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TRENDS IN ROUTE PLANNING WITH THE TOOLS OF INTELLIGENT DISTRIBUTION LOGISTICS

ADÉL ANETT SZABÓ[1]–BÉLA ILLÉS[2]–ÁGOTA BÁNYAI TÓTH[3]

Abstract: The basic purpose of the article is to provide a sufficiently detailed and comprehensive overview about route planning concepts, logics, trends and opportunities for the relevant companies in the sector. Lack of resources or the strategic point of view or some other certain reasons are often obstruct the small and medium-sized companies to have a deep-dive validation of these factors - causing significant competitive disadvantages in terms of strategy and planning. If we do not see through properly the to-do tasks, possibly areas for development, managed by the operation we can significantly make harder decision-making process at any level. However, in the knowledge of all these, strategy of development or a possible system introduction – including methodology and required toold - can easily be determined.
Keywords: Industry 4.0, Logistics 4.0, Route planning, Intelligent logistics, Distribution logistics

1. CONCEPTUAL AND HISTORICAL OVERVIEW

In order to identify the relevant professional literature and research results first we need to clarify the basic definitions, processes and tendencies.

Considering all the domestic and international relations road transport has the greatest significance in supply chain. Due to this it is obvous that any optimization activity in the area has a significant impact on all the relevant companies of the entire chain [1].

In the beginning of the 21th century urbanization and growth of population caused a significant increase in affordable demand – and in parallel expanded volumens, transport loads, energy usage and unfortunately harmful emission.

The core competence of transportation is maximized customer satisfaction parallelly with cost minimization which is naturally and most of the cases is contradictionary.

The higher level we complete needs of our customers the more resource is needed, meanwhile output of costout activities are also frequently ended up with decreased service level [2]. However over the exchanges transportation activities and solutions impact some other certaion processes of the supply chain and the related strategic and operational decisions [6, 7].

1.1. Various challenges in planning

As the member of the European Union – although market has also expanded – companies have to face with a significantly increased level of competition which requires continuous optimization in the entire supply chain process.Of course, it is valid globally for all the players of the market – the longer and more complex is the transportation route, the planning process has more challenges and tasks. Unpredictable demand is a long-standing,

[1] PhD student, University of Miskolc, Institute of Logistics, Hungary
adel.szabo1@gmail.com
[2] university professor, University of Miskolc, Institute of Logistics, Hungary
altilles@uni-miskolc.hu
[3] PhD, University of Miskolc, Institute of Logistics, Hungary
altagota@uni-miskolc.hu

constant issue for the most companies which has just been further strengthen by the past events and the pandemic challenges. Below list includes some challenges of supply and distribution tasks but not limited to:

- Decreased ordering lots, parallelly increased frequency in deliveries.
- Time windows for loading are getting tighter based on customer's requiements.
- Quality requiements are increased significantly and continuously, meanwhile regulations are changing constantly.
- A positive trend but parallelly an issue to-be-solved is the regulations of employment of the drivers – companies face with these HR and logistics-related trends: strict respection of working hours is not only a nice-to-have but an important and prior safety aspect.
- A basic and constantly existing requirement of all the market players to reduce average cycle time (from point of order till the handover to customer).

In summary, count and impact of challenges related to planning, cost of resources and competition level is in increasing trend, while required cycle time decreased – need for improved service level is bigger than ever.

1.2. Types and specifics of routes and the operative methods of route planning

Cost minimization is a basic and prior expectation about logistic route planning. To be able to achieve significant improvements there are multiple operational and strategic factors to be considered. In fact there are two options to meet it: decreasing the necessary delivery performance or optimization of the fleet utilization. Operational route planning can support in planning of the proper round, while as a strategic task localization of the sites is a key priority. With appropriate provessional background and experience planning can meet a great cost-saving achievement, however if the aim is to approximate the optimum route there is a need for relevant mathematical methodologies and computerised planning.

The route itself means the sum of the total delivery distances completed from the loading point of the vehicle till unloading the cargo – including loaded and "empty" running of the truck. In road transport the below basic route-types can be determined – in fact these exist in majority of the transport methods:

1.2.1. Simple route (line route): in case of forwarding between two points, illustrated on Figure 1.

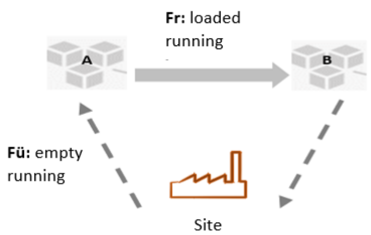

Figure 1. Simple route. Source: own editing

Based on simple route capacity utilization can be calculated according to below, we need to determine these factors:

F_r - loaded running
$F_ü$ - empty running
G - carrying capacity
Q - goods quantity

From these above we can calculate accordingly:

- Total vehicle running: $F = F_r + \sum F_ü$
- Running utilization: $f = F_r / F$
- Forwarding performance: $Á = F_r \cdot Q$
- Loading performance: $R = F \cdot G$
- Capacity utilization: $k = Á_{tkm} / R_{tkm}$

1.2.2. Round route: multiple points are touched during the route. In case of *delivery tour* we unload the goods at multiple points while in case of *collecting route* the opposite happens: we collect the cargo from multiple places and ship to the destination. In case of *mixed route* delivery and collection is managed in one round, possibly on different loading and unloading points according to Figure 2.

