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STATISTICAL MODELING OF A RENT-A-BIKE IN GoNM SYSTEM

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Abstract

Public transport is very important and is becoming an increasingly popular means of transport, especially in large cities, where the mobility of the car owners is seriously jeopardized for various reasons. It is also important to mention the role of public transport in the economic development of cities and regions, improving ecological conditions and increasing passenger safety. The Bicycle Rental system works in accordance with generally accepted technologies for managing rental locations and allows optimization of all processes related to customer service. Bicycle rental systems are becoming more and more in demand as this type of city transport becomes popular. In this research, we used methods for statistical modeling of bicycle rental in the GoNM system, Novo mesto Slovenia.

Key words*: transport, bike, modeling.*

1 INTRODUCTION

Public passenger transport (PPT) [1] is important for every municipality, as the current transport system faces well-known problems such as congestion, environmental impact, lack of parking areas, increased safety risks and high energy consumption. Urban transport is crucial for the functionality of any city. High-quality and usable urban transport not only affects the functionality of the city as an economic and social center, but also reduces the number of passenger cars on the streets. The wider Novo mesto region, with about 30,000 inhabitants, is an important industrial center and is heavily dependent on urban traffic. Unfortunately, the urban traffic of Novo mesto still has a relatively weak influence on the transport connectivity of the wider area. In fact, more and more people are opting for bicycles as an alternative to the car, especially during the warmer times of the year. Of course, this mode of travel has certain advantages over heavy rush hour traffic, constant congestion, endless road work that is hard to get around. And let's not forget the bigger parking problem every year. It is almost impossible to park a car in the middle of the day in the city center. It is easier to walk or ride a bike as the conditions for their use are increasingly favorable. The main novelty is that now rented bikes do not need to be parked at docking stations. You can find and unlock them with the mobile app, remove them for an hour, a day or a week - then simply lock them and leave at the end of the trip without looking for a special parking space. A good bike, however, costs a lot, and modern models are generally comparable in cost to a used car. This makes it easier for many city residents to hire a bike when needed. In addition, many cycling marathons, mountain biking, and a more active, healthy lifestyle in general have become increasingly popular in recent years. And again, not everyone can afford to buy their own appliances. And here rent also comes to the rescue. Well, when there is a contractual lease, they need to be managed and the material assets used must be taken into account. These bikes now account for most of the 18 million public bikes in 1,608 cities worldwide. Bicycles that do not require parking are significantly cheaper. By transferring the lock and payment functions directly from the docking station to the bike, the use of the service is greatly simplified. In this research, we used methods for statistical modeling [2] of bicycle rental for 2020 in the GoNM system, Novo mesto Slovenia (Fig. 1).

Fig. 1 *5 Stations in city of Novo mesto*

Cycling has proven to have positive effects on health and the increase in traffic safety for cyclists with a critical mass of road users [3]. The priorities of passenger bicycle traffic are as follows:

Social benefits:

• Improving traffic conditions and shifting to public transport compared to a car.
• Reduce travel time by providing real-time traffic information.
• Reduction of environmental pollution.
• Improving road safety.
• Promoting cooperation between local public and private bodies.
• Promotion of the culture and history of participation in different locations.
• Equal opportunities for development with e-promotion for all commercial companies.

Economic benefits:

• Reduced environmental impact of emissions.
• Reduced energy consumption.
• Increased and supported vibrant economy.
• Increased user and community satisfaction.

• Increased technology capacity and thus helping the community to meet its needs.
• Coordination of public transport services with information services provided in exchange facilities.
• Efficient use of urban space, while improving the image of the urban area and promoting the development of local businesses.
Financial benefits:
• Increasing tourist demand.
• Strengthening the local economy through tourism and trade.
• Better coordination of investments for the development of tourism services in accordance with the specific requirements to be recorded by the users of the platform.

2 METHODOLOGY

Statistical modeling implies the use of mathematical models and statistical assumptions to create sample data and predict the real world. A statistical model is a collection of probability distributions on a set of all possible experimental results. Statistical modeling refers to the process of applying statistical analysis to data sets. It provides a mathematical relationship between one or more random variables and other non-random variables [4, 5]. The use of statistical modeling for raw data helps data scientists approach data analysis in a strategic way, and provides intuitive visualizations that help identify the relationships between variables and make predictions [6, 7]. Analysis of variance (ANOVA) models are restrictive in that they allow only categorical predicting variables. The standard ANCOVA model incorporates covariates into an ANOVA model in a straightforward way. The multiple regression equation is represented by

$$y = f(X1, X2, ..., Xm) + E \qquad (1)$$

where y is the dependent variable (the resultant attribute), $X1, X2, ..., Xm$ are independent explanatory variables (feature factors), and E is a perturbation or stochastic variable that includes the influence of unaccounted factors in the model.

3 RESULTS AND DISCUSSION

Fig. 2 represents network of bicycle rentals and returns based on 5 different locations (BTC, NT, USG, SU and ŠC) in Novo Mesto.

