



IMPROVING QUALITY OF SERVICE ON THE BUS LINE 236 IN THE CITY OF ZAGREB

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Abstract

A good transit service in cities has a reliable timetable with a frequency such that arrivals at stops make the line attractive for the passengers waiting for a bus. This should especially be mandatory for shorter bus feeder lines such as bus line 236, which connects Zagreb University Campus to three tram lines and one bus line in the eastern part of the city. However, there have been reports of a bad quality of service by the students, such that two types of complaints are most common: infrequent service since the buses depart every 20 minutes, and excessive time losses when transferring from the tram network to the bus line on trips to the campus, with buses sometimes leaving transfer terminal despite students alighting the tram moments before. The transit operator provided us with historic data, and we collected time and passenger data for ten days using GPS data loggers with manual passenger counts by students to determine vehicle utilisation, time utilisation, and schedule adherence. By analysing the data, we determined the possible improvements on the line in the form of changes to the existing timetable and improved vehicle frequency while maintaining the same number of drivers and vehicles. Also, we investigated the possibility of extending the coverage area of the line so that it could not only serve as a feeder to the tram network but also to additional bus lines passing nearby to improve line utilisation.

Keywords: bus line, campus, City of Zagreb, public transport, quality of service

1 Introduction

In the City of Zagreb, where public transport consists of 19 tram and 147 bus lines operated by Zagreb Electric Tram (ZET) [1], the University Campus Borongaj was established in 2007 on a former military base territory. Currently, there are five faculties located on campus. There are plans for other faculties in Zagreb to relocate to campus, for a final capacity of 35000 students [2].

The campus is opened for students in workdays and Saturdays. In the winter semester, classes last from October to January, with winter exams in February. In the summer semester, classes last roughly from March to June, with exams in July and September, and summer vacations in August. The demand for public transport is significantly higher during classes compared to the exams.

For the campus, there were many plans to make it the most modern campus in Croatia, stated by the Zagreb Urban Development Plan 2021-2027 [3]. However, large-scale projects never became a reality, so the campus of today offers limited services for the students. The last initiative encompassed tram network extension to the campus, railway station, student dormitory, improved student restaurant, innovation complex, and additional buildings for the faculties [4].

2 The current state of the bus line 236

The bus line 236 was introduced for students travelling to the campus. There are two terminals, Kampus fakultet and Čavićeveva-Gospića, both being stops as well. The first departure is at 06:50 to the campus, and the ride lasts for about three and a half minutes. The ride from the campus lasts about eight and a half minutes. The cycle time is 20 minutes, and the last departure is at 20:00 from the campus. In total, there are exactly 40 cycles every workday, and during the weekends and holidays, the line does not operate. Since only one bus operates on the line, the interval is equal to the cycle time. In each hour between the first and the last departure, buses depart from the campus at 00', 20' and 40', and to the campus at 10', 30' and 50'. This is done by two driver shifts, and driver exchange occurs at 13:30 at Čavićeveva-Gospića terminal – exactly after a half of the total cycles.

Fig. 1 displays both routes of the line as a yellow curve, highlighting all the stops on the routes. The bus travels in a circular pattern close to both terminals. The campus itself has two stops. The line has a length of 1.6 km to the campus with only one stop in between, and 2.9 km from the campus, with four stops between the terminals. Totally, the line has a 4.5 km circumference, which is rather short for a bus line with two terminals serving as driver resting points.

The black line on Fig. 1 shows the corridor of a connecting bus line 215 with red squares as its stops. Lines 215 and 236 share two bus stops – Borongajska Kampus and Getaldićeva. Students using line 215 also use the stop southern of the Kampus fakultet stop, walking five minutes on Savudrijska Street, especially when travelling to the campus in the morning.

The red line in Fig. 1 is a tram corridor where lines 2, 3, 13, and 33 operate and the students make their transfers, with blue squares marking tram stops. Students transfer to the bus usually at Čavićeveva-Gospića terminal, and to the tram at Getaldićeva-Gospića stop because tram corridor connects the city centre to the west. The walking distance in both cases is less than 100 metres, but the students must cross signalized intersections in both cases.