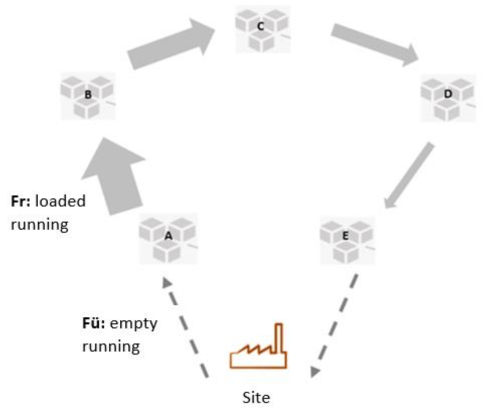

Figure 2. Round route. Source: own editing

Based on round route capacity utilization can be calculated according to below, we need to determine these factors:

N - count of rounds
s - delivery distance
Q_i - quantity shipped in round 'i'

From these above we can calculate accordingly:

- Total vehicle running: $F = \sum F_r + \sum F_ü$
- Running utilization: $f = \sum F_r / F$
- Forwarding performance: $Á = \sum F_{ri} \cdot Q_i$
- Loading performance: $R = F \cdot G$
- Capacity utilization: $k = Á_{tkm} / R_{tkm}$

Within round routes there are futher types to be differentiated based on relatins of the delivery points and routes. One vehicle can complete multiple routes within the way of leaving and arriving to the site, these are the so called routes. *Shuttle route* happens when rounds are planned in the same sequence based on Figure 3.

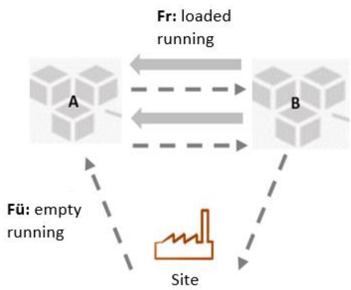

Figure 3. Shuttle route. Source: own editing

From these above we can calculate accordingly:

- Total vehicle running: $F = \sum F_r + \sum F_ü$
- Running utilization: $f = \sum F_r / F$
- Forwarding performance: $Á = N \cdot s \cdot Q_i$
- Loading performance: $R = [(2 \cdot N - 1) \cdot s + \sum F_ü] \cdot G$

When rounds are planned in different sequence routes are called *multi-round routes* according to Figure 4. First round is the delivery route, touching three stops. Second round is the collecting route, also completing three stops, followed by the line route back to the site. Planning tasks like these above are complex ones, where cost-saving can be achieved solely with effective organization.

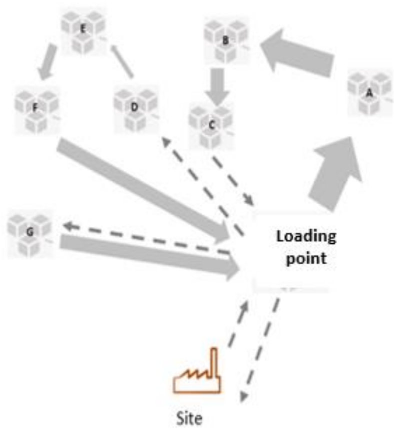

Figure 4. Multi-round route. Source: own editing

In case of *satellite* routes we are talking about round routes inserted into additional round routes. As it is illustrated on Figure 5 there is a delivery route started from the pickup point which unloads good at points A…F, while loads additional cargo at point C which is delivered to point F. At points E and F there are also goods collected and transported to pickup point.

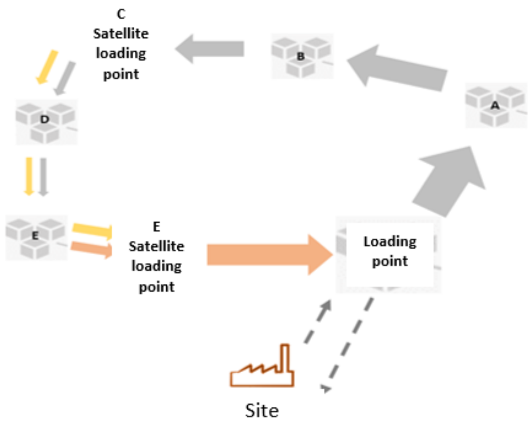

Figure 5. Satellite route. Source: own editing

1.2.3. Combined route: in case of combined routes simple round deliveries are connected to each other completed in sequence, where unloading point of the vehicle is not matching the first pickup point. It is clearly visible on Figure 6. that after completion of the round delivery the truck does not get back to the site but picks up cargo at point D which is put on point E. With the help of these routes there are empty routes saved, to be able to achieve there are certain conditions needed to be met.

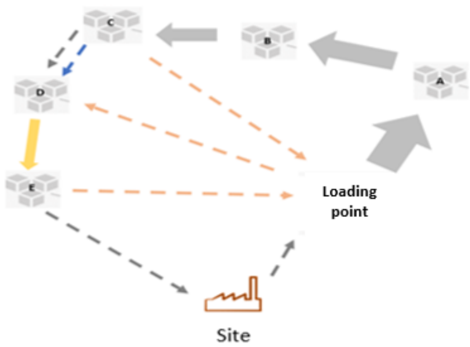

Figure 6. Combined route. Source: own editing

2. ALGORITHMS USED IN ROUTE PLANNING

Manual route planning methodologies introduced in above are less popular in these days. With the widespred of digitization computer-supported planning becomes the basic process – having increased importance and attention. For the task of the route planning itself there are multiple algorithms, as the part of the software determining the output delivery route of a certain cargo. This might happen with the socalled *session* routing, when a new calculation is run in every new incoming planning task or with the other way: *forwarding.* This second one means that planning is managed based on the previously determined routes. In case of forwarding the program just picks up one from the existing outgoing possibilities. Whether it is session routing or forwarding the algorithm has to meet some certain requirements summarized on Figure 7. These are the below: [8]

- *Exactness and simplicity,* which are self-explanatory.
- *Robustness,* this requirement ensures that users can work with the given systems properly and reliably in case of operating with greater networks. During the usage there might need certain maintenance activities for both the software and hardware elements, refreshment of topological or master data – all these required to happen without any delay or issue in the daily operation.
- *Stability,* is also an essential and basic clause in case of an algorithm. Independently from the running period it is required to keep the balance, namely the fix route set.
- *Justiceship and effectiveness.* although these are obvious but in many of the cases contradictory purposes. Global effectiveness and individual relations are often require compromise. Before making any decision about these above it is inevitable to determine the exact purpose of the optimation. If we prefer to increase the effectiveness of the network traffic then we need to minimize the package delays and maximize the throughput which are obviously conflicting. So we need to find the opportunities which are able to improve comprehensively, but considering the smaller part-goals of the complete system.

