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Transportation Research Procedia 55 (2021) 172–179

Transportation Research Procedia

www.elsevier.com/locate/procedia

14th International scientific conference on sustainable, modern and safe transport

Software Support of City Logistics´ Processes

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Abstract

City logistics has increasing importance in relation to the sustainable development of urban transport. It is therefore very important that all processes related to the city logistics should be optimally planned in advance. Many software companies offer a variety of software tools, which can be used for optimization and planning in city logistic tasks. This article aims to define and describe the various processes that take place in city logistics and then demonstrate, how selected software tools can help in optimizing the whole process of city logistics.

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Peer-review under responsibility of the scientific committee of the TRANSCOM 2021: 14th International scientific conference on sustainable, modern and safe transport

Keywords: city logistic; computer simulation

1. Introduction

The concept of city logistics includes a number of logistics activities and processes Lan et al. (2020). Some types of processes are very similar, others are very different. In this paper, the concept of city logistics represents processes that aim to transport goods from a warehouse on the outskirts of the city (agglomeration) to customers in its center. It can be both the supply of shops and the delivery of consignments directly to households. Also the processes of reverse logistic can be considered. We could say that this is actually a last mile delivery problem. However, this article also includes the method of assembling and grouping shipments in the warehouse (distribution center) and also the arrangement of the warehouse itself, which for the needs of city logistics may differ from a regular warehouse.

Many authors address in their scientific papers problems related to the city logistic. They present different kinds of problems and propose methods or improved optimization algorithms for their solution. This approach is very valuable from scientific point of view, but the implementation of these solutions in real logistic processes is very difficult for

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Peer-review under responsibility of the scientific committee of the TRANSCOM 2021: 14th International scientific conference on sustainable, modern and safe transport
10.1016/j.trpro.2021.06.019

overwhelming majority of logistic companies. Most of these specific solutions so remain unused in practice, because it is very difficult to understand to these scientific methods for many employee in logistic companies. On the other hand, all logistic companies would like to optimize their processes to save time or money, so the different software tools are used in practice for this purpose. We want to create the overview of different processes in city logistic and recommend some available software tool, which can be used in practice. The situations, which can be solved by some software tools and collection of data, which have to be collected before use of these software tools are also discussed.

2. Literature review of tasks for city logistic planning

For the proper and efficient functioning of the city logistics system, it is essential that the implementation of this system be carefully planned for the selected city Kučera (2018). According to Schliwa et al. (2015) and Crainic et al. (2020) the tasks for city logistic planning can be divided into following groups:

- location of the logistics center,
- warehouse design and layout,
- method of withdrawal from stock and completing shipments,
- delivery route planning (vehicle route planning problem).

This division will be used for further specification of city logistic processes in particular cases.

2.1. Possible location for logistic center

City logistics systems are often based on use of one or more logistic centers called "Gateways" because of their function as a "gateway" to town Krampe (2012). At present, there are not many cases where there are no logistics or distribution centers in the vicinity of a large city. Unfortunately, the origin of them is not always suitable for city logistics needs. It can happen that the logistics center is on the opposite side of the city from the customers who have to be served from this center. To satisfy the needs of customers, it could be then necessary to choose the path through the city center, where congestion occurs very often (Fig.1). Because of this, the delivery routes and times can be too long.

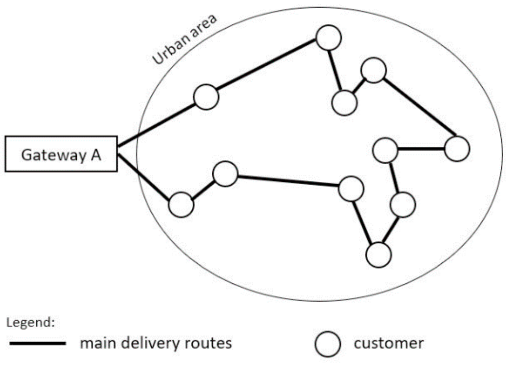

Fig. 1. Example of city area with position of logistic centers

The solution for larger urban areas lies in use of more logistic centers at the outskirts (Fig. 2a) or in use of logistic centers within the urban area, so called multistage model (Fig. 2b).

