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Abstract

In the proposed paper, structural analysis of relevant parameters of the maritime coastal line Zadar-Preko (Croatia) was conducted. Passenger and vehicle traffic are observed during a three-year period. Based on the official data processing, parameters of the existing line capacity utilization are determined on a monthly basis. The passenger and vehicle turnover is presented as well as the utilized and non-utilized carrying capacities of the line. The highly seasonal nature of the turnover is emphasized as a result of tourist season, including the discussion on the line unprofitability for the shipping company which is directly due to the seasonality. In this connection, the need for a Government grant is further discussed with a view to maintaining sufficient carrying capacities and line frequency. For further research, a conceptual system is suggested to be based on computer simulations aimed at optimizing the operation of the terminal.

Key words: Coastal line Zadar-Preko, utilization of shipping capacity, traffic seasonality, unprofitability of shipping line, traffic optimization

1. Introduction

Croatia is situated along eastern coast of the Adriatic Sea. There are 718 islands, 389 islets and 78 reefs within the Croatian waters, with 312 islands populated by at least one permanent resident [6]. Considering the direct length of 526 kilometers between two most distant geographical points of the Croatian coast, such a great number of islands, islets and reefs represents the most indented coast in the Mediterranean [3,

4]. The most populated islands are Ugljan and Pašman, located entirely in the Zadar County, with 6182 and 2711 residents respectively [6, 16]. The passenger and vehicle traffic from the Croatian mainland to Ugljan and Pašman is operated by Jadrolinija, Croatian liner shipping company for maritime transport of passengers and vehicles.

High traffic seasonality can be seen along the Croatian Adriatic coast due to intense tourism activity during summer months. This fact represents a challenge for optimization of ferry lines. Peak loads of ferry lines during July and August reach 100 percent of capacity utilization. On the other hand, during winter months, ferries are almost empty. In a study carried out in 2017 [19], authors found out, based on the traffic simulation software used during the peak load period, that the ferry line Zadar-Preko was fully utilized and that there was no parameter change in the software simulation that could bring positive effect in order to further increase either the number of vehicles carried on that ferry line or reduce vehicle queuing to board ferries. They concluded that there was no way to further optimize the system that was already working with its maximum capacity without improving the total capacity by increasing the number of ferry departures per day or replacing the ferries with larger ones.

In this paper, a statistical analysis is used to identify trends of traffic changes over time on the Zadar-Preko ferry line. Furthermore, by extrapolating the existing data, conclusions are made about probable changes in the ferry line in the next years, and suggestion is made for computer simulation to be used to predict the emergence of vehicle queues on the terminal in order to optimize the line capacity and decrease vehicle queuing.

2. Basic properties of the Zadar-Preko ferry line

The coastal line Zadar-Preko consists of two separate segments: ferry (431) and passenger line (431A). Ferries for the carriage of vehicles depart from Zadar's new port Gaženica. The second segment departs for Preko from the old port of Zadar (Jazine) and carries passengers only. The line has recorded the highest passenger turnover among all the Adriatic routes for many years, which has been somewhat exceeded by the Split-Supetar line in recent years only [1]. Busiest ferry lines in Croatian domestic ports are shown on Figure 1 by the number of passengers and vehicles carried.

