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AN ANALYSIS OF THE BICYCLE NETWORK IN BANJALUKA: PHYSICAL VS. DIGITAL INFRASTRUCTURE

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This article focuses on the relationship between the physical structures which enable cycling in a city, and the modern digital services supporting this type of transport. The contemporary urban context is conditioned not only by global technological trends, but also by the growing environmental awareness. The case of Banjaluka provides the background for the analysis of this ongoing urban process, emphasizing the importance of cycling, as well as the efficiency and functionality of its networks. After presenting the general condition and physical features of the cycling infrastructure in Banjaluka, the article analyzes both the potential of digital upgrading through the use of bicycle applications and the possible benefits of a dockless cycling system. As a result, suggestions and recommendations for the overall improvement of the cycling network are provided, on the level of both the physical and digital infrastructure. By introducing these emerging global concepts to the local level, the article also contributes to the popularization of cycling as a sustainable mode of transport.

***Key words*: urban cycling, sustainability, infrastructure, digitalization.**

INTRODUCTION

The modern city is changing rapidly, generating new challenges which need to be addressed in a sustainable manner during the process of urban upgrading and further development. However, although considered to be one of the major imperatives for every urban agenda, the current level of sustainability is still far away from the 2030 goals, especially in the developing and underdeveloped areas of the world. Additionally, it should be noted that the sustainable city represents just one of 17 goals set by the UN towards achieving human prosperity (UN, 2015). According to studies conducted by organizations dealing with urban mobility in the former Yugoslavia, Banjaluka (Bosnia and Herzegovina) lags behind Novi Sad (Serbia) and Ljubljana (Slovenia) regarding the number and length of bicycle paths and lanes (CZZS, 2020), while simultaneously providing the most expensive public transport and the cheapest hour of car parking (VOA, 2020). This approach to urban development is in sharp contrast to the goals set by an agreement between the mayors of European cities (Covenant of Mayors), also signed by Banjaluka. It further accelerates the misuse of spatial resources and the decline of urban efficiency, environmental quality and overall sustainability. Therefore, by giving priority to cars over bicycles and/or public transport (an average of one car per three inhabitants), the CO_2 reduction targets set in the document Sustainable Energy Action Plan of the City of Banjaluka (Grad Banjaluka, 2010) have become unattainable. In this agreement, Banjaluka also committed itself to the popularization of bicycles as a type of transport and an indisputable global trend, but action related to this aim has been slow and insufficient. Currently, the construction of roundabouts that do not recognize bicycle traffic as a separate category represent a priority, while the construction and marking of new bicycle paths and lanes is still not on the agenda of the city officials. Consequently, the traffic safety of cyclists has not increased and the expected popularization is slow, leading to problems already recognized in many other cities: an apparent gap between declarative cycling promotion and actual policies and ongoing planning practice, conditioned by different political settings and a power (im)balance (Plyushteva and Barnfield, 2020); the prioritization of the concept of motorized traffic (Koglin and Rye, 2014); and the promotion of the 'utility' transport model, resulting in the marginalization of cycling (Koglin and Rye, 2014; Aldred, 2015). However, the construction of a third-generation public bicycle system with associated terminals has improved the general impression of this type of alternative transport in Banjaluka.

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Considering that the rapid development of internet connections and mobile phones has also generated a huge number of cycling applications intended to enable and facilitate the use of bicycles, overall improvement is possible. In addition to the need for building and connecting the physical cycling infrastructure, it is also necessary to implement modern public bicycle systems, supported by applications for finding, navigating and parking. As a result, the opportunity to achieve a sustainable modern city is created by connecting all these elements into a complete, logical and functional network of efficient bicycle traffic. Currently, in Bosnia and Herzegovina activities in the field of cycling are mostly noticeable at the level of local communities, but there are also regional and interstate projects indicating a supranational character of bicycle networks (European Cyclists' Federation, 2016). Countries such as the Netherlands, which invest heavily both in the use of bicycles and the cycling infrastructure facilities, instruct the lower levels of government to provide adequate facilities for this mode of transport, and examples of where this has been successfully achieved (e.g., Copenhagen) indicate the necessity for developing better policies and infrastructure to support and emphasize cycling (Koglin, 2015a; Freudendal-Pedersen, 2015a). Additional focus should be given to the level of activism and advocacy, contributing to the establishment of better cycling networks (Aldred, 2013).

Having in mind the (im)balance between international trends and local application, the article studies the relationship between the physical cycling infrastructure and its digital upgrading, focusing on the case study of Banjaluka. The main aim is to determine their current features and the efficiency of the preferred synergy (or a lack thereof) in achieving urban sustainability and environmental awareness, while identifying the potential and limitations with regard to the overall improvement of the cycling system, its public perception and use. The methodology is based on the analysis of available studies and other sources (e.g., plans, strategies, projects, agreements) related to the selected international examples and the local case study. The main emphasis is given to their socio-economic context, the level of cycling infrastructure and its development, as well as the specificities of its use. The case study focuses on several elements targeting cycling infrastructure – planning legislation and the level of its implementation, and the structure of the bicycle network (length, capacity, efficiency, safety), as well as its current condition and the level of maintenance.

