PLANNING OF RAIL FREIGHT UNIT TRAIN OPERATION IN THE LIBERALIZED ENVIRONMENT – INSTRUMENT FOR DYNAMIC ASSIGNMENT OF PATHS ON RAILWAY NETWORK

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Abstract: Reliability, speed and accuracy of transport according to customer needs is an essential aspect that affects the competitiveness of rail freight transportation. All resources used for planning, assuring and realization of individual transport are limited. The basis is that all operations must be planned, because it is the best way, how to provide service as required by customers with the least possible use of the capacity of the resources and also does not overload them. This paper considers the problem of improving short-term train path planning and operation path management that the ad hoc assignment of train path to the definite trainset operating under real-time information and automated assigning system. The proposed instrument performs dynamic assignment of ad hoc request for train running to appropriate train path through a fast and efficient solution procedure based on the assigning algorithm. The instrument reduce time for path assignment and enable to dispatchers use more time on solving real-time operational problems caused by disruptions. The procedure has been tested on real-life data from one of the major railroads in Central Europe.

Keywords: rail freight transport, planning, path assignment, train operating company, infrastructure manager.

1. Introduction

Railway transport is a dynamic system. The train operating company (TOC) must fill the conditions on the goods transport market. On the other hand, the TOC must satisfy the customers demand as much as possible. Creation of the train path is based on the customer requirements.
Unfortunately, the assignation of train path is an elemental limitation in the planning of freight train running. This is done by the fact that train path creation and assignment is not in the TOC competence, but infrastructure manager. Moreover, there is a long-term plan of assigned capacities of train paths being created one year before the timetable regular construction. This plan is needed to be abided as much as possible, because the train paths were already paid by TOC. There is a high potential of risk for TOC, that it won´t be possible to get another train path (the ad hoc train path) due to quality reasons or no capacity available. Last but not least the ad hoc train paths are more expensive than regularly constructed train path, what affects the final price.
This document is focused on problematics of ad hoc straight unit trains. In the past, this problem was not being solved much, for example due to prioritizing of operational problems with the shipments. Customer´s requirements is not always possible to provide by trains from the regular timetable or train formation diagram. There are various influencing factors, like for example the arrival of the ship, technology of production, etc. Some of shipments are organized only few times per year, so it´s not possible to create the train path in regular construction for them. Also there are shipments, which are being organized without future plan, so it´s impossible to predict the real organization time. In some destinations, there is not possible to create the paths for regular timetable construction due to loss of orders, what again causes increased demand for ad-hoc paths.
As already mentioned, the current trend is customer oriented behaviour, where the train path plan is being adjusted based on the customer wish. There is a risk, that if the train paths were ordered as regular ones, it might cause sanctions for operator due to non-used/refused capacity, or wasting of the other capacities. All the cases of transport demand, which is not possible to be solved by regular trains, are planned ad hoc, as mentioned below:

- Unit trains, not mentioned in regular timetable.
- Unit trains, mentioned in regular timetable, with ride planned per demand.
- Late regular trains.
- Trains, which are operating delivery of shipments above the regular timetable and train formation diagram. (Internal document ČD Cargo, 2013)

In first and last mentioned case, the planning process works like below. First, client has to create order of transport, resp. ad hoc train. This kind of order client has to send current time before the estimated/demanded departure of train. After that order is being handled via system for long-term trace planning. If it´s not possible to handle the ad hoc order in the current scope, the order is returned back to the client and he is offered another operative solution. The order of ad hoc train has to include the starting and final destination details, sender and final recipient data, information about all transport operators, who will handle the shipment, borders crossing stations of the path, also information about length and weight of the train, goods, estimated time of handing/departure/arrival of shipment

and moreover important characteristics about shipment (for example dangerous goods). Ad hoc trains are being aligned in order of importance after the regular trains. (Internal document ČD Cargo, 2013)
The aim of this document is to find the algorithm for ad hoc path assignation. The algorithm will be used in the operational planning for satisfying of customer demands or internal parts of TOC's.
Every train, which is not using the year regular timetable or any other timetable, is ad hoc train. A train which for example is using another timetable is a regular train whose timetable is scheduled 14 days before the drive, and in this period there is no other change of the timetable or planned capacities.

