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Innovative Methods of Improving Train Formation in Freight Transport

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***Abstract*—**The paper is focused on the operational model for transport the single wagon consignments on railway network by using two different models of train formation. The paper gives an overview of possibilities of improving the quality of transport services. Paper deals with two models used in problematic of train formatting - time continuously and time discrete. By applying these models in practice, the transport company can guarantee a higher quality of service and expect increasing of transport performance. The models are also applicable into others transport networks. The models supplement a theoretical problem of train formation by new ways of looking to affecting the organization of wagon flows.

Keywords—Train formation, wagon flows, marshalling yard, railway technology.

I. Introduction

EUROPEAN Commission and government of European countries declared in the many official documents aim to shift part of the volume of freight transport from road to railway [1]. This change should occur in particular to decrease pollution, reduce road fatal accidents, and eliminate congestion on the road network in metropolitan areas. One of the possibility, how to fulfill EU transport policy goals is improving the flexibility and quality of services provided by railway cargo operators in the transport services segment of single wagon consignments [2]. It is necessary that for this purpose create the right conditions and get back lost customers by offering innovative services. However, the providing of services does not mean an automatic change of the volume of freight transport from road to rail. It needs to change the whole technological process, so that the service should be acceptable for the operators from the perspective of the customer for acceptable cost.

The significant share of the overall quality of transport services in the railway sector also provides the technology of movements of wagons from the loading station to the unloading station [3]-[5]. The variability of transport by rail infrastructure is very extensive and it´s not effectively move each wagon separately. Significantly affect to the technology of movement the formation of freight trains.

Train formation is an integrated part of the disciplines of rail traffic operations. As is apparent from the term the subject of train formation is organization of wagon flows in freight transport [5], [6]. Problematic of train formation is theoretically challenging and highly extensive.

Output of the train formation problem is to preparing the plan of train formation, which is one of the most important documents for the management of network operational processes in rail freight transport.

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II. Subject of Train Formation

Selection of quality characters which was realized in accordance with algorithm as in Fig. 1. After detailed findings and search was this scheme used as so called map of quality planning, because quality planning underway continue in these systematic steps. There were defined six basic characters of quality in the research information, availability, reality, flexibility, customer care, understanding and knowledge of customers Transport technology can be improved by two ways. The first method is aimed on innovation of technical resources that are the product of innovation in other disciplines and industries [7]. These include innovations of various construction materials in vehicles, signaling equipment and safety devices in the railway yard. The second method is focused on innovation, organization, and it controls the movements of trains and wagon flows on the transport network. Thus, modifications and technological innovation of the processes the composition of freight trains in marshalling stations.

Transport of every wagon separately between loading and unloading stations is not possible. Wagons are added to train, which systematically transport them between stations. In the loading station is wagon added to the train that will bring him to the station where they are assigned to another train. This subsequent reassignment between freight trains in the special station can be wagon reached the destination station, where is prepared for unloading. Delivery of the wagon means that the wagon is decoupled from train at the destination and stay on the designated track. That´s why the organization of formatting the freight trains and the related technology has the significant impact on the whole process of relocation of freight wagons between the loading and unloading stations.

III. The Wagons Flows

Information about wagon flows among the most important base case. Wagon flows are consisting of loaded and empty railway wagons [8]. Individual wagon flows are collected and added into train flows. Wagon flows can be generally sorted, combined, and added into different train flows. Therefore, the goal is to achieve the best combination wagon and train flows with respect the predefined conditions - so called optimal variant of train formation plan.

IV. Direction of Wagon Flows

The optimal routing of wagon flows between the stations on selected lines with respecting the restrictive conditions is appropriate to use of operations research methods, mainly the graph theory.

Routing uniquely determines the transportation path between all networks. Capacity of track section and station must be respected and also the fact that the cost of relocation carriages should be minimal [9]. There can be used for route calculation the method of graph theory or methods of operational analysis.

Let the graph, where V is a non-empty set of vertices of the graph and represents the station of railway network and H is the set of unidirectional pairs of type where the elements of H are called edges of graph G and they represent the different track sections. Graph can be edgewise evaluated when the each edge is assigned a real number c (h). Evaluation of edges may represent a numeric parameter of edge – e.g. length, capacity, cost, and others.