After the introduction, the theoretical framework is presented, considering the relevant concepts and authors, as well as representative international examples. The case study of the bicycle infrastructure in Banjaluka is analyzed in the third section. The position of the public bicycle system and its physical features are considered, as well as the use of bicycle applications within the current system of urban mobility. The discussion section considers the future of cycling infrastructure in Banjaluka, its further development and the policies which could enhance the number of urban cyclists. The conclusion provides recommendations for improving bicycle traffic in the local context, at the level of both legislation and the physical structure (network and facilities).

CYCLING NETWORKS IN A CONTEMPORARY CITY

The phenomenon of cycling and its increasing popularity in a sustainable vision of the urban future have been highlighted and studied by many authors across various disciplines dealing with the contemporary city and society. Conceptually grounded in social and/or mobility theories, they highlight a number of issues contributing to the further understanding of urban bicycling, its position, role, specificities and modes. This goes from comprehensive insights into the rising popularity of cycling (Cox, 2019), the challenging relationship between cycling and the economy (Spinney and Lin, 2019; Spinney, 2020) and issues of promotion (Koglin, 2020), to the problems of shifting public perception and the fragile role and importance of all participants (Freundendal-Pedersen, 2015a; Freundendal-Pedersen, 2015b). All these contributions reveal both positive and negative examples of planning practice, which declaratively supports cycling as a preferred mobility mode, while frequently limiting its application, decreasing its effectiveness and sustainability through politically-driven transportation policies (Koglin, 2015a; Koglin, 2015b; Koglin, 2017).

Developing cycling systems: physical infrastructure

The positive effects of cycling have been recognized by many cities, resulting in an increased number of studies and charters dealing with sustainable development and sustainable traffic (Puecher and Buehler, 2017). Some of them have shown that the implementation of public bicycle systems can encourage new groups to use cycling as a mode of transport, thus increasing their incidence in the total traffic (Buehler, 2013). Furthermore, this accelerating trend has had an impact on the urban physical structure (Pucher and Buehler, 2017). Consequently, new bike paths, lanes and other service facilities (e.g., garages, special bridges and loops for cyclists, bicycle highways) will be needed to support the requested functionality of a growing cycling system and its network (Transport for London, 2010). Fleming (2012) claims that many developing cities, whose policy is to increase the number of cyclists in urban traffic, will need at least one bicycle garage – not only as a parking space, but as a message that cycling is officially recognized.

The main communication lines (paths, lanes and bicycle paths) define the basic dimension of a network, as well as its directions, while both individuals and organizations have to be involved in creating the concept of a cycling infrastructure. Consequently, the Strategy of the European Cycling Federation (European Cyclists' Federation, 2017) states that the cycling infrastructure should provide safe and attractive riding with the intention of increasing the number of bicycle users, at the expense of automobile traffic. It should also provide safe, direct and attractive routes and roads in a connected network. Building the right infrastructure represents a direct incentive to increase the number of bicycle users in a city, but similar impact has also been detected through the introduction of individual systems, such as bicycle sharing – e.g., *Cycle Superhighways* in London (Li *et al*., 2018). However, by observing the bike-sharing system as a form of transport, the opportunity for improving the cycling infrastructure might be missed, as well as a potential increase in cycling (Koglin and Mukhtar-Landgren, 2021).

Upgrading cycling systems: digital infrastructure

London Since both direct and indirect contacts and joint activities represent our everyday reality, new modes of mediation have been developed, influencing all areas of our lives – including cycling. Through micro and nano technology these interactions have created countless networks. In this context, the importance of developing synergy between physical cycling structures and digital infrastructure should be highlighted, since it affects the social level of our communication. This emerging network consists of individual elements, technological innovations and users. According to Castells (2018), our societies increasingly strive for a structure formed around a dual opposition between the network and the individual. Based on this assumption, a new model of social development – informationalism – also reflects in the way bicycles are used as a mode of transport. In this particular case, the interaction between bicycles and information technologies forms a new urban paradigm. The digitalization of modern society has become an omnipresent imperative and the emergence of digital services serving and upgrading public bicycle systems influences both the efficiency of organization and economic profitability.

The information age has also brought networks of public bicycles into the system of cycling infrastructure, organized according to different schemes. These schemes include both old and new spaces, triggering structural transformation and creating new forms, processes and networks which reflect an ongoing social transition. Form vs. process is a duality, complementary and opposite, existing both together and separately. The applications for using public bicycle systems are not tangible like a bicycle path, or a bicycle parking canopy, but they still exist and communicate with users. Castells also claims that communication through computer systems enables real-time dialogue in an interactive and multilateral environment, gathering people around common interests. This kind of networking provides completely new possibilities in cycling, enabling the discovery of shortest routes or parking spaces.