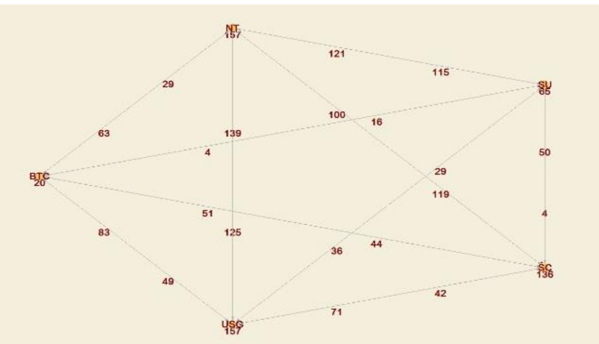

Fig. 2 *Network of bicycle rental and return based on 5 different locations*

The tables given below present statistical data of the considered rent-a-bike system. Table 1 presents the number of bike rentals from location to location.

Table 1 Number of daily bike rentals

	BTC	NT	SU	ŠC	USG	Σ
BTC	20	63	16	51	49	199
NT	29	158	121	119	125	552
SU	4	115	66	50	36	271
ŠC	45	101	4	137	43	330
USG	83	139	30	42	158	452

Table 2 presents the sum of daily bicycle rentals and returns based on 5 different locations for each day.

Table 2 Sum of daily bike rentals and returns

SUM	BTC	NT	USG	SU	ŠC
BTC	20	29	49	100	44
NT	63	157	125	115	119
USG	83	139	157	29	42
SU	4	121	36	65	4
ŠC	51	100	71	4	136

Table 3 gives the average number of bicycle rentals and returns for each day.

Table 3 Average number of daily bike rentals and returns

AVERAGE	BTC	NT	USG	SU	ŠC
BTC	2.857	9	7	2.2857	7.2857
NT	4.142	22.5	17.857	17.285	17
USG	11.85	19.8	22.571	4.2857	6
SU	0.571	16.4	5.1428	9.4285	7.1428
ŠC	6.428	14.4	6.14285	0.5714	19.571

Tables 4 and 5 give the maximum and minimum number of bicycle rentals and returns for each day, respectively.

Table 4 Maximum number of daily bike rentals and returns

MAX	BTC	NT	USG	SU	ŠC
BTC	5	17	11	4	9
NT	7	27	27	21	22
USG	14	25	27	6	7
SU	1	21	7	16	8
ŠC	8	18	11	3	25

Table 5 Minimum number of daily bike rentals and returns

MIN	BTC	NT	USG	SU	ŠC
BTC	1	4	1	0	6
NT	3	21	11	14	12
USG	8	15	18	2	5
SU	0	12	4	5	6
ŠC	5	9	3	0	16

Tables 6, 7 and 8 give the median, variance, and standard deviation, respectively

Table 6 Median of daily bike rentals and returns

MEDIAN	BTC	NT	USG	SU	ŠC
BTC	3	8	7	2	7
NT	3	22	15	17	17
USG	12	19	23	4	6
SU	1	16	5	10	7
ŠC	6	14	5	0	19

Table 7 Variance of daily bike rentals and returns

VARIANCE	BTC	NT	USG	SU	ŠC
BTC	1.809	20.6	9.66	1.5714	1.2380
NT	2.809	4.952	34.1	7.2380	10.666
USG	4.809	10.14	9.95	1.5714	0.6666
SU	0.285	9.619	1.80	15.952	0.8095
ŠC	0.952	9.619	7.47	1.2857	9.9523

Table 8 Statistical properties of network of bicycle rental and return based on 5 different locations for each day

STANDARD DEVIATION	BTC	NT	USG	SU	ŠC
BTC	1.345	4.546	3.10	1.2535	1.1126
NT	1.676	2.225	5.84	2.6903	3.2659
USG	2.193	3.184	3.15	1.2535	0.8164
SU	0.534	3.101	1.34	3.9940	0.8997
ŠC	0.975	3.101	2.73	1.1338	3.1547

Table 9 presents the number of bike rentals on each day in a week for the whole year.

Table 9 Rent a bike for all year

Day	#
Monday	303
Tuesday	311
Wednesday	357
Thursday	301
Friday	292
Saturday	153
Sunday	107

Table 10 provides information on duration of bike rentals.

Table 10 Statistical propeties for rent s bike for every day

Day	Av. time for a bike (min:sek)	All bikes (min:sek)	Min time for a bike (min:sek)	Max time for a bike (min:sek)
M	0:38:42	15:13:38	0:00:21	19:41:47
T	0:39:49	3:33:42	0:00:19	21:59:28
W	0:32:51	13:03:00	0:00:19	11:18:32
T	0:35:58	19:38:42	0:00:20	21:32:04
F	0:48:46	22:32:13	0:00:18	23:47:14
S	0:51:05	19:11:24	0:00:01	23:52:12
S	0:57:25	18:19:31	0:00:24	23:53:45

Table 11 presents the parameters that impact bicycle rental and return (for the 5 stations).

