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# PREDICTION OF FUTURE PASSENGER INTENSITY ASSIGNING IN THE DIRECTIONS AND TIME SLOTS

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## Abstract

This paper is focused on the prediction of passenger intensity on the Ostrava – Valasske Mezirici railway line in Moravian-Silesian Region, Czech Republic. The paper analyses available transport data about passenger behaviour. Data describes assigning passengers to appropriate directions and time slots in detail, emphasis is placed on daily and weekly variation of travel demand. Based on the provided travel behaviour researches, a model of assigning passenger intensity was designed. Travel surveys and available data sources from realized infrastructure studies were used. The prediction is harmonized with local specific conditions and proceeds from travel behaviour in previous years. The obtained assigning of passenger demand was exploited when designing a new operating concept for the suburban rail in the area. A model composition of the vehicle units and the frequency of connections in the respective sessions were suggested based on the obtained data.

*Keywords: passenger transport, travel demand, transport supply, suburban railway transport, variation of transport demand*

## 1 Introduction

The solved area is located in the Czech Republic, in the Moravian-Silesian Region. The task of predicting future passenger intensity was solved for the track No. 323 between cities Ostrava and Valasske Mezirici.
There is a planned modernization of the line and introduction of a new operating concept. A significant qualitative improvement of transport services is expected compared to the current situation. For the purpose of track modernization, a feasibility study was carried out, which included a framework model based on frame numbers and estimates for the future. The transport model does not provide sufficient input to prepare the operational concept, in particular the data for determining the number of routes per hour and the capacity of the trains.
As inputs for the design of the operational concept, it is necessary to know the demand for transport in individual hours, the distribution of demand into the relevant track sections and the sources and destinations of the trips. Based on these decisions, it is possible to assess the introduction of another transport segment, i.e. fast trains connecting important sessions. Finally, it is desirable to consider the variation in transport demand during the day, week and year. All calculations are essential for the design capacity and the required number of multiple units needed to ensure the operational concept.

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## 2 Methods

### 2.1 Current movement of passengers

#### 2.1.1 Origin-destination matrix for stations

The starting point of the prediction of the future development of the number of passengers is the analysis of the current situation which will serve as an input to this prediction. For a comprehensive picture of the existing transport relations, authors drew on various publicly available sources, whose data were put into context as far as possible. It is important to take into consideration that the authors do not have a comprehensive transport model, which doesn‘t exist for this area, but only fragments. They do not have exact current data on the number of passengers on trains either, as obtaining this data is demanding.
Data from the National Population and Housing Census (2011) [1] were taken into account to determine daily commuting. All municipalities in the reasonably considered neighborhood of each station were taken into account. This allows the authors to create a origin-destination matrix. However, it is not possible to determine a modal split from the census [2]. The authors prepared a procedure for making a qualified estimate, which consists in assessing the attractiveness of the connection for the major transport modes for the purpose of determining the modal split. The attractiveness of the connection by individual car transport, the possibility of using the bus service (frequency of connection, travel time, average walking distance) and the possibility of using the railway transport (frequency of connection, travel time, average walking distance) were assessed. The result was a qualified estimate of modal split for regional rail transport for all pairs origin-destination municipality of the assessed municipalities [3].
The product of an absolute number of trips in the origin-destination matrix for each relation and the coefficient corresponding to the modal split of the regional rail transport in the given relation we get the potential in rail transport for the given relation. Subsequently, the potentials in rail transport from the origin-destination matrix were assigned to the network. A station usually includes data for more than one municipality because it provides services to several municipalities. On the other hand, there is no case on the track No. 323 where there is more than one station in one municipality. The result of this procedure is the origin-destination matrix for stations containing the potentials of relations between them.