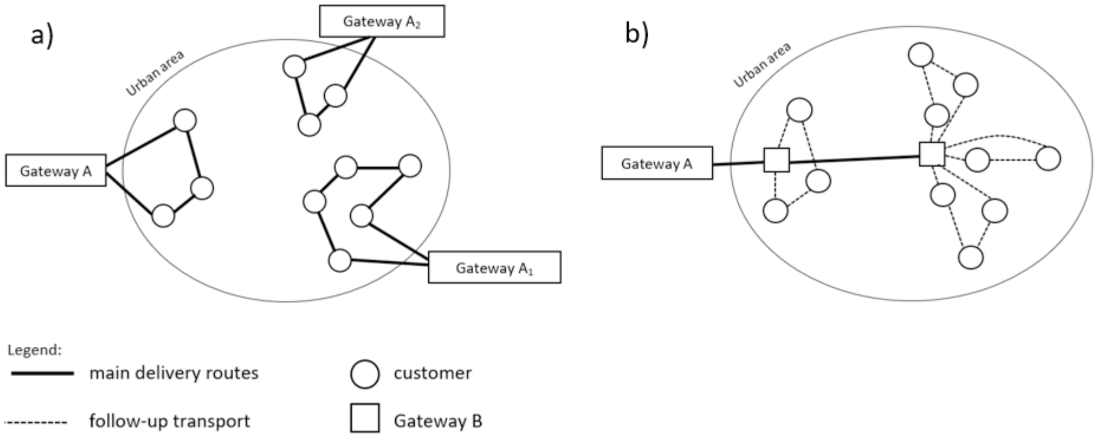

Fig. 2. (a) use of more logistic centers at the same level; (b) multistage model

The customers are served from the logistic center whose location is most convenient. The concepts with more logistic centers allow shorter routes and delivery times, and better planning of vehicles capacity utilization. The disadvantage of the system in the Fig. 2a is that it may require a construction of new center/centers which location has to be carefully planned. The system in the Fig. 2b mostly uses existing infrastructure (e.g., warehouses or industrial areas within the urban area). In this case, the "Gateways B" are mostly chosen from a set of given objects. This model can also use cargo bikes for delivery from "Gateways B" to customers because of short delivery routes Ledvinová (2019). In cargo bike systems, mobile containers are often used as the "Gateways B". Therefore, their position can be changed as needed.

Different approaches for determination of optimal location of "gateways" around the city are presented in Boonmee et al. (2017). Paper from Boonmee et al. (2017) is primarily focused on facility location of emergency humanitarian logistic, but there are many similarities with location problem of logistic center. Optimization parameters are also very similar. The model formulation and mathematic approach are very well described, but it is not mentioned, if it is possible to use some software tool to obtain solution in short time and with proportionate effort. One of few identified papers, which describe use of GIS tools for location of city logistics centers is from authors Çakmak et al. (2021). But they used GIS tools only for one part of solution, not for complete solution. Nevertheless, this paper can be used as a brief "manual" for location of "gateways".

2.2. Planning of inner warehouse layout

The solution to this problem depends on many factors Kučera (2019). The first factor is the type of goods stored and the types of transport units in which the goods are stored. The used shelving system and the size of the storage positions are derived from this. If the goods are stored on pallets, a uniform size of the storage position is usually chosen. In case different types of goods on pallets reach very different maximum heights, it is possible to choose different height of storage positions. This makes better use of storage space, as it eliminates empty space above pallets with low height of stored goods Silva et al. (2019). Another influencing factor is the way the goods will be handled. The warehouse with the automatic stacker (AS/RS) will have a different arrangement in comparison with the warehouse, where the goods are handled by means of forklifts. The way the warehouse is selected is also influenced by the way in which the warehouse position is selected for a specific type of goods. Overview of used approaches can be found in Ang and Lim (2019), Gu et al. (2010) or in Yener and Yazgan (2019). If the goods in the warehouse are arranged randomly (one type of goods is stored in different non-adjacent positions), it is possible to choose narrow aisles between the racks, which allow the passage of only one handling means. When blocking an aisle with a handling means, it is possible to pick up another type of goods in another aisle that is not blocked. In the case of zone placement of goods in the warehouse, it is necessary to choose aisles with such a width that will allow passing, overtaking, or turning of handling equipment. This reduces the utilized area of the warehouse. The width of the aisles must also be adapted to the case where automatically guided trucks are used in the warehouse. Among many studied papers wasn't found any, which targeted minimal aisle width for given types of handling equipment and minimal maneuver area for transport means.