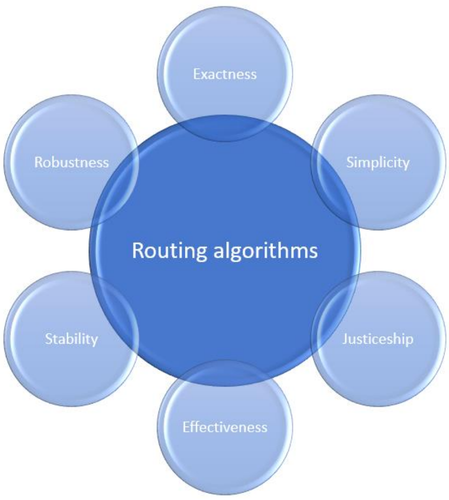

Figure 7. Requirements of Routing algorithms. Source: own editing

Based on their basic operation routing algorithms can be classified into two basic groups. *Non-adaptive* algorithms calculate offline, namely not based on realtime measurements or estimations based on traffic or topology. Since this static type of planning is not able to react effectively for errors or bugs can be used in cases where matter of route selection is evident. The other portion is the *adaptive algoritms* which corrugate route planning decisions based on the current topological, traffic-related events or changes. Due to this these are also known as *dynamic* route planning method. Source of information for planning is based on local data, which is the basis of the decisions about any change. Decisions cover the timing of route changes (based on topology change or in some certain period) and metrics of optimization (i.e. based on distance, processing time or number of jumps). There is a general direction, independently from topology or traffic data: if the route planner is on the optimum way of a route between two points then the optimum way between the route planner and the ending point is going to fit onto that same route. This is the *principal of optimality* which ensures that optimum routes directed from certain sources to the given goal creates a tree. These trees are called sink tree, which are not necessarily unique, there might be multiple variants with the same distance. Purpose of the routing algorithm is to discover these sink trees and use them for the route planning activities.

2.1. Types of route-selection methodologies

As it was mentioned above algoritmhs has two basic way of the decision making during planning: based on topology and traffic data.

Amongst topologic algorithms these below are the most important.

- *Planning based on shortest route:* this, basically simple way of planning, provides the complete picture of the road network based on calculating the optimal routes of the task. Graph of the network in this case contains nodes (giving the route selections also) and edges (giving the data connecton). This logic simply searches the shortes route amongst the nodes within the graph. Under ‘shortes route’ we might have multiple interpretations, so need to include in calculation some additional edge-weights like distance, bandwith, traffic, communicational cost, linelenght, delays, etc. Based on the combination of these factors the shortes or fastest optimum route is calculated by the program. There are several algorithms known and used for this type of calculation, one of the most popular is Dijkstra’s, which is detailed in the article later.
- *Flooding:* in this case there is no available information or map about the entire network, decisions are made by the route selector based on local knowledge. Actually the point of the methodology is to send every single incoming cargo on any outgoing route except the one it arrived in. This is resulted in several duplications, so there are some restrictions needed to be implemented – i.e. with jump-counters, which supports to set the distance of the route from the souce till the endpoint or with registering the packages to prevent duplications. In majority of the planning purposes this methodology is not practical but there are some options where this is the most productive way, such as like data spreading. Besides this the system is very robust, helping minimalization of the necessary pre-settings and ensures finding some path in case of elimination of some possible routes. Flooding can be used as the basis of some other algorithms which are much effective but require more maintenance and settings. Since it selects always the shortest path causes the less delay in the process.
- *Distance vector-based routing:* basis of the methodology is that there is a known shortest distance and the indentifier or the proper route for every goal – these are listed and maintained in a spreadsheet. These spreadsheets are refreshed based on the information-exchange with the nearest neighbours so the routers always have the

latest and greatest data to the goal-adresses. The data itself is the preferred routing line to the goal-address and the estimated distance of the route. If the router knows the distance to the neighbours calculation can be completed for all of them and the best estimation can be selected for the planning.

- *Connection-based routing:* this option plans based on the connecton of the process steps run by the routers and delivers the complete topology to all the routers. Optimum route is found by Dijkstra algorithm, the process is illustrated on Figure 8 in below.

Figure 8. Connecton-based routing. Source: own editing

- *Hierarchical routing:* with increasing the network the above-introduced data spreadsheets are also expanding proportionately. This extends database, the software and hardware and all the relevand resource needs. Over a certain size there is a need for a hierarchy in the route planning activity. In these cases route selectors are divided into areas in with planning is processed – huge networks require multi-level hierarchies.
- *Data spread-based routing:* in certain applications hosts have to send messages to other or all the other hosts (i.e. radio show spreading). There are multiple ways of processing, the most primitive is when the source sends separately all the packages to every single destination. It is waste of resources and requires a huge amount of master data – due to this the less preferred solution. An improved solution is the socalled multi-purposed selection, when every package contains the list of destinations which determines the count of the outgoing routes. Effectivity and utilization of the necessary resources is greatly improved with this way.
- *Multi-sending routing:* there are other applications sending packages for multiple receivers (i.e. living video broadcasts). In these cases there is a requirement to be able to determine properly the group of receivers, and this is where multi-sending routing can be a great support. This schema specifies the exact maintenance of the groups and the identification of the members. Data spread-based routing introduced above helps to send out the data packages based on the sink trees – so it is ensured that only the group members get the relevant data.
- *Any-sending routing:* with this logic the package is sent to the nearest member of the group. It is used in cases when the point is to provide the information independently to which node the information is sent to. As a supportive algorithm distance vector-based or connection-based routing is suitable for route selection.
- *Routing for moving hosts:* there is a basic and increasing need from users for network reachability from any point of the world globally. This requirement is met by the relevant algorithm - first with localization of the given hosts. The basic principle, which ensures planning in these cases is that moving hosts communicate with the "home" hosts and identified based on it.