#### 2.1.2 Daily variation of passengers

The demand for transport is uneven at certain times of the day. The course of demand for transport within one day is expressed by a curve, which is defined as a daily demand variation. The actual course depends on many factors, the most important ones are usually the type of day (workday / weekend), the daily routine of the region and local customs and specifics [4].
The daily routine is often based on the type of municipality. Nowadays, small municipalities are not the centre of the inhabitant‘s life because of sub-urbanization. They are mostly used frequently for overnight stay. The morning trip to bigger towns and the afternoon return predominate. There are also medium-sized towns where the citizens of small municipalities commute, but at the same time the citizens of these cities commute to larger cities. Passengers from small municipalities approximately correspond to the number of passengers from these towns. The last category include the core cities of the agglomeration or centers of the metropolitan area, where dominate commuting from the surroundings in the morning and coming back in the afternoon [5].

#### 2.1.3 Weekly variation and other influences

At present, there is a relatively significant share of trips on weekends and public holidays. The Beskydy Mountains, which is an important local touristic region, can be considered the main destination of the trips. Tourists at weekends with favorable weather use the track No. 323 mostly in the opposite direction than on working days. The number of passengers on Saturdays is often higher than on a working day, the section between Frydek-Mistek and Frydlant nad Ostravici is used tens of percent higher. Another influence on weekly variation is week-long commuting to schools in more distant destinations, which is the most apparent on Friday afternoons and Sunday afternoons, but with comparison to every day commuters it has a marginal affect on predicted demand (in this case) [6].

### 2.2 Future movement of passengers

#### 2.2.1 Growth coefficient for stations

The authors utilized variations described in Section 2.1. for the determination of the number of passengers per day. Recent data due was not available at this time due to limited availability. The load values from "Beskydy" feasibility study [7] were compared with the diploma thesis [8] and other censuses carried out in the following years and were subsequently standardized because a constant decrease in the number of passengers was identified over the years. Subsequently, the standardized number of passengers corresponds to the year 2010, from which the most valid dataset comes from.

Furthermore, the authors used relevant data for the period after the modernization of the track No. 323. These data come from the study [7] and describe passenger section load after the completion of the track modernization. The period after modernization corresponds to the year 2025. These data are available to the authors only in the form of loading of individual sections, therefore it is necessary to perform the conversion below.

On the basis of these data, an increase in the number of passengers at the relevant stations and adjacent sections was determined. The calculation was performed according to the following eqn (1).

$$k = \frac{z_{2025}}{z_{2010}} \qquad (1)$$

where k is the coefficient of the passenger number growth, $z_{2025}$ expresses the predicted passanger section load according to the transport model for 2025 after the modernization and $z_{2010}$ expresses the standartized passenger section load according to 2010.

Using the eqn (2), the values for the estimated movements (boardings and gettings off) at all stations were received.

$$p_{2025} = p_{2010} \frac{(k_p + k_n)}{2} \qquad (2)$$

where $p_{2025}$ expresses the predicted passenger movements at station in 2025, $p_{2010}$ expresses the passenger movements at station in 2010, $k_p$ represents the passenger growth coefficient immediately preceding the assessed station and $k_n$ represents the passenger growth coefficient immediately following the assessed station [9].

#### 2.2.2 Number of passengers per hour and direction

Based on the passenger data at individual stations on the track No. 323 and data describing the section load, it is possible to determine the estimated demand for transport for the given direction and specific hour. For the allocation of passengers to the network, data on the daily variation of passengers at the station was used, divided into individual directions and their movements (boardings / gettings off) [10]. The result of this procedure is an indication of the number of passengers for each hour, their direction of travel and movement (boarding / getting off) at the station. After assigning the values of the anticipated demand for transport to the respective direction and hour, the obtained values were aggregated and tables with the expected section load in the respective direction and hour could be compiled. The validation of the section load was carried out in the vicinity of important nodes Frydek-Mistek and Frydlant nad Ostravici. The verification was carried out on data obtained during the field survey carried out in April 2019.

# 3 Results

By applying the procedures described in the Section 2, the authors gradually reached the expected output – the number of passengers load in each section for a given hour and direction. Partial outputs are presented below.

## 3.1 Current origin-destination matrix output

Table 1 shows the station potentials for the respective directions to the initial or terminal station of the track. Looking at Table 1 on the obtained slope coefficients, it is clear that boarding passengers predominate in the direction to Ostrava, the direction to Valasske Mezirici is less preferred. The endstations of the monitored section have potentials of 1 in the appropriate direction, since it is an entry into the solved area and other travel relations in the node are not considered. For the stations Frydek-Mistek and Frydlant nad Ostravici, data from the authors‘ survey was used as a validation of predicted data.