For example, the application *Strava* offers the opportunity to socialize with other users, analyze and select individual routes, access GPS maps, and have an insight into comments and photos (Delaney, 2020). The *Nextbike* application primarily provides bicycle rental, as well as navigation between individual terminals on city maps. In addition, it provides driving history or an account balance, also allowing the report of bicycle breaks. Similar applications offer an upbuilding of collectivity and, through various campaigns, motivate users to ride bicycles more. For example, via the *Bike Citizens* platform, it is possible to bid for any campaign whose purpose is to promote bike commuting on a daily or weekly basis, within school or business activities. Smartphone apps can also trigger and upgrade the sense of community between bicycle users, ultimately causing positive effects on their behavior (Cheng and Lee, 2015). Consequently, the use of applications to improve and promote bicycle traffic has an impact on reducing pollution and noise, creating cities for people and their wellbeing. Additionally, a bike-friendly city transformation, based on bicycle apps, contributes to flexible mobility, reduced pollution, savings, and positive health effects for users (Shaheen *et al*., 2010).

The logic of networks (Castells, 2014) could be also applicable in the case of public bicycle systems, especially their third and fourth generation, which are emphasized in this article. The potential of networks and networking has increased with the help of technological changes, and wireless communication has become a platform through which various digitized products are delivered. Dockless bike systems are a good example of this concept, confirming that new technologies increase the ability of people to adopt both new forms of communication and new forms of transportation. For example, the evolution of the third generation (bicycles with stations) into the fourth generation indicates the shift from the material to the digital realm. The physical terminals for parking rented bicycles have been replaced by geofencing technology, which determines the space for picking up or leaving bicycles on a digital level. Consequently, some studies indicate that the users of dockless bike-sharing create slightly different paths and habits compared to the users of station bike-sharing (Wergin and Buehler, 2017). Based on this, it can be concluded that the introduction of new systems enriches existing networks. Furthermore, the new hubs can include parking islands, which are often positioned in the areas of car parking spaces, pushing motorized traffic out of urban centers. Dockless bike-sharing, as the fourth generation, can also contribute to the reduction of all types of pollution and diminish users' stress, positively affecting urban life.

Raising cycling awareness: the synergy of physical and digital networks

Considering all the benefits of cycling, it is necessary to continuously work on the popularization and integration of cycling into society. The area of Southeast Europe (SEE) still does not perceive bicycle transport as modern and competitive, relating bicycles to poverty. Therefore, the education of users, and potential users, is an important factor in creating an environment for the acceptance and development of all public bicycle systems. Cities in SEE, such Zagreb, Novi Sad and Sarajevo, which surround Banjaluka, already have public bicycle systems with fixed stations, which could be upgraded to the fourth generation, and it is only a matter of time before cities, especially large and congested ones, develop this type of transport to some extent. As a result of their bicycle networks, cities will reduce pollution and harmful emissions and residents will get more diverse and efficient public transportation. Since 2015, the fourth generation of bicycle-sharing (*dockless bike-sharing*) has had the most predominant growth. While the third generation is rooted in Europe and the USA, the precipitous growth of the fourth generation has been launched in China, by the Ofo and Mobike companies. In 2017, some cities in the USA and Europe also started to apply this system. Over time, several names have been used to describe its main feature – dockless, free-floating or stationless. This system provides the possibility of picking up and leaving bicycles anywhere within the designated urban zone. According to the European Bicycle Manufacturers Association (EBMA, 2019), in 2019 the dockless system also appeared in cities in Austria, Belgium, the Czech Republic, France, Germany, Italy and the United Kingdom, with oscillating numbers of both bicycles and operators. However, it is not present in

SEE, except in Tirana (Albania), which introduced it in 2018 (Mobike, 2020). Unfortunately, after only seven months of operation, the operator reduced the service area, and by the beginning of 2020, the system in Tirana had stopped working. Considering all the pros and cons of the dockless system, its availability, flexibility, efficiency and affordability should be underlined as positive characteristics. On the other hand, the negative features include the appearance of scattered (so-called "zombie") bicycles, blocked sidewalks and exposure to vandalism. Since the system relies primarily on the use of smartphones (for locating available bikes, payment, malfunction reports, inappropriate parking, etc.), it is less accessible to the elderly population. The use of applications that serve the use of bicycles in the city (*Nextbike* and *Bike citizens*) could be perceived as a possibility which enables both the development and upgrading of urban systems and networks in bicycle transport. Furthermore, the scope and the manner of use of these sharing systems should be regulated by means of several parameters, one of which is appropriate legislation at both the state and local community levels (Lin and Spinney, 2020).

However, it is not enough to pass legislation or even build infrastructure. It is necessary to promote, learn, and work toward the culture of using bicycles as a form of transport, involving the whole society in the process. The dockless bike-sharing system is a type of shared micromobility. Some studies show that this form of transport could represent 8-15% of all trips up to 5 miles (Shaheen and Cohen, 2019). These distances can be covered by bicycle in less than half an hour. Medium-sized cities, such as Banjaluka, do not have city centers of this size, so all points of interest in the city center area can be reached by cycling within 15 minutes. This approach should enable new public spaces and improve the quality of existing ones, and as a whole it will contribute to a better quality of life in cities. For example, the idea of Carlos Moreno's "fifteen-minute city", based on the assumption that most daily activities must be at a maximum distance of 15 minutes of walking or cycling (Moreno, 2019), has already been introduced in Paris. In this way, networks are limited by a time distance of fifteen minutes, but they have no restrictions because they can use the internet platform, which makes them global.

