Computing and Informatics, Vol. 40, 2021, 1160–1173, doi: 10.31577/cai_2021_5_1160

MODELING PUBLIC TRANSPORT NETWORK SYSTEM BY USING STATISTICS, NETWORK THEORY AND ANT COLONY OPTIMIZATION

Matej Babič

Faculty of Information Studies
Novo mesto, Slovenia
e-mail: babicster@gmail.com

Ladislav Hluchý

Institute of Informatics, Slovak Academy of Sciences
Dúbravská cesta 9
845 07 Bratislava, Slovakia
e-mail: Ladislav.Hluchy@savba.sk

Šter Branko

Faculty of Computer and Information Science, University of Ljubljana
Slovenia
e-mail: branko.ster@fri.uni-lj.si

Janez Povh

Faculty of Mechanical Engineering, University of Ljubljana
Slovenia
&
Development Center
Novo mesto, Slovenia
e-mail: janez.povh@fs.uni-lj.si

Abstract. In some countries, bicycles are often used to access public transit stations, but the proportion of out-of-the-way travel is much smaller due to the limited availability of bicycles. Public bicycles are innovative rental or free bicycle schemes in urban areas that can be used for day-to-day mobility as one-way use is possible and can be considered as part of a public transport system. Different from traditional, mostly leisure bike rental services, they provide fast and easy access and have a variety of organizational layout, business models and useful technology for smart bikes (rented via smart cards or mobile phones). We find that bicycle-sharing systems that complement the traditional public transport system could potentially increase the competitiveness and attractiveness of sustainable modes of urban transport and thus help cities to promote sustainable daily mobility. Finally, we emphasize that the availability of open sources of urban transport information, such as public transport in our case, is crucial for analyzing urban mobility patterns. The aim of the research is to analyze and model PPP bicycle rentals using mathematical and computer methods. The article presents the application of the statistical and topological properties of bicycle rental and return network theory in city Novo mesto. The article uses swarm intelligence, a colony of ants to optimize the development of wheels across 14 stations. The wider city Novo mesto region with a population of almost 30 000 people, as a key industrial center, is heavily dependent on urban transport.

Keywords: Trasport system, ant colony, network theory

1 INTRODUCTION

It is essential that we constantly monitor the use, acceptance and quality of the public bicycle system. Marketing should also aim to encourage people who discovered urban cycling through a public cycling scheme to get their bike and use it daily or for leisure activities. This can help to increase the share of urban cycling in general [1]. A key element for successful long-term operation is the development of a well-planned financing strategy. In many cases, startup resources from the public side may be available, but there is little thought about what will happen after this stage. Individual strategies need to be found for each type of scheme. Usage data and critical feedback help optimize bicycle distribution and ensure good availability and quality for users. High acceptance, even among the general public and in use, is a good argument for maintaining the system in the long term. Following a well-established public cycling scheme, the interest of potential users can be reduced. Therefore, it is crucial to remind people of the benefits of the system and to encourage its use in order to reach a stable or growing number of users. The hilly topography throughout downtown can be a barrier to deployment, but can be eliminated by using wheels with additional electric propulsion. Climate does not seem to play such an important role, as successful programs have been implemented under different climatic conditions. Creating favorable framework conditions for urban cycling public bicycles can be an open door to encourage urban cycling. However, people only use a bicycle if it is safe, convenient and the fast way to travel. Therefore, only cities with a minimum and safe cycling infrastructure, and an integrated cycling promotion strategy fulfill the good framework conditions for the implementation of the public bicycle scheme. This includes measures such as traffic calming, the establishment of a cycling network and secure parking, information, marketing and education [2]. Information and communication technology [3] is changing the way cities organize policy making and urban growth. Smart cities [4] base their strategy on the use of information and communication technologies in several fields, such as economy, environment, mobility and governance to transform urban infrastructure and services. Statistics [5] is a form of mathematical analysis that uses quantified models, presentations for a given set of experimental data or real studies. Statistics examine methodologies for collecting, reviewing, analyzing, and inferring data. Metaheuristic solution of combinatorial optimization problems is a modern and fast growing research field [6]. This is mainly due to the importance of combinatorial optimization problems in both science and industry. Ant colony [7] is the most successful metaheuristic method for solving discrete optimization problems, which belongs to the family of swarm intelligence algorithms. It derives the idea from the involvement and behavior of real ants in their search for food. Ant colony optimization is divided into several classes: Ant System (AS), Elitist Ant System (EAS), Rank-Based Ant System (ASrank), Min-Max Ant System (MMAS), and Ant Colony System (ACS). The aim of the research is to analyze public-private partnership bicycle rentals using mathematical and computer methods. The goal of this research is to show where to put the additional six stations at the request of the Novo mesto municipality.