**Table 1** Proportion to directions per station (section Ostrava – Frydlant n. O.)

| Station | Total number of commuters [-] | proportion to direction Valasske Mezirici [-] | proportion to direction Ostrava [-] |
|---|---|---|---|
| Ostrava-Kuncice | - | 1,00 | 0,00 |
| Vratimov | 351 | 0,28 | 0,72 |
| Paskov | 226 | 0,40 | 0,60 |
| Liskovec u Frydku | 82 | 0,62 | 0,38 |
| Frydek-Mistek | 887 | 0,33 | 0,67 |
| Baska | 266 | 0,15 | 0,85 |
| Przno | 108 | 0,21 | 0,79 |
| Frydlant n. Ostr. | 468 | 0,11 | 0,89 |

## 3.2 Comparison of daily variations

A daily variation of passenger movements at the stations Paskov and Frydek-Mistek was prepared to determine the actual course of the curve. The Paskov station represents a station near a small municipality, the Frydek-Mistek station represents a station in a medium-sized town. The available data on the 2011 and 2014 from Paskov Census and in 2019 from authors‘ survey were used ror Paskov Station. For Frydek-Mistek Station the data on the 2019 from authors‘ survey were used [6]. All surveys took place on an average workday in the middle of the week, with an emphasis on the passengers‘ boarding and getting out the trains and their assignment to directions.

The rules described in Section 2.1.2 in the above cases were applied. The suburbanization trends and the prevalence of morning commuting to larger cities are apparent from the Paskov station data and balanced boarding and gettings off confirm the rule for medium-sized towns in the case of the Frydek-Mistek station. When comparing the daily variations at the stations Paskov and Frydek-Mstek, it can be concluded that the variations are comparable.
The daily variation of passenger movements for the Paskov station was applied to stations connected with small and daily variations of passenger movements for stations Frydek-Mistek and Frydlant nad Ostravicí were applied for stations in larger settlements, where similar development of the number of passengers is expected and commuting from surrounding municipalities is noticeable.

## 3.3 Future movement of passengers

The method described in Section 2.2 was applied for the determination of future passenger movements. Based on the data of passengers movements at stations and data describing the load of track sections, it was possible to determine the estimated travel demand for the given direction and specific hour. For each station, passengers' boardings and gettings off have been computed. Furthermore, the direction in which the passenger is boarding or getting off has been taken into account. The existing division of passengers into directions according to Section 2.1.1 was used for routing.
The data collected from 2010 to 2019 were used for this purpose and daily variations of passenger movements were created. Subsequently, the daily variation of the respective station was applied to the absolute number of passenger movements, and values were obtained for specific hours of the average working day.

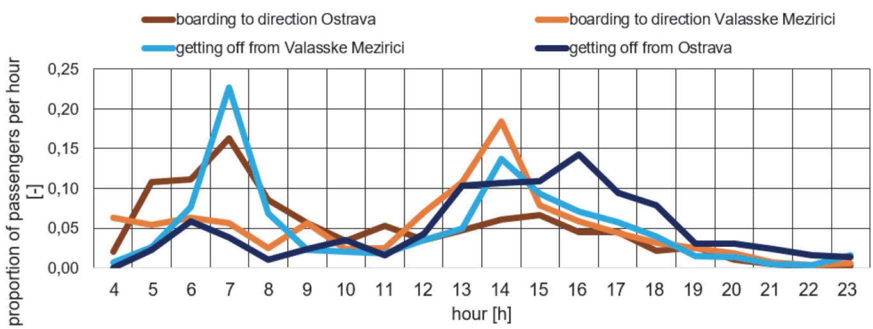


**Figure 1** Daily variation at station Frydek-Mistek – proportion to directions

Tables with an estimated number of passengers in respective directions and sections per hour were created from the data analyzed so far on transport demand by their synthesis. The validation of the section load was carried out in the vicinity of transport nodes with the quarry of transport demand, it was performed on data obtained during the authors' survey in April 2019.
Table 2 below shows the expected section load in the direction to Ostrava per hour, values are rounded up to tens. The authors are aware of some inaccuracies stemming from the insufficient volume of data obtained and the difficulty of predicting travel behavior. However, given the design horizon and feasibility study submission, a more accurate analysis is possible only on the basis of a complete transport model with significantly larger data inputs. For the purposes of designing the operational concept, timetable and vehicle circulation, it is possible to be satisfied with the values obtained and their possible deviations.

