

Increasing the mobility of University North students by improving the railway infrastructure: Case study on the Varaždin-Koprivnica route

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Abstract

The trend of an increasing number of student travellers from the University of the North, the University Centers of Koprivnica and Varaždin also affects the quality of their mobility. The mobility of student-passengers in rail passenger transport is directly related to the quality of service and the inevitable maximum safety aspect, but also to the appropriate railway infrastructure. According to the above, it is necessary to analyse the current state of transport infrastructure and propose activities to increase the mobility of student-passengers. This paper analyses the current status of student-passenger mobility in railway passenger transport, and also analyses the regional features of road and railway transport infrastructure, state road DC-2 and railway R202 Varaždin-Dalj, located between the cities of Varaždin and Koprivnica, with regard to route characteristics and infrastructure facilities. As part of the work, a survey was conducted through questionnaires, and questionnaires were completed by students-travellers of the University of the North.

Introduction

University North is the young public university in the Republic of Croatia. About 4,000 students' study in two centres, Varaždin and Koprivnica. About 1500 of them in Koprivnica, and the rest in Varaždin. About 80% of the 27 undergraduate, graduate, and doctoral programs are in the STEM field. Spatial mobility is a characteristic of today's population of students-travellers of the University North who, for the purpose of studying, travel daily to the City of Koprivnica or Varaždin. The growth and development strategy of the University North is aimed at expanding and expanding the existing study programs, which will result in higher demands of transport service users, and as a result a larger number of daily migrations between Varaždin and Koprivnica. Given this, the current situation indicates the need to create new lines and optimize existing ones, as the current situation does not meet the identified needs of service users. One of the safest modes of transport is rail transport [1], which emphasizes the need for additional investments in the development of railway infrastructure on the route Varaždin-Koprivnica. Furthermore, the analysis of the number of tickets sold during 2017 and 2018 showed an increase in the number of rail trips by 22.91%, which further indicates the need to invest and optimize this mode of transport.

Regarding the daily migration of trips to the university by different modes of transport, the trend of an increasing number of students from the University North, University Centres Koprivnica and Varaždin also affects the quality of their mobility. The mobility of student-passengers on the route Varaždin-Koprivnica may depend on the quality of service, which is reflected in the comfort of travel, travel speed, accuracy of the timetable, travel costs and the inevitable safety aspect.

Given the insufficient mobility of student-passengers of the University North on the route Varaždin-Koprivnica, it is necessary to analyse the current state of mobility of student-passengers, road and railway infrastructure – stat

road DC-2 road and railway R202, vehicles used by student-passengers on the route, and analysis of timetables and segments in railway passenger traffic.

The main goal of this paper is to show the need for the creation of new railways on the Varaždin-Koprivnica railway, as well as to show the need for investment in infrastructure to respond to growing traffic requirements.

Primary and secondary research and survey methodology

The primary goal of the research is to identify the number of students and passengers using rail transport. The main goal of the secondary research is to present current trends in the development of mobility in European cities and identify possible solutions that will increase the mobility of students and passengers on the route Varaždin-Koprivnica.

Focus on the primary and secondary research

This paper is based on a primary study in which 265 students from the University of the North participated. Respondents were selected by targeted sampling, because the main goal of the research is to prove that the current level of mobility of students of the University North and passengers who use rail transport on the route Varaždin-Koprivnica does not meet current needs.

In addition to primary research, the paper is based on secondary research that covers literary references of professional and scientific papers published in relevant databases. Moreover, the aim is to identify previous research and its results in order to point out the insufficient number of professional and scientific papers dealing with problems related to the quality of transport service provision and the optimization of current railway infrastructure capacities.

Following the primary research, the results of secondary research related to the analysis of road and railway infrastructure were presented in order to show the real situation and determine the potentials for improving the transport service through infrastructure improvements and related superstructures.