2 METHODOLOGY

In [8] authors have explored the influence of different attributes on the choice of cycle path, such as length or time of travel, gradient, existence of a cycling object, such as bike lanes, intersections, age and experience of the cyclist, and traffic volume. The vast majority of riders choose a bike because of the shortest route. In some cases, the shortest route for the rider to reach the destination means to cross the railway line or other obstacles that cyclists would rather avoid. Other articles suggest that most riders embark on a short distance trip. This modeling has sometimes been studied in conjunction with pedestrian traffic. The municipality of Novo mesto uses the GoNM system. Municipality Novo mesto (MONM) has started a bicycle rental project. This urban transport planning process often considers bicycles and pedestrians as a system of passenger network. Therefore, it is necessary to develop a methodology for estimating and analyzing bicycle rental demand. This system consists of the following stations (vertices in our network).

Code of Stations	Names of Stations
P1	Bus Station – Topliska Road
P2	BTC City Novo mesto
P3	Center – Seidlova Road
P4	Drska – Segova Street
P5	Main Square
P6	Kandijska Bridge
P7	Locna – Seidlova Road
P8	New Square
P9	Elementary School Brsljin
P10	Elementary School Smihel
P11	Podbreznik
P12	Ragovska Street
P13	School Center Novo Mesto
P14	Slavka Gruma Street

Table 1. List of stations of GoNM system

Using network theory, we will analyze the topological properties of different cycling networks. Using statistical methods, we will analyze the time graphs of bike rentals. The triadic census is a count of how many of the 16 possible types of triads are present in a directed graph. This model can be used to design bicycle road networks. MONM cycling research data is used to study the characteristics of the model. The model is used to study the bike rental network at MONM.

The artificial ants used in optimization with ant colonies are procedures that make up solutions using probabilities. In the gradual (step-by-step) assembly of the solution, the ant takes into account the heuristic information about the problem it solves and about pheromone trails that change during the course of the solution and that express, up to a given moment, information about the current solution to the problem. Although one ant is a very simple and primitive creature, the colony of ants is a very organized unit and very effective in solving complex tasks, e.g. finding the shortest route between two points. A stronger concentration of pheromones in the pathway means that other ants are more likely to follow this path. Figure 1 represents Ant System Algorithm [9].

The ants indirectly interact with each other through traces of the chemical substance of pheromones, which they dispose of along the way, thereby altering the environment. Pheromones evaporate over time, but the intensity on shorter paths nevertheless increases. Ants that choose the shorter route get to the food earlier and return faster, so they can drop the trail several times in the same time interval. Figure 1 shows ants in real space. Initially, we have two ants that start their journey and do the same probability (0.5) deciding between paths. The ant that chose the shorter path came faster to the finish line. The ant that chose the shorter path returns to the nest and leaves a trail of pheromones behind. The next ant detects pheromones and chooses a shorter path. After a few repetitions, more