- *Routing with ad hoc hosts:* an improved version of the moving host concept is when the route selectorsa are also in move. In these cases all the nodes consist of a host and a route selector, route discovery and maintenance is managed in continuous steps according to Figure 8.

Beside topological algorithms an other important logic and aspect of classification is the traffic-based programs. When there is an overload in the network productivity falls down and there is a delay in fulfilment. This state is called congestion. The most effective way of managing congestion is to decrease the load of that given delivery layer in the network, since significant or long-standing congestion can result the breakdown of the entire network. Due to this the aim is to work out a system that prevents congestion in every possible way.

It is important to mention that congestion-management differs from traffic control. While first helps the network complete the required load request, traffic control applies for the movement between the sender and the receiver: prevents faster delivery then the receiver is able to accept. However in both of the cases the way of solution is the slow-down of the operation of the hosts. Congestion-management steps are illustrated on Figure 9.

- *Maintenance:* simpliest way is to build the proper network for the transit traffic or have continuous control to be able to extend it in case of need.
- *Traffic-based route selection:* in order to maximizie capacity utilization and manage congestion personelized routes and traffic patterns can be a great way of prevention.
- *Entry validation:* if there is no option for capacity extension the only solution is to refuse new loads for the system in case of need.
- *Load elimination:* in final case cargos cannot be accomplished are eliminated – it is worth to select the packages has the greates impact on the entire system.

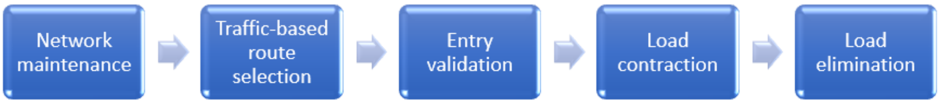

Figure 9. Solutions of congestion-management. Source: own editing

Practical examples for routing algorithms

- *Dijkstra:* one of the most common routing algorithms, named after Edsger W. Dijkstra based on a work published in 1959 [10, 11]. The operational logic of the algorithm for finding the shortest path is illustrated in Figure 10, with a brief overview examining ‘n’ points, all or some of which are connected by edges of a given length. It is assumed that there is at least one edge between two points. The basic problem is to construct a minimal cost graph of the ‘n’ vertex in which there is only one path between each vertex. These edges can be divided into three groups in the algorithm:
  - A: *Edges accepted during the procedure*.
  - B: *Edges to be selected for group A.*
  - C: *The missing edges.*

  In parallel, the vertices can be divided into two groups:

- I.: *The endpoints of the edges that are in group A.*
- II.: *Missing vertices (only one edge can lead to missing vertices)*

The procedure begins with a Group I peak and is selected from Group II peaks from the group of edges whose endpoint is in I. Initially, group A is empty. Then, by repeating the following two steps continuously, we arrive at the steps B and II. group is emptied. Finally, the edges in group A give the tree sought by the algorithm [12]. These steps are:

- 1. The shorter edge of group B is inserted into I and the shorter edge of group II. endpoint in group I.
- 2. We consider the edges that start from the vertex previously placed in group I and the vertex II. they arrive in a group. If any of these is longer than the corresponding II. in group we reject it if it is shorter then we replace it and put that edge in group B.

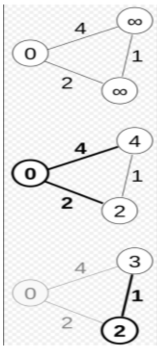

Figure 10. Running the Dijkstra algorithm on a small-sized graph [24]

- *A-star algorithm:* It was created by Bertram Raphael, Nils Nilsson and Peter Hart in 1968 and is actually an extension of the Dijkstra algorithm [12]. Due to its completeness and efficiency, it is often used in IT despite the high use of storage capacity due to the need for stored data. During the procedure, the peaks are weighted depending on the goal, and the algorithm performs a 'best first' search. Starting towards the vertex of the graph with the smallest value - the value of the vertices is obtained using an evaluation function - it looks for the cheapest path to the destination. It requires a list of elements that have already been examined and vertices that have been discovered but not visited. The 'cheapest' route to each vertex is known, as is the search graph and the start and destination. Detected nodes are sorted by the value of the vertices, so there is always the most favorable node in the first place. During the run, the algorithm first removes the node with the smallest value from the list and performs a test on it. First, we decide whether the surrounding elements have been crawled, if so (that is, they are included in the set of examined elements), then the algorithm proceeds, and for the other elements, it calculates the cost of accessing it through the given node. And if one is already on the list of discovered nodes, it also compares it to the journeys made through the current nodes. If it is not smaller than them, it is omitted from the list, and for the remaining ones, it calculates the route elements and adds them to the list. After all this is done, the current point is added to the list of discovered items and re-selects a point from the list to be discovered. This continues until the next item becomes the target or the list becomes empty. Once you have reached the target the task is completed, if it is emptied without the list it finds that there is no connection between the two points. The operation of the algorithm is shown in Figure 11.

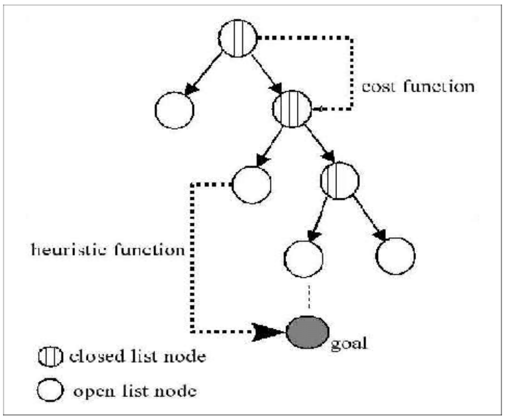

Figure 11. Operation of A-star algorithm [24]

- *Frederickson's algorithm*: developed by G.N. Frederickson based on the work of Lipton and Trajan for graphs the concept of r-divisions [16]. The algorithm breaks the graph into smaller regions and then further subregions, thus helping to solve the problem of temporal constraint, as multi-priority rows will be of more size. It actually performs the search by running the Dijkstra algorithm, but since the sub-regions are small, the search operations will not be costly either, the queuing operations will also be smaller. The operation is shown in Figure.