Assessment of graph edges is in the matrix C in which the element c (i, j) is the valuation of edges connecting vertices i and j for all vertices. Unless there is no edge between the vertices, place it $c_{ij} = \infty$. The task is to find the minimum path between all vertices of a graph, provided that the path exists.

A suitable algorithm for solving this task is Floyd algorithm. However, in Floyd's algorithm it is considering with no restrictions. So this solution can be used to determine routing paths in perspective when the results would serve as the basis for the investment plan [10]. To solve the routing wagon flows with respect capacity of the tracks can be used modified algorithm flows with minimal cost.

V. The Comprehensive Solution of Train Formation

The train formation plan is prognostic model for determining the best organization of wagons flows to the trains. The problem is the variability of transport options of organization of wagon flows of freight trains (direction and movement from the forwarding station to the destination station) and the best combination gives the final solution.

The main idea of this model is based on a three-level hierarchical structure stations. Namely:

- stations authorized for sending cargo wagons – base station of the core network;
- satellite marshalling station (station of first train formation);
- main marshalling yards.

The station of core network belongs to the attraction area of only one satellite railway station. Each of satellite station belongs to the attraction area of only one main marshalling yard [11]. Single wagons consignments are taken from the stations of the core network by pick-up trains to the nearest satellite station or directly to marshalling yard. In the satellite station are wagons connected to the train sets from pick-up trains to the sectional trains (for transport to the main marshalling yard). The main marshalling yard forms the direct trains to other major marshalling yards to their attraction area. The advantage is reducing redeployment of wagons (max. 2) during the transport [6]. This technology reduces the average transport time of the wagon on the network. Described train formation technology can be called as a time-continuous or discrete time technology.

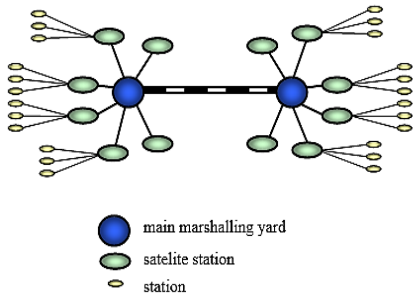

Fig. 1 The basic scheme of a three-level hierarchy of stations

VI. Innovation of the Train Formation

Next innovations of train formatting are based on improvements complex method of train formatting. The main marshalling yard create only direct single group continuously trains between all others major marshalling yards. The advantage is a smaller amount of shifting in intermediate station (max. 2), thereby reducing the average time of transportation of the wagon on the network.

Proposed technology can be applied as:

- time continuously;
- time discrete - so called night jump.

A. Time-Continuous Train Formation Technology

The model assumes full day train formation by collecting of wagons to train according norms of weight or length of train set. Criterion of optimization in model which was proposed is the average transport time of the wagon or time losses of wagon. Time loss due to simplification consist of transport time of the wagon in the sectional train between the satellite and the main marshalling yard and conversely – *t1* and the residence time of the wagon while direct train is collecting in the first major marshalling yard – *t2*. These times can be calculated by (1), (3):

$$t_1(x) = \frac{2d}{v} \quad [hours\ per\ wagon] \tag{1}$$

$$d = q\sqrt{\frac{p}{x}} \quad [\text{km}] \tag{2}$$

$$t_2(x) = \frac{24\,mx\,(x-1)}{2n} \quad [hours\ per\ wagon] \tag{3}$$

To calculate the average time loss of the wagon is used the function:

$$t(x) = t_1(x) + t_2(x) \quad [hours\ per\ wagon] \tag{4}$$

where, x -number of main marshalling yards, d - average distance of train run from the satellite to the main yard [km], v - average technical speed of train;[$km.h^{-1}$], p - area of state [km^2], q - average conversion factor square root of area attraction area of the main marshalling yard in length d, m - the average number of wagons per train running between the main marshalling yard, n - the average daily number of loaded and empty wagons moved between the main marshalling yards.