Tram lines generate almost 100% transport demand on the bus line. Therefore, it is important for the students to have efficient transfers with minimum time losses, especially for the students that have already made additional transfers before. However, students seldom cannot catch the bus when exiting tram, because the drivers, usually complying to the timetable, leave just moments before, even though they could see the students alighted from the tram walking to the bus stop. In the morning, this problem is especially critical because students must be on time for the classes, and since the next bus would not depart in 20 minutes, many students choose to walk the 1.6 km, because for a walking speed of 5.4 kph they can reach the campus in 17 minutes.



Figure 1 Bus line 236 with stops

3 Methodology

For the analysis, ZET provided us the data for an entire day – October 11th, 2022. The data contained vehicle specs, departure moments from source terminal and arrival moments at destination terminal, precise to a minute. Passenger data included alighting and boarding at each bus stop.

Additional data was collected by the students for ten workdays – five in February 2023 and five in March 2023. Each day was done in three student shifts, ensuring all-day coverage, and every day of the workweek was covered twice. Time data, provided by GPS data loggers, and precise to a second, included arrivals and departures for each bus stop. Passengers were counted manually, resulting in boarded and alighted passengers for each bus stop.

The collected data was processed and analysed in Microsoft Excel, by segments between the stops, routes, bus types, departures, and cycles, providing the analysis by days, hours in a single day, and percentiles.

Since there are two stops around the campus where the bus is only making a circle, the number of passengers in the buses does not represent passenger demand from the Kampus fakultet terminal to Kampus restoran stop. Additionally, the first contact point of the bus and tram network is at Getaldičeva-Gospića stop, so the number of passengers from that stop to Čavićeva-Gospića terminal also does not represent passenger demand because nearly all passengers alight at Getaldičeva-Gospića stop. The relevance of the segment Getaldičeva-Gospića to Čavićeva-Gospića is also diminished by the fact that students travelling to the campus sometimes board the bus at Getaldičeva-Gospića stop. Therefore, we assigned these passengers as boarded at Čavićeva-Gospića terminal. To conclude, we define demand-relevant route to the campus from Čavićeva-Gospića terminal to Kampus fakultet terminal, and from the campus, the demand-relevant route is from Kampus restoran stop to Gedaldičeva-Gospića stop.

The analysis of passengers travelling on the two demand-relevant routes showed that the ratio of the average number of passengers in vehicle weighted by segment length and the total number of boarded passengers travelling is 99% to the campus, and 94% from the campus. Therefore, the analysis will be accurate enough if passenger exchange on stops between the terminals is ignored. In other words, for each route, the number of boarded passengers will be an enough accurate transport demand indicator.

4 Research results

The average operating speeds are 27km/h to the campus, and 22km/h from the campus, which is satisfactory. From the campus, the bus usually slows due to three left turns on intersections, and to the campus, there is one critical left turn, but all these together in general do not create significant problems for normal operation.

Table 1 Bus types in the data collection period

Period	Doors	Seats	Surface	Length
2022-Oct	4	42	30m ²	18 m (articulated)
2023-Feb	3	33	15m ²	12 m (solo)
2023-Mar	4	41	22m ²	18 m (articulated)

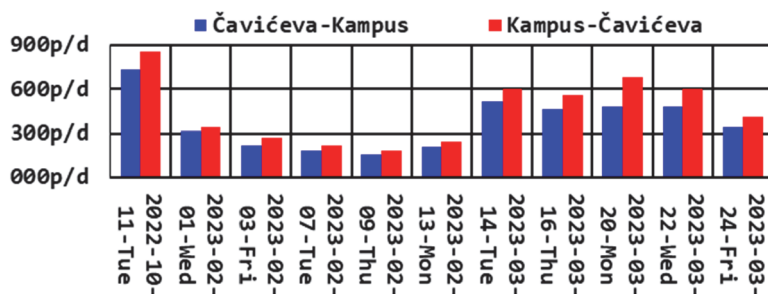


Figure 2 Number of boarded passengers per day for one day by ZET and the remaining ten by data collection

The bus types that operated on the line in the observation period are shown in Table 1. Articulated buses operated in 55% of total departures collected.

Daily analysis is shown in Fig. 2 as the number of boarded passengers in an entire day of operation (p/d). The highest number of boarded passengers comes from the only day provided by ZET, where there are on average 790 boarded passengers per route, followed by March 2023 with 510, and February 2023 with 230 passengers boarded per route. The data is not surprising since October and March are the first months of winter and summer semester when the lectures begin, and February is mostly the month of winter semester exams. Also, the demand tends to be higher on Monday than Friday, but during the exams, this does not need to be true. Whether the students have lectures or the exams, they must arrive on time, so the service needs to be constantly reliable.