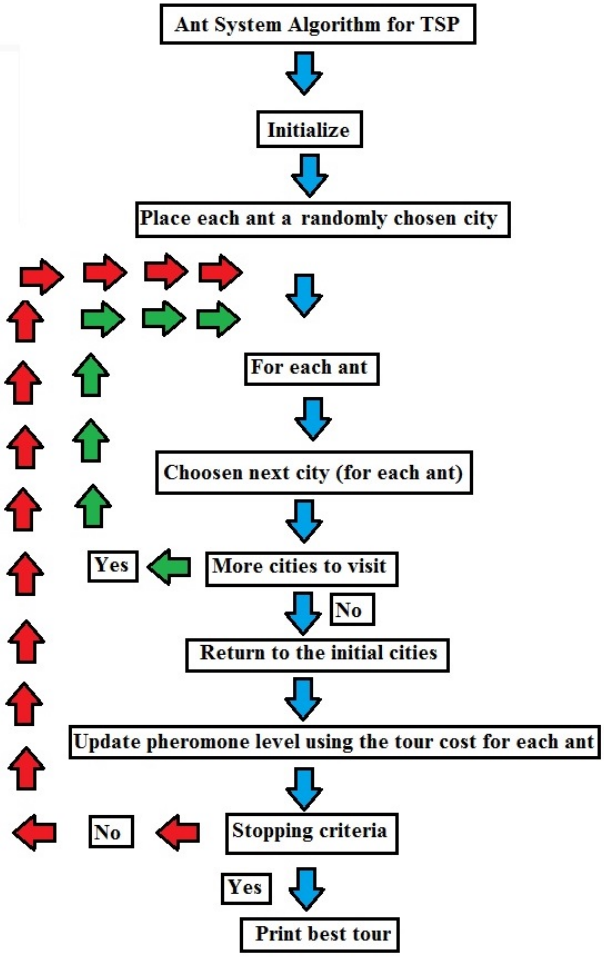

Figure 1. Ant system algorithm

and more ants are taking the path with a higher concentration of pheromones and further enhancing it. After a while, only a shorter route becomes operational.

3 RESULTS AND DISCUSSION

3.1 Exploratory Network Data Analysis

In 2019, there were 14 stations (Figure 2) where a bike could be borrowed.

Data on bicycle use were obtained by the City of Novo mesto and cover the total real loan from the introduction of the system in April 2019 to the end of November

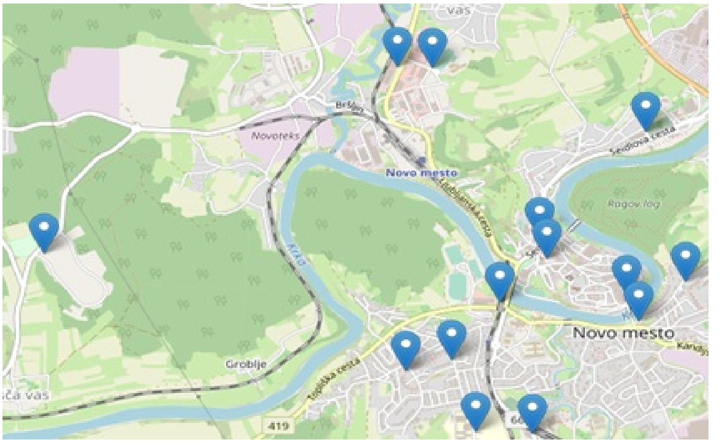

Figure 2. Micro locations of 14 GoNM stations in the city of Novo mesto in 2019

2019. In a directed network there are sixteen possible triads. This routine counts the number of each type of triad present in a directed network. The triads are labelled abcZ where a is the number of reciprocated ties, b is the number of unreciprocated ties and c is the number of null ties. The Z term is a letter (U, C, D or T) used to differentiate between different triads in which these numbers are the same. For an undirected network there are only 4 possible triads, namely 003, 102, 201 and 300. Table 2 presents the topological properties of the triad types of bike sharing network, which were calculated using the Pajek program [10].

Triad Type	Number of Triads
type 1 triad – 003	2
type 2 triad – 012	17
type 3 triad – 102	35
type 4 triad – 021D	9
triad type 5 – 021U	4
type 6 triad – 021C	12
type 7 triad – 111D	30
triad of type 8 – 111U	36
triad type 9 – 030T	10
triad type 10 – 030C	1
type 11 – 201 triad	39
triad type 12 – 120D	7
triad type 13 – 120U	17
type 14 – 120C triad	19
type 15 – 210 triad	84
type triad 16 – 300	42

Table 2. Topological properties of the triad network types

Station	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
P1	0	5	1	5	7	10	10	19	15	10	4	8	20	10
P2	6	6	2	24	8	8	445	18	17	15	12	5	8	20
P3	1	1	8	5	9	25	11	11	21	185	14	43	9	27
P4	15	4	5	17	10	5	9	10	10	16	10	39	42	16
P5	12	1	10	15	8	1	5	5	18	24	30	25	37	32
P6	8	1	11	5	1	13	18	21	31	35	21	18	35	25
P7	7	14	2	8	1	15	10	31	1	32	17	15	25	35
P8	6	12	3	7	10	5	19	40	14	5	5	14	18	28
P9	9	1	1	23	24	2	10	31	20	7	31	5	10	16
P10	19	8	5	25	17	9	45	35	5	10	7	3	14	8
P11	8	18	10	10	10	16	12	4	4	9	8	20	8	9
P12	4	16	7	5	5	29	15	5	2	18	5	10	7	5
P13	3	1	4	1	27	4	35	25	25	15	10	6	12	13
P14	2	5	3	6	2	17	16	15	9	42	9	9	38	10