2.2. Primary research - Survey methodology of the Mobility of Students and Passengers on the Varaždin – Koprivnica Route

The research was conducted by surveying students of the University of the North, through a survey form, users of rail passenger transport, on the route Varaždin-Koprivnica, and the final procedure of electronic data processing in the table Excell operating system Microsoft Office.

2.2.1. Questionnaire

In order to determine the current situation and current needs for passenger transport on the route Varaždin-Koprivnica, a primary survey was conducted on a sample of 265 respondents. The questionnaire consisted of questions aimed at identifying the most commonly used modes of transport, assessing the safety of a particular mode of transport, assessing satisfaction with the technology available in passenger trains running on the route Varaždin-Koprivnica, comfort of such trains and questions focused on user opinions related to the need for additional by investing in infrastructure.

2.2.2. Survey analysis

When asked which mode of transport students used on the route Varaždin-Koprivnica, 53.33% of students answered that they used the train as a means of transport, while 46.67% of students used a car for transport, which is shown in Chart 1.

This indicates to the greater attractiveness of public transport in the eyes of students in relation to the use of cars, and can be interpreted by subsidizing public transport for students, which significantly reduces the cost of using a car.



Chart 1. Modes of student transport for travelling on the Varaždin-Koprivnica route

Source: created by the author

When asked from the aspect of safety which mode of transport is more acceptable for travel to the university on the route Varaždin-Koprivnica (see Chart 2), 86.67% of respondents stated that the railway method is more acceptable for transport compared to car use, while 13.33% of respondents considered a car safer than rail transport.

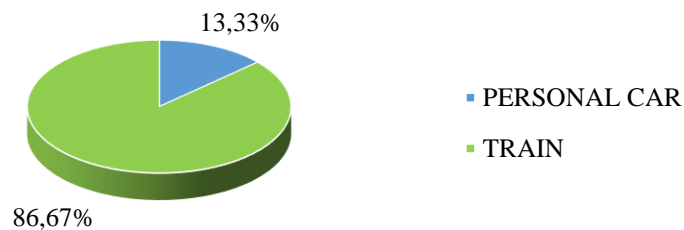


Chart 2. The most acceptable transport mode from the safety aspect

Source: created by the author

When it comes to the quality of rail service, the term technology refers to the availability of internet connection and electrical connection. Of the total number of respondents, 45.83% rated the train technology as good, 29.17% rated it as very good, 12.5% rated it as excellent, 8.33% rated it as sufficient, and 4.16% rated the technology as insufficient. The obtained results can be interpreted with regard to the average age of trains running on the route Varaždin-Koprivnica and the increasing demands in relation to the development and availability of technology in the daily lives of respondents.

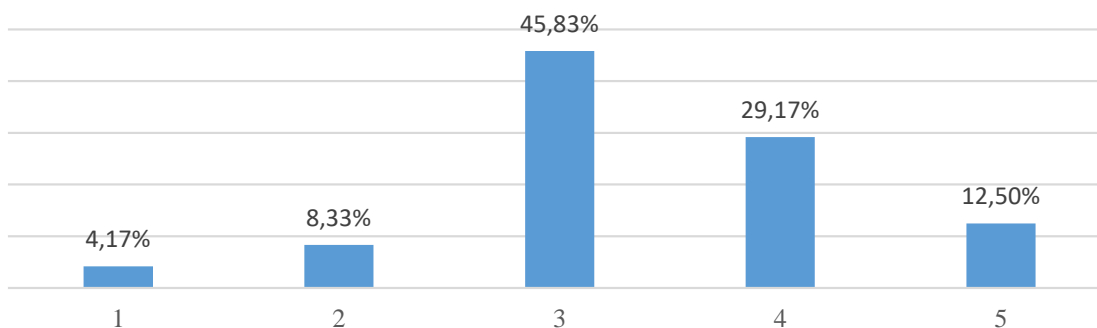


Chart 3. Student satisfaction with the state of technology found in the train they travel with

Source: created by the author

One of the parameters of the quality of the provided transport service is the comfort, ie the accuracy of the train. Of the total number of respondents, 8.33% said they were not satisfied with either the accuracy or comfort of the train, 16.67% were partially satisfied with the accuracy and comfort of the train, 62.50% rated the comfort and accuracy as good, while 12.50% rated the accuracy and rated the comfort as very good. None of the respondents were completely satisfied with the accuracy and comfort.