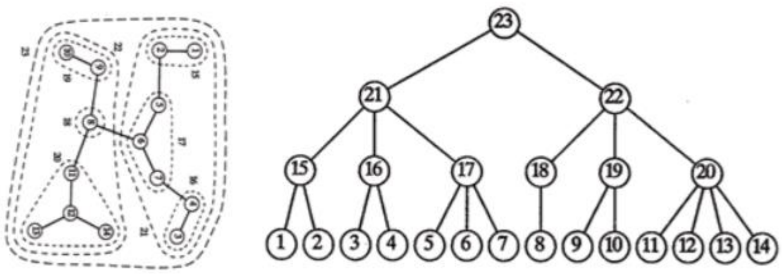

Figure 12. Logic of Frederickson's algorithm [25]

- *Improved Frederickson's algorithm:* the above method was further developed by Monika R. Henzinger, Philip Klein, Staish Rao and Sairam Subramanian, which greatly accelerated the calculation for plane graphs. For graphs with non-negative edge lengths, this gives a linear-time maximum flow solution if the origin and destination are on the same side. The program is suitable for the calculation boundaries of a planar network to be similar to the best-fitting planar bipartite graph, and to find the maximum flow if the starting and ending points of the planar graph are on different sides.

- *Genetic algorithms*: these programs are used when optimization problems arise, usually in a problem space where the problem can be described by a continuous function and the minimum or maximum of the function is sought - which means that it best fits the conditions. For this reason, the result of a run is not a specific solution peek, but a certain population of solutions that go through multiple crosses (mutations) to get the best solution to the end, the process is illustrated in Figure 13 [18]. The so-called fitness function of the algorithm determines how optimal the current solution is and the stronger it is, the more it fulfills the expected conditions - while the weaker ones are selected.

  Running the algorithm consists of the following elements
  - *Initializatino of the original population.*
  - *Evaluation of fitness functions for the initial population.*
  - *Selection.*
  - *Cross-mutation.*
  - *Calculation of fitness values of new individuals.*
  - *Placement of new individuals in the new population.*

  The algorithm runs until one of the following conditions is met:
  - *Generation limit*: the maximum number of runs of the algorithm.
  - *Maximum fitness limit*: the value where we assume the solution is appropriate.
  - *Average fitness limit:* this is used in cases we are looking for more solutions.
  - *Convergence setting:* when the results no longer improve during rerun.

  An important shortcoming of genetic algorithms is that while they are perfectly suited to searching for a global optimum, an additional heuristic solution is needed to find the exact maxima and minima within it [22].

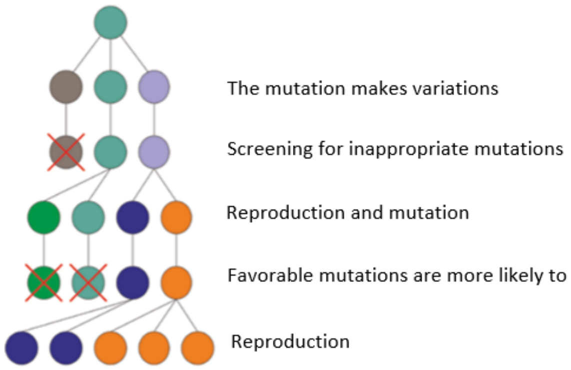

Figure 13. Operation of a genetic algorithm [25]

- *Ant colony algorithm:* the model developed by Marco Dorigo is based on the food acquisition method of ants [23]. The ants search for food on a random route, but on the way back to the flea they emit a pheromone, which, with its attractive property, makes the other ants move again in that direction when they get food. The more ants follow a given route, the more ants choose the pheromone, which is further enhanced by the proximity of the food source, as the more ants can turn on that route (Fig. 14) [24]. Projected on a route-finding task, the ants represent the transport vehicles and the route grows until all points to be visited are included in the calculation. During the operation of the algorithm, each vehicle (ant) starts from the starting point and selects the next location from the available ones depending on the vehicle capacity. The vehicle returns to the starting point when it has visited all the sites to be visited or the vehicle capacity has been reduced to 0. The algorithm increases the number of vehicles as long as all vehicles are in motion - the next vehicle can start after its first return and all ants must touch all points. The solution encourages vehicles to use the best road, but in its improved versions, it will also be possible to take into account other factors such as vehicle utilization, benefit optimization, time requirements, and so on [23, 24].

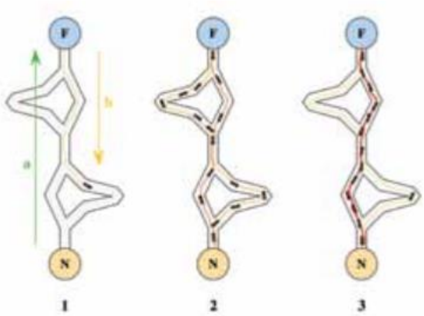

Figure 14. Operation of the Ant colony algorithm [25]

In addition to the popular logics listed above, there are countless solutions to a wide variety of problems in practice - in their final form or even under development. Special conditions require customized solutions that provide ongoing work for researchers and IT professionals in the field. Often, in addition to the above logics, a program is developed to solve a particular factor or subtask within a route planning task. Examples include implementing the logic of planning on uneven, difficult terrain, planning on the "most beautiful" line instead of the shortest route, or planning multi-day round trips. Special solutions of this kind are more complicated because it is not clear the exact division of the problem or at which stage which design method gives the optimal solution. In order for the designed system to function properly even in physical conditions, it is necessary to design and take into account additional aspects, which can be solved with the help of algorithms as part of the softwares.