Table 3. Bicycle rental and return network by 14 different GoNM stations for all days

Table 2 shows the different types of bicycle rental network triads. With the increasing bicycle stations and increased popularity of using bicycle it is expected deeper understanding of the public bicycle tranport by using concepts of triad census network analysis such as sub-graph analysis. A triadic census provides a method to detect substructure in the public bicycle network, more specifically the tendency for certain types of triadic ties. Most triads have type 15, 84, and least type 10, 1. Triads of types 9, 12, 13, 16 are transitive, triads of types 6, 7, 8, 10, 11, 14, 15 are non-transitive and type 1, 2, 3, 4, 5 triads do not contain links to satisfy the transitivity conditions. There are thus 76 transitive triads, 221 non-transitive triads and 67 triad types in the bicycle rental network that do not qualify for transitivity. As you can see, we have the most non-transitive triads in the bike rental network. Table 3 shows the bicycle rental and return network by 14 different locations for all days in July. Table 4 presents the statistical characteristics of bicycle rentals for each day.

Day	Average (h:min:sec)	Minimum (h:min:sec)	Maximum (h:min:sec)
Monday	0:38:42	0:00:21	19:41:47
Tuesday	0:39:49	0:00:19	21:59:28
Wednesday	0:32:51	0:00:19	11:18:32
Thursday	0:35:58	0:00:20	21:32:04
Friday	0:48:46	0:00:18	23:47:14
Saturday	0:51:05	0:00:01	23:52:12
Sunday	0:57:25	0:00:24	23:53:45

Table 4. Statistical characteristics of bicycle time rentals for each day in a week

Table 5 represents basic statistical characteristics, average, maximum, minimum, standard deviation and median calculation. The highest average bike rental is on Friday, 92.78 bicycles, and the lowest on Sunday 41.85. Most bicycle rentals are at the Main Square station on Tuesday and the lowest on Saturday at the Šmihel – Šmihel elementary school. The standard bicycle rental deviation ranges from 17.35 to 36.63. The median reaches values between 44 and 97.5. It is interesting to note that the short-distance bicycle rental (Main Square, Kandija Bridge and Ragovska Street) is very high. This means that bike rentals are high on short distances. We can conclude that the reason for this is the urban environment. Table 3 presents the number of bicycles borrowed in 2019 for each day of the week. Somehow the expected result is that bike rentals days are Saturday and Sunday, when no business day is the minimum. On Friday, we have the most bike rentals, 1 327, and on Sunday, the least, 596. The total bike rental for 2019 is 7 380 bicycles. Table 4 presents the statistical characteristics of bicycle rentals for each day. The maximum average bike rental time on Sunday and Saturday is about the same time, around one hour. It is significantly smaller during working hours. The minimum bike rental time ranges from 1 min on Saturday to 24 min on Sunday. The maximum rental time is Sunday approximately one day, specifically 23:53:45

Station	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
P1	122	111	110	128	100	40	30
P2	85	88	101	93	110	57	39
P3	79	85	84	82	106	27	25
P4	85	79	87	90	107	65	48
P5	117	144	142	127	157	97	45
P6	69	52	76	57	79	57	43
P7	65	67	76	72	83	38	49
P8	93	116	124	107	128	52	41
P9	47	71	51	50	55	26	23
P10	21	29	24	25	25	4	11
P11	51	28	35	48	41	35	47
P12	92	92	87	84	75	48	45
P13	105	117	140	114	138	65	85
P14	83	103	90	104	95	48	55
sum	1114	1182	1227	1181	1299	659	586
mean	79.57	84.42	87.64	84.35	92.78	47.07	41.85
max	122	144	142	128	157	97	85
min	21	12	20	9	25	4	7
sd	26.57	32.24	33.97	29.93	35.30	21.28	16.72
median	84	86.5	87	87	97.5	48	44

Table 5. Number of bicycles borrowed at each station for each day during March–November 2019 and basic statistical characteristics

Table 6 presents description of GoNM stations with different parameters for which we expect to have impact on the relevance of each station: the proximity to cycling lane (YES, if cycling lane is very close, NO otherwise), proximity to residential neighbourhood, proximity to shopping centre, distance to shopping centre, proximity to public buildings, distance to public buildings, distance to closest GoNM station, number of working places in the proximity, and finally, the last column contains the numbers of bike rentals in the observed period.

