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The City of Zagreb Lower Town Urban mobility development program

Igor Majstorović[a,*], Maja Ahac[a], Saša Ahac[a]

[a] *University of Zagreb, Faculty of Civil Engineering, 10000 Zagreb, Croatia*

Abstract

Common development issues in historic city centers are dense urban blocks (with buildings that do not follow modern construction standards), narrow traffic corridors, and low mobility of pedestrians and cyclists. Modern solutions, like smart traffic control systems, parking restrictions, the introduction of speed limitations and dynamic yellow lanes, increasing control of existing yellow lanes, and the establishment of multimodal solutions, are introduced to eliminate traffic problems in these areas. When it comes to the abovementioned development issues, the historic Lower Town area in Croatia's capital Zagreb, with residential and commercial buildings and infrastructure dating from the beginning of the 20th century, is no exception. Following a very strong earthquake that hit in March 2020, severely damaging the structures in Zagreb's historical center, a program for the complete reconstruction of this area is being developed, which will contain the Urban mobility development program. This paper presents the process and the results of Zagreb City's Lower Town urban transport reprogramming performed by the University of Zagreb, Faculty of Civil Engineering. The main premise of the Zagreb historic center reconstruction program is that the quality of life in the area will be improved through the regeneration of neglected and unorganized city blocks, as well as the planning and construction of new public spaces. The aspiration is the transformation of Lower Town into the "15-minute city". The prerequisite for this is (1) improved mobility and (2) reshaped transportation system, with the emphasis on cost-effective technical solutions and the integration of zero-emission modes of transport, and green mobility. At the same time, it will be necessary to preserve buildings and infrastructure that are part of the identity of the City and to prevent the transformation of the reconstruction process into a process of gentrification.

Keywords: reprogramming; urban transport; decarbonization; mass transport

* Corresponding author. Tel.: +385-1-4639-125
E-mail address: igor.majstorovic@grad.unizg.hr

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1. Introduction

The two dimensions (or functions) of urban space are (1) dwelling, occupying, inhabiting, and (2) locomoting, traveling, circulating (Moudon, 2019). Therefore, every city that strives to be competitive in an intense process of economic globalization must emphasize its flexibility in satisfying its resident's welfare, trade, and transport needs (Ahac et al., 2018; Balletto et al., 2021). The transport system should be adapted to all groups of the population, while ensuring the necessary safety of all users, with an emphasis on pedestrians and cyclists as the most vulnerable groups (Moreno et al., 2021). Many discussions about urban and/or transport system planning revolve around the term mobility, i.e., the ability of people to cross the distance from point A to point B freely and easily, and, from a traffic point of view, quickly. Ultimately, this results in the thesis that we can live wherever we wish, and that traffic planners would create ways for us to get to where we want to go very quickly. But the big issue here is that points A and B are not fixed. Like other cities, Croatian capital Zagreb is constantly evolving, the lives of its inhabitants are changing, and their travel patterns are adapting accordingly. Residents are commuting further and further, visiting shops in dislocated shopping centers, or expanding the circle of their daily activities. In response to the demand for increased travel length, significant resources need to be invested in the planning and construction of transport infrastructure that will transport people further and further, i.e., faster and faster.

According to the City of Zagreb Statistical Yearbook (2020), Zagreb consists of 70 settlements with a total area of about 641 km^2. According to the latest Census of Population, Households, and Dwellings (2013), 790.017 residents live within the City's administrative limits, and 87% of them occupy the Zagreb settlement. Since its establishment as a City in the year 1850, Zagreb's development was influenced by the topography of the region. The historic settlement's location at the foot of Mt. Medvednica, and the spatial restrictions that discouraged its development towards the south (rail line at the south part of the historic settlement and the River Sava, Fig. 1.) resulted in the predominantly longitudinal development of the City in the east-west direction.