Each day, there are more passengers travelling from the campus than to the campus, meaning that students prefer to use another means of transport such as bus line 215 when travelling to the campus.

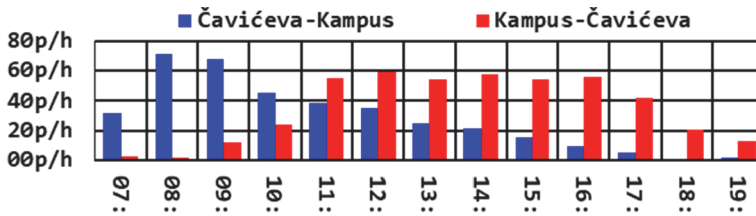


Figure 3 Number of boarded passengers per hour during a workday – averages for the entire data sample

Fig. 3 shows the number of boarded passengers per hour (p/h) for both routes in the entire sample, divided into hourly intervals (e.g. 10: is referring to the period from 10:00 to 11:00). Periods from 06:00 to 07:00 and from 20:00 to 21:00 are not shown because of a negligible number of passengers. This figure confirms the usual behaviour of passenger demand, with more students to the campus in the morning, and more students from the campus in the afternoon. However, in total, there are less passengers travelling to the campus, and the difference comes from the students who can use both lines 215 and 236 for their trips. When they travel to the campus, the line 215 is more convenient because they don't have to transfer since they have to arrive on time, and when travel from the campus, they can see a 236 bus waiting at a terminal, they aren't in a hurry, and if they like, they can conveniently transfer to Line 215 on the two shared bus stops. There are more students to the campus in the morning since lectures begin usually in the morning, and this steadily drops to less than 10 p/h after 16:00, such that:

- From 08:00 to 10:00, 38% of total daily passengers to the campus board,
- From 08:00 to 11:00, 50% of total daily passengers to the campus board.

Peak student trips from the campus in the afternoon are more mildly distributed, with 14:00 as the central point, such that:

- From 13:00 to 15:00, 25% of total daily passengers from the campus board,
- From 12:00 to 16:00, 50% of total daily passengers from the campus board.

Boarded passengers as percentile distribution is shown in Fig. 4. As the timetable has constant 20-minute intervals, the number of passengers per vehicle is equivalent to passengers per 20 minutes, i.e. passengers per hour is three times the value per vehicle.

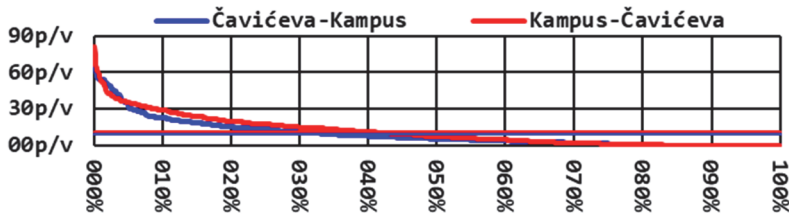


Figure 4 Boarded passengers per vehicle as percentile distribution for the entire data sample

Two horizontal lines represent the average values, meaning that on average buses transport 10 passengers per vehicle, and the median value is approximately 5 passengers per vehicle. The curves represent each departure in the sample from the highest to the lowest. Maximum value of just above 80 p/v occur from the campus, and it proves that there is no need for a higher-capacity articulated buses, and the solo bus that operated with 33 seats and 15 m² standing surface under the maximum 81 passenger per vehicle will have the occupancy of 3.2 p/m², which is below the typical comfort threshold (4 p/m²). And if the same bus type is observed, there will be only 5% of rides where all seats are occupied.