Station *a*	Prox. to Cyc. Lane	Prox. to Resid.	Prox. to Shopping	Dist. to Shopping	Prox. Public Houses	Dist. to Pub. h.	Dist. to GoNM	# Working Places in Neighb.	Total Rentals
P1	YES	YES	YES	76	YES	240	600	many	641
P2	YES	NO	YES	5	YES	100	300	many	573
P3	YES	NO	NO	700	YES	110	300	many	488
P4	NO	YES	NO	700	NO	800	400	medium	561
P5	YES	NO	NO	1800	YES	96	230	medium	829
P6	YES	YES	NO	1500	YES	140	230	few	433
P7	YES	YES	NO	2000	YES	290	1 000	few	450
P8	YES	NO	YES	50	YES	100	300	many	661
P9	NO	YES	YES	300	YES	100	300	medium	323
P10	NO	YES	NO	800	YES	140	750	medium	139
P11	NO	YES	NO	2000	NO	3 000	3 000	medium	285
P12	NO	YES	NO	2200	YES	300	400	few	523
P13	NO	YES	NO	1000	YES	10	600	many	764
P14	YES	YES	YES	30	NO	800	400	medium	578

Table 6. Parameters that may affect the total number of bike rental at GoNM stations

We wanted to know in where to put the additional 6 stations at the request of the Novo mesto municipality. Table 6 shows the parameters that affect bicycle rental according to economic and demographic criteria. These parameters are the proximity to the bike lane, proximity to stand neighborhoods, total number of bike rentals in 2019, proximity to mall, distance to mall, proximity to public buildings, distance to public buildings, and distance to the nearest GoNM station. The penultimate column represents the decisive YES/NO and the last one represents the distance (the sum of the distances relative to the other distances in the table). Figure 3 presents the planned new stations between the marked stations, which are marked red. We were interested in how the cycle path affects the placement of additional stations.

Table 7 presents the impact of the bike lane on the placement of new stations between the existing stations. By 1 we have marked that the bike lane is near the station; by 0 that it is not; and by 0.5 that the bike lane is on the part of the route between the two stations.

We use ACO settings: population size 30, evaporation rate 0.2, deposition rate 0.3, parameter alpha 1 and parameter beta 2.

3.2 Regression Tree Explanation of Total Number of Rentals

In this subsection we present results of regression tree analysis, which indicates the factors relevant for the total number of rentals at each GoNM station. Figure 7 shows that the most visited GoNM stations (the stations with higher total number of rentals in the observed period) are those which have

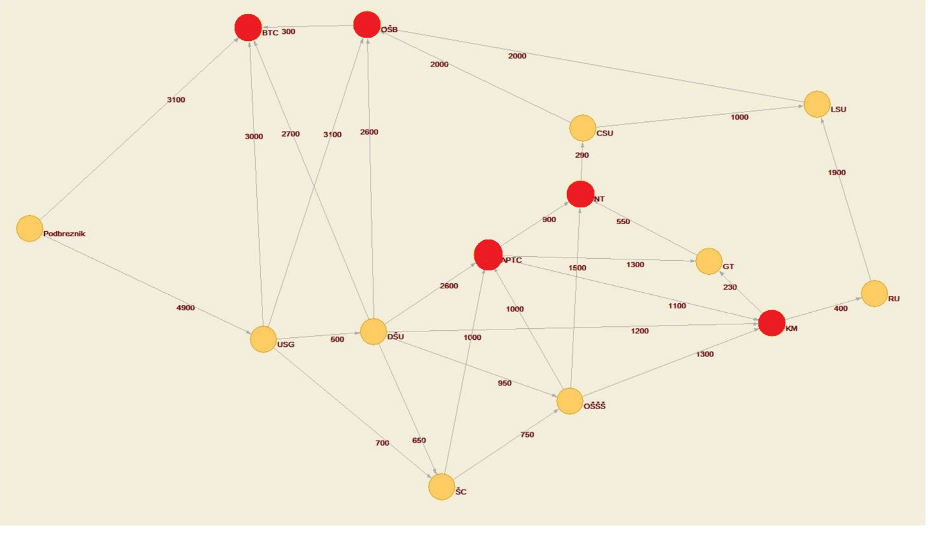

Figure 3. New stations foreseen between the marked stations, which are marked in red according to Table 6

- distance to the closest GoNM station less than 675 m,
- distance to the closest public building less than 98 m.

