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# SIMULATION AS TOOL FOR LOGISTIC CHAIN OPTIMIZATION

**Abstract.** Simulation is one of the methods in which a real system is substituted with a computer model where experiments are practiced and then subsequently analyzed and evaluated. After the application of the results of simulation and verification of its effects the results are applied in the real system with the aim to optimize processes. It seems that simulation is appropriate tool which offers all useful information about how model system works in given conditions. Simulation in planning and optimizing allows better and faster understanding of processes and guarantees that operational devices will work at the top of their effectiveness. Simulation plays an important role in optimization of logistic chains organization. There is a need to analyze strictly, find narrow places, remove them and consequently to repeat simulation with the new data. It is also very profitable to parallelly simulate more possible alternatives when there is a change in input data and consequently to compare them. The model of logistic chain created by simulation will considerably influence right decisions in process solving related to distribution. Subsequent optimization of logistic chain management can be aimed at the organization where the sum of final costs for transport and warehousing is minimum in compliance with basic parameters of customers' service level.
In the paper classic systems of the management of logistic chains are compared, namely direct distribution and indirect distribution made by technology Cross-Dock canter. Final comparative analysis of both systems simulation points out not only to their advantages and disadvantages but also to the possibilities of their optimization and application in particular operational conditions.
**Keywords:** Logistic chain, simulation of process, distribution, transportation chain, Cross-Dock technology.

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## Introduction

Simulation as a tool for process optimization is one of the basic practices used in companies to improve their existing situations. Optimization can be characterized as a process leading to the search for solutions that are better (more advantageous) than the current state. It is therefore a process of improving that seeks the optimum but may or may not achieve it. Although simulation is not one of the optimization methods, it is a very often used tool in the conditions of the Industry 4.0 concept with which it is possible to analyse processes and then optimize them by applying a suitable mathematical method (Illes et al., 2022).

Thus, simulation is one of the experimental methods in which ae real system is replaced by a computer model, on which experiments are performed which are then analysed and evaluated. After applying optimization and verifying its effects, the results are applied back to a real system and the whole process can be repeated. Therefore, simulation is a suitable tool providing all the necessary information about how a modelled system works in the given conditions. However, the results obtained by the application of simulation tools are conditioned by the correct (i.e., real) setting of input parameters. With purposefully set input values, the entire simulation process can then be deformed, and the resulting simulation product loses value (Plakhin et al., 2017).

An important role in the organization of logistics chains is also played by the ongoing concept of Industry 4.0, which is primarily production-oriented, but also necessarily affects the transport sector. By applying the Industry 4.0 concept, processes and applications of new technologies are gradually optimized.

Given that transport and warehousing are the most cost-creating logistics subsystems, it is necessary to analyse individual logistics distribution strategies and thus to establish acceptable criteria for the selection of a suitable distribution system. There are several linear or networked goods distribution systems, each of which has its advantages and disadvantages and is suitable for a certain capacity, frequency, periodicity, etc. Recently, the Cross-Docking system is often preferred at the expense of the linear shuttle service system, and the last-mile logistics, in which the Milk-Round technology plays an important role, is also often mentioned. One of the tools that is able to confirm or refute the advantage of the system of each of the distribution systems is the simulation of logistics chains or their distribution parts.

## 1. Simulation organization of transport chains

Simulation as a tool for process optimization is one of the basic practices used in companies to improve their existing situations. Optimization can be characterized as a process leading to the search for solutions that are better (more advantageous) than the current state. It is therefore a process of improving that seeks the optimum but may or may not achieve it. Although simulation is not one of the optimization methods, but it is concept with which it is possible to analyse processes and then optimize them by applying a suitable mathematical method (Hlatká et al., 2020).

Thus, simulation is one of the experimental methods in which ae real system is replaced by a computer model, on which experiments are performed which are then analysed and evaluated. After applying optimization and verifying its effects, the results are applied back to a real system and the whole process can be repeated. Therefore, simulation is a suitable tool providing all the necessary information about how a modelled system works in the given conditions.

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Simulation also plays an important role in the organization of transport or rather logistics chains. The results of simulation of the organization of logistics chains must be analysed thoroughly, bottlenecks identified, removed and then simulation must be repeated with new data. (Kampf et al., 2016) It is also advantageous to simulate several possible alternatives in parallel while changing input data, and then to compare them. A thorough and complete model of a logistics chain will significantly support correct decision-making in solving distribution-related processes. Subsequent optimization of logistics chains focuses on such an organization, where the sum of the resulting costs of transport and warehousing is minimal while maintaining the basic parameters of the level of customer service (Ližbetin et al., 2016).