2. Problem definition

The rail cargo operator, who provides wide network of current wagon load and also unit trains, which are connected via system, has in the environment of liberalised market take care about ordering of train paths and their using. In time of renaissance of rail transport is not possible to apply process, used in the past, when ad hoc trains were being handled only by experience and knowledge of dispatchers. It is necessary to find systematic and efficient solution for using of ordered, but useless paths. It is necessary to minimize infrastructure costs for TOC.

3. Analysis of railway infrastructure charge

The railway infrastructure managers must deal with several factors that affect the assignment of the train route capacity. Those factors are:

- overload of the key infrastructure segments;
- global increasing amount of trains in the whole system;
- growing amount of passenger trains in the peak times;
- decreasing stability of the rail transport sector;
- increasing length of the transport lines, which causes higher variance of train paths;
- requirement for a more precise cost division of the provided services.

Some railway infrastructure managers have decided to change the system for calculating the transport infrastructure using cost. They have also decided to introduce a system with incentives and sanctions for regular using, or not using of the ordered services. (SŽDC, 2016) Those steps have a direct impact on the TOC's. The cost of the train running in the Czech Republic contains two basic parts. The calculation formula is:

$$C_c = C_{pk} + C_{pd} \tag{1}$$

Cpk is a cost of assignment of capacity (train paths assignment)
Cpd is a cost of using the infrastructure

The price of assignment of capacity is calculated by the formula:

$$C_{pk} = K_1 + K_2 \cdot L + K_3 \cdot D \tag{2}$$

K_1 is a price of proceeding and assigning of train path and assigning of infrastructure capacity
K_2 is a price of train route compilation
K_3 is a price related with the day of assignment of train path
L is a length of train path
D is an amount of days which the train path is assigned

The price depends on the submission time of the application, resp. on the length of time between the submission and the time of the train running. Despite the fact, that the core of this paper are ad hoc trains, it is necessary to calculate with non-used train paths planned regularly. (SŽDC, 2016) It is no doubt that is a necessary solve all tree infrastructure tariff parts.
The second part is a price of using railway network. The price Cpd is calculated:

$$C_{pd} = L \cdot Z \cdot K \cdot P_X \cdot S_1 \cdot S_2 \tag{3}$$

Cpd is a cost of using the infrastructure
L is a length of train path
Z is basic price
K is coefficient of the railway line category of the (regional, mainline)
Px is product factor (train categories)
S1 and S2 are specific factors (weight, ETCS (European Train Control System) equipped vehicle)
In case of S2 factor fulfilling by the train, the carrier gets 10 % discount from the Cpd.

If the train path will not be used, the infrastructure manager charge penalty for non-usage. This penalty is charged by the formula:

$$F = T \cdot L \tag{4}$$

F is penalty for non-used infrastructure
T is a sanction index (the level on this sanction is depend on the individual line and their using)
Larger TOC uses planning tool for planning and ordering of train paths use. This system usually allows to edit own train paths, modelling of the train runs and impact of modelled steps. (Oltis Group, 2017d)
In the process of train path planning is necessary to use data stored in databases – for example data about infrastructure, another trains, lockouts, goods flows, locomotives, etc. Thanks to the link in the system is possible to deal with every feature. The results can be tested immediately. The program can calculate financial cost deviations from proposed technology. (Oltis Group, 2017b)

Table 1

Inputs and Outputs of the information system for freight train operating company

Inputs	Outputs
Data about railway network	Freight transport timetable
Data about trains and locomotives	Matrix of relation for train formation
Archive data about goods flows	Data for managing of marshalling yards
Lockout plans	Plan of the freight trains composition
	The lockout orders
	Orders for the Infrastructure Manager System

Source: Authors with (Oltis Group, 2017b)

In context of the operational work planning for unit trains, the result are trains paths. These train paths are edited by the capability of the transport infrastructure capacity. The infrastructure capacity is ordered by the infrastructure manager system. (Oltis Group, 2017d) The result is complex background data from rail timetable for other systems used by another TOC's and infrastructure manager.
System approach methods and logic methods (analysis and synthesis) have been used for fulfilling the main objective of the paper. System approach in management tries to achieve application of functional analysis concept and application of general systems theory in management. It is characterized by complex view of objective reality that is assessed as a multi-dimensional organized unit. The contribution of this approach is based on inner relations management system analysis, in acceptance of importance of both mutual influences of inner factors and interaction of the system with its environment. (Habr, 1972)