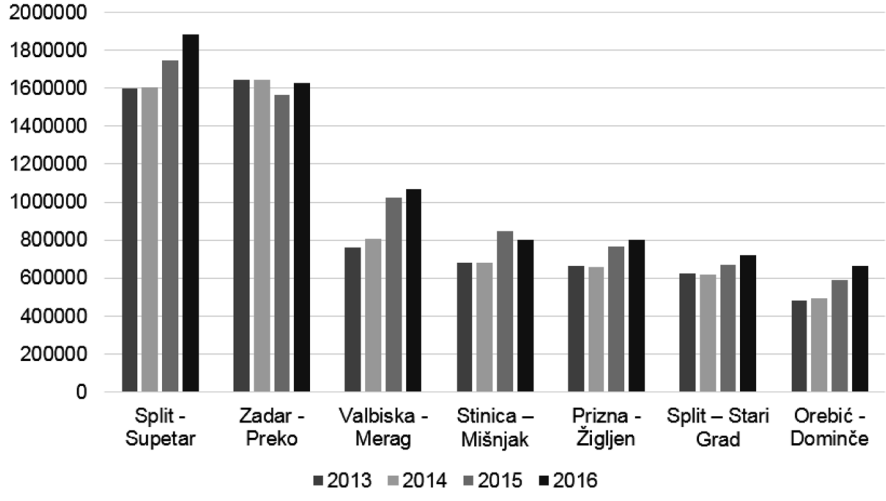

Figure 1 – Statistical data for Adriatic ferry lines with heaviest passenger traffic Authors according to [1,2]

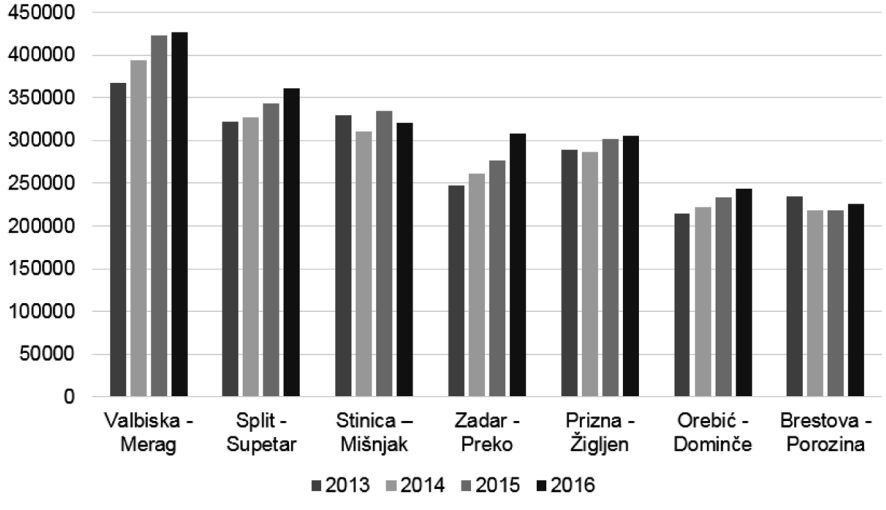

Figure 2 – Statistical data for Adriatic ferry lines with heaviest vehicle traffic Authors according to [1,2]

Unless specified otherwise, all of the data regarding the Zadar-Preko coastal line will apply to both segments. The number of departures on a monthly basis for particular vessels on this line during years 2013, 2014 and 2015 are obtained from [9] and vessels' data regarding the line operation are obtained from [7]. Passenger and vehicle data

for the line are obtained from [12]. It should be noted that passenger and vehicle data are only approximate. Data accuracy was dependent on vessel crews who manually counted passengers with monthly commuter fare tickets. Still, such approximation is assumed to be accurate enough for the study.

Passenger ferry schedules are divided into two periods during the year: high and low season. During the high season (summer months), more vessel departures are added to the schedule in order to sustain higher volume of passengers and vehicles. During the low season (winter), the volume of passengers and vehicles is significantly decreased and therefore the number of departures is slightly reduced for cost optimization purposes.

3. Data analysis

Statistical data on the number of passengers and vehicles carried on a monthly basis, as well as on the type of vehicles carried on ferry line Zadar-Preko are obtained from [1]. The collected data referred to the three years' period from 1st January 2013 to 31st December 2015. In order to better estimate the line utilization, it was necessary to make corrections for larger vehicles such as buses and long trucks, because they take up more space on board the ferry parking area than passenger vehicles. The estimated average length of large vehicles was based on three standard vehicle types: buses, small cargo vehicles and large cargo vehicles. For passenger vehicles, the Car Equivalent Unit standard (CEU) was used.