Both physical and digital cycling infrastructure are important for the future of cities, especially in the era of global warming and the COVID-19 distress. Simultaneously, it is estimated that the number of cyclists will increase in the coming years as a result of technological progress, largely due to the growing number of innovations in this field. However, the application and development of urban cycling are still conditioned by local specificities and numerous limitations generated by administrative frameworks, socio-cultural background and the level of environmental awareness.

BANJALUKA CYCLING INFRASTRUCTURE

Banjaluka is a medium-sized city in Southeast Europe (Figure 1), with less than 200,000 inhabitants (Grad Banjaluka, 2021). It is the administrative, political, financial and cultural center of Republika Srpska, one of the entities of Bosnia and Herzegovina. With a predominantly flat topography and promenades lined with trees, largely inherited from the reign of the Austro-Hungarian monarchy, Banjaluka has more than adequate conditions for the development of bicycle transport. In addition to developing its own cycling network, Banjaluka needs to initiate activities which would bring it closer to higher-level networks, such as Eurovelo.

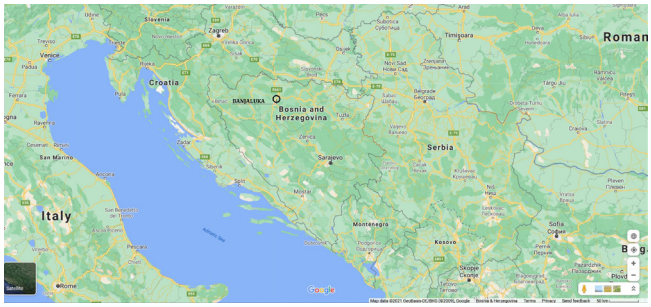

Figure 1. Position of Banjaluka on the map of the region/Europe (Source: Google maps, 2021)

Unfortunately, unlike regional centers of similar size, e.g., Novi Sad and Ljubljana, Banjaluka is currently not included in any of the 17 Eurovelo cycling routes covering a total length of over 90,000 km across Europe (Eurovelo, 2021).

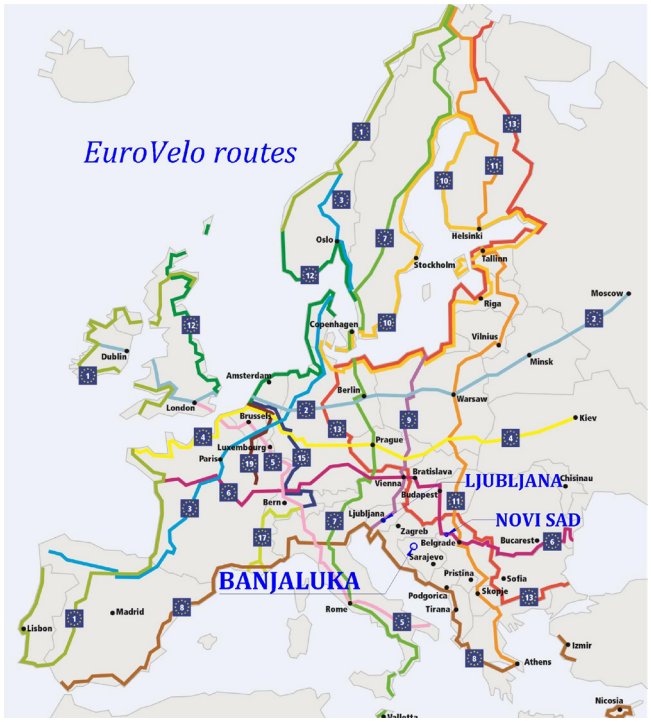

Figure 2. Eurovelo routes 2021 vs. the position of Banjaluka, Novi Sad and Ljubljana (Source: Eurovelo, 2021)

For example, Novi Sad is located on the Eurovelo 6 route, connecting the Western and Eastern European countries, while Ljubljana is on the Eurovelo 9 route, connecting the northern and southern parts. Meanwhile, Banjaluka is between the eighth (marked light brown) and thirteenth (marked red) route, so their potential connection would represent a chance for entering this network (Figure 2). As one of its hubs, Banjaluka would become closer to more developed European cities. Furthermore, membership in the *Civinet Slovenia – Croatia – Southeast Europe* network, dedicated to sustainable planning and mobility

management, could also be beneficial since it consists of cities and other participants from Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Macedonia and Serbia (Civinet, 2021). Simultaneously, Banjaluka should strive to be recognized by the *Copehnagenize* list, on which Ljubljana already occupied eighth place in 2017, as a city with a high level of implementation policies related to bicycle traffic.