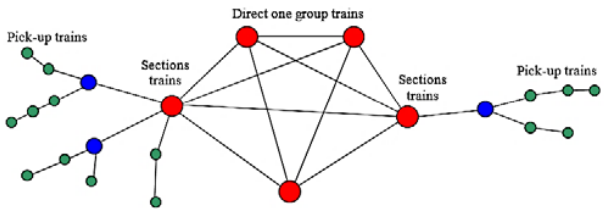

Fig. 2 Realizations of time-continuous train formation technology

The optimal number of main marshalling yards is calculated of the function:

$$t'(x) = 0 \tag{5}$$

Equation (5) cannot be solved analytically. The value of "x" can be calculated using one of the methods of numerical mathematics. When omission of the definite article can be analytically calculated initial approximate solution:

$$x_0 = \sqrt[5]{\frac{q^2 n^2 p}{576 m^2 v^2}} \tag{6}$$

The biggest problem of the model is to determine the coefficient "q". Author of the normal forms of the attraction area is recommended $q = 4$.

Designed relations are the simplification of the problem and do not include other parts of the wagon stay on the network and the capacity of the main marshalling yards.

If the network has "s" marshalling yards, each marshalling yard needs on average $\frac{(s-x)}{x}$ the sorting tracks for train formation to own satellite station and "$x - 1$" the sorting tracks for train formation to other main marshalling yards.

This model requires a large number of sorting tracks and causes an increase of delays in the collecting process.

B. Time Discrete Train Formation Technology

This model is a qualitative upgrading time-continuous train formation. It is based on the same principles, i.e. three-level hierarchy stations, one-way transport service, and creation of one group direct trains between all main marshalling yards.

Trains are created and runs only for a limited period during the day with compliance with timetables. This condition is based on customer requirements for the implementation of goods manipulations in daylight hours on working days.

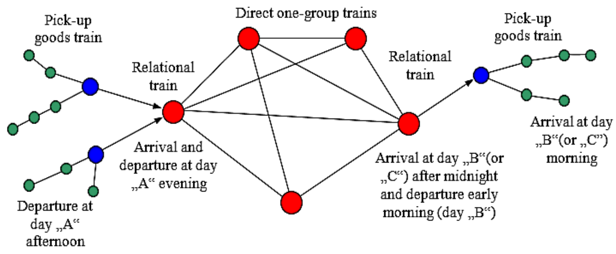

Fig. 3 Implementation of time-discrete train formation technology

After loading the goods to wagons in the afternoon of the first day (day "A") are wagons transported to the nearest main marshalling yard via satellite stations. Subsequently, it starts processing the target sets of trains and creation of direct one-group trains to all other main marshalling yards. These trains leave the marshalling yard in the evening hours. Wagons are collected separately according the target station in the own attraction area. They await the arrival of trains from other major marshalling yards. Processes in main marshalling yard during night hours are just focused on sorting wagons whose destination station in the attraction area of the marshalling yard.

The next day (day "B") for longer distant relations, exceptionally, on the third day (day "C"), from midnight come for sorting the one group train to the main marshalling yard from other major marshalling yards. Their wagons pass through to sectional trains to the satellite station or pick-up trains for stations of the core network. Activities in main marshalling yards finish after leaving the trains until late afternoon. In the satellite stations the trains are divided to distribution trains to operate the stations of the core network. These wagons are transported to their destination station in the morning. The benefits of time discrete train formation:

- Shortening the period of transport according necessary technological time;
- Reducing the transport time of wagon - loading in the day "A", unloading in the day "B" (exceptionally day "C");
- Delivery of goods within logistic technology "just in time";
- Optimization of the rotations locomotives;
- Temporal separation of passenger and freight transport on railway network;
- High productivity of workers operating in the marshalling yard concentrated in the night hours, while the day-time activities marshalling yards are minimized and use of operational staff is minimal;
- During daylight, hours can be realized the repairs and maintenance of equipment in the marshalling yards.