For a bus-sized unit, the 11.8 m long Volvo B8RLE was used [17]. The 5.04 m long Iveco Daily Van [8] was used for small delivery vehicles. The length of the truck depends on the length of the attached trailer. The 13.62 m Schwarzmueller 3-axle semitrailer platform was used as a trailer example [15]. For towing type vehicles, the MAN TGX was used [13], of the estimated length of 3 m measured from the front of the vehicle to the attached trailer. This length added to the trailer length gives the vehicle unit total length of 16.62 m. Three examples of cargo vehicles and buses were taken as the estimated unit value of the mean vehicle length:

$$\frac{(11.8 + 16.62 + 5.04)}{3} = 11.1\,\text{m} \tag{1}$$

The capacity of passenger RO-RO ship is usually expressed in CEU, where the unit of measurement 1 RT43 represents the Toyota Corona RT43 car of 1966, with length of 4.125 m. Out of the estimated mean value for large vehicles, the CEU standard for such a vehicle takes up 2.69 RT43 units. That number is calculated as the mean length value divided by length of one RT43 unit:

$$LV_{CEU} = \frac{11.1}{4.125} = 2.69\,\text{m} \tag{2}$$

This value was used for further calculation of the correction of the ferry capacity utilization. It should be noted that such corrections are only the estimated value, because vehicles vary in length. Also, the maximum number of on-board vehicles in the parking area of the ferry depends on parking tidiness, separation between vehicles, etc. Capacity utilization for the carriage of passengers and vehicles was obtained by dividing the monthly number of transported passengers/vehicles by the total capacity of the line during that month. Given that trucks and buses take up more space, the ferry utilization was calculated using RT43 units, where a car takes one RT43 unit, and a large vehicle takes 2.69 RT43 units. The transported vehicles per equivalent of RT43 units during the observed period were calculated according to:

$$RT43_{EKV} = (Total - LV) \times 1 + LV \times 2{,}69 \tag{3}$$

where $(Total - LV) \times 1$ represents the number of equivalent unit segments $RT43$ for transported cars, and $LV \times 2{,}69$ represents the number of equivalent unit segments RT43 for large vehicles.

For each month during the observed period, the number of transported vehicles represented in RT43 units is calculated using Equation (3), the results of which are shown in Table 1.

Table 1 – Calculation of RT43 equivalent units

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013.	**Tot**	**10714**	**10182**	**13799**	**16521**	**21251**	**27047**	**38536**	**43116**	**22752**	**16999**	**13592**	**13291**
	LV	2534	2559	3280	3415	4655	4584	4564	3743	3928	3414	2944	3066
	RT43 ekv.	15123	14635	19506	22463	29351	35023	46477	49629	29587	22939	18715	18626
2014.	**Tot**	**10905**	**11252**	**15164**	**18787**	**21054**	**28390**	**39674**	**47205**	**22711**	**18276**	**13964**	**13888**
	LV	2688	2918	3500	3804	4241	4197	4646	3794	3944	3947	3334	3530
	RT43 ekv.	15582	16329	21254	25406	28433	35693	47758	53807	29574	25144	19765	20030
2015.	**Tot**	**11395**	**11053**	**15551**	**18440**	**21934**	**29873**	**43415**	**49974**	**25181**	**18809**	**16233**	**14557**
	LV	3037	3225	4257	4747	5115	5513	5757	4909	4831	4079	4262	3630
	RT43 ekv.	16679	16665	22958	26700	30834	39466	53432	58516	33587	25906	23649	20873

Made by authors

The comparison of the monthly number of passengers and vehicles by the year is shown on Figure 3.