Physical cycling infrastructure network

Considering the planning of cycling infrastructure in Banjaluka, the most interesting document comes from the 1970s – *Banjaluka Planning Advice I (UN Development Program, 1971)*. Its content was later included (almost unchanged) in the 1975 Master Plan of Banjaluka, and the unfinished Master Plan from 1991, defining the concept of bicycle paths (*Studija razvoja biciklističkog saobraćaja na urbanom području grada Banjaluka*, 2008). Unfortunately, through analysis of the existing planning documents, as well as their implementation, it can be concluded that the parties involved in the planning and construction of the city did not follow the stated guidelines (*ibid*.). Banjaluka is currently in the process of drafting and adopting the Master Plan 2020-2040 and it still has to prepare and adopt its own sustainable mobility plan (SUMP), already developed by cities like Ljubljana and Novi Sad. These steps will hopefully highlight the actual importance of sustainable transport, especially cycling.

Nowadays, the physical bicycle infrastructure of the city is mostly based on bicycle paths and lanes, with an insufficient number of bicycle parking lots and a few canopies. Furthermore, there are numerous examples which testify that the cycling infrastructure is neglected comparing to motor traffic. This problem is seen in the fact that either the cycling infrastructure does not exist, or it is below the standards and recommendations of experts. A common problem is the discontinuity of bicycle paths or lanes, as well as the lack of suitable interconnections, which directly affects the safety of cyclists. The GPS recording of the cycling network (*.kml* file) provides an insight into its anatomy (Figure 3). The network fragmentation is evident – there are numerous interruptions resulting from undefined integration into the lanes of motorized traffic, while multiple intersections of cycling routes collide with bus stops, or their flow is interrupted by the installation of bus stop canopies. Consequently, certain bicycle routes are incomplete and the absence of network hubs is visible. Although local authorities declaratively support the development of this type of transport and refer to the positive practices from cities in developed countries of the European Union, the condition of the cycling system and its incomplete network violate the safety of cyclists.

The current state of the built bicycle infrastructure is reflected in a total of 31 km of paths and lanes, out of which about 15 km are usable (CZZS, 2020). The degree of usability is influenced by the level of interconnections between network segments, the degree of physical damage, and the unintended and illegal use of areas reserved for cyclists for the purpose of parking motor vehicles, which is the most common case. These barriers can be perceived as malignant points and cannot be considered as integral parts of the network.

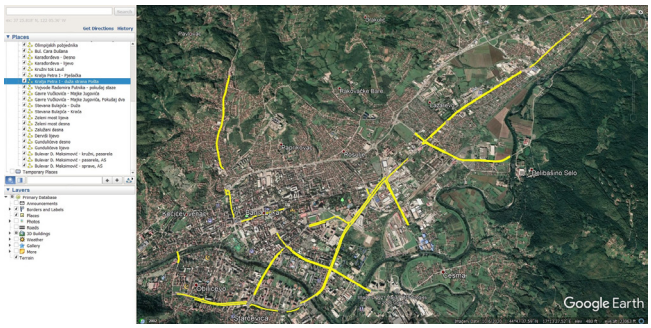

Figure 3. Map/network of existing bicycle paths and lanes in Banjaluka (Source: Authors, 2021)

The data provided in Figure 4 demonstrates the current condition of cycling infrastructure in Banjaluka, even though it does not consider the size of the selected cities and their populations. However, the comparison between Banjaluka and Ljubljana (twice as populated) reveals that the length of cycling paths in Banjaluka should be at least 200 km.

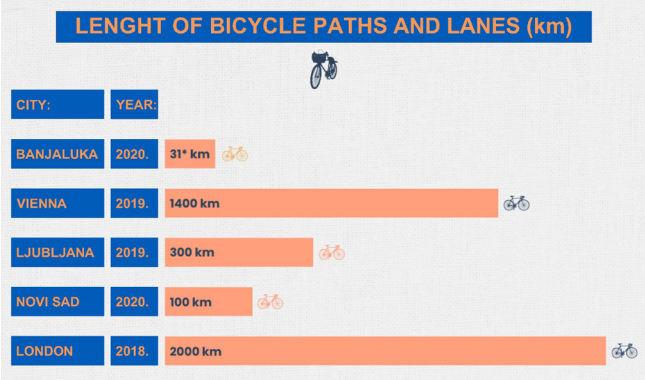

Figure 4. The length of existing bicycle paths and lanes: Banjaluka vs. selected cities
(Source: drawn by authors using Center for the Environment data, 2021)

Additionally, it should be mentioned that Banjaluka has a number of basic cycling infrastructure problems, such as insufficient and inadequate bike paths and lanes. Although authors suggest the construction of bicycle lanes with a minimum width of 1.5 m, or bicycle paths with a minimum width of 2.0 m (Janković and Janković, 2018), institutions and individuals do not recognize such information during planning and implementation, creating substandard lanes (e.g., Vojvode Radomira Putnika Boulevard, Gavre Vučković Street and Put srpskih branilaca). Tsar Dušan Boulevard (Figure 5) also demonstrates ambiguities and illogical decisions since it includes a (future) hub which should become a part of the network and several unconnected linear elements. To solve this specific problem, it is necessary to make a new hub, as well as to add the missing segments for bicycle paths/lanes.