The usual possibilities for simulating the organization of transport chains are:

1. Direct transport (a shuttle service system), i.e. transport from suppliers to customers without the use of distribution warehouses.
2. Indirect transport, i.e., transport where there is a change in the type of transport or transport system in distribution centres (warehouses).

Both the handling systems can still have several subsystems, each of which needs to be analysed and its suitability for a given transport type or a transport system assessed. In many cases, a transport chain forms part of a logistics chain, in which case it is necessary to consider other subsystems of the given logistics chain (Fedorko et al., 2021).

### 1.1. Direct transportation chain

Direct transport systems use a simple linear method of connecting suppliers and customers during distribution (see Fig. 1). From the organizational point of view, the shuttle transport service is one of the simplest ways of operating between two points without any intermediate stops. The simplicity and speed of transport and the absence of reloading and warehouses in the chain favour it to a large extent over other systems (Strnad et al., 2021). The performance level of the shuttle transport system is extremely high, and it can therefore operate at a relatively low cost recalculated to a unit transported. However, it is conditioned by the fulfillment of the set (relatively high) capacity. Each transport unit in the shuttle system has a constant capacity and therefore needs to obtain a specified volume of transport from the source to the customer. Therefore, the shuttle service system requires a relatively high transport demand which is as evenly distributed as possible throughout the year. Low flexibility in capacity is a disadvantage of the system (Bukvić et al., 2021).




**Fig. 1.** Shuttle distribution system (Source: author)

In addition to the shuttle transport service, which is a typical example of direct transport, various subsystems are also used, which try to eliminate the main disadvantage that lies in the relatively high and regular scope of transport. These are mainly conventional linear service (see Fig. 2), which also uses, in addition to the start and end points, customer points on a given route. The supplier's capacity is thus divided among several customers and the advantage of high performance at a low unit price is maintained (Maretić & Abramović, 2021).




**Fig. 2.** Conventional linear distribution system (Source: author)

Circular service is another subsystem, which is like a conventional linear service system, but the location of customers is not typically linear and customer requirements are asymmetric (see Fig. 3). The advantages of this system are like those of a linear system, but this variant accepts spatial distribution and changing capacity requirements of customers. The system is quite often used as final distribution in last-mile logistics (Abramović et al., 2021).

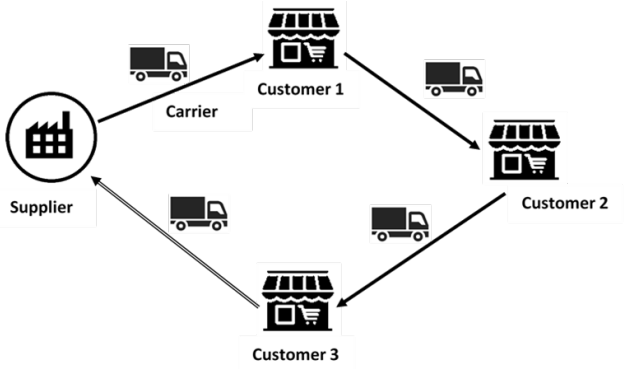



**Fig. 3.** Circular distribution system (Source: author)

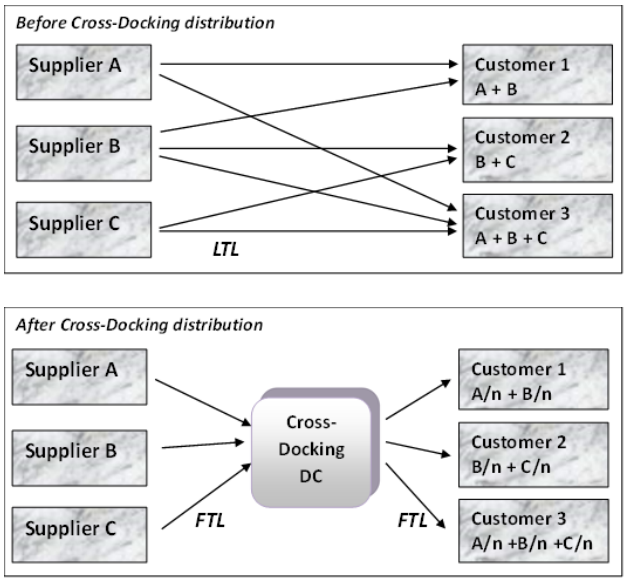
### 1.2. Indirect transport by Cross-Docking distribution center

In indirect transport, warehouses, or distribution centres (DC), which in part act as warehouses, are used in distribution. Due to the fact, that warehouses are integrated in a transport chain, it is necessary to consider the additional costs associated with keeping stocks in warehouses and the operation of warehouses. In addition, these costs should be offset by savings in transport costs, namely through using the capacity of means of transport or

through using transport systems with a higher capacity, which will reduce the unit price of transport (Pasagic Skrinjar et al., 2017).