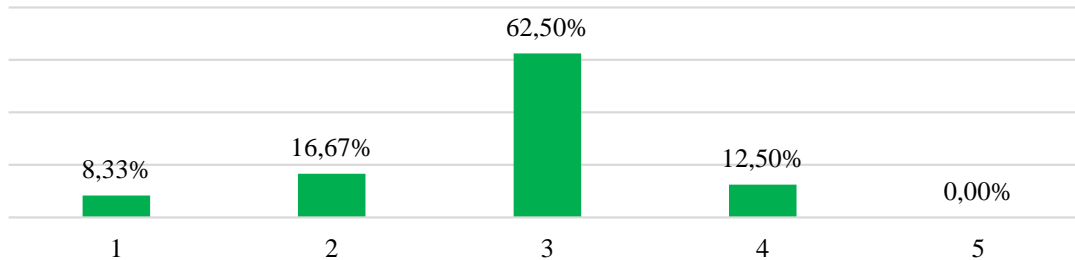


Chart 4. Stud. satisfaction with the accuracy and comfort of the train according to the timetable
Source: created by the author

When asked if they think the level of quality of passenger train service should be improved, 100% of respondents said that the level of quality should be improved. This indicates that the existing level of quality, which is reflected in the comfort of the train, accuracy and available technologies in the passenger compartments, is not sufficient, and that respondents consider it necessary to invest in the above, to increase the quality of service provided.

When asked if they think that investments in railway infrastructure should be increased, 91.67% of respondents answered that they should be increased, while 8.33% of respondents said that it is not necessary to increase investments. According to the research, it was determined that the respondents believe that it is necessary to further invest in the development and upgrade of existing infrastructure, which in turn will increase the quality of the provided transport service.

However, in order to conclude on the feasibility of investing in infrastructure and to explain the reasons why respondents mentioned rail transport as safer and much more attractive than road transport, it is necessary to analyze the current road transport infrastructure used for passenger car transport. on the Varaždin-Koprivnica route. Similarly, it is necessary to analyze the railway superstructure, as well as the infrastructure, in order to determine the places where improvements can be made.

2.4. Secondary research - Literature Review

The use of public transport compared to the use of cars results in significantly less congestion and environmental pollution. However, the use of public transport provides users with much less comfort compared to the use of cars, as public transport often involves a greater number of transfers and the use of different modes of transport to reach the desired destination. [2] However, the use of public transport, especially rail transport, is of great importance when it comes to urban development due to the speed of connection and safety of passengers using rail for transport [3]. Furthermore, the use of rail transport is also encouraged by the European Union, which emphasizes the importance of increasing the total number of passengers transported by rail by 10%, which will result in a reduction in environmental pollution by about 50%. In addition, expert and scientific research has shown that, compared to other modes of transport, rail transport has the least impact on the environment. [4] The use of public transport is often highlighted as one way to increase the mobility of older people and people who do not own a car.

Furthermore, with the growth of the urban population, it is necessary to reduce the number of cars on city roads in order to reduce traffic congestion and air pollution, i.e. to maintain satisfactory air quality in urban areas. [5]

One of the characteristics of rail transport is the timetable and its accuracy. In order to ensure the accuracy of rail transport, it is necessary to optimize the existing railways. Optimization is based on the application of tools from operational research, ie mathematical models that simulate the current mode of traffic flow and identify possible improvements. [6] However, the optimization of the current capacity of the railway network often depends on the condition of the infrastructure and its use. Insufficient track gauge with growing demand for transportation has much less potential for optimization. Given this, in practice, desire lines are often developed that indicate the need to upgrade or expand existing infrastructure capacity. Wish lines are often determined by the number of inhabitants, ie the number of passengers of a certain mode of transport; and they are often irrational, which is why in many cases the created lines of desire need to be optimized. [7] Expert and scientific research has shown that the relationship between infrastructure and demand, ie transport demand, is complex and that defining and creating an optimal strategy requires consideration of a large number of different variables, which further affects the complexity of the optimization process. [8]