The layout of the warehouse also depends on its planned throughput. If it is necessary to store large volumes of goods in a short time, it is possible to choose other than a rectangular connection of aisles. The connection of aisles to the central corridor at an angle of, for example, 45 degrees, or aisles designed in an arc, make it possible to shorten the total distance that the handling equipment must cover s mentioned in Cardona et al. (2015). This non-traditional arrangement only pays off with a high required throughput. With small daily volumes of handled goods, the difference in distance traveled compared to the classic rectangular arrangement of aisles is almost negligible.

2.3. Possibilities for withdrawal from warehouse and completing shipments

In solving this task, it depends, among other things, on what is the smallest unit of delivery of goods to the customer. The simplest case is when whole pallets of goods are removed from storage. Completion of the entire shipment for one customer is very fast and is not very demanding on the number of workers and the amount of handling equipment. The simplicity of this case also lies in the fact that one truck can hold approximately 33 pallets. However, if the smallest dispensing unit is one box (out of many stored on a pallet), the situation is much more complicated. A consignment for one customer may contain many different types of goods in boxes of different sizes, which must be suitably arranged on a pallet or in a roll container. Completion of the shipment will take much more time than in the previous case. Completing the order for individual pieces of goods has the highest time required for removal from storage. The methods for storage and routing policies in warehouse can be found in Silva et al. (2020), Masae et al. (2020) or in De Koster et al. (2007).

For removal from storage, it is also necessary to plan the technology with which removal and completion will take place. The two main options are parts to picker and picker to parts. In the case of parts to picker, automatic systems are used and the worker stands in one place. In the second case, the worker (or workers) must go through the warehouse in a suitable way and get all the items in the order. In this case, the choice of the navigation system in the warehouse is also important. The employee can be navigated to the warehouse position only by means of the numerical designation of individual warehouse positions, or it can be used, for example, the pick by light or pick by voice system. Less common is the use of pick by vision technology (augmented reality).

2.4. Conditions for planning delivery routes

The solution of the delivery problem is affected by a number of restrictive conditions Masłowski et al. (2019) and Eshtehadi et al. (2020). The main limiting condition is the type and size of vehicle used. The limitation lies not only in the amount of goods that the means of transport can transport at one time (volume or weight limit), but also in whether it is possible to reach the destination with the chosen means of transport. Obviously, a large truck cannot be used to deliver consignments in the narrow streets of the city center. Another limitation may be that some parts of the city center are only accessible at certain hours (e.g. early in the morning or in the evening). To this end, it is also necessary to take into account customer requirements for the time period when the shipment has to be delivered. Planning delivery routes can also affect the intensity of traffic in the city Slávik and Gnap (2019). Overview of methods for vehicle routing problem with different kinds of restrictions and requirements can be found in Zajac and Huber (2021).

Delivery route planning is also affected by the volume and size of shipments for individual customers. During delivery, consignments should be unloaded from the vehicle gradually from behind, i.e. shipments that do not belong to that customer should not be handled by the customer. After planning the delivery, it is possible to load the consignments in the correct order without any problems, but this order may no longer be optimal in terms of the use of the loading area. Consignments can be stacked in a means of transport in many different ways. With a suitably chosen arrangement, the volume of the means of transport will be used better and it will be possible to add one or more consignments. However, the order for unloading may not be optimal. Other restrictions may occur, for example, the length of the driver's working time or, in the case of electric cars, the length of their operational range.

3. Software to support logistics planning

Today, the implementation of all the above mentioned activities can be prepared with the help of computer technology. If there are several solution options, it is possible to use simulation software and with its help decide which of the solution variants is more advantageous for a specific situation Comi and Rosati (2013) and Taniguchi et al. (2020). The following section provides examples of commercial software that can be used for the solution of selected and above mentioned tasks. It will also describe what data needs to be obtained to work with the relevant software.