On the other hand, stations with the distance to the closest GoNM station larger than 675 m or with distance to the closest shopping center larger than approx. 190 m have the lowest number of rentals.

Station	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
P1	0	0.5	1	0	0.5	0	0	0	0.5	0	0.5	0	0	0
P2	0.5	0	0.5	0	0	0	0.5	1	1	0.5	1	0.5	0	0
P3	0	1	0	0.5	0.5	0.5	1	1	1	0.5	1	0.5	0.5	0.5
P4	0	0	0.5	0	0	0	0	0	0.5	0.5	0	0	0	0
P5	0	1	1	0.5	0	1	0.5	0.5	1	0.5	0	0.5	0.5	0.5
P6	0	1	1	0.5	1	0	1	1	1	0.5	0	0.5	0.5	0.5
P7	0	1	1	0.5	0.5	0.5	0	1	1	0.5	1	0.5	0.5	0.5
P8	0	1	1	0.5	0	0.5	1	0	1	0.5	0.5	0.5	0.5	0.5
P9	0.5	1	1	0	0	0	0	1	0	0.5	1	0.5	0	0
P10	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	0.5	0.5
P11	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
P12	0	0.5	0.5	0.5	0.5	0	0.5	0.5	0.5	0.5	0.5	0	0.5	0.5
P13	0	0.5	0.5	0	0.5	0.5	0.5	0.5	0.5	0.5	0	0.5	0	0
P14	0	0.5	0.5	0	0.5	0.5	0.5	0.5	0.5	0.5	0	0.5	0	0

Table 7. Parameters that affect bike rental based on economic and demographic criteria

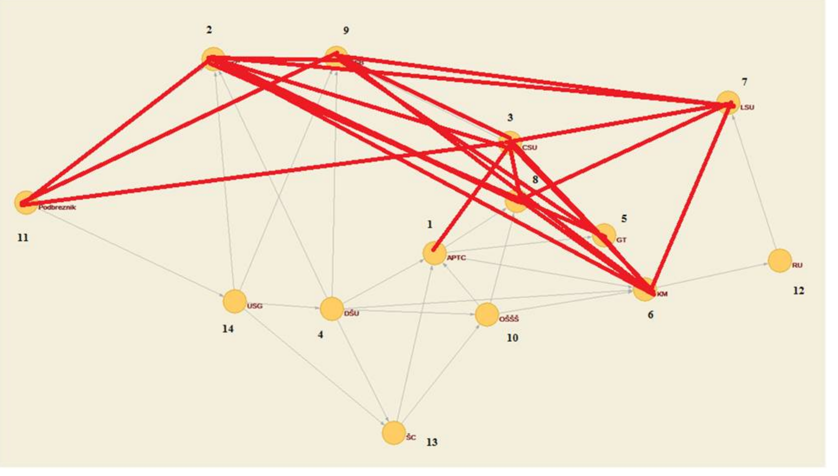

Figure 4. Connections between stations where the bike lane is located according to Table 7

The data are presented in Table 7. By 1 we denote that the cycle path is near the station; by 0 that it is not; and by 0.5 that the cycle path is on the part of the path between the two stations. Figure 4 presents the connections between stations where the cycle track is located according to Table 7. Figure 5 represents the predicted locations for data analysis. Figure 6 represents the shortest path of