However, it should be emphasized that the railway mode of transport is the basis for the integration of transport, since due to its capacity and speed it can transport a large amount of cargo, ie a large number of passengers over long distances. A previous survey, which focused on determining the existing satisfaction, the current situation in passenger transport in the Varaždin area, found that in 2015, almost 40.57% of passengers transported by rail were actually students. Furthermore, the same survey showed that almost 42.29% of passengers listed Varaždin as their final destination, while 29.14% of passengers started their journey in Varaždin. [9]

Speaking about the quality of transport and the parameters that users take into account when assessing the quality of transport by rail, it should be mentioned that almost every passenger experiences the quality of transport differently. Some of the most frequently cited criteria for assessing the quality of transport are speed, duration of the trip, temperature in the passenger compartment, toilets and their cleanliness in the passenger compartment and interior, or the condition of the seat in which passengers are transported. [10] Modern trends arising from the development of Industry 4.0 also place the application of new technologies that can significantly affect the quality of transport and the passenger experience as one of the requirements of the railway system. [11]

3. Transport infrastructure analysis on the Varaždin – Koprivnica route

The Varaždin-Koprivnica route lies on the section of the state road no. 2 (DC-2), whose total length is 347.5 kilometers, of which 47.30 kilometers are within the route and the R202 Varaždin-Dalj railway (Varaždin-Koprivnica route) that is a regional single-track railway and connects the northern counties with the eastern counties, merging with the TNT-RH2 railway corridor.

3.1. Analysis of the Road and Rail Transport Infrastructure on the Varaždin – Koprivnica Route

According to a study by the independent body EuroRAP (European Road Assessment Programs) that conducted a safety analysis of DC-2 (state roads), it was rated with five different safety levels, 41% of DC-2 sections received three stars (3 stars for high-risk sections), 30% received two stars (2 stars for high-risk stocks), 20% received four stars (4 stars for low-risk sections), 8% received 1 star (1 star for high-risk stocks), and less than 2% of the section received five stars (5 stars for the least risk sections). The DC-2 section from Varaždin to Ludbreg was assessed as particularly risky. The mentioned section is an integral part of the Varaždin-Koprivnica route. [12]. It follows that the potential of rail transport is significantly higher in terms of safety than the potential of road transport.

The Varaždin-Koprivnica railway is parallel to the Croatian-Hungarian border, and the total length of the railway (from Varaždin to Dalj) is 250 km, while the distance between Varaždin and Koprivnica is 41.989 km. The speed of the railway train that allows the allowed infrastructure speed of 100 km/h is partially limited by the speeds $V_{max} = 40$ km/h (total length of 1742 m), 50 km/h (total length of 1464 m) and 80 km/h total at a length of 2160 m).

These limitations of the permitted infrastructure speed on the line cause an extension of train running time and consequently significantly reduce the mobility of students-passengers of the University of the North.

4. Discussion

Based on the conducted primary and secondary research, it was determined that the current users of railway transport believe that there is room for improvement of the existing infrastructure.

In addition, users were found to find rail transport to be significantly safer than road transport. This is supported by the fact that EuroRAP assessed the Varaždin-Ludbreg route as a section of high-risk road. This implies that there is potential for the development of rail transport through the investment cycle.

Furthermore, based on the conducted research, it was determined that there are four possible directions for developing and increasing the mobility of students and travelers of the University of the North; reconstruction and modernization of railway infrastructure, modernization of railway superstructure, increase of transport accuracy and timetable modeling.

Better conditions for passenger and freight traffic are provided by the railway R202 Varaždin-Dalj, where regular speeds of 100 km/h (with speed limits), in contrast to the state road DC-2, where the transit is very high, and consequently a large number of traffic accidents.

