridge 2009; Chen et al. 2006; Karageorgos, et al. 2003; Zoghلامي, Hammadi 2007) and neural networks (Hsui et al. 2010).

In addition, the discrete or continuous approach related to the Petri networks should be considered (Macias et al. 2004) as well as the object-oriented one (Dotoli et al. 2005) or heuristic algorithms which are responsible for meeting the adopted criteria (Bucki, Suchánek 2012), the business-intelligence tools (Suchánek 2011), genetic algorithms (Kofjac, Kljajic 2008; Reis et al. 2010) and other mathematical and special approach presented, e.g. in (Giribone et al. 2007). In many cases it is preferred and, at the same time, very effective to use a combination of different methods and approaches. The reason is, among others, the fact that the overall logistic systems are usually too complex to be modeled mathematically, or they require excessive computational needs, which prevents their use in real-time. Simulations are carried out outside the real system. However, in order to accomplish their goal, they must be carried out on models using real data in accordance with the actual state. In addition, they must provide the most recent information for use in the control process. For this reason, simulation includes a complex structure of the control system. This requires defining and creating as well as setting all channels of communication between separate levels. During a comprehensive description and design of the control architecture using the simulation three layers can be used as shown in Figure 1.

Figure 1. A model combining layers of control, real and simulation activities



Source: based on Suchánek 2012:144.

The control layer represents management procedures focused primarily on actual operations. The input values, which are used as comparative data in the course of the simulation, are included in the plan. The actual adjustment procedure is performed on the basis of the verification in the simulation layer. There can be carried out simulations based on all kinds

of models which may, to a significant extent, depend on the correctness of the model. Moreover, implemented mathematical tools can help in testing selected assumptions as a basis to make effective decisions.

Implementation of simulation for a comprehensive management system assumes that certain benefits and the possible shortcomings resulting from the simulations will emerge.

The benefits of simulation may include the following:

- creating a model leads to better understanding of the modeled real system (it results in proposing new solutions related to improving management or reorganization of the structure of production; these solutions are created in the process of creating a model based on a detailed analysis of the real system);
- a significant acceleration of the calculation time (years of actual operation of the system can be reduced to just a few seconds or possibly minutes) or slowing down the simulation process if its pace makes it impossible to monitor the course of events;
- simulation offers a comprehensive look at the studied issue and enables the multi-criteria analysis by tracking various parameters (e.g. the workload of production machines, the time course of each operation, work in progress, etc.);
- a simulation model can be used as a training device to acquire experience during e.g. training of employees;
- simulation provides answers to questions like: What if?

Disadvantages of simulation include the following problems:

- the absence of guarantee that the model will be adequate to the existing real system even in a situation where its creation takes a lot of time and effort;
- depending on the complexity of the simulated system creating a model may take too long and require huge financial outlays;
- simulation may have a lower accuracy than an analytical solution due to the fact that it contains an element of chance therefore, if a system can be represented by a mathematical model, its use is usually better than the simulation.

Disadvantages of simulation can be removed using proven simulation software or, in the case of development and producing own software, with a redefinition of the output model.

Conclusions

The emphasis on lowering costs associated with the functioning of the company and raising the efficiency lead to the search for innovative methods that improve efficiency and reduce losses. In the area of manufacturing

logistics there is a whole range of factors which can have a direct impact on logistic systems. However, this depends not only on the machinery equipment. A significant impact is also played here by the human factor, ways of storing, spatial dislocation of production, “greening” manufacturing processes, etc. The fact that factors with a lower weight have an increasing influence along with a growing range of production should be taken into account as well. Hence, it becomes necessary to carry out an analysis of all the relations in the system. However, the analysis should be started by conducting detailed description of the discussed production system and production logistics as a whole. The main unknown is to secure continuous improvement and optimization procedures. One possible method is simulation which must always be based on adequate model of the whole system. It seems that the most suitable option which is supported by modern technologies is the parallel integration of the simulation layer used to complex system control of the company.

Acknowledgement

This article was created with the support of the project “Innovation of Study Programs at Silesian University in Opava, School of Business Administration in Karviná” No. CZ.1.07/2.2.00/28.0017 and the research project “Diagnose, Simulation und Logistik der Gebäude-Dämmprozesse” Project No. PL 10/2012, Austrian Agency for International Cooperation in Education and Research (OeAD-GmbH).

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