4. Discussion

In this chapter algorithm **for assigning the train path to the railway infrastructure** is described. This algorithm chooses the most appropriate path between available paths (ordered paths in regular timetable) or between available paths and ad hoc (new) path. The algorithm could be used in the short time planning and operative control of train running. The algorithm completes the totally missing element in the planning of freight railway transport and assignment (and management) of infrastructure capacity (especially in the Czech Republic).
The input data for algorithm are:

- ordered paths of individual freight trains,
- time possibilities of available train drivers, their work plan,
- available path offered by the infrastructure manager,
- routing of freight wagons,
- customer´s demand.

In the everyday railway traffic, the algorithm has to be connected with usually used information systems for TOC's and infrastructure manager. During the test, done by authors, the algorithm worked with sample data.
During the whole process of checking capacity of railway infrastructure, the algorithm works with the paths database, which contains paths ordered by the TOC and available ad hoc paths. At the end of the process demands on paths are placed into relevant databases.
The algorithm in the TOC's information systems structure and infrastructure manager information systems structure is on the figure 1.

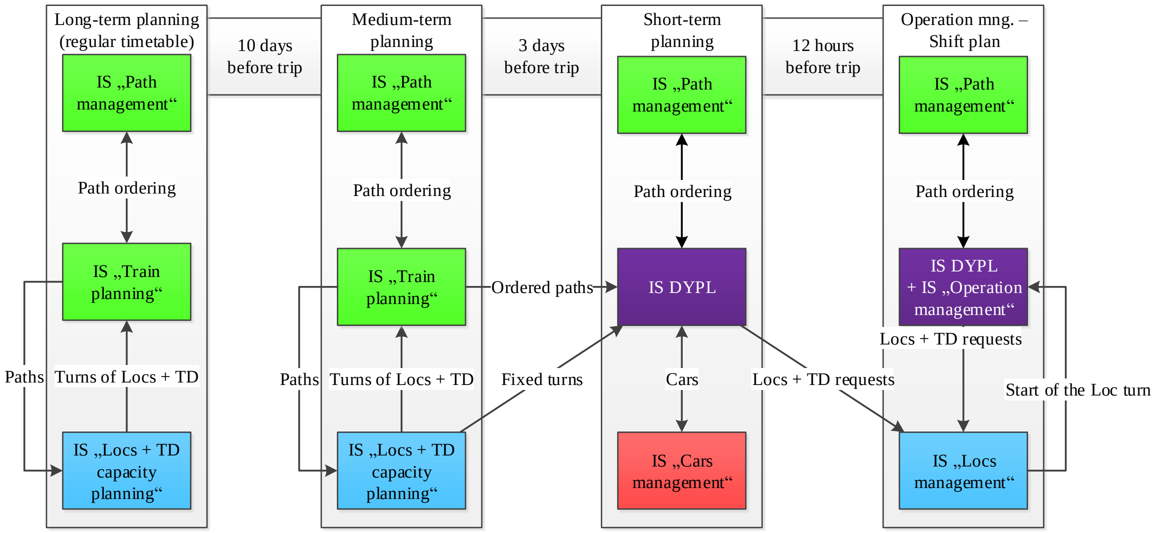

Fig. 1.
Structure of information systems used for train operation planning
Source: authors

The aim of the algorithm is to lay principles for further research on the management optimization of available resources whose are planned in the long term. Those resources have to be listed with the real facts that occur at any time between the entry of the train request into the TOC's planning systems and the output which is a scheduled train in the infrastructure manager's operational control system. For each individual train path, the algorithm will provide basic capability possibilities, then planning of infrastructure capacities and assignment of specific capacities on the railway infrastructure. For example, if there will be a request to secure ad-hoc path from starting point A to a destination B (over a period of more than 1 month), a departure at x and an arrival at x + t, the system will find solution for that situation based on predetermined criteria. The all of new incoming transport requirements will take in account the options that will be defined from the previous planned shipment including in the timetable.
The purpose function $f(x) = min$
Due to the fact, that pattern we are interested in is composed of variable parts, there will be a new pattern, which will work in the same time like a minimization function.