The regional importance of railways is extremely important for the City of Varaždin, and the networks have a favorable geographical position at the so-called northwestern gates of Croatia and good transport links with the rest of Croatia and important transport hubs abroad.

4.1. Reconstruction and Modernization of Railway Infrastructure and Superstructure

Reconstruction of the railway section Varaždin-Koprivnica, envisages an allowed infrastructure speed of 100 km/h, and includes upper and lower construction, signaling and safety devices, plans for security and modernization of railway-road crossings, all in order to improve the railway infrastructure in terms of passenger and student mobility.

On that section, on the lower railway structure, due to the poor condition of the railway body, it is planned to install a layer of geotextile and geogrid, possibly as a geocomposite, with the installation of tampons, while the upper structure is planned to be renewed with new rails 60E1. with new prestressed concrete sleepers and elastic fasteners in crushed stone. It is planned to raise the level of security at the railway-road crossings by installing devices for securing the crossings with light and sound signalization and half-bumpers. [13]

Considering that the discussion is focused on the modernization of the vehicle fleet and the introduction of modern technology trains in passenger transport on the route Varaždin-Koprivnica, and as a result, a low-floor diesel-motor train is proposed, because it allows:

- increasing the quality of transport service: comfort, air conditioning, multiple seats, passenger information system, wheelchair transport, bicycle transport, top speed of 120 km / h, video surveillance,
- increasing the mobility of student-travelers,
- increasing the level of passenger transport safety.

4.2 Improving Timetable Accuracy

The accuracy of the timetable largely depends on the age of the fleet of the operator HŽ Putnički prijevoz d.o.o., on possible failures that directly affect the accuracy of the timetable, the delay in the departure of trains from the station or stop. The operator or provider of passenger transport services, by diverting from other railways and / or introducing technologically advanced low-floor diesel motor trains on route Varaždin-Koprivnica, may affect the accuracy driving according to the timetable.

4.3. Modeling of the Train Timetable

Train timetable modeling is based on the demand of student-passengers and their journeys to the University North in accordance with the first and last days of classes.

Table 1. Modeling of the train timetable on the Varaždin-Koprivnica route

Departure	Train No.	Arrival	Duration	Transfer
7:56	3605	8:40	0:44	0
8:46	NEW DMV	9:30	0:44	0
10:20	3607	11:05	0:45	0
12:48	3609	13:33	0:45	0
14:00	NEW DMV	14:48	0:48	0
14:37	3611	15:25	0:48	0
19:18	6403	20:02	0:44	0
21:15	NEW DMV	21:59	0:44	0
22:15	3619	22:59	0:44	0

Source: [14]

Table 2. Modeling of the train timetable on the Koprivnica-Varaždin route

Departure	Train No.	Arrival	Duration	Transfer
8:13	3606	9:06	0:53	0
9:03	3608	9:48	0:45	0
13:06	6402	14:00	0:54	0
14:04	NEW DMV	14:49	0:54	0
14:41	3612	15:26	0:45	0
19:18	3612	15:26	0:45	0
20:29	3620	21:14	0:45	0
21:15	NEW DMV	21:59	0:44	0

Source: [14]

This modelling will have a positive effect on the use of rail passenger transport by students of the University North, given the compliance of the timetable with the first and last day of classes, and the quality of service provided.

4.4. Comparison of the cost of travel by car, bus and train

Looking at the duration of the trip and the cost of transporting students to study at the University North, on the route Varaždin-Koprivnica, to travel by car on the state road DC-2 at a distance of 48.0 km takes 47 minutes, while the road DC-20 takes 57 minutes for a distance of 58.3 km.

