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Professional paper

One Approach to Forecasting Methodology in Rail Passenger Traffic

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Abstract –**The paper presents a methodology for predicting the number of passengers on a line that is being modernized by increasing the existing speed to 160 km / h. The forecast was made for two scenarios: without project and with project. The process is complex and involves the application of correlation methods, growth rates, surveys, and heuristic forecasting models.**

Keywords –**forecast, railway, heuristics, surveys.**

I. INTRODUCTION

Forecasts or predictions are estimates of the occurrence, process, or condition that are highly likely to be expected in a given period in the future. They are based on quantitative and qualitative parameters in the past period and according to the estimation of the development of important parameters that are expected in the future. The process of making a forecast is called forecasting. The main issue with a forecast is a number of factors that affect it. Many of these are factors are sometimes difficult to assume, and even more, to estimate.

In this paper we present a methodological approach to forecasting the number of passengers on a selected section of line that will be modernized (upgrading the speed to 160 km/h (the speed is defined in the project ToR) and for two scenarios: Scenario 1 (S1) without project and (S2) with project. The process itself is complex and involves the application of correlation methods [1], growth rates [1] and heuristic forecasting models [1,2].

II. FORECASTING METHODOLOGY

A. Forecasting approach

In many cases, forecasts are made for two or more scenarios, and their number depends on the number of variant solutions in the project. For this paper, the forecast of passenger traffic volume was prepared for two scenarios:

- Reference (baseline) scenario, representing the "*without project*" scenario, i.e. the existing condition of the railway infrastructure on is maintained. Passenger traffic forecasts in this scenario are based on the projected operating characteristics of the line.
- Scenario for modernization of the line, with newly designed technical and operational characteristics, "*with project*" scenario. In this scenario new equipment and track parameters are foreseen for speeds of 160 km/h.

B. Reference period

The selected approach in the study cover three basic periods:

- the period preceding the planned project, where the data is gathered for the data base and further analysis,
- the period during which the project is implemented,
- the period during which a project is monitored, with the aim of assessing the cost-effectiveness of the project.

The period preceding the planned project usually covers a period of 10 years with special emphasis on the last years of the observed period, depending on the availability of certain data. It is desirable, if possible, for a longer period, as well as to particularly emphasize and analyze the characteristic years in which significant trends of traffic volume movement occurred, either in the negative or in the positive direction.

The next step is to determine the project implementation period, as well as the key years of the intersection of the estimated size (number of passengers). Most often, these are five-year intervals, rarely ten-year intervals. Also, it is necessary to take into account the years in which the completing of infrastructure and other projects significant for the exploitation of the observed line (and connecting lines, significant stations, etc.) occurs. The project lifetime of railway projects usually covers a period of 30 years.

C. Development program for the railway line/network

The program of construction and modernization of the railway network is implemented in accordance with the Strategy and the Master Plan of Transport (development projects and priorities for investment in transport sector). Railway development projects are incorporated into the State Spatial Plan.

D. Basic methodology for forecasting

Given that traffic forecasts for such projects should cover a period of 30 years, and given the instability of all significant

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socio-economic indicators in the previous period, the estimation of traffic demand in the future is based on the Gross Domestic Product (GDP) growth projection, the results of the surveys conducted, as well as a number of other socio-economic parameters and indicators.

It is expected that the modernization of the railway section will help to keep the existing traffic, but also to attract part of the road transport (modal shift). Modal shift is based on an estimate of the cost of traveling by road and the cost of rail travel, from the perspective of the user. The cost of travel includes the difference in the price of transport and the travel time (results from modernization of the railway). In order to properly estimate the number of modal shift passengers, it is necessary to take into account the responses of the previously surveyed passengers and companies.The applied model for the forecast of demand in passenger traffic is based on:

- expected increase in GDP in the coming period will affect the growth of employment and population standards, which will also lead to an increase in population mobility and overall demand for transport services,
- shorter rail travel times and higher quality rail offer (organization of trains in tact mode and more trains) will lead to a passenger transport modal shift from road to rail.

It is expected that the modernization of the railway will increase the market share of rail traffic by attracting a portion from road traffic (diverted traffic).

Shifting or change in mode of transport percentage is based on an estimate of the cost of travel by road and rail, from a user perspective, where the cost of travel and travel time (after modernization) is included in the cost of travel.

The diversion of passengers from road to rail is always present when a new high-level service is created on the rail. An example in Serbia is the introduction of new diesel engine sets on the Beograd - Pancevo - Vrsac route, which has led to the transfer of passengers from bus to rail, to the extent that has led to problems in bus companies operating on this line[3].

Forecasts of passenger traffic in the scenario "without Project" is based on the projected exploitation characteristics of existing lines.

In view of the estimated demand, it is expected that in the scenario "*with project*" shorter travel time compared to road transport and organization of passenger transport as a periodic type timetable mode, with frequent departures of trains, lead to a redistribution of a part of passengers from road to rail. The assumed redistribution was determined on the basis of experience and research in the available projects and studies, and a survey of passengers at bus and train stations was conducted.