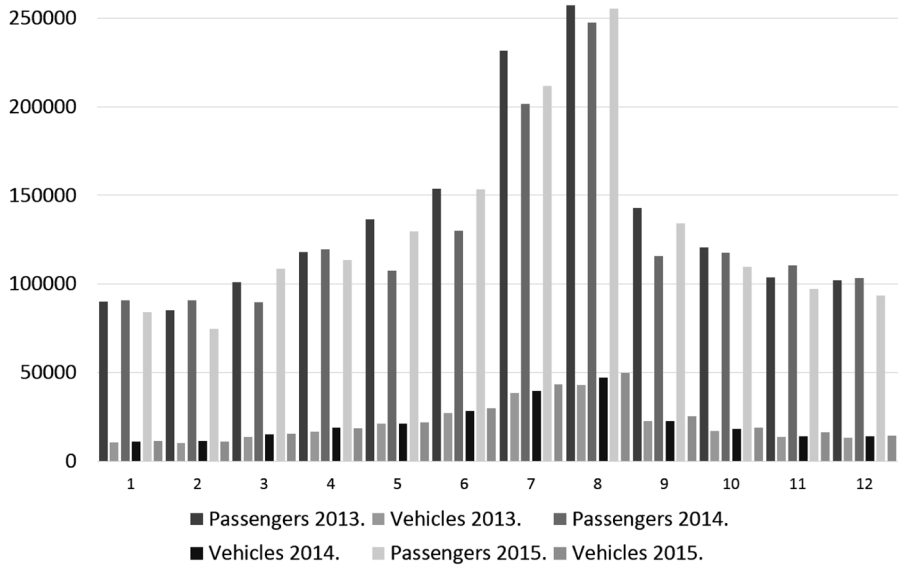

Figure 3 – Monthly statistical data of transported passengers and vehicles on the Zadar-Preko line for the period January 2013 – December 2015 Authors according to [1,2]

In the year 2014, the passenger traffic decreased by 8.4% as compared to 2013. In 2015, it increased again by 3.4% compared to 2014. Vehicle traffic was constantly increasing. In 2014, the traffic of transported vehicles increased by 5.4% compared to 2013, while in 2015 it increased by 5.8% compared to 2014.

The traffic increase corresponds to the general traffic increase in the domestic public maritime coastal transport. According to [1], transport of passengers and vehicles in the public coastal maritime transport in the Adriatic in 2015 increased by 2.2% compared to 2014 (passengers) and 5.9% (vehicles). The total capacity of the line is obtained as the sum of the monthly capacity of all vessels operating on the line. The capacity utilization of the Preko-Zadar line for passengers and vehicles is shown on Figure 4.

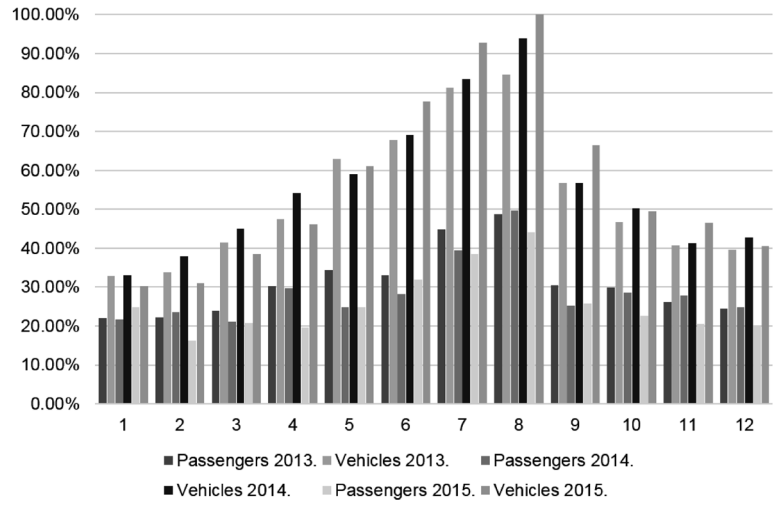

Figure 4 –The Preko-Zadar line monthly capacity utilization for passengers and vehicles for the period January 2013 – December 2015.
Authors according to [1, 9]

The ratio of used and unused capacity by the month is shown on Figures 5 and 6.