Unfortunately, this is not the only problem. The emerging cycling network is often blocked by improperly parked cars, dumpsters for communal waste, inadequately constructed sewage and water shafts, weather conditions (Figure 6) or poorly maintained urban greenery. Another severe problem is the arrogance, carelessness and inattention of motor vehicle drivers, who largely do not perceive cyclists as equal participants in traffic, in spite their extreme vulnerability.

Figure 5. Tsar Dušan Boulevard: existing cycling network (yellow) and missing sections (red)
(Source: drawn by Authors using Google Maps, 2021)

Figure 6. Cycling path, Gavre Vučkovića street, Banjaluka
(Source: Authors, 2021)

Digital cycling infrastructure network

Simultaneously with physical changes, the cycling infrastructure in Banjaluka has been upgraded by digital tools, which could contribute to the popularization of bicycle transport. Some of the recent applications supporting public cycling systems have found their place in Banjaluka – e.g., *Nextbike* and *Bike Citizens* app (Milaković and Stupar, 2019). They are constantly being improved and perfected as new versions come out, which should be a pattern for the maintenance and improvement of bicycle paths, lanes, canopies and other physical forms enabling the use and development of bicycle transport. The system of public bicycles with stations requires initial registration (a physical visit) and payment (for a one-off, monthly or annual ticket, with the last two categories providing 30 min free cycling per day). After that, the use of the application is quite simple and bicycle rental is further simplified by using a QR code. The added value of this application is the ability to use it in any city where this system is represented (e.g., Germany, Austria, Croatia etc.), connecting cities both outside and inside the EU. The bike-sharing system and the *Nextbike* application are now featured with recognizable bikes and parking places (Figure 7).

Another application is *Bike Citizens*. It is a navigation tool and travel guide for over 450 European cities (Sexty, 2017). It is still in a trial phase in Banjaluka, and in the future it should be fully active. Its database is constantly updated,

Figure 7. Nextbike sharing system and print-screen with the map of Banjaluka
(Source: Authors, 2019)

offering the choices of longer or shorter routes, asphalt or pebble. This application is a very useful tool for navigating according to personal interest, offering the opportunity to select one of the possible combinations during a ride. Exploring the city is possible with voice control, which can be very useful while cycling. Application maps can be purchased or obtained for free if the user cycles for long enough each day. Like the *Nextbike* application, *Bike Citizens* also stimulates urban cycling in a positive sense (Figure 8), reducing traffic jams and improving ecological parameters.

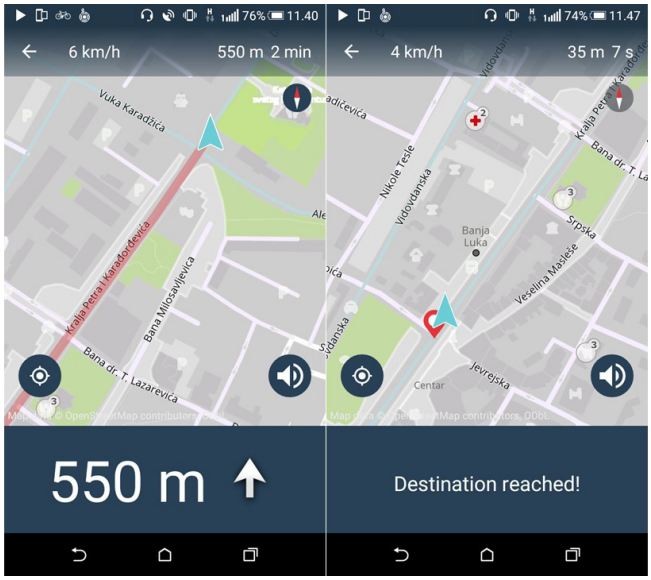

Figure 8. Bike Citizens screen with the map of Banjaluka
(Source: Authors, 2019)

Banjaluka is not an exception with regard to this practice of stimulating urban cycling. The presence of a public bicycle system with an accompanying application for rental (*Nextbike*) has led to an increased number of cyclists, their higher visibility and the construction of new parking lots and canopies. Building a digital network at the local level, based on these and similar IT platforms, is leading to positive processes, at least declaratively. Digital technology allows us to develop new bicycle transportation systems and Banjaluka is the owner of a third-generation bicycle rental system. However, its evolution into the fourth generation requires time and effort. The presence of GPS signals and mobile and wireless internet has enabled this transformation, as

well as a system of public-private partnership. Banjaluka still does not have a system for renting public bicycles of the fourth generation, but a new system and a new way of using bicycles as a mode of transport can affect the way infrastructure networks are formed and used in the future (Milaković and Stupar, 2019). Complementing the existing system of public bicycles with the fourth generation would certainly be a challenge for the city, but it would represent an additional incentive to reduce the intensity of motor traffic in urban areas and reduce pollution, as well as improve general wellbeing.