In the development of the forecasting model, a combined approach was used: quantitative (using mathematical and statistical modeling) and qualitative (using heuristic modeling: intuition, personal experience, and value system based on survey responses).The factors considered in the development of the forecast model are:

1. data on the volume of road and rail passenger traffic,
2. data on the flows of railway passengers on the specific stations (domestic, international, arrived and dispatched),
3. plan for the line modernization and construction schedule,
4. a survey of rail passengers,
5. a survey of expert opinion (by Delphi method),
6. assessment of the passengersmodal shift (alternative, ambivalent and antagonistic passengers),
7. Estimation of the socio-economic parameters for the relevant period (GDP, population, demographic data,…),
8. Average year daily traffic on the Corridor and estimated rate of modal shift of car users to rail transport.

The results of the forecast (outputs) are:OD matrices; Volume of passengers per station; Passenger traffic density.

III. HEURISTIC MODEL - SURVEYS

A. Passenger surveys

In the process of traffic planning, in addition to information on space, economy, population and transport infrastructure, an information base is created through transport research. The quality of the designed traffic solution will depend on the quality of the data collected from the real-life systems.

Passenger satisfaction surveys are conducted regularly and according to established rules. In the UK, the National Rail Passenger Survey (NRPS) has been in existence since 1999 and measures the satisfaction of passengers with different railway companies in England, Scotland and Wales [4]. The analysis of the work of all the railway companies is done, through their comparison and the satisfaction of the passengers on different routes and stations. National Rail Passenger Survey (NRPS) is used to: raise the standards of the rail industry through outreach, create an environment conducive to continuous progression (most rail companies create work plans to improve segments where results are unsatisfactory), passenger safety (priority in planning railway companies and in railway improvement activities), and by identifying substandard areas to invest in them in the future (to prioritize passenger needs).

The Rail Passenger Survey is mainly used to measure passenger satisfaction with rail services [3,4]. In this research, the survey was also used to estimate the number of passengers, and to determine the shift of passengers from road to rail. Passengers were surveyed at 10 rail and 10 bus stations on Corridor X in November and December 2019. The sample covered is large enough (over 3500 passengers) to identify statistically significant estimates of passenger satisfaction with potential shift of passengers from road to rail. The survey questions are presented in Table I.

For some types of surveys, certain questions should be allowed to have multiple answers, such as:

- Do you use any other form of transportation to reach the station?
- What do you think would be the priority for further investment in rail transport?
- What additional station services should be introduced?

For the question "What do you think would be the priority for further investment in rail transport?" more answers can be offered (e.g. increase of speeds on lines, reconstruction / revitalization of existing lines, connecting rail with other modes of traffic), and that multiple responses can be selected.

TABLE I
QUESTIONS ON THE SATISFACTION OF RAILWAY USERS

	Sex:
	Female/ Male
	Age:
	to 18 years / 18 to 30/30 to 40/40 to 50/50 to 65 / over 65
	Profession:
	full time / part time / seasonally employed / unemployed / dependent / other.
	Purpose of the journey:
	Business / School-College / Shopping / Tourism / Administration / Homecoming / Other
	How often do you use the train as a means of transportation?
	Daily / several times a week / several times a month / several times during the season / rarely / almost never
	What is the train route that you use most of the time?
	From:_____ / To: _____
	Compared to other modes of transport (bus, car, van, ...), how would you compare the cost of a train ride on the route you travel?
	More expensive by train./ Same price./ Cheaper by train. / I do not know.
	What is the total earningsin your household?
	up to 30 000 dinars / from 30 000 to 60 000 dinars / from 60,000 to 90,000 dinars / over 90,000 dinars
	Do you use any other form of transportation to get to the train station?
	Car / bus / motorcycle / bike / on foot / other transportation (comment)
0	**Do you think that the quality of the rail service on your line has increased since ….?**
	Yes, it has increased significantly. / Yes, it has increased. / It remained the same. / No, it's worse. / I do not know.
1	**Is the train timetable suitable for passengers?**
	Yes, it's much better. / Yes, he's better. / It's the same. / No, it's worse. / I do not know.
2	**What rating would you give for the regularity of train traffic?**
	Traffic without delay./Works with very little delays./Traffic with small delays. / Traffic with long delays./I do not know
3	**In your opinion, what would be the priority for further investment in passenger rail transport in your region?**
	New trains. / Increase train speed. / Electrification / Increase safety / Level crossings / Railway stations. / Other
4	**What additional services / objects in stations should be introduced?**
	New ticketing services. / New info systems / Park & Ride Facilities and services / Something else
5	**If you are not a rail user, please provide a reason.**
	Unreliable / Unfavorable timetable / High cost / Long travel time / departure and arrival delays

Some other questions may be added to indicate the criteria for choosing the mode of transport:

- If there are more alternatives / modes of transport on the route you are traveling on, by what criteria would you choose the mode of transport? This should be defined by type of travel (suburban/regional, long-distance and international).
- What quality of service is important for regional transport? (e.g. ticket price; time of travel; time of departure; comfort; reliability).
- What is important for long distance / international transportation? (e.g. ticket price; time of travel; time of departure; comfort; reliability).