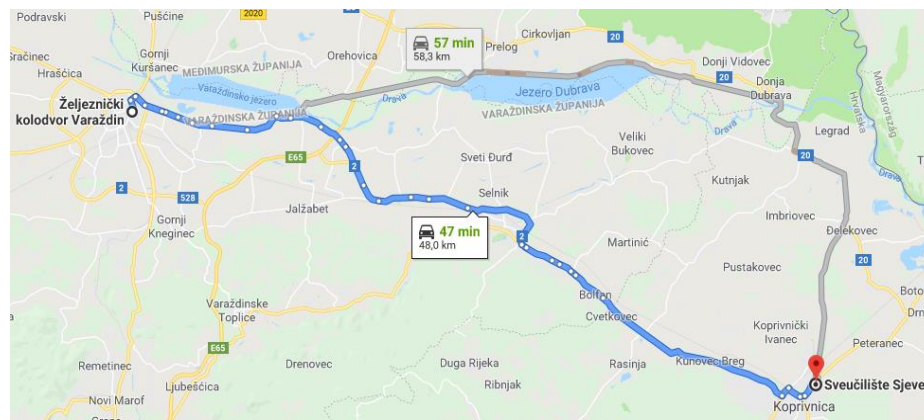


Figure 1. Distance and travel time by car on the state road DC-2 and DC-20

Source: <https://www.google.com/maps/dir/>

In the calculation of travel costs by road, ie car, diesel fuel at the price of 9.52 kn and car consumption 7 l/100 km, on the route of travel on the state road D2 for the distance traveled 48.0 km in a time of 47 minutes, and consumption 3.37 liters of diesel fuel, the cost of travel is 32.08 kn in one direction, including departure from the parking lot at the Varaždin railway station to the University North, University Center Koprivnica. For bus travel, the bus ticket costs 40 kn in one direction, from Varaždin bus station to Koprivnica bus station, the journey takes 1 hour to 1 hour and 10 minutes according to the schedule of Varaždin bus station at a distance of 47.5 km. There is no discount on the bus ticket for students because the distance does not exceed 50 km.

For a train journey, a one-way ticket costs 14.90 kn, and the ride takes 44 to 48 minutes, while the maximum lasts 1 hour and 12 minutes, depending on the train you are traveling on, for a distance of 41,989 km. Figure 2 shows railway stations and stops on the route Varaždin-Koprivnica.

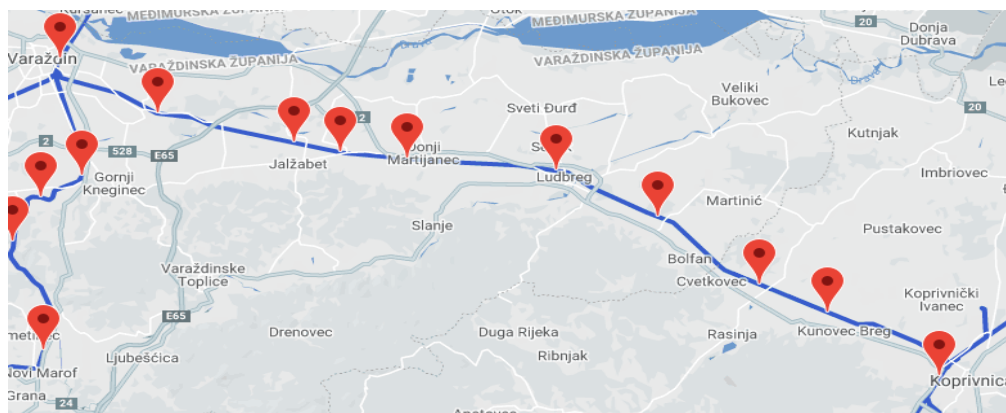


Figure 2. Distance and display of railway stations and stops of the Varaždin-Koprivnica

Source: <http://www.hzpp.hr/karta?p=16&mp=743>

Table 3. Comparison of the cost of travel by car, bus and train on the route Varaždin-Koprivnica with the time of travel and distance travelled

	DIESEL (kn)	Ticket (kn)	Distance (km)	TIME SPENT (min)
Car	32,08	-	48,00	47,00
Bus	-	40,00	47,50	60,00
Train	-	14,90	41,989	44,00

Source: [14]

4.5. Results from the point of view of sustainability

The consequences of the results from the point of view of sustainable student mobility by rail passenger transport on the line Varaždin-Koprivnica and modernization of railway infrastructure and rolling stock are manifested in strengthening modernization and development, and socially responsible management of railway infrastructure. Investing in the safety and stability of railway infrastructure and student mobility in rail passenger transport, is a visible aspect of sustainability, as well as an indispensable factor in continuing cooperation with carriers and other partners in connecting with the wider community and direct and indirect impacts, their growth and development.