In distribution logistics, when transporting goods with the same or similar purpose from several suppliers to multiple customers a warehousing system called Cross-Docking is used. With this system, the goods delivered to a distribution centre are not stored but they are transported continuously in the required quantity and composition to a specific business unit. Compared to conventional warehouses, this logistics system largely eliminates the costs associated with keeping stocks. In addition, transport costs can be reduced during distribution through a suitable combination of vehicle capacity and a reduction in the number of trips. The resulting total costs per a transport chain can thus be advantageous when using the Cross-Docking system (Jurkovic et al., 2021).

A comparison of the distribution before and after the introduction of the Cross-Docking system is shown in Fig. 4.




LTL - Less than truckload, FTL – Full truckload

**Fig. 4.** Distribution system before and after the Cross-Docking (Source: author)

However, Cross-Docking requires accurate synchronization of all incoming and outbound shipments. This requires high-quality information security and powerful reloading technology. Cross-docking is currently used quite often, especially in the distribution phase of supply chains. This is mainly due to the already mentioned fact that this technology allows simultaneous reduction of transport as well as warehousing costs, which represent the largest share of total logistics costs, and thus it contributes to the optimization of the supply chain (Ližbetin, & Stopková, 2021).

## 2. Comparison of systems for organizing logistics chain

A transportation chain is defined as an efficient sequence of sub-processes in transport, handling, packaging, and storage necessary to move goods from manufacturers to consumers. To organize transport chains in distribution processes, as already mentioned, possibly as direct transport or distribution, or as indirect transport or distribution (Hruška et al., 2021).

Direct distribution is performed by one type of transport, without reloading, usually by one means of transport. The participants in such a transport chain are: a manufacturing company that wishes to place its product on the market, a transport company that performs the transport, and a consumer to whom the product is intended. All distribution activities are usually organized by the manufacturing company at its own expense and risk. The manufacturer cooperates directly with a relatively small network of customers or with its own network of stores (Hamdi et al., 2021).

The following factors are the main prerequisites for the use of direct distribution:

- a small number of potential customers,
- high spatial concentration of the customers,
- relatively high and evenly distributed transport demand,
- relatively rapid loss of utility value of the product sold (e.g., food),
- high cooperation of suppliers and customers (Motaghedi-Larijani et al., 2018).

Direct distribution is used mainly in the transport of agricultural products, bulk materials, or special-purpose types of products. Given that the purpose of such a distribution system is the transport of a significant amount of goods without intermediate reloading, the fulfillment of a relatively large capacity of the means of transport is a necessary condition for its implementation (Pečený et al., 2020). The advantages of this type of distribution mainly include direct connection between the supplier and the customer, information, and control of the entire distribution process by the manufacturer, which in practice allows a very quick response to any changed requirements from the customer. The overall level of stocks in the distribution channel is low, which has the effect of reducing logistics costs. Another advantage is in fast and direct market information, immediate control over concluded transactions and the possibility of a flexible response to changes in demand (Široký et al., 2021).

Its disadvantages include the problematic filling of the relatively high capacity of the transport system and the associated high amount of product stocks in the supplier's warehouse. A high number of medium- or small-scale individual orders can have the effect of increasing transport costs. In direct distribution, it is necessary to focus on a smaller number of customers with requirements for even high-capacity transport, or a higher speed of delivery of larger quantities of goods. The supplier must also be prepared to provide additional services required by the customer, not only services at the place of delivery but also services related to the quality of transport.

Indirect distribution is in practice a more frequently used strategy for the distribution of goods. The participants in a chain are, in addition to a manufacturer, various carrier, consumer and warehouse keepers, or logistics

groups that take over part or all the distribution-related activities. In this system, the manufacturer is relieved of organizing a transport chain and this role, as well as the risk and costs, is taken over by one of the participants in the chain. This distribution chain organizer, typically a transport operator or a logistics company, also seeks to increase the level of customer service by offering additional services (Jimo et al., 2019).

The advantages of the system on the part of the manufacturer include lower level of stocks of finished products in stock, simpler administration, fewer individual orders and the associated lower transport costs. The disadvantages of the system include larger stocks of finished products in a distribution channel (in distribution warehouses) and reduced information for manufacturers about customer feedback, thus slowing down the ability to respond quickly to changes in the market situation (Fabry et al., 2022).

The indirect distribution strategy has many variations in servicing the market and it is therefore essentially suitable wherever direct transport of large quantities of goods from one supplier to one customer is not required. In indirect distribution, a combination of two or more modes of transport or a combination of means of transport within one mode of transport may also be used to reduce the total costs. The combination of means of transport or modes of transport into a transport system must guarantee reliable performance of transport in compliance with the specified quality parameters as are speed, specified transport time, accuracy of delivery for loading, etc. (Hruška et al., 2021).