**Table 2** Expected passenger section load per hour in the direction to Ostrava

| from | to \ hour | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| Valasske Mezirici | Hostasovice | 20 | 20 | 20 | 20 | 10 | 20 | 10 | 10 | 30 |
| Hostasovice | Morkov | 20 | 20 | 20 | 20 | 10 | 20 | 10 | 10 | 30 |
| Morkov | Verovice | 30 | 30 | 30 | 30 | 20 | 20 | 10 | 10 | 30 |
| Verovice | Frenstat p. Radh. | 30 | 50 | 50 | 50 | 30 | 30 | 20 | 20 | 30 |
| Frenstat p. Radh. | Kuncice p. Ondr. | 30 | 50 | 130 | 110 | 20 | 30 | 50 | 50 | 50 |
| Kuncice p. Ondr. | Celadna | 40 | 80 | 160 | 150 | 40 | 40 | 50 | 50 | 60 |
| Celadna | Frydlant n. Ostr. | 50 | 120 | 210 | 200 | 60 | 60 | 60 | 60 | 70 |
| Frydlant n. Ostr. | Przno | 110 | 210 | 430 | 460 | 150 | 100 | 110 | 90 | 170 |
| Przno | Baska | 120 | 240 | 470 | 500 | 160 | 110 | 110 | 100 | 180 |
| Baska | Frydek-Mistek | 130 | 290 | 520 | 550 | 190 | 130 | 120 | 110 | 200 |
| Frydek-Mistek | Liskovec u Frydku | 80 | 490 | 660 | 820 | 410 | 250 | 200 | 230 | 180 |
| Liskovec u Frydku | Paskov | 80 | 500 | 670 | 850 | 410 | 250 | 190 | 230 | 170 |
| Paskov | Vratimov | 90 | 530 | 700 | 880 | 420 | 260 | 190 | 230 | 180 |
| Vratimov | Ostrava-Kuncice | 110 | 570 | 750 | 930 | 450 | 270 | 200 | 230 | 190 |

Table 2 shows the stations at which there is a significant refraction of demand for transport and a change in the frequency of the offered connections or vehicle capacity can be expected.

## 3.4 Application in operational concept designing

Table 2 shows the passenger load on each track section at the appropriate hour. This output makes it possible to determine a suitable operational concept for track No. 323. It is obvious that the utilization of the sections is variable, in the part of the track between Frenstat pod Radhostem and Valasske Mezirici the number of passengers is usually up to 50 passengers per hour and the differences between the peak and saddle hours are minimal. In this section it is about ensuring a minimal transport service, which corresponds to a one train connection hourly.

On the other hand, in the section between Frydek-Mistek and Ostrava, the estimated number of passengers is almost 1,000 passengers per hour. It is necessary to consider the capacity strengthening of the trains, as well as shortening the interval. It is also apparent from the outputs that there is a significant change in the number of passengers in Frydek-Mistek and Frydlant nad Ostravici [11]. These passengers are heading to Frydek-Mistek or Ostrava. This implies the need to introduce fast suburban trains for this large group of passengers [12]. Conversely, there is no need for such a number of trains during the saddle period. In relation to the number of passengers, it is also possible to determine the optimal train capacity, capacity coverage during the morning rush hour is crucial.

In addition, the outputs allow to determine the range of periods of the rush hour and transport saddle, the extent of periods with shorter intervals or additional train lines could be determined accordingly.