DISCUSSION

In order to increase the level of sustainability and the quality of life, Banjaluka needs more investments in cycling infrastructure. While keeping the focus on new tracks and lanes, the local administration should also deal with the existing elements of cycling infrastructure, maximizing the level of utilization by adding missing lines and hubs.

During the COVID-19 pandemic the importance of bicycle transport in Banjaluka and the communication through modern technological platforms have been emphasized. Many European cities have used this fact as an opportunity for changing their physical environment. For example, Paris is abolishing a half of its 140,000 parking spaces, creating new zones for pedestrians, cyclists and greenery (Forbes, 2020). The environmentally sustainable transformation is, therefore, a direction which should be followed at both the global and the local level, and Banjaluka has to find the best model to be applied in this challenging moment.

The existence of cycling infrastructure affects the use of bicycles as a means of transportation, and medium-sized cities should include a largely separate cycling infrastructure (Heinen *et al*., 2013). Consequently, Banjaluka should focus on the construction of bicycle roads as a separate infrastructure, in the form of bicycle paths. Paths have an advantage over bike lanes since they offer a higher level of safety, which is one of the main parameters when selecting a preferred form of transportation. In addition to the primary physical facilities of cycling infrastructure, which are undoubtedly paths and lanes for cyclists, the existence of parking facilities largely determines the number cyclists, and the manner of bicycle use. Some studies indicate that facilities at the micro level greatly influence the choice of the bicycle as a mode of transportation (Rybarczyk and Wu, 2014). If used as transport to the workplace, it is desirable that the bicycle parking is as close as possible to the goal, protected from theft and atmospheric influences. Furthermore, employers inclined to the green city concept should provide a suitable place for showering and changing in addition to the parking space. In short, by providing the necessary infrastructure and increasing its total share in the urban matrix, the number of cyclists and their total trips will be increased. To solve these and similar problems, political will and strict law enforcement are needed to ensure both the existence of a quality cycling infrastructure and its full functionality. Cyclists are looking for fluidity in the use of their resources, and these problems should be addressed without any delay.

At the level of digital infrastructure, these problems could be solved by reprogramming and removing ambiguities, but also by supplementing the content with the items requested by users. In a study carried out in Portugal, the authors found that users of digital cycling infrastructure are looking for GPS options, interactivity, a list of places of interest, route calculation etc. (Meireles and Ribeiro, 2020). Any improvement is a chance to increase the share of cyclists in urban transport, and thus a chance to achieve sustainability goals, which should be an absolute imperative for all stakeholders. Therefore, the introduction of a fourth-generation bicycle-sharing system is a challenge, which has also been recognized in Banjaluka. However, there are many questions regarding the mode in which it is planned, conducted, regulated and implemented. Certainly, the emergence of a dockless bicycle-sharing system in Banjaluka would help increase the total number of bike rides with a minimal investment, without a need to build fixed stations. With the existence of the third generation, the preconditions for the emergence of a hybrid bike-sharing system are already present. Complementing the existing network with new features toward a stationless system would be possible primarily at the digital level, but the duality of the cycling infrastructure would also be achieved. Namely, the new network would include new users, additionally motivate the use of bicycles and achieve the effect of putting additional pressure on decision makers. That would result in creating new bicycle paths, lanes, parking lots, canopies and other elements of physical infrastructure. An enriched network of bicycle resources leads to the enrichment of the general content in urban cycling, resulting in the popularization of bicycles. Given the limited infrastructure and the relatively small current number of potential users, the future of a dockless public bicycle system in Banjaluka could rely on the existing third generation, or it could be supplemented. Today, there are 5 user terminals with 36 bicycles (Grad Banjaluka, 2021) and over 1,100 subscribers from around 200,000 inhabitants, and this number is growing. According to the available data, the average number of daily rents during a working day is 60-70, most of them taking place between 7 and 8 AM, and 4 and 5 PM. Consequently, with the potential introduction of the dockless system in Banjaluka, around one percent of the existing bicycle rides would belong to the stationless system, and the total number of rides would increase. The conditions for the installation of the fourth generation are similar to the previous one. The existence of an internet connection on the territory of the entire city (with already widespread smartphones) already meets the basic technical and technological requirements. What is noticeable is the fact that bicycles from the rental system are often used at the time of departure to/return from work. In this way, workstations become secondary hubs, and the third-generation public bicycle system terminals become the primary hubs of the network. In the case of the fourth-generation public bicycle system, the notion of a secondary hub would become the notion of a primary hub, since a non-stationary bicycle is not bound by the position of the terminal. If the intention is to suggest an exact location for parking bicycles, it is feasible to install adequate and quality parking solutions in any targeted area. Some innovative solutions can be found in Novi Sad, where the realization of the initiative "*binacikl*" is in progress. Representing urban

furniture, it combines the function of parking for bicycles and a stage for performing and promoting cultural and artistic content (Promeni Srbiju, 2021).