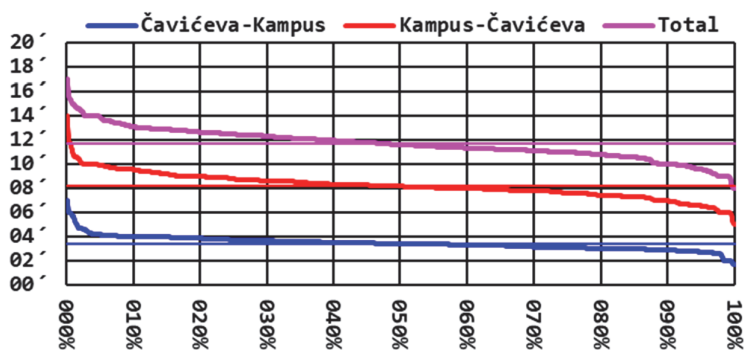


Figure 5 Percentile travel times – both routes and total

Fig. 5 represents travel times for both routes and total travel times. The curves represent percentages arranged from maximum to minimum, and horizontal lines represent the averages. As cycle time on the line is equal to the interval of 20 minutes due to only one bus operating on the line, in the current scheme, the median travel time of 11'35" (the average is 11'40") makes a 58% of the cycle time spent by driving, which is very generous to the drivers. Even the highest possible time of 17'00" does not exceed the 20-minute cycle threshold, leaving possible space to reconsider the timetables.

If the reduction of cycle time from 20' to 15' would be considered, then the average travel time would be 77% of the cycle time, and there would be 1% cases of no rest, 12% cases of 0' to 2' rest, and 80% cases of 2' to 5' rest. So, although the ratio of resting time to the cycle is acceptable, resting intervals would be short.

5 Solution proposals

For the solutions, we considered no additional costs for the operator. Currently, one bus operates throughout the day with two driver shifts, so the proposal should have the number of drivers and vehicles the same.

Regarding bus type, as it was shown in Fig. 4, the number of passengers did not reach the comfort threshold, so a solo bus would withstand the passengers. However, Fig. 2 showed significant differences between lecture periods and exam periods, so for more comfortable rides, articulated buses can be considered for classes, and the solo buses for the exams. However, this will result in even lower vehicle utilization, since the average 10p/v is well below the seat threshold for the solo bus (33 p/v).

Since we showed in Fig. 5 that time utilization will be optimal even if line cycle time is reduced to 15 minutes, due to short distances between the terminals, we propose turning one of the terminals to an ordinary stop and reducing cycle time to 15 minutes in critical periods. Then, using the data from Fig. 3, we propose for critical periods to be 08:00 to 10:00 in the morning driver shift, and for the afternoon driver shift, we recommend timetable changes the same way if the afternoon demand becomes higher in the future.

For more smooth transfers from tram to bus on the route to the campus, a special timetable ruling for transfers should be implemented – for example, if the bus on its left turn after Getaldičeva-Gospiča stop spotted a tram on the stop, the driver should be obliged to wait at Čavičeva-Gospiča stop for the passengers alighting from that tram to board the bus. Otherwise, the passengers could report the driver. However, the means of proving driver misbehaviour by technology should be precisely outlined for this to function.

Since the bus line serves as a connection of the campus to bus line 215 and tram network, the possibilities for line extension to Slavonska avenue should be considered, so that the students can transfer to the lines operating on that corridor. In this manner, students would be better connected to the city centre and the western parts of the city. However, for this extension, schedule adherence could become a problem due to new corridors that the line will have to use, Čavićeva Street and Slavonska Avenue, that are congested in peak periods. To keep the interval minimum, this could demand an additional vehicle and driver shifts.

6 Conclusions

The research conducted in this paper showed that improvements on the bus line 236 – conversion of one of the terminals to a stop, shrinking of cycle time and the interval to 15 minutes in critical periods, and a special timetable ruling for efficient transfers – are very much possible to implement, with minimum sacrifices for drivers, but noticeable improvements of the service for the students. In addition, we encourage further research to verify if the extension of the line to Slavonska Avenue is feasible.

The future prospect of this line is most likely to be a terminated operation when tram network extends from Vukovarska Avenue to Dubrava terminal via the campus, together with establishing a train stop to integrate the campus to the suburban rail network. Although these are stated in the current transport development plans for the City of Zagreb, there are certainly several years for line 236 to operate, and transport demand on it should be constantly monitored for a seamless service.

At the time of finishing this paper, ZET made changes to the timetable [5] on March 11th, 2024. The change was implemented from 08:00 to 10:00 by shrinking cycle time and the interval from 20 to 15 minutes like in our proposal [6]. The five minutes of cycle time were reasonably taken from the route to the campus.

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