2.2. Route planning and scheduling

Computer scheduling systems operating with special software are intended to solve the above-mentioned route planning problems, i.e. to improve the service and at the same time reduce the associated costs. The two concepts should not be confused - much simpler route

planning software or scheduling classification modules do not create a route schedule, the order of the points involved is determined manually with fixed routes or areas based on the territorial principle. These programs place orders for fixed tours and monitor the system for one factor: that volumes do not exceed vehicle capacity. Solutions usually do not specify the crawl order either. This is one of the simplest tasks for route planners, some of which can be used to design vehicles with adequate efficiency. For more complex needs, scheduling software, CVRS (Computered Vehicle Routing and Scheduling) must be used.
Bonyolultabb igényekhez járattervező szoftvereket, CVRS (Computerised Vehicle Routing and Scheduling) kell használni.

2.2.1 Structure, features and advantages of scheduling systems

As the name suggests, routing is only a part of Scheduling systems (JTR) - including routing processes and software - JTRs performs complex planning for the entire order book and fleet, as shown in Figure 15. The design takes into account all the factors that affect the scheduled plan - such as time and capacity constraints, product combinability, vehicle size - and provides an optimal solution for this, all visualized on a map. If necessary, any factor can be modified using an interactive program that can be connected to other corporate computer systems, making it visible to any user in the supply chain. It naturally draws attention to the consequences of interventions that may conflict with the conditions, thereby also promoting optimized design [4].

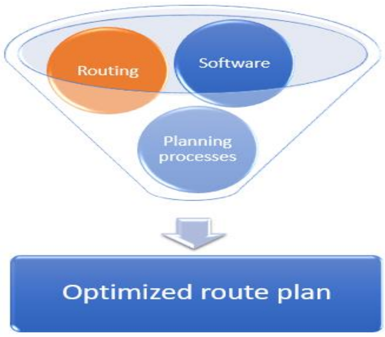

Figure 15. Basic elements of JTR systems. Source: own editing

It is important that integrated scheduling systems provide their services tailored to the needs of their users - these may include order processing, flight optimization, and performance recording and controlling tasks [3].

Accordingly, scheduling software is built on a triple unit of database, processing modules, and procedures. The database contains:

- *Customer records.* Accurate and sufficient data generation and ongoing maintenance are essential for proper system operation. Typical master data includes unique reference code, customer name, customer address, business days, business hours, loading time, vehicle acceptability, and so on. The same data apply to depots (places of issue and reception of goods), supplemented by product information, capacity data, etc. Since master data is usually generated in batches or from corporate management systems or other databases, it is very important to use the appropriate interfaces in the data transfer.

- *Topological records (road network and settlement data).* JTRs generally use high-precision, digitized vector maps, as the quality and accuracy of the map (length of sections, average speed of travel, intersections, cornering options, constraints) greatly influence the design. The longitude and latitude map points given by the coordinates greatly facilitate the subsequent expansion of the area to be supplied. The maps used usually guarantee an accuracy of 10 m, are made using GPS and contain street-level information along with attributes of traffic regulations. This allows customers and the points to be visited by the flight to be marked on the basis of precise coordinates and real-time traffic data, thus helping to optimize planning.
- *Various modifying and restrictive conditions (*such as reception times given by principals, restrictions on certain road sections, etc.).
- *Details of completed transactions,* and
- *transport requests received but not yet fulfilled.*

The most important of the processing modules are:
- *The freight demand processing module,* which settles the needs for additional modules performing scheduling by settlement. The output of this is the transport needs per reception point per settlement.
- *The map information module* models the map conditions of the geographical area to be served. In this way, routes between settlements can be determined by the target function of the minimum distance traveled (topological model), which is performed using the geographical data of the settlement list, the road network data and the input data of the customer address list.
- With the help of the *scheduling module*, the schedule plan with the best capacity utilization can be compiled – taking into account the map data and restrictive conditions. As an output, the schedule list and the related management information are displayed.

Design tasks can be divided into two major groups according to their characteristics.

Task characteristics that affect the quality of planning include, for example, whether multiple re-planning, order sharing, adding latency, target functions (shortest time, distance, cost optimization, etc.) are feasible, while the other group includes characteristics that specify what plan accurately (e.g., daily, weekly, multi-round, shift work, etc.). Systems are generally universal and can be customized depending on the users. In general, however, it is well defined which design considerations must be met, as illustrated in Figure 16 [30].

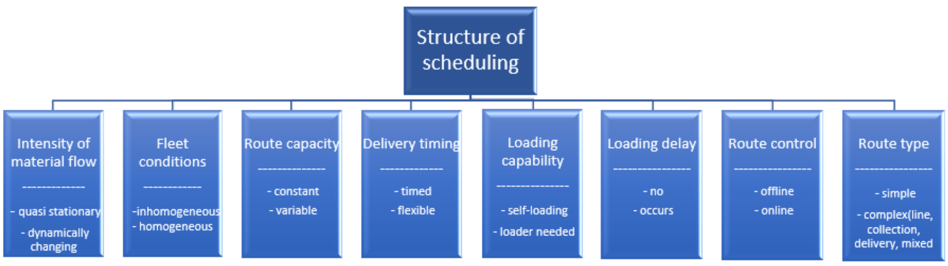

Figure 16. Basic elements of JTR systems. Source: own edition

Knowing the master and task data, the schedule plans are created automatically with the help of the systems. The more complex and comprehensive the system, the more efficient planning can be implemented with it, and the possibility of subsequent, manual correction is necessary if necessary, as numerous continuously and unpredictably changing factors play a role (number of vehicles, traffic, number of drivers, etc.)

Reports from integrated scheduling systems support many areas with either textual or visualized reporting tools.