$$C_{c\ opt} = K_1 + K_3 \cdot D + L \cdot Z \cdot K \cdot P_X \cdot S_1 \cdot S_2 + T \cdot L \tag{4}$$

where:
K_1 is a price of proceed and assign of train path and assign of infrastructure capacity
K_3 is a price related with the day of assignment of train path
D is a number of path using days
P_x is product factor (train categories)
Z is a basic price
K is coefficient reflecting the category of railway line (regional, mainline)
L is a length of train path
T is a penalty for non-used infrastructure
S_1 and S_2 are specific factors (weight, ETCS equipped vehicle).

Limitations:
Analyse of requirement on the transport services and available infrastructure capacity. The requirements like system inputs are variable by the character and location of origin. The proposed deal with the three basic types of input requirement (figure 2).

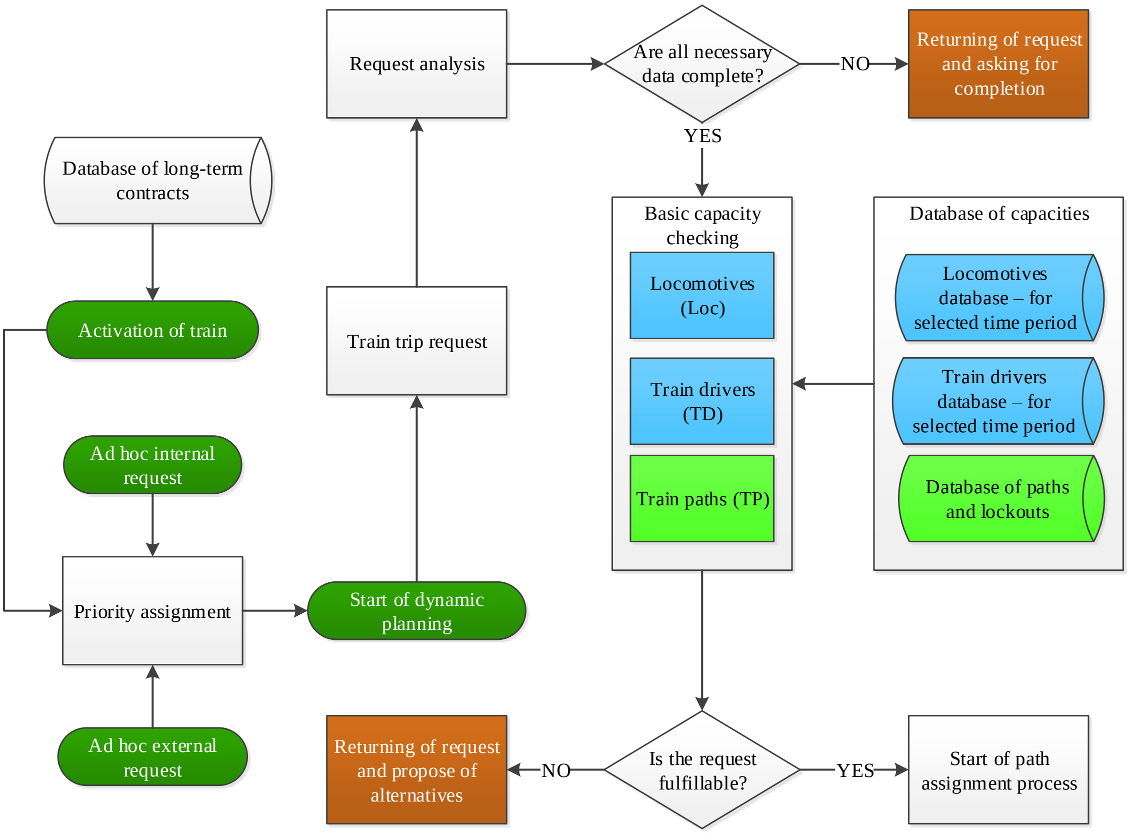

Fig. 2.
Scheme of request analysis and inputs
Source: authors

The first is a requirement that should be the most occurring. That requirement is a train running based on long-term plan (the regular timetable request) with unchanging dispositions and a simple assignment of already scheduled capacities to the given train path. After activation of the long-term requirement (assuming that it is a long-term contract and customer will inform on time, when it will be proceeded), the algorithm is entered in the system. This category also includes regular (daily or almost daily) trains. The creation of train run according to the optimally planned capacities has a direct link to the quantification and assignment of the real costs to a solution for the individual specific business. The assignment of cost will be made on the outputs from the current TOC's operational management information system or another information system.
The second requirement is internal. It could be e.g. the requirement to transport empty wagons to the loading station or the requirement of the TOC's train run for their own use.
The third requirement is a random one-time or random repeated request for transport services (ad-hoc train request).
Individual requests gain assigned priority based on customer information. Priority assignment is not the goal of this paper. On the other hand, it is necessary to present it here, as they will be determined by the customers and by their requirement of transport importance and by train categories.
Between important factors for priority determination belong:

- international train path on the rail freight corridor (RFC),
- another international train path,
- customer requirement on the Just in Time carriage,
- train paths ensure carriage of single load wagons service.

RFC are currently pushing carriers to improve the accuracy of trains running on freight corridors. In specific cases is possible to change the priority of trains. Trains carrying single wagon loads between marshaling yards have to get extra care because the delay of such a train affects to the transport times and the regularity of the operation of next trains.
The first step in the infrastructure capacity solution is paths sorting according to transport type. The instrument load the ordered paths from the relevant database. In the next step, the algorithm tries to find a most appropriate path. The first criterion is using of suitable paths for the definite carriage type. If the carriage consists the single load wagons or groups of wagons for which it is possible to use the route dedicated for the single load wagons

services, the path is used. By this process paths that are generally suitable for another type of transport are excluded (figure 3). There remains a review of common freight train paths where a specific product factor is not used.