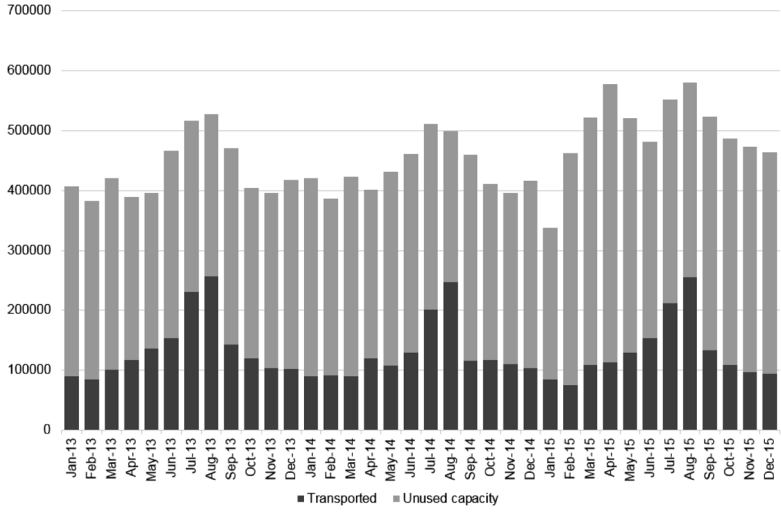

Figure 5 – The ratio of used and unused passenger capacity of the Zadar-Preko line for the period January 2013 – December 2015.
Authors according to [1, 9]

The utilized passenger capacity is significantly smaller than the vehicle transport utilized capacity. Passenger capacity utilization during the study period ranged from the lowest of 16.2% in February 2015 up to 49.5 % in August 2014. On the other hand, the vehicle capacity utilization was significantly higher and ranged from the lowest of 30% in January 2015, up to 100% in August 2015. It means that during that month all ferry lines were completely full. Factors like different lengths of vehicles or parking tidiness should be considered, however, they only affect the results in the magnitude small enough to remain valid for the purpose of this study.

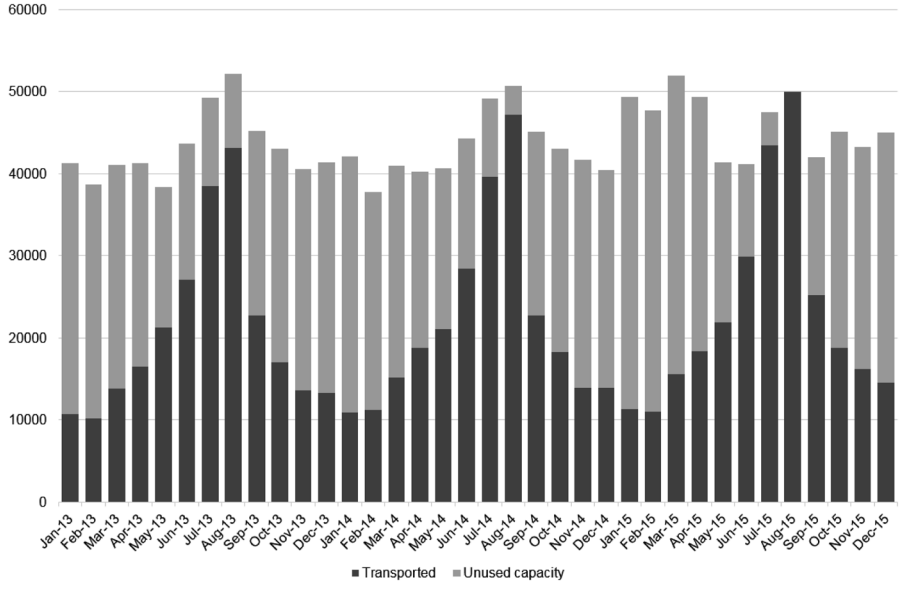

Figure 6 – The ratio of used and unused vehicle capacity on the Zadar-Preko line for the period January 2013 – December 2015. Authors according to [1, 9]

August is the month when capacity utilization has the highest average value of 93% for vehicles, and 47.5% for passengers. For vehicles, January is the month of the lowest capacity utilization with an average value of 32%. For passengers, the lowest utilization rate was reached in February, amounting to 20.7% on the average.

The average monthly capacity utilization of 100% in August 2015 suggests that there were situations where vehicles could not board immediately and had to wait for the following ferry departure. Such inconveniences for passengers traveling with their vehicles are expected only during July and August, while in other months it would probably not occur.