3.1. Solution of location-allocation problem

When searching for the optimal location of the logistics center around the city, it is possible to use some of the software from the family of geographic information systems (GIS). A very powerful tool is an extension called ESRI's ArcGIS Network Analyst software. This software has algorithms that allow automatic calculation of location-allocation tasks. To find a solution, it is first necessary to create a network of roads in the software, which connect the assumed positions of logistics centers with customers. After the creation of this network, the locations of customers who are to be served from logistics centers are marked. Attributes can be assigned to each customer, such as the expected volume of delivered goods or the frequency of deliveries. It is not easy to find or estimate this data and it is not always possible to obtain relevant data. In some cases (e.g. when delivering consignments to households), the set of customers changes. It is therefore necessary to use data that have been obtained on the basis of estimates and statistical processing of demographic data for individual parts of the city. These parts may respect the administrative division of the city, or may be created on the basis of parameters related to the type and nature of the delivered goods. It is also necessary to identify potential candidates for the location of the logistics center. Although the software itself can design suitable locations for a selected number of logistics centers, these locations may not be suitable, for example, due to existing buildings or the inability to obtain ownership of the land. The selected locations eliminate this problem and a suitable location is selected only from locations that are suitable for the construction of a logistics center. After selecting the locations, it is still possible to use this software to create areas that will be served from individual logistics centers. The distance from the center or the maximum travel time from the center to the customer can be selected as the optimization criterion.

3.2. Design of the internal layout of a logistics center or warehouse

As this is a building construction, it is very likely that one of the CAD family's software will be used to design the warehouse. Using Autodesk's AutoCAD software, for example, is commonplace in this area. A much less used feature of this software is a tool called Vehicle Tracking. This tool allows you to simulate the spatial position of any vehicle while passing through a defined area on the selected route. It is therefore possible to find out what is the minimum width of the aisles between the racks, so that the chosen handling technique can move in and go into them without any problems. The software can create envelope curves of vehicle movement. From them, it is then possible to find out whether, for example, a forklift truck will be able to turn from the main corridor into the aisle between the racks and what space it will need for this maneuver. When defining a vehicle, it is necessary to enter its parameters, i.e. what is the distance between the wheel axles, what is the minimum turning radius and the like. The software can simulate passing through a curve at different speeds, as the radius of the turn increases with increasing passing speed. It is thus possible to estimate the average speed of movement of the handling equipment and to determine the time required to complete the sample order. The use of this software is especially useful in cases where we decide between different variants of the placement of shelves inside the warehouse.

3.3. Simulation of withdrawal from warehouse and completion of shipments

For this type of activities it is possible to use one of the simulation software that can simulate production processes. There are a number of these software. For complex simulation of activities in the logistics center, for example, Tecnomatix Plant Simulation from Siemens is suitable. With this software, you can find out, for example, the minimum number of forklifts that will be needed to pick up a selected number of orders. The simulation can be run with the same parameters but with a different warehouse layout, which allows you to compare variants in terms of warehouse throughput or the amount of handling equipment required. It is also possible to determine the energy consumption for the drive of handling equipment and thus better estimate the operating costs of the logistics center. This software also makes it possible to simulate the movement of individual workers in a warehouse and, as with handling equipment, to determine the necessary minimum number. The depth of the simulation extends to the work calendars of individual employees. In the case of manual handling of goods, this software makes it possible to determine the ergonomic parameters of the workplace and the degree of stress on the muscle groups of workers. It is therefore possible to estimate how physically demanding the planned activities will be for workers and whether it will not be necessary to change them in a given job position in shorter time intervals.

In this software, it is possible to further simulate the number of places designated for loading and unloading and thus determine whether vehicle queues will be created in front of the logistics center. It is also possible to simulate the number of assembly lines and determine the space requirements for this part of the warehouse. The simulation not only enables the determination of initial values at the start of operation of the warehouse, but it is also possible to simulate the maximum values that can be reached in the warehouse in the future. This makes it possible to determine various scenarios for the future development of the logistics center. The simulation does not have to be limited to only one building in the logistics center, it is possible to simulate the operation in several interconnected buildings at the same time. The software can work with both discrete events (fixed service time, etc.) and with different distributions of the probability of occurrence of events (e.g. different removal times depending on the arrangement and location of goods in the warehouse).

3.4. Support in planning delivery routes

A number of logistics planning software is also available in this area. Delivery tasks can be handled both in software that is only distributed locally within one country and is tailored to a specific customer, and in software that is distributed worldwide. Locally distributed software includes, for example, PlanTour from Digitech company in the Czech Republic. On the other hand, ESRI's ArcLogistic software, which uses the algorithms of the Network Analyst extension already mentioned, is widespread worldwide.