## 4 Conclusion

A prediction of future passenger intensity assigning in the directions and time slots was made for the design of the new operational concept. Passenger movements (boarding and getting off) at stations were determined from available surveys. These movements were assigned to the respective track direction using the origin-destination matrix. In accordance with the procedure described in Section 2, a daily variation was determined for each type of station.

Subsequently, the data from the current period were converted into future passenger load of track sections and stations. Demand growth coefficients for the period after the modernization were used. The decomposition was carried out in the respective directions and with respect to the daily variation of the passenger movements. Based on this decomposition, the data was aggregated and output describing the number of passengers in the directions and time slots was made.

It is possible to determine a suitable operational concept for track No. 323 on the basis of output. There are sections where a minimum range of transport service is sufficient - the hourly interval of trains. On the contrary, in the section between Frydek-Mistek and Ostrava, it is essential to carry out the capacity strengthening of trains, as well as shortening the interval. This also implies the need to introduce fast suburban trains for a large group of passengers commuting between these two cities. In relation to the number of passengers, it is also possible to determine the optimal train capacity. Operational concepts for rush hour periods and transport saddle periods can be designed.

In conclusion, the authors would like to state that there are no sophisticated considerations in Czech conditions. A design of the operational concept for the modernization or reconstruction of railway tracks is usually accomplished without a detailed analysis. As a result of this procedure, the track is often oversized for the intended operational concept or, conversely, the infrastructure is inadequate and it is not possible to introduce a sufficient number of trains.

## References


[1] Sčítání lidu, domů a bytů 2011 (ČSÚ), https://www.czso.cz/csu/sldb, 10.04.2020

[2] Kraft, S., Marada, M.: Delimitation of functional transport regions: Understanding the transport flows patterns at the micro-regional level, Geografiska Ann. Ser. B Human Geograph, 99 (2017) 1, pp. 79-93, doi: 10.1080/04353684.2017.1291741

[3] Janoš, V., Kříž, M.: Pragmatic approach in regional rail transport planning, Zeszyty Naukowe Politechniki Śląskiej, 100 (2014), pp. 35-43, doi: 10.20858/sjsutst.2018.100.4

[4] Drábek, M., Pospíšil, J.: Fluctuations in Passenger Railway Service Period, Young Transportation Engineers Conference 2018, Praha, Czech Republic, 2018, pp. 1-8

[5] Wardman, M., Lythgoe, W., Whelan, G.: Rail Passenger Demand Forecasting: Cross-Sectional Models Revisited, Research in Transportation Economics, 20 (2007), pp. 119-152, doi:10.1016/S0739-8859(07)20005-8

[6] Fridrisek, P.: New Operating Concept on the Track Ostrava - Valašské Meziříčí, master thesis, Praha, Czech Republic, 2019.

[7] Composite authors: Studie proveditelnosti Beskydy, SUDOP Brno, AF CITYPLAN, Brno, 2015.

[8] Solansky, S.: Assessment of the extent of infrastructure and its capacity on track Valašské Meziříčí - Ostrava for current and prospective operation, master thesis, Univerzita Pardubice, 2011.

[9] Pekel, E., Kara, S.S.: Passenger flow prediction based on newly adopted algorithms, Applied Artificial Intelligence, 31 (2017) 1, pp. 64-79, doi: 10.1080/08839514.2017.1296682

[10] Wang, D., Yao, E., Yang, Y., Zhang, Y.: Modeling Passenger Flow Distribution Based on Disaggregate Model for Urban Rail Transit, ed. Sun F., Hu D., Liu H.: Foundations and Practical Applications of Cognitive Systems and Information Processing, Advances in Intelligent Systems and Computing, 215 (2014)

[11] Zhu, Y.T., Wang, F.Z., Shan, X.H., Lv, X.Y.: A Model for Seat Allocation of Railway Passenger Transport Based on OD's Priority, Advanced Materials Research 2014, 989–994 (2014), doi:10.4028/www.scientific.net/amr.989-994.2344.

[12] Janoš, V., Vávra, R.: Comparison of Different Conceptions of Suburban Railway Transport, 2019 Smart City Symposium Prague, IEEE Press, New York, 2019, doi: 10.1109/SCSP.2019.8805699