For ship operators, profitability of the line during winter months is a large issue. In that period, vessels navigate almost empty and the ratio between costs and profit

is unfavorable for them. The problem is solved by government subventions that are available for non-profitable coastal lines which meet the legal requirements for obtaining such government subventions.

There is a slight difference between the decrease in transport capacity in the winter time and the one in summer months. Further travel reductions would cause traffic problems to population of islands of Ugljan and Pašman, who are using the line on a daily basis for their basic needs.

According to a survey conducted on the Zadar-Preko line [11], the largest percentage of passengers answered that the purpose of their trip was job-related commuting, immediately followed by educational purposes. A lower percentages of passengers answered that the purpose of their travel was of private nature, shopping, and/or visiting. It should be noted that the survey was conducted during the winter period, while in the summer time the results would be much different due to numerous tourists and school vacations. One of the objectives was to identify the habits and needs of the population living on islands Ugljan and Pašman throughout the year and using the Zadar-Preko passenger line. Given that the majority of passengers commute for work or school, any reduction in the frequency of departures during winter months was expected to create a significant negative impact on the satisfaction of passengers. The same survey showed that the availability of transport at any given moment was desired most of all by 83% of surveyed passengers.

Line operators are not allowed to reduce the frequency of departures below the minimum determined by the government. According to the concession granting conditions, the minimum frequency of transportation per week is prescribed as follows:

- 101 departures out of the season,
- 116 departures in the preseason and postseason and
- 126 departures in high season.

Number of departures per month on the Zadar-Preko line is given in Table 2.

Table 2 - Total number of vessel departures per month on the Zadar-Preko line 2013-2015

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	802	562	872	716	748	576	1176	1118	558	864	576	870
2014	514	454	836	612	542	986	1116	1012	620	890	840	532
2015	610	806	508	910	1276	568	1060	1738	992	1330	866	1192

Source: [1]

Apart from the frequency of departures, the conditions for line concessions also state the minimum vessel speed of 8 knots and the maximum vessel age of 35 years. As for results, the vehicle traffic on the elaborated line is constantly increasing (5.3% from 2013 to 2014, and 5.8% from 2014 to 2015). Irrespective of unavailability of relevant official data for subsequent years, a simple trend extrapolation shows the probable traffic increase by the approximate amount observed.

4. Trend forecast and optimization possibilities

In order to draw a conclusion on the forecast of the demand for transport capacity over a longer period of time and with greater reliability predictions, it would be necessary to observe and determine the correlation factors with other indicators such as the number of visitors' overnight stays during the season, the domestic GDP and GDPs of foreign guests' respective countries, the analysis of tourism capacity of the islands of Ugljan and Pašman, and the islands' development strategies for the next year, movement trends of islands' permanent residents, the number of commuters who travel on a daily basis to work using this line, the number of pupils and students who use the line, as well as other indicators correlating with the line to a lesser or greater extent. A more accurate determination of the correlation with other indicators could give the answer to the question why the number of passengers from 2013 to 2014 had fallen by as much as 8.4%, while at the same time the vehicle traffic increased by 5.8%. It would be possible for the line optimization to be carried out according to various criteria, such as maximizing the number of transported vehicles, minimizing vehicles' waiting time (queuing), minimizing the shipping company and/or the terminal or total costs, maximizing the line capacity utilization, etc.

Various authors used different approaches to model queues at cargo or passenger terminals. For example, in a paper (2006) authors used the theoretical queuing model to simulate cargo loading and discharging operations at the bulk cargo port of Bakar, Croatia [10]. In another study [14] a similar approach was used to model the port container terminal system with costs as the optimization criterion to determine the optimal number of berths and to calculate the required capacity with other subsystems of the port container terminal, with the aim to explain behavior indices and decision-making procedures to improve the effectiveness of the port system. Machine learning methods including artificial neural network and support vector machine algorithms are used to predict vehicle waiting queues at ferry terminals in Seattle [18]. In a study of optimization of the ferry line between Java and Sumatra, author recommended increasing number of operational docks and ships on national holydays when the vehicle waiting time typically increases up to more than 10 hours from the baseline of 10-30 minutes [5]. Here, an example is given to optimize timetable lines in order to minimize queues for boarding vehicles on board the ferry.