**Conclusions**

Cross-Docking is a method based on indirect distribution through a warehouse, which, however, brings additional costs associated with loading operations and storage. This negative should be offset by lower transport costs. However, if, in direct distribution, road sets are used sufficiently and the loads from several suppliers cannot be cumulated, then the benefits of this system disappear. Naturally, the opposite is also true, i.e., if road sets are unused in capacity and it is possible to cumulate the loads from individual suppliers, which will reduce the number of trips, then there is also a reduction in transport costs. However, this reduction must be higher than the costs associated with the implementation of the Cross-Docking system.

However, when calculating the total costs for the implementation of the logistics chain for indirect transport, it is necessary to add the costs of warehousing and the costs related to handling, combination of shipments, unloading, loading, etc., to the transport costs.

Total costs for indirect transport must be lower than the cost for direct transport, see equation 1. (Xi et.al., 2020):

$$\sum_{k=1}^{n} N^{\mathrm{IDT}} = N^{T} + N^{W} + N^{H} \leq \sum_{k=1}^{n} N^{\mathrm{DT}} = N^{T} \quad (1)$$

$N^{IDT}$ - total costs for indirect transport (€),
$N^{DT}$ - total costs for direct transport (€),
$N^{T}$ - transport costs (€),
$N^{W}$ - warehousing costs (€),
$N^{H}$ - handling (reloading) costs (€),
n - number of transportation chain (Xi et al., 2020).

The Cross-Docking method can be considered as a method that brings positive effects, but its success depends on its correct application. It is mainly about the arrangement and organization of a logistics chain as a self-contained, i.e., not only to solve the suitability of distribution itself but also its connection to subsequent processes.

Considering the results of the research, the following can be considered as the basic conditions for the introduction of the Cross-Docking system:

- Insufficient capacity utilization of road semi-trailer sets.
  The system almost always (if only this criterion is accepted) appears to be advantageous when using the capacity of road sets below 60 %. When using them between 60 and 80 %, the application of the system can be considered, but it is necessary to consider a summary of other criteria, such as regularity or frequency of transport trips, etc. It does not make sense to consider the application of the system when using road sets over 80 % (Humič et. al., 2019).
- Sufficient transport distance.
  As transport distance increases, so do the benefits of implementing the system. This is because the level of costs associated with implementing the system is essentially constant. But the transport costs decrease roughly linearly depending on the transport distance when there is accumulation of the loads from individual senders or accumulation of trips during distribution. The so-called critical distance cannot be determined precisely, it depends on many factors, such as in particular, warehousing prices and transport prices. However, it almost certainly does not make sense to consider implementing the system at distances below 100 km Jensen et. al., 2019).
- Convenient location of a Cross-Docking centre.
  A Cross-Docking centre can basically be located anywhere on the route between suppliers and customers. However, three basic concepts can be applied:
  1. The centre is close to suppliers (e.g., regional logistics centres).
  2. The centre is close to customers (e.g., the Gateway concept).
  3. The centre is at the centre of gravity between suppliers and customers (e.g., international logistics centres), (El Yaagoubi et all., 2022).

The choice of a suitable concept depends on the number and distribution of suppliers, the number and distribution of customers, the utilization of capacity in transport and distribution, the basic function of the centre with respect to the national or international level, etc. However, when using mathematical models in determining the location, the density of the infrastructure, the throughput of the transport network, etc. must also be

considered. Incorrectly set input data and limiting criteria may invalidate the results of the location model.

However, when considering the application of the system to the concept of organization of transport chains, several other criteria related to distribution logistics must be considered:

- Possibilities of information flow between suppliers and customers (EDI, email, ...).
- Participation and responsibility of suppliers (regular deliveries on time, specified quantity of goods, ...).
- Customer readiness (customers must be informed in time and ready to accept shipments).
- Equipment of the Cross-Docking centre with information and handling technology (pelletizing, depalletizing, variability of means of transport, ...).
- Number and location of potential suppliers.
- Number and location of potential customers (e.g., in how large attraction area customers are located), (Ashima et all., 2022).

The actual decision on the system and a method of organizing a transport chain is usually responsibility for a transport operator. This operator must always assess the technical and technological possibilities (alternatives) of the organization of a transport chain and then evaluate them in a relevant economic way. The operator must also evaluate whether to organize a transport chain as monomodal (either direct or indirect), or as multimodal, where most of the route is travelled, for instance, by rail.

The task of simulation and subsequent optimization of logistics chains is to indicate such an organization, where the sum of the resulting costs of transport and warehousing is minimal while maintaining the basic parameters of the level of customer service.

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