The application of both systems would enrich and improve the bicycle infrastructure network at all levels, as well as public transport in general. Banjaluka still has to take a few steps toward this kind of change. One of them is the activation of new hubs, such as the Vrbas University Campus, which has a large number of potential bicycle users. The next step would be building new bike paths and lanes. After that, it is necessary to create a quality data system on the cycling infrastructure, through which it will be possible to obtain information about and within the network. Also, it is necessary to perform a partial or complete survey of public transport that includes the bicycle-sharing systems, with a special emphasis on mastering the "last mile" in using the dockless systems. The introduction of transporting bicycles inside buses should be also formally enabled, at least for folding ones, which would be a way of implementing intermodal travel. Funding of the public bicycle system and its supplement (dockless bicycles) would be enabled through sustainable transport subsidies, which would also be used to purchase all kinds of bicycles that can be used as a transportation vehicle. Furthermore, the construction of a bicycle parking space near important and busy facilities and institutions is conceptually extremely important. Whether it is a marked place, a canopy or even a bicycle garage, these facilities represent the starting and ending points of linear travel within a network (Figure 9). They also represent hubs from which network directions are further developed, offering users more connectivity within city matrices. It is possible to achieve the concept of duality of the bicycle infrastructure network by including these nodes into navigation applications, or into apps enabling the operation of public bicycle systems.

Figure 9. A canopy for bicycle parking, city center, Banjaluka (Source: Authors, 2021)

CONCLUSION

Cycling infrastructure nowadays exists on two levels – physical and digital (technological), together forming a network of a wider system in which a city operates. The need for a better, cleaner, more environmentally and energy-conscious city exists as an imperative, but its actual implementation often lags behind. The use of bicycles as a mode of transport promotes better connectivity between inhabitants, the urban environment and its *genius loci*. This symbiosis, if achieved, should provide greater wellbeing of local communities. Banjaluka should prepare and adopt documents such as the Sustainable Mobility Plan, already common in the cities of the European Union and some regional centers (e.g., Belgrade and Sarajevo). Through these plans, the position of the cycling infrastructure is strengthened, stimulating the movement of pedestrians and cyclists in the indicated directions, preferring the green areas of cities, without traffic jams. Also, through these documents, legal measures for the removal of advertising facilities, catering facilities (especially restaurant gardens, as in Banjaluka), and other obstacles from cycling routes could be implemented. These documents should also indicate the importance of certain systems (e.g., the park and ride system), providing the necessary elements. The example of Ljubljana, as one of the regional centers and role-models for Banjaluka, reveals many creative solutions which might be used (Ljubljanainfo, 2021). Unfortunately, cycling in Banjaluka is still under-appreciated, and even in winter, snow is often cleared onto cycling lanes, indicating a low level of general awareness.

Therefore, it is also necessary to change the collective consciousness, perception of the significance of cycling, and its sustainability, emphasizing the importance of cycling as a transport mode. Planning professionals certainly have their share of responsibility for the current situation, but the final direction of urban development depends on political and financial decisions, which are often delayed or unsynchronized with sustainable goals, and without an updated legislative framework.

Considering all these premisses, some recommendations for improving the cycling network and transport in Banjaluka could be created:

- The completion, rehabilitation and improvement of the existing physical parts of the network, primarily bicycle paths and lanes (e.g., Tsar Dušan Boulevard). It is necessary to make the existing infrastructure functional;
- The construction of new bicycle paths and lanes, with the technical characteristics modeled according to the successful examples from the European Union;
- Enabling and marking the movement of cyclists in both directions of one-way streets, especially in the center (e.g., Srpska Street, King Alfonso XIII Street etc.);
- The conversion of roads, whereby roads intended for motorized traffic will become areas reserved for pedestrians and cyclists; and
- The removal of physical disturbances from cycling infrastructure, such as improperly parked cars, or municipal waste dumpsters.

Regarding the setting of significant hubs in the network, it is necessary to act according to the following goals:

- The completion, rehabilitation and improvement of hubs within the network, places where certain bicycle routes intersect, whether they are intersections or

roundabouts;

- The construction of new bicycle parking lots, canopies and bicycle garages. The position of these facilities should follow the position of important institutions and facilities (e.g., schools, higher education and administrative institutions); and
- The establishment of a *park and ride* system, which implies the existence and use of public parking garages for cars. These systems are situated on the outskirts of the city, or at least on the outskirts of the city center, from where users continue to the city center by public transport, or by bicycle. These garages thus become hubs of paramount importance in a cycling network.

The digital level of the network should be improved by:

- The maintenance and improvement of existing digital services in Banjaluka used for bicycle transport;
- The initiation, development and implementation of new digital services, both for public bicycle systems and the users of private bicycles;
- Installing the necessary equipment on/in public transport vehicles to be used for bicycles, achieving intermodality; and
- The establishment of a functional and accessible database on physical cycling infrastructure, terrain characteristics, recommended routes, the characteristics of public bicycles etc.

The improvement of urban mobility in Banjaluka is an important task to be completed for its future development, but the upgrading of its cycling network and its physical and digital infrastructure is certainly an important element of its sustainability. Whether this aim is achieved or not depends on many factors, but the first step should be related to general environmental awareness, both at the level of governing structures and the local community.

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