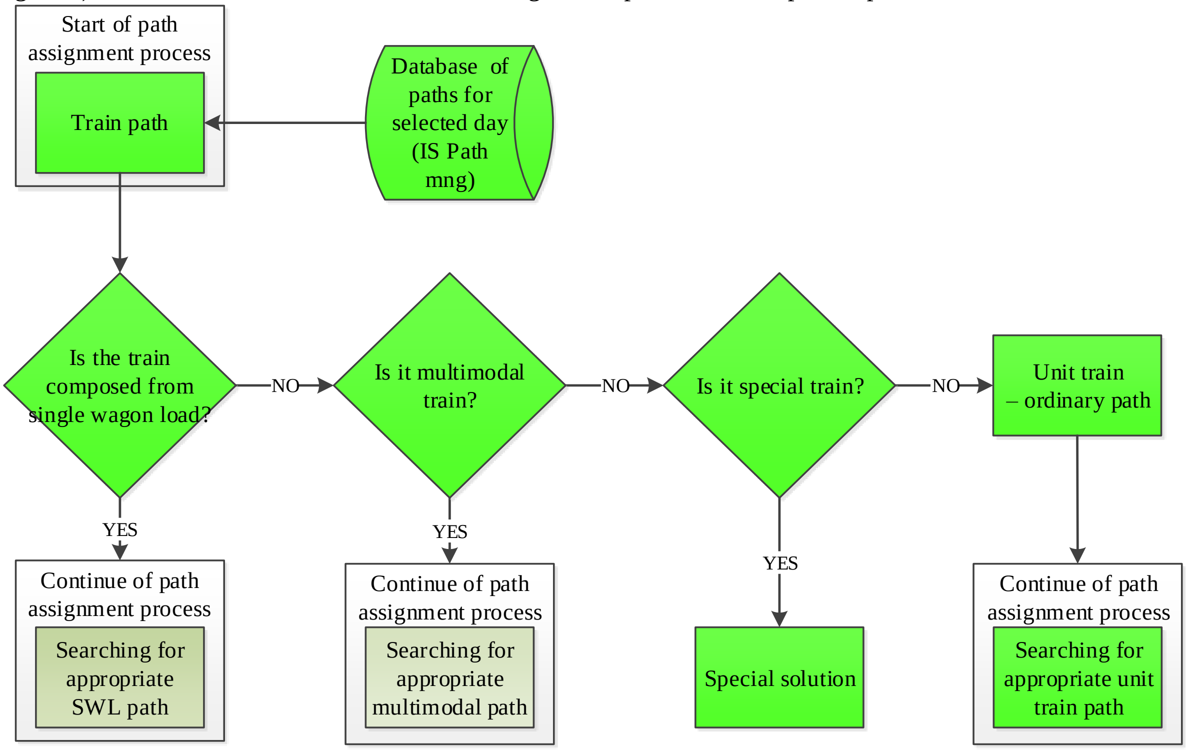

Fig. 3.
Scheme of choosing appropriate assignment process according to products factors
Source: authors

The instrument has been developed mainly as a solution of the process of service provided for unit customer trains without specific features because almost of this type of train are running ad hoc. The freight transport without specific features is a current term of product factor in the price model, which is focused on the trade segment (in this case it means, that it is not passenger transport, single wagon loads or unstandart trains). This case is the most basic one from group of cases with usual unit customer train. The unit customer train is a usual product for propose which is specified in this paper. It checks to see if train path is in the database of ordered paths. If such a path exists, the algorithm assigns that path to a particular train running and after the assignment of the locomotive and the train driver sends a request for activation of the path to the Infrastructure Manager's information system. It is shown in figure 4.
If the algorithm finds the proper path, the algorithm still works. It searching the path with product factor for a usual freight train. The algorithm does not consider the possible combination of the paths and this will be the further scientific activity.
If a suitable train path is found, the path will be assigned and activated as is described in the previous paragraph. If will not be found the proper path with suitable product factor, the algorithm start to find in another product factors (product factors for single load wagon, etc.). If a suitable path is found, a change of parameters (change of the product factor) of the path. This change is realized through the infrastructure manager's information system which ensured in the following process. It includes assigning a route for a given path and then activating the path. (figure 4).