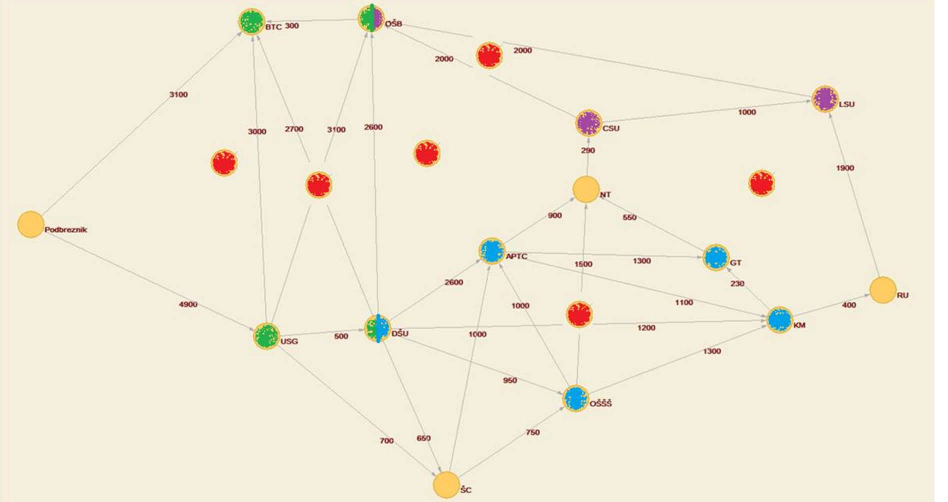

Figure 5. Estimated locations for data analysis

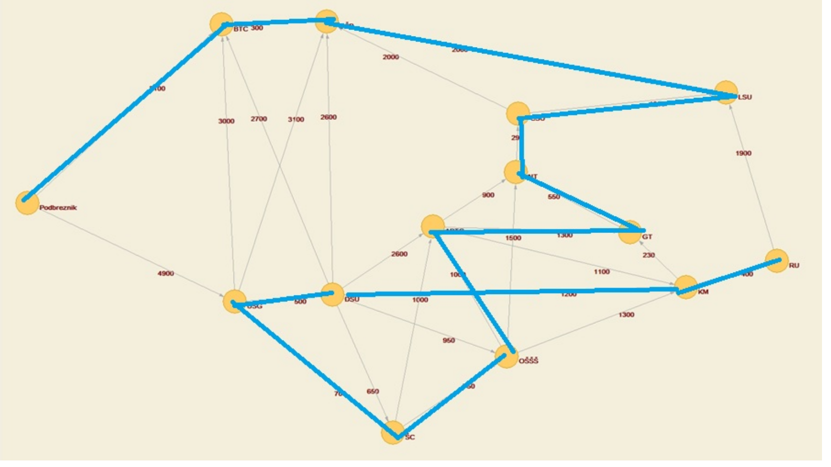

Figure 6. The shortest way to get around 14 stops (12 190 m)

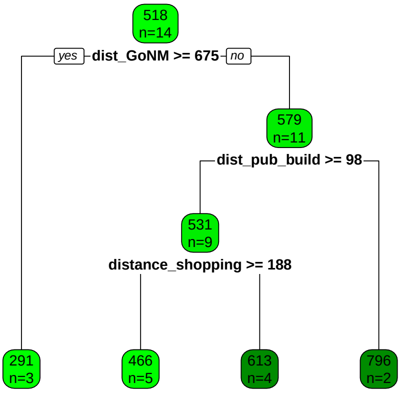

Figure 7. Regression tree explanation of the total number of rentals

bicycle development across 14 stations (12 190 m) obtained by swarm intelligence, an ant colony.

The regression tree analysis shows that the most important factors for the number of rentals at each GoNM station are the proximity to other GoNM stations, public buildings and shopping centers.

4 CONCLUSION

In this article we have presented the statistical and topological characteristics of the public bicycle rental network for 2019 in Novo mesto. The use of bicycles means a reduction in the number of vehicles on the roads, which reduces traffic congestion, reduces driving speed (more fluid traffic) and results in a very significant reduction in atmospheric pollution, resulting in fewer respiratory diseases, less economic loss from work due to sick leave, less health care expenditures, 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 statistical analysis of the data and the topological characteristics of the bicycle rental network can help. We shown application one of method of swarm intelligence in public transport system, especially in a bike sharing system in optimization problem. We used ACO for find shortest path. With the increase of cycling stations and the increased use of network analysis methods, it is expected that a better understanding and organization of public passenger transit could be developed using further research concepts of different types of triad network such as sub-graph analysis, distribution analysis and stability analysis.

Acknowledgement

The investment is co-financed by the Republic of Slovenia and the European Union from the European Regional Development Fund.