Route-optimized timetables will be available to drivers, while routers will be able to retrieve master data from the system, as well as lists of visits to the road network - even graphically. In addition, comprehensive management decision support is provided from the information in the summary lists and the demand satisfaction lists. The process is illustrated in Figure 17.

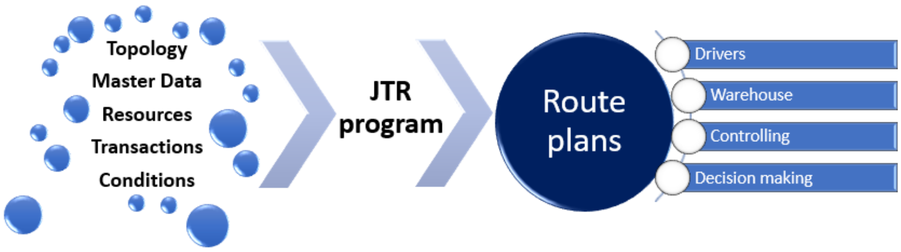

Figure 17. Planning process of JTR. Source: own edition

The range and quality of services will, of course, depend on the use of the procedures and processing modules used, and the quality of the information. More complex, multi-purpose scheduling systems perform strategic tasks in addition to day-to-day operations, such as shore optimization, new freight area analysis, or fleet management.

Significant savings can be achieved through their use - up to 15-20% cost and vehicle savings [5], based on a survey of 600 companies in the UK, which can be grouped around the following areas:

- *Improving vehicle utilization:* moderate vehicle mileage, reduced fuel consumption, reduced vehicle load capacity and improved mileage utilization, resulting in a reduced number of vehicles.
- *Improving driving conditions:* better use of work, reduced downtime, more even employment.
- *More efficient dispatcher work*: the need for planning time is greatly reduced, thus the related need for manpower is also adjusted, operational vehicle management is improved, and manual data recording is eliminated.
- *Improved service quality:* higher customer satisfaction rate, shorter order processing time, decreasing backlog,
- *Environmental aspects:* reduced road load, less harmful combustion products, less pollution.
- *Increased efficiency of warehouse processes:* longer order picking time, reduced warehouse material handling workload, more accurate flight departures due to more efficient planning.

Of course, scheduling systems can not only be used in day-to-day operations, but also support a number of tactical and strategic tasks, such as:

- *Obtaining new orders*, optimizing quotes.
- *Defining an optimized vehicle fleet* with decision making support for the number of vehicles, type composition, vehicle replacement, new assignments.
- *Providing inputs for data analysis*, such as analysis of supply patterns, examination of order time windows, cost analyzes.
- *Analysis of changes in customer requirements* and their impact on the operation, such as changes in volume, seasonality, changes in the frequency of supply.
- *Analysis of changes in regulatory requirements*, such as changes in drivers' working hours in the context of the vehicle fleet.
- If necessary*, localization of a new depot or optimize the current one.*
- *Need for cross-docking depots, optimization of current depot boundaries.*

2.2.2. Strategic aspects for the implementation of scheduling systems

Adequate volume and / or task complexity may justify the replacement of manual planning, possibly with a partially automated but not relevant program, with a scheduling program. A key issue is the ratio of resources invested to expected efficiencies, which are often quite difficult to quantify. This is especially true in the case of small and medium-sized enterprises, where there are not enough resources (time, manpower, material) to analyze and optimize the processes - even if it is a core activity of the company. If the decision is made to implement the system, it is worthwhile to complete the process through the following steps, which is shown in Figure 18.

Exploring the problem of the current scheduling process and the areas to be developed. Common problems include inaccuracy of routes, lack of performance forecasting, lack of crawl order planning, unsustainability of time windows, lack of warehouse picking planning, significant - and therefore unmanageable - quantities of returns, and exceeding vehicle employment times. Each of these is a design flaw that can be easily optimized with an appropriate, relevant program, thereby increasing the efficiency of the entire process. By identifying the deficiencies, we can determine accurately and well-defined the complexity of the required scheduling system, as well as the cost and time schedule for its implementation.

Based on the above, we can get to the next step: to select the most suitable systems to perform the specific task. Nowadays, countless companies offer endless possibilities in terms of relevant programs, in addition to cost factors, ‘customizability’, reliability, degree of collaboration, and other conditions can be important issues. It is important that the system meets the company’s prescribed requirements for the nature of the task, vehicle number, design accuracy, and so on. for.

It is advisable to run so-called demos before the final selection, with the company's own data, so under real conditions and volumes, the operation and suitability of the system for the given company can be seen. If and which system proves to be appropriate, it is worth collecting real user experiences and references, either among other businesses or their customers.

Before making a final decision, the following questions may be warranted:

- *Support,* availability of immediately available support. As a scheduling system is a complex set of complex areas, often not explored during planning, certain conditions are not considered during the planning process. Since physical processes cannot stop due to a design error, it is essential that the operator of the given system has an appropriate and sufficiently flexible support service. A very important factor, of course, is the cost implications of all of this, the farther away the reach is to be calculated at a very high cost - which often rivals implementation fees. It is important to build a strategic relationship in these collaborations so that both parties properly position and dedicate their resources and processes.

- *Frequency of system updates.* Both software and hardware need constant updating and maintenance. In this case, too, the importance of cooperation on both sides must be emphasized: from the maintenance of the program by the service provider to the updates made and required by the user, both in terms of physical and software components.
- *"Customization".* Standardization is a basic requirement for both cost-effectiveness and process interconnectivity. Nevertheless, it is often necessary to tailor the related processes and the systems that support them due to certain - not negligible - factors. If it is necessary for such a company to discuss the possibilities of this before the introduction, the issues of feasibility on the part of the service provider.
- *Training, aids.* Users of similar systems use these programs for multiple purposes, levels, and processes. There is a fundamental need on their end to have well-utilized, quick-to-learn, and immediately accessible training materials available, supporting the entire chain in real time.
- - *Data update, map accuracy, database maintainability.* Today, well-supported and continuously updated systems are in use, but it is important to clarify in advance with what investment and efficiency all the data and elements of the system can be updated.