In the area of Koprivnica-Križevci, Međimurje and Varaždin counties - northern Croatia, on February 21, 2019, the Agreement on long-term partnership in the development of railway transport and integrated passenger transport was signed, and integrated transport is only one of the introductions to increased mobility of students. Although there is a system of public bicycles in Koprivnica, it is planned to install e-bicycles at the railway stations in Varaždin and Koprivnica in 2021, which would directly contribute to the mobility of students of the University North, to arrive at the university on time and in an environmentally and energy-friendly manner.

5. Conclusions

This paper explores the possibilities and proposes measures with activities related to increasing the mobility of students-travelers of the University of the North on the route Varaždin-Koprivnica. The analysis of the traffic infrastructure revealed that on the state road DC-2, regardless of its rehabilitation, ie reconstruction, a large number of traffic accidents still occur, with material damage, minor and major injuries and fatalities. Unfortunately, the human factor is mostly crucial in traffic practices, where it directly affects safety and the possibility of causing traffic accidents. On the railway infrastructure on the line R202 Varaždin-Dalj, route Varaždin-Koprivnica, it was determined that the infrastructure requires urgent renovation and modernization, given the age of the facilities, installed materials and devices and equipment.

The survey found dissatisfaction of student passengers with the level of quality of passenger train service, the existing technology of trains running on the line R202 Varaždin-Dalj, route Varaždin-Koprivnica, and dissatisfaction with the comfort and accuracy of the timetable. Moreover, the vast majority of surveyed student-passengers also stated that it is necessary to increase investments in railway infrastructure.

In order to increase the mobility of students on the route Varaždin-Koprivnica and, as a result, reduce travel time, it is proposed to improve the railway infrastructure by reconstructing the railway R202 Varaždin-Dalj, Varaždin-Koprivnica. The reconstruction includes upper and lower buildings, signaling and safety devices, with the simultaneous provision and modernization of level crossings, all with the aim of improving the railway infrastructure in terms of passenger and student mobility. Improving the railway infrastructure would remove sporadic speed limits of $V_{max} = 40 \text{ km / h}$, $V_{max} = 50 \text{ km / h}$ and 80 km / h by introducing an infrastructure speed of 100 km / h .

New modeling of train timetables, introduction of new routes within the existing ones and introduction of DMV series 7 022 or 7 023 would correct and harmonize the departure time of trains on the Varaždin-Koprivnica route and vice versa towards the first and last days of classes at the University North. With the introduction of additional DMVs (low-floor diesel motor trains) there is the potential for increased demand, which also influences the railway service provider to further improve the quality of service.

Improving the railway infrastructure and quality of service in railway passenger transport on the route Varaždin-Koprivnica will increase the mobility of students-passengers, minimize travel time, adjust train schedules to the first and last days of classes, and travel comfort will improve by introducing more modern trains using modern technologies, timetable accuracy and travel speed will be improved, passengers will be better informed, all of which will increase the safety of student-passengers in rail passenger transport.

The limitations of the research are related to the impossibility of generalizing the obtained results to the rest of the territory of the Republic of Croatia that encounters a similar or the same problem, a similar or the same potential. Future researchers in this field are advised to conduct research that would cover the entire territory of the Republic of Croatia, as well as to investigate the satisfaction with rail passenger traffic in the territory of the Republic of Croatia. Such research would provide a basis for drawing a conclusion on the development potential of rail passenger transport.

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