REFERENCES

[1] Roman, M.—Roman, M.: Bicycle Transport as an Opportunity to Develop Urban Tourism – Warsaw Example. Procedia – Social and Behavioral Sciences, Vol. 151, 2014, pp. 295–301, doi: 10.1016/j.sbspro.2014.10.027.

[2] Frade, I.—Ribeiro, A.: Bicycle Sharing Systems Demand. Procedia – Social and Behavioral Sciences, Vol. 111, 2014, pp. 518–527, doi: 10.1016/j.sbspro.2014.01.085.

[3] Anderson, M.: Mobile Technology and Home Broadband 2019. Pew Research Center, 2019. Available at: https://www.pewresearch.org/internet/2019/06/13/mobile-technology-and-home-broadband-2019/.

[4] Deakin, M.: From Intelligent to Smart Cities. Chapter 2. In: Deakin, M. (Ed.): Smart Cities: Governing, Modelling and Analysing the Transition. Taylor and Francis, 2014.

[5] Illowski, B.—Dean, S. L.: Introductory Statistics. OpenStax College, Rice University, 2013.

[6] Korczynski, W.—Byrski, A.—Dębski, R.—Kisiel-Dorohinicki, M.: Classic and Agent-Based Evolutionary Heuristics for Shape Optimization of Rotating Discs. Computing and Informatics, Vol. 36, 2017, No. 2, pp. 331–352, doi: 10.4149/cai_2017_2_331.

[7] Kumar, A.—Kumar, R.—Sharma, A.: Energy Aware Resource Allocation for Clouds Using Two Level Ant Colony Optimization. Computing and Informatics, Vol. 37, 2018, No. 1, pp. 76–108, doi: 10.4149/cai_2018_1_76.

[8] Buehler, R.—Pucher, J.: Sustainable Transport in Freiburg: Lessons from Germany's Environmental Capital. International Journal of Sustainable Transportation, Vol. 5, 2011, No. 1, pp. 43–70, doi: 10.1080/15568311003650531.

[9] Red Apple Tutorials: Traveling Salesman Problem Using Ant Colony Optimization. Video Presentation. `https://www.youtube.com/watch?v=9KVg3gv_OcA`.

[10] De Nooy, W.—Mrvar, A.—Batagelj, V.: Exploratory Social Network Analysis with Pajek. Second Edition. Cambridge University Press, 2011.

Matej Babič received his Ph.D. degree in computer science from the Faculty of Electrical Engineering and Computer Science of the University of Maribor, Slovenia. He studied mathematics at the Faculty of Education in Maribor. He is Assistant Professor at the Faculty of Information Studies, Novo mesto, Slovenia. His research interest is in fractal geometry, graph theory, network, intelligent systems, hybrid machine learning, topography of materials after hardening and public transport systems.

Ladislav Hluchý is the Vice-Director of the Institute of Informatics of the Slovak Academy of Sciences and also the Head of the Department of Parallel and Distributed Computing at the Institute. He received his M.Sc. and Ph.D. degrees, both in computer science. He is R & D Project Manager, Work Package Leader in a number of 4FP, 5FP and 6FP projects, as well as in Slovak R & D projects (VEGA, APVT, SPVV). He is a member of IEEE, ERCIM, SRCIM, and EuroMicro consortiums, the Editor-in-Chief of the Journal Computing and Informatics. He is also (co-)author of scientific books and numerous scientific papers, contributions and invited lectures at international scientific conferences and workshops. He also gives lectures at the Slovak University of Technology in Bratislava, Slovakia, and he is Supervisor and Consultant for Ph.D., Master's and Bachelor's studies.

Branko Šter received his B.Sc. and M.Sc. degrees in electrical engineering and his Ph.D. degree in computer science from the University of Ljubljana, Slovenia, in 1993, 1996 and 1999, respectively. He works at the Faculty of Computer and Information Science, University of Ljubljana, as Professor. His main research interests include machine learning and hardware implementations of neural networks.

Janez Povh is Senior Researcher at the Faculty of Mechanical Engineering, University of Ljubljana. He received his Ph.D. in 2006 on topic application of semidefinite and copositive programming and combinatorial optimization at the Faculty of Mathematics and Physics, University of Ljubljana. His research focus is development of new methods in mathematical optimization, based on the intensive use of supercomputers. He is Project Leader of several industrial, European and national scientific projects in the domain of mathematical optimization, high-performance computing and big data analysis.