Once the decision is made on exactly which scheduling system to choose, the next important step will be the installation and its process. This means the appointment and training of appropriate specialists, the establishment of connections (interfaces) between the system and other programs and processes, as well as the complete master data entry.

Calibration and "fine-tuning" of the design take place in parallel with the training. During this, the users get the right practice, make the feedback and redesign the individual steps and parameters if necessary.

Depending on the complexity of the systems, these are longer or shorter processes, but long-term collaboration is strategically important - in many cases essential - for user businesses.

Figure 18. Introduction process of JTR. Source: own edition

2.3. Flight planning options with "smart devices"

Of course, choosing the right logic and system alone does not mean a guarantee of optimized operation - it only provides the basics for a properly functioning system.

Numerous international and domestic software and related hardware, IoT (Internet of Things) tools are available today to implement high-tech transportation management. I would like to highlight the opportunities that can be exploited in this regard by presenting some good practices.

Considering today's intelligent logistics processes, one of the first concepts that comes to our mind is the importance of data. Technological advances create a wealth of usable data that can be analyzed to successfully develop a particular business - in almost any industry and process. The same characterizes the forwarding and scheduling activities. Large amounts of data flood the field of logistics, however their proper use and interpretation requires the utilization of advanced analytical tools. Such tools include, for example, data mining or machine learning, the usage of artificial intelligence. Not only in transparency and optimization, but also in process development, analyzation can be of great help to market participants [30]. There are numerous areas and good examples of the successful use of this data, and the list below is intended to highlight their importance without being exhaustive.

- *Forecasts:* Analyzing data from past events can be greatly helpful in identifying and responding to expected future trends. For example, many businesses struggle with the problem of seasonality, and historical data provide significant support for addressing it and developing preventive transportation strategies.
- *Scheduling with prediction models:* by digitizing capacities and optimizing deliveries, they can achieve significant efficiency gains and thus cost reductions.
- *Design support with sensors:* DHL vehicles are a good example, but the use of sensors embedded in transport vehicles is becoming more widespread. Not only are they a great help in traffic planning, with the immediate availability of route updates, but they also support, for example, the conclusion of new contracts with reliability and timeliness data. In the long run, it has not only economic but also negligible environmental effects, for example by reducing CO2 emissions. Special developments of great importance in the FMCG sector are temperature sensors in transport vehicles (including TIBA cars, for example). By being able to monitor the condition of the vehicles being transported and the traffic data, they can greatly reduce any losses in perishable products.

  Traffic safety curiosity is UPS's management, which minimizes drivers 'left-turning maneuvers in traffic - as a result of Big Data analyzes, reducing not only the chance of accidents on the roads, but also reducing mileage and increasing the number of packages delivered [30].

  A common area of application is even vehicle maintenance planning, as in-vehicle sensors provide accurate information on the current condition, details of maintenance operations to be replaced and their timing.
- *Machine learning, MI possibilities:* with the help of structured data from a constantly and dynamically changing environment, it becomes possible to simplify capacity allocation and route optimization.
- *Automation*: robotics and automation are close concepts and have the same goal: to minimize human intervention in processes. Its main advantages include cost-effectiveness in the long run, programmability and load-bearing capacity, and consistent quality of work. One of the most interesting areas of transportation is unmanned transit, i.e. drones. Several will predestine an "explosion" in the area in the coming years, and this seems to be hampered by the clarification of only a few

practical factors. At present, drone transport is carried out in four segments: retail goods, food, medical and industrial products. For each category, very important technical, social and legal conditions need to be clarified, culminating in even different levels of development in each country and region. Major U.S. companies (JD.com, Amazon, DHL), as well as African (Rwanda and Ghana Africa,) countries, Australia, Finland, Iceland, Switzerland, and some Far Eastern countries (China and Japan) are widely using drone transportation for food, medicine, medical products or various industrial products, such as automotive. Operation itself can be done in two ways: by using a drone service provider or with your own vehicles. The largest of the former are Wing, Zipline, Flytrex, Flirtey, Matternet, Volans and Antworks, while the latter include DHL, JD.com, Amazon, Walmart, Zomato and SF Express - typically postal companies or e-commerce companies. Mention should also be made of shipments within the framework of the World Food Program or UNICEF's humanitarian activities. One of the biggest difficulties with drone shipments is the lack of regulations or differences. In general, the requirement is to have the ability to fly out of sight, but the parameters and conditions of luggage transport over densely populated areas are also very important [30].

- *IoT, M2M:* the world of traceable people, vehicles and infrastructure is already available to a wide range of businesses. Smart cameras, RFID devices, connected transport devices and operators, real-time traceable packages, “smart pallets” are all designed to promote the efficiency and security of the supply chain, with countless and growing opportunities in the field [30].

The number of opportunities is endless and constantly expanding, which, thanks to globalization, can be utilized by related companies much sooner in domestic relations.

3. SUMMARY

Understanding the structure of scheduling systems and the basic algorithms that perform planning can greatly contribute to the efficient planning of the system of transport companies, as well as to the decision-making process on the strategic issues of the organization's design. Depending on the profile, more methods and systems may be available, and providing usable structure and data is key to the smooth operation of your day-to-day business. Especially in a competitive market environment that businesses currently face both domestically and internationally. Constantly changing, evolving technology and, at the same time, growing expectations govern the daily lives of actors, where investments in various tools and methods require strategic decisions and expenditures on the end of businesses. Development is rapid and high, which is not only desirable but also essential for survival.

In shipping, intelligent solutions are evolving and becoming widespread, which can further increase both competitive advantage and the risk factors associated with costs - so it is important to strategically plan for these and examine compatibility with our existing system.

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