VII. Application of Proposal Technology

Application of proposal technology used three type of railway station: main marshalling station (MMS), satellite stations (SS) and intermediate stations (IS). For the fulfilment of preconditions of availability of any station in the service area of the MMS will consider max. three hours according to the proposed timetable. After that, the framework timetable would be as follows:

- Collection of wagons from the first IS to SS- 1.5h;
- Operation in SS - 1.5h;
- Collection of wagons in the first MMS- 1h;
- Operation in the first MMS - 3h;
- Transport to the in the last MMS - 7h;
- Operation in the last MMS - 3h;
- Delivery wagons from last MMS - 1h;
- Operation in SS - 1.5h;
- Delivery wagons from SS to IS - 1.5h;
- Total: 21h

Timetable is based on the following assumptions: average speed of the pick-up train to SS is 30 km/h average speed of relational train to MMS is 60 km/h the average speed of a direct one group train between MMS is 60 km/h. Service time in MMS means the time from the arrival of the last final train before the departure of the last direct train.

VIII. Conclusion

Notwithstanding the guaranteed support railway by funding European Union is necessary that railway undertakings provide competitive transport services like other kinds of transport.

The method of optimization single wagon loads by use a time-discrete model of train formation offers solutions for infrastructure manager and operators. This model represents one of the possible ways to meet the development strategy of the European Community's railways. By applying this model in practice can railway operator, which offer transport of single wagon consignments guarantee a higher quality of service and then expect an increase in performance. The model is also applicable for other network systems.

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References

[1] Camaj, J., Dolinayova, A., Lalinska, J., Bariak, M.: The Technological Problem of Simulation of the Logistics Centre. IN: ICLT 2015: 17th International Conference on Logistics and Transportation on April, 8-9, 2015 at Dubai, UAE. World Academy of Science, Engineering and Technology, International Science Index, Economics and Management Engineering, eISSN: 1307-6892, p. 2613-2617.

[2] Camaj J., Masek, J.: The Train Formation as Important Tool for Increasing the Freight Transport Services. In: Horizons of Railway Transport. Scientific papers. - ISSN 1338-287X. - Vol. 2, No. 1 (2011), p. 27-32.

[3] Camaj, J., Lalinska, J., Masek, J.: Simulations of Continental Logistics Centre from the Perspective of Technologist. IN: ICIMSA 2014 International Conference on Industrial Engineering, Management Science and Applications 2014. Proceeding book of conference. Beijing: IEEE, 2014. p. 305-308. ISBN 978-1-4799-6541-0.

[4] Camaj,J., Lalinska, J., Masek, J.: The Management of Assessment and Allocation of Marshalling Yards and Designation Their Catchment Areas. IN: ICIMSA 2015 International Conference on Industrial Engineering, Management Science and Applications 2015. Proceeding book. Tokyo.

[5] Camaj J., Dolinayova, A.: The Organization of the Wagon Flows with Respect to the Economic Criteria of Railways Companies. In: LOGI 2011: 12th International Scientific Conference, November 24th, 2011 in Pardubice. Czech Republic - ISBN 978-80-263-0094-6. p. 140-148.

[6] Camaj J., Masek, J.: Location of Marshalling Yards as Basic Problem for Time Discreet Train Formation. In: Horizons of Railway Transport 2011. International Scientific Conference: Terchová, Slovak Republic, September 29th and 30th, 2011. – ISBN 978-80-554-0426-4. - p. 36-42.

[7] Camaj J., Gasparik J.: Railway Station Evaluation for Systematic Train Forming on the Railway Network. In: Scientific Papers of the University of Pardubice, Series B – The Jan Perner Transport Faculty 14 (2008) ISSN 1211-6610. p. 257-263.

[8] Camaj J.: Optimization of Train Formation on Transport Network. Dissertation Theses. University of Zilina, Faculty of Operation and Economics of Transport and Communications. p. 107 s.

[9] Cerny J: The Capacity Problems of Marshalling Yard for Time-Discrete Time Formation. IN: Vědecko technicky zborník ČD No. 10, Czech Republic: Praha: General Department of Czech Railways. 2000. ISSN 1214-9047.

[10] Dolinayová A. et al. (2014).The Impact of the Railway Freight Transport Market Liberalisation on the Social Transport Costs. VEGA Agency by the Project 1/0701/14, Running Report.

[11] Kendra M.; Lalinska J., Camaj, J.: Optimization of Transport and Logistics Processes by Simulation. In: ISTEC: 3rd International Science, Technology and Engineering Conference, December 13-14-15, 2012, Dubai, United Arab Emirates (UAE). - ISSN 2116-7383. - p. 886-892.