According to available data of line utilization, it is evident that in the busiest part of the year, during the summer season, there are many examples of line overloading which forms queues of vehicles that are waiting at the terminal in order to board the ferry at the next departure, even though they arrived on time for a targeted departure in the timetable. Optimization of ferry lines is aimed at avoiding such overloads that take place due lack of capacity of scheduled ferries and reduce queues of vehicles waiting at the terminal to be boarded.

One of the methods of optimization is the traffic simulation at the terminal. The simulation requires the exact timetable data, the capacity of individual ferries and

frequency of vehicle arrivals at the terminal during the day. The mentioned data are not easily available. The Port Authority does not have detailed statistics about the distribution of vehicle arrivals during the day and without those data no simulation of vehicle arrivals at the terminal can be achieved with the expected accuracy.

With the availability of the required data it would be possible to make control simulation using the departure timetable, capacity of ferries and distribution of arrivals of vehicles, and then to detect any queues created within the running simulation. Since the frequency of vehicle arrivals cannot be affected by optimization, it has to stay fixed. However, timetables and capacity of ferries can be changed (e.g. ferry departure frequencies). By variation of these parameters, it is possible to create a series of simulations for each combination of chosen parameters and record the resulting simulated queues at the terminal.

In such a system, it is necessary to set limitations so that the solution to the problem is realistically feasible and not only theoretically modeled. Some of the limits could be the maximum capacity of the ferry (dependent on the size of the moor, the port basin sea depth, the availability of vessels owned by the shipping company, etc.), the maximum financial cost of the line, the minimal time between two departures (dependent on the duration of one full cycle of ferry travel), and the maximum number of ferries operating at the same time, to mention some.

Moreover, there is a possibility of modification of timetables in the summer period by decreasing the passenger-only departures from Jazine to Preko while increasing ferry departures from Gaženica to Preko, in order to balance the cost increase caused by additional ferry departures. During the winter months, when there is no high line utilization, ferry lines could be reduced and passenger-only lines from Jazine could be increased. That would lead to some cost savings owing to the shorter route taken by the non-ferry vessel and its lower fuel consumption. As a result, the cost savings achieved during the modified, out-of-season timetable could provide more frequent departures during the summer season. At the same time, passenger satisfaction during the winter period should not be affected, since the frequency of departures would remain the same but would operate more economically by increasing the number of non-ferry lines and decreasing ferry departures.

5. Conclusion

The utilization of transport capacity of coastal line Zadar-Preko was analyzed in the paper. Based on the statistical analysis of passengers and vehicles transportation data and on the comparison of available shipping capacities, it was concluded that during the year there are extremely large seasonal traffic differences. During the high season the vessel capacity used for the carriage of vehicles is completely full, while the off-season line utilization is very low.

According to the trend of changes in the traffic observed over time, the traffic will very likely grow in the years to come by approximately 5% per year. The forecast of

the precise future trend requires a more detailed correlation analysis of the relevant parameters that affect the traffic of passengers and vehicles.

Line optimization is possible to achieve, however, within certain limits. It would be desirable to increase either the frequency of ferry departures or vessel boarding capacities in order to reduce vehicle queues during seasonal peak loads.

In order to obtain a complete insight into all aspects of optimization of the Zadar-Preko line and to make concrete recommendations, while considering the expected increase in traffic over the next years, it would be possible to perform the "Ferry Queue Management System" software simulation with the introduction of additional ferry capacity. The aim of the research should be the minimization of cost increases that would be achieved through the introduction of additional ferry capacity while maintaining the reasonable length of vehicle queues at the terminal, considering the expected future traffic increase.

More specific processing of queues at the micro level is not possible without an insight into the distribution of vehicle arrivals at the terminal during the day. In order to obtain such data and considering their unavailability (at the moment), it would be necessary to count the number of vehicles during a specific period within high season months and determine the distribution of their arrivals at the terminal. The required data and traffic system simulations would result in better insight into the possibilities for a more accurate optimization of the line.

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