Table 11 Parameters impact on bicycle rental and return (5 stations)

	average time traveling (s)	average year	credit	Distance (m)	Y
BTC-BTC	2949.80	49	29	0	20
BTC-NT	835.28	39	76	2400	29
BTC-SU	1786.25	37	105	1800	100
BTC-ŠC	4448.07	27	82	3000	44
BTC-USG	4972.95	40	19	700	49
NT-BTC	3266.48	34	55	2400	63
NT-NT	5463.84	32	88	0	157
NT-SU	1936.53	35	98	300	115
NT-ŠC	6960.47	26	80	1800	119
NT-USG	4713.71	38	122	1900	125
SU-BTC	6155.00	42	16	1800	4
SU-NT	757.79	35	119	300	121
SU-SU	7677.65	38	64	0	65
SU-ŠC	2161.50	36	4	1600	4
SU-USG	5575.73	40	28	1600	36
ŠC-BTC	1716.73	31	49	3000	51
ŠC-SU	1391.68	26	116	1800	4
ŠS-NT	1093.04	39	50	1600	100
ŠS-ŠS	7763.23	33	136	0	136
ŠS-USG	4805.43	36	41	700	71
USG-BTC	4641.67	38	48	700	83
USG-NT	3434.55	37	121	1900	139
USG-SU	2204.25	42	36	1800	29
USG-ŠC	5509.26	36	42	700	42
USG-USG	6873.86	44	156	0	157

The model of multiple regression for the rent-a-bike system, depending on the average traveling time (in seconds), average age of users, credit and distance (in meter) estimates the number of bike rentals, Y, as:

$$\begin{aligned} Y &= \text{Average time travel} \times 0.0028 \\ &- \text{average age} \times 0.14 + 0.79 \times \text{credit} \\ &- 0.011 \times \text{Distance} \end{aligned} \tag{2}$$

At stations with the maximum number of bicycle rentals, it is necessary to increase the number of bicycles, and where the number is the low, it is necessary to reduce the number of bicycles. From the tables one may identify stations with zero rentals and which day of the week. It is expected that there are less renatls on Saturday and Sunday. The busiest location over the weekend is the ŠC-ŠC route around the school, and the SU-SU route on Saturday, which is due to the fact that this is the location where young people mostly spend their time. From this we can conclude, for instance, where the child / adolescent who has borrowed a bicycle (on the route ŠC-ŠC or SU-SU) is most likely to be located.

In cities where cycling is already well accepted, the idea can add another valuable element to promoting and using a bike.
Table 12 presents the real and modeled data.

Table 12 Real and modeled data

	Y	MR (41 %)
BTC-BTC	20	51
BTC-NT	29	56
BTC-SU	100	89
BTC-ŠC	44	66
BTC-USG	49	42
NT-BTC	63	47
NT-NT	157	108
NT-SU	115	101
NT-ŠC	119	85
NT-USG	125	109
SU-BTC	4	30
SU-NT	121	115
SU-SU	65	94
SU-ŠC	4	12
SU-USG	36	41
ŠC-BTC	51	31
ŠC-SU	4	98
ŠS-NT	100	45
ŠS-ŠS	136	152
ŠS-USG	71	60
USG-BTC	83	64
USG-NT	139	105
USG-SU	29	35
USG-ŠC	42	63
USG-USG	157	164

4 CONCLUSIONS

In this article, we present the statistical properties of the public passenger network in the municipality of Novo mesto. The use of bicycles means a reduction in the number of vehicles on the roads, which reduces traffic congestion, reduces driving speed (smoother traffic) and results in a very significant reduction in air pollution, which means less respiratory diseases, less economic losses due to absence from work due to illness, less health care spending, less deterioration on planted areas and buildings, greater attractiveness of the city center due to improved quality of life in cities and reduced energy consumption.

The hilly topography throughout the city center can be a barrier to deployment, but can be remedied by using bikes with an additional electric drive. Climate does not seem to play such an important role, as successful programs have been implemented under different climatic conditions. It is important to create favorable framework conditions for urban cycling: public bicycles can be an opening door to promote urban cycling. However, people only use a bicycle if it is a safe, convenient and fast way to travel. Therefore, only cities with a minimal and safe cycling infrastructure and an integrated strategy to promote cycling offer good framework conditions for the implementation of the public bicycle scheme. This includes measures such as traffic calming, setting up a cycling network and safe parking, information, marketing and education. It is advisable to start a public bike scheme in the spring or early summer when people enjoy the nice weather and most likely cycling. Locations where public bikes can be found in the city center should be easy for the user to find. The location of public bicycles must be well planned according to the expected demand.

The existing examples show that renting bicycles to users during the day often leads to an uneven distribution of bicycles throughout the city. In this case, it is necessary to redistribute the bikes to ensure the availability of the bikes, as this avoids frustration for users who cannot find a bike or cannot leave a bikes at full racks.

Public bicycles must be available on the website of the important public transport station. This allows the combined use of bicycles and public transport services and increases the attractiveness of the system.

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