It is very important that the survey has minimal number of questions, and to carefully approve and choose the questions. As defined in the survey, passengers were divided into three groups of passengers:

1. Alternative passengers: predominantly use the road transport system and sometimes existing rail system, but they will shift to rail in future (20% of these passengers in our survey).
2. Ambivalent passengers: always use the bus system and never use the existing rail system. They are potential rail passengers (in our survey approximately 63%).
3. Antagonistic passengers: use bus system, and never usetrain. They are not willing to shift to rail regardless of the service quality (17% of total number of passengers).

F. Survey of expert opinion

The basis for the *without project* case forecast was made as a quantitative forecast as it is based on the data obtained on passenger and transport.

Forecast for the case *with project* used a qualitative approach and heuristic methods forecasts. Heuristic methods allow to direct experts' intuitive opinions, to obtain quantitative characteristics and to increase the quality of prognosis. Experts opinions are given foralternatives or specialists are ranked for individual factors and results are

processed using mathematical statistics. In order to obtain the most objective evaluation of experts in forecasting heuristic methods, it is necessary to follow the following principles:

- form an expert group objectively;
- ensure independent expert judgment;
- stage the research in several rounds.

The essence of heuristic methods is to form a group of specialists capable of assessing the prospective development of passenger transport. It usually consists of selected specialists who are well acquainted with the work of the system.

In this case, we choose the Delphi technique [5] to collect expert data. Delphi Technique seeks to eliminate the negative impact of authority and preserve the positive effect of diversity in expert opinion. It consists of several steps, the first being the preparation for the survey. Then a group of questions is asked again and the answers are analyzed. The next iteration uses the results of the previous survey to ask questions in a specific way.Due to the sensitivity and accuracy of the forecast, it is necessary to formulate questions clearly and precisely. The survey was conducted on selected experts through an online form. Each expert provided basic personal information and answers to questions related to the rail passenger forecast. The number of experts should not be small in order to avoid the excessive influence of the individual opinions of the experts on the collective evaluation. However, it should not be too big to avoid losing the opinion of some experts, which is significantly different from the opinion of the majority. The sample size can be determined by using mathematical statistics over the coefficient of variation of their responses. If the general population has a normal distribution, the sample size can be determined from:

$$N = \frac{t^2 V^2}{\varepsilon^2} \tag{1}$$

where:

t – argument taken from the normal distribution table for a given probabilityα,

V – coefficient of variation;

ε – estimation error.

After processing the data and the results obtained by the Delphi method, verification and consistency of the experts' opinion on the forecast is made.

Next, the values of the forecast are compared with socio-economic characteristics as well as with the conclusions of similar projects from the previous period, as well as with other factors that have a direct impact (socio-economic development, socio-demographic development, goals and measures of transport policy and plans and measures for railway development).

Experts are required to estimate the number of passengers through a percentage reduction or increase in existing values for two time intervals. The first time horizon is the moment when the conditions are obtained for the entire line to be constructed and reconstructed. The experts were contacted directly with a request to participate in the survey, and were selected on the basis of their position, place of work and knowledge/education. The survey offered two groups of questions: the first group identifies the expert and his expertise, while the second group requires answersand experts to make a prediction of a certain parameter (Table II).

TABLE II
QUESTIONS IN THE EXPERT SURVEY

1	What job / function were you involved in: (Railway worker, manager, planner, researcher, policy maker, etc.)
2	Rate your competency, knowledge and experience? (1 min - 10 max)
3	For scenario *without project* estimate the percentage of change in the number of passengers in the next 5 years: • decrease / increase /remain by %.
4	For scenario *without project* estimate the percentage of change in the number of passengers in the next 20 years: • decrease / increase /remain by %.
5	For scenario *withproject* estimate the percentage of change in the number of passengers in the next 5 years: • decrease / increase /remain by %.
6	For scenario *without project* estimate the percentage of change in the number of passengers in the next 20 years: • decrease / increase /remain by %.
7	How would modernization and speed increase on the line (scenario *with project*) affect the number of international passenger trains in Serbia? • decrease / increase /remain by %.

F. Conclusion

The process of forecasting passenger demand is always dependent on the data available. When there is a transport model of a line or an area the forecasting model will be based on the data obtained from the model. However, if there is no available data, or the data is not of acceptable quality, the forecasting must be more complex and include both historical data and surveys, qualitative and quantitative approach. As we have presented in the paper, combination of several statistical methods should be validated and complemented with the quality survey data. Complex approach and combined analytical tools can produce the quality forecasting results even when the historical data on system behavior are not available or not complete.

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