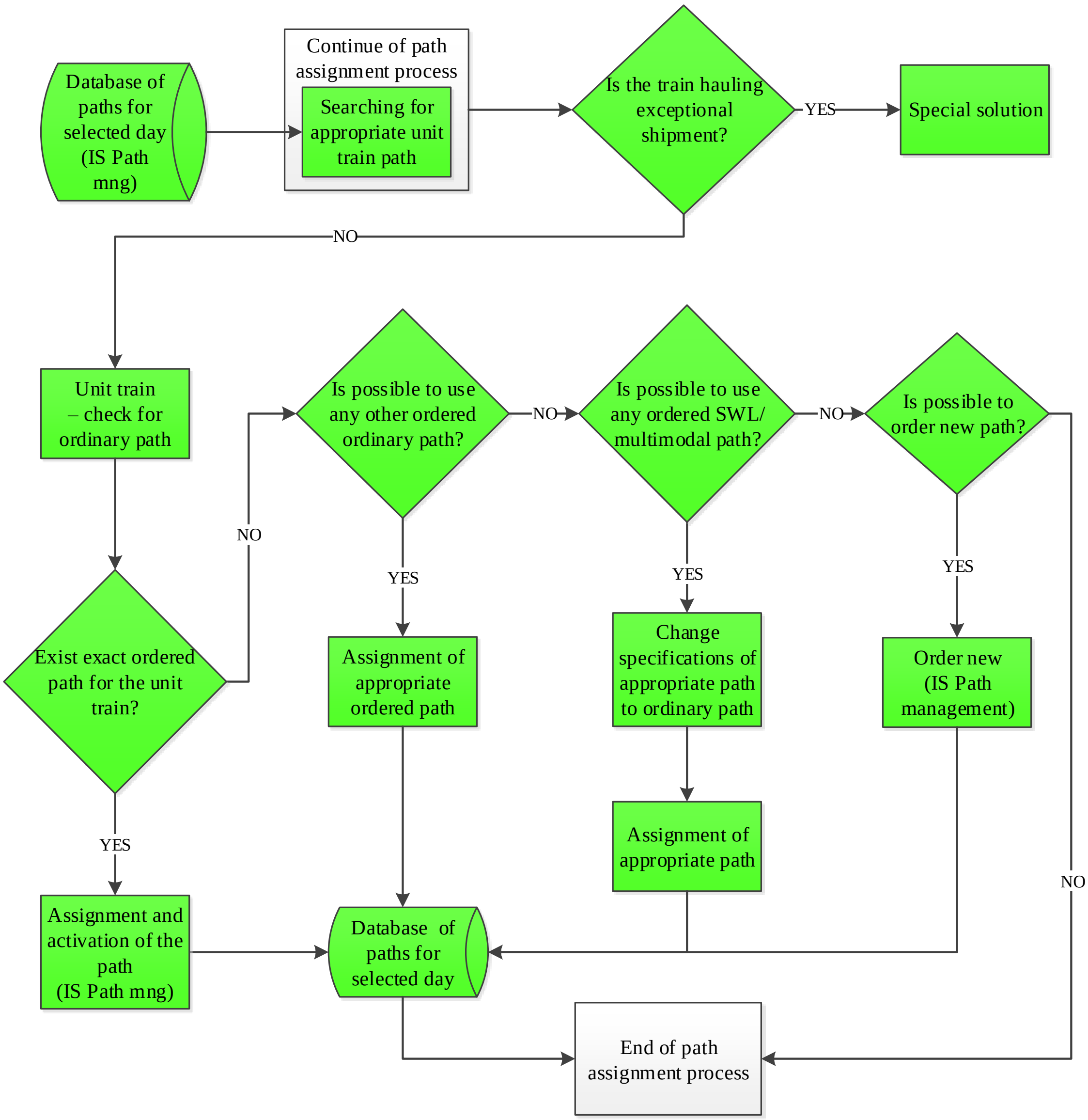

Fig. 4.
Scheme of ensuring train path for ad hoc ordinary unit train
Source: authors

If the path request cannot be accepted, the algorithm uses to the last step, what means sending a request to the Infrastructure Manager's information system to order ad hoc train path. The process of sending a request to ad hoc path is supposed to be used in marginal cases. In the demands for train running, where train path for single loaded wagons is ordered or multimodal train is used the algorithm, too. The specifics of the process are in the different product factor. The process of searching for suitable paths is running similar. In the end of the algorithm the possibility to use specific factors related with ETCS is checked. If the used locomotive is equipped by the ETCS, the specific factor S2 is used (figure 5). If the used locomotive is equipped by the ETCS, the specific factor S2 is used.

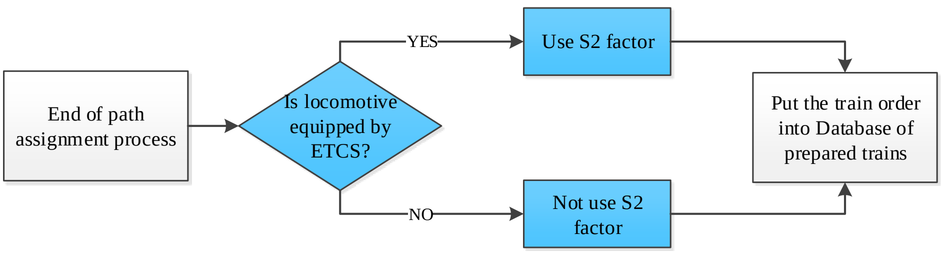

Fig. 5.
Scheme of using ETCS factor
Source: authors

5. Conclusion

The necessity to increase quality, punctuality and efficiency of freight railroad transport on one hand and competitiveness and effort to increase customer service including time flexibility on the other hand put even more pressure on planners and dispatchers. Modern real-time information systems are able to remove routine work in the short-term planning and operational management and simplify the preparation of ad hoc trains running. In this paper is considered the path assignment problem and proposed procedure that allows under real-time information automated assigning of the train paths. The proposed instrument performs dynamic assignment of ad hoc request for train running to appropriate train path through a fast and efficient solution procedure based on the assigning algorithm. The algorithm enables higher utilization of ordered paths. On base of information from customers is possible to reassign the capacities of the sources e. g. locomotives and drives. The capacities that are not at that time assigned are released into the database for other utilization. The procedure has been tested on real-life data from one of the major railroads in Central Europe. Generally, the procedure enables the maximum utilization of train paths and due to that is increasing the efficiency of whole railway system.

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