When planning delivery routes, it is necessary to have a network created along which the means of transport will move. For this network, it is necessary to set parameters such as one-way streets, the maximum allowed load of bridges, the maximum height of the vehicle for passing under bridges and the like. It is also necessary to have a defined fleet of vehicles that will be used for delivery. In addition to the capacity, each vehicle can also have a cost function set, so it is possible to estimate the total cost of delivering all shipments. ArcLogistic software can also work with time windows for the delivery of consignments and optimize the delivery route accordingly, so that the delivery time and thus the driver's work is as short as possible. Of course, other optimization criteria can also be selected. It is also possible to include historical or online traffic data in this software to find out what the expected delay will be due to the high traffic density in the city. It is then possible to adjust the start or route of the delivery so that the total delay in the delivery is as small as possible.

In addition to the above-mentioned software, which is used to plan distribution to logistics companies, there are also software that can be used by local (city) governments to regulate traffic in the city. These software include, for example, Aimsun Next software, which belongs to the Siemens group. Similar software is OmniTrans from DAT.Mobility. Although these software are not directly related to the implementation of city logistics by a logistics company, they are of great importance in solving city logistics from the perspective of local government. Both software enable modeling of transport flows, which is important especially with the planned increase in the volume of traffic, for example due to the construction of new logistics centers in the immediate vicinity of the city. With their help, it is possible to estimate where there are bottlenecks in the city's road network and thus react in advance to the increased traffic load. It is also possible to simulate the impact of various restrictions on the city's road network, which have the task, for example, of calming traffic in the city center or increasing pedestrian safety by reducing the maximum permitted speed. It is also possible to determine the impacts and impact of the implementation of the ban on the entry of certain groups of vehicles into the city center on traffic in other parts of the city. From the point of view of modeling, these are macroscopic transport models. Aimsun Next software can also work with a microscopic traffic model, in which it is possible to simulate, for example, signal plans of individual intersections in the city. Thanks to this function, it is then possible to remove some bottlenecks that are involved in traffic congestion.

4. Discussion

From the literature review it is evident, that there are many modification of methods and algorithms which can be used for solution and optimization of logistic tasks. All these methods can be used for improvement of some parameters of city logistics processes, but most of the methods provide solution only for cases with some specifics or with some limitations and constrains. In real production environment (within logistic company) it is not possible to try to implement and combine many of these methods together. Each logistic company want to save operational costs. This can be reached through the use of suitable commercial software instead of complicated implementation of newly proposed scientific method. This software may not offer the very best solution ever according to the newest scientific methods and procedures, but provided solution can be used in practice in very short time e.g. on daily basis and such solution is sufficient for the logistic companies.

In our work we tested what kind of software can be used to find nearly optimal solution for some tasks of city logistics processes. We found that the use of tested software is not very difficult and that it is not necessary to know optimization algorithms in detail way (as described in scientific papers) to obtain improved usable solution than which was used up to now. We realize that the company which is concerned with city logistics has available wide range of software tools to solve logistic processes. Some of these tools can be used on daily basis (route planning) some for optimization processes. The use of all these software tools to obtain good results has common condition: the quality input data sets have to be used.

5. Conclusion

In this paper, individual groups of activities that affect the processes in city logistics were presented. Software tools that can be used to solve them were mentioned for the defined tasks. The two main groups of software tools were presented: the group of computational software (e.g. ESRI ArcGIS or AutoCAD) and the group of simulation software (e.g. Tecnomatix Plant Simulation, Aimsun Next or OmniTrans). Both groups of software tools can be used for both planning tasks and optimization processes. The use of these software tools can help in logistic companies to improve their efficiency. In our paper we didn’t want to provide the complete list of all available software tools usable for solving city logistics. The aim was to show that for most activities, it is possible to find out in advance with the help of computer technology how these activities will take place and what impact they will have on, for example, transport in the city or the flow of supplies in the city center. Many types of city logistic processes with their typical tasks and with suitable software tools for their solution or optimization were presented. These summarized information can be used in practice for better planning of city logistic processes.

Acknowledgements

The work was supported from ERDF/ESF “Cooperation in Applied Research between University of Pardubice and companies, in the Field of Positioning, Detection and Simulation Technology for Transport Systems (PosiTrans)” (No. CZ.02.1.01/0.0/0.0/17_049/0008394).

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