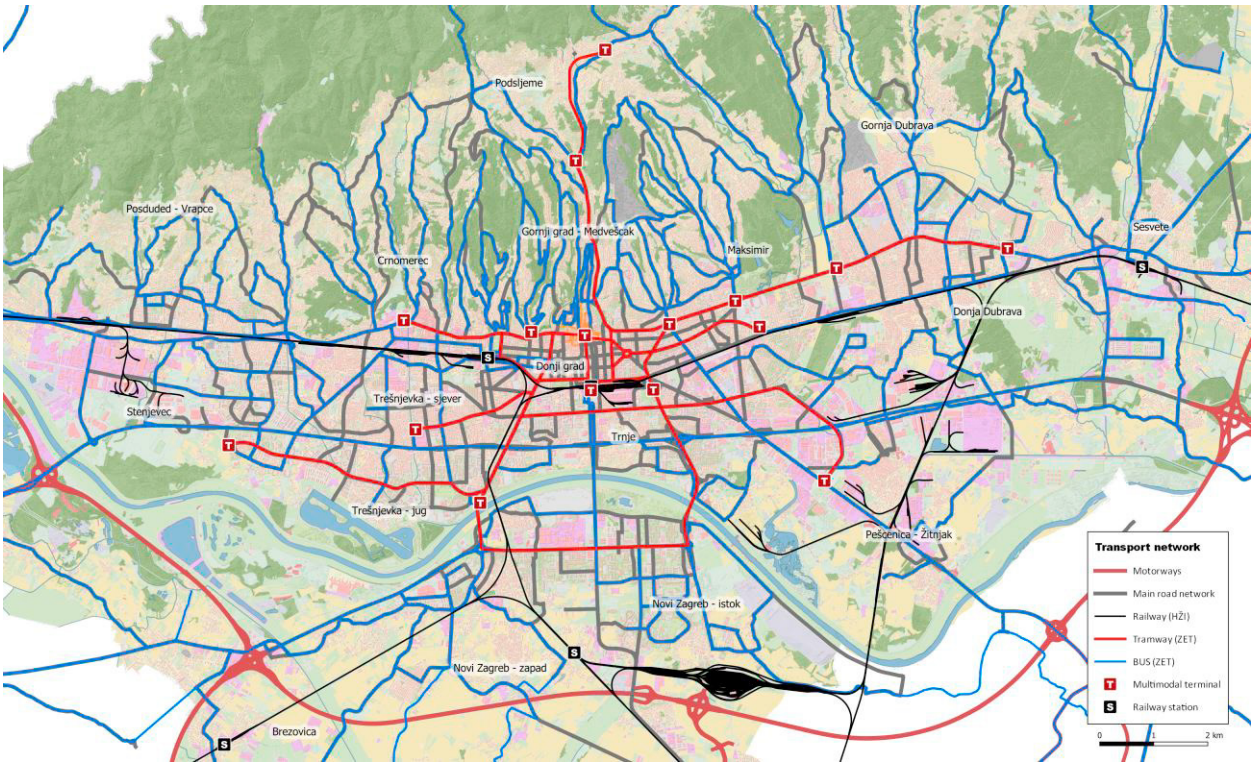

Fig. 1. Zagreb transport network in 2020.

Today, the River Sava divides the City into two main parts: old settlements on the north bank, and New Zagreb (Novi Zagreb), built in the last 50 years on the south bank. Old settlements consist of historic Upper Town (Gornji grad) dating from the beginning of the 20th century and Lower Town (Donji grad) built after WWII. The Zagreb railway junction, formed more than 150 years ago, is the largest and most important passenger and freight railway junction in the Republic of Croatia, where the Mediterranean TEN-T corridor and the planned Alps-Western Balkans TEN-T corridor intersect. 50 years ago, a marshaling yard was built in the southeast outskirts of New Zagreb, and the railway network was modernized (Kreč et al., 2006). The railway system has been identified as the basic problem in terms of efficient spatial and traffic planning of the Lower Town from the very beginning of the City's development. Layout and the design of existing rail infrastructure is a barrier for the more dynamic development of other transport infrastructure, and traffic integration of the surrounding area. In addition to rail, public transport in the City area includes a tram and bus system. The tram system forms the backbone of public transport, while bus lines, which mainly start at tram terminals, represent a radial extension of the system. Most of the tram network took its present form in the mid-1980s, while the last longitudinal extensions were performed in the 2000s (Study on the Tram Traffic Development in Zagreb, 2020). The city motorway bypasses Zagreb on its southern side and represents the starting point of the motorway network of the Republic of Croatia. City avenues form the longitudinal backbone of the road traffic system within the area. This primary road network is served by the streets with different roles and profiles. The development of this secondary road network in the past two decades consisted of partial reconstructions and the introduction of new traffic restrictions. In recent years, the development of cycling infrastructure has begun, but it comes down to marking bicycle paths on the existing pedestrian corridors.

The complex traffic situation in the entire area of the City has been analyzed in numerous traffic-spatial and urban-architectural studies. However, these studies propose and valorize different scenarios of individual transport system development, and they do not favor a scenario appropriate to the new millennium. Only a few integral studies have been prepared, in which a comprehensive analysis of the transport system was performed. These integral studies presented technical solutions for improvements of the transport system. The main issue of the transport development of the City lies in the fact that the central area of the Lower Town, and the entire Upper Town, are protected for their historical architecture. Here, the introduction of new structures and infrastructures is strictly controlled – according to the Spatial Plan of the City of Zagreb (2017), adapting existing historical functions and content to contemporary needs can be accepted only if the interventions in historical structures are minimal. Finally, in the year 2020, the Transport Master Plan for the Zagreb region was developed. The primary goal of this Master Plan was to create a long-term concept of transport system development and a transport policy suitable for the economy and residents. The document gives strategic preconditions for future transport projects that should be financed by the European Structural and Investment Funds. It proposes optimal solutions for infrastructure construction, organization, operation, and management of all modes of transport. These solutions are meant to increase the level of multimodality and intermodality, improve urban and regional mobility and create and encourage environmentally friendly transport systems, which will reduce the CO_2 emissions by encouraging the use of public transport and green mobility.

A few weeks after the enactment of the Master Plan, and the pronouncement of nationwide lockdown due to COVID-19 pandemic, a 5.5 ML earthquake with the epicenter seven kilometers north of Zagreb's historical center severely damaged many residential, commercial, and public buildings and structures. Nine months later, 5.0 ML and 6.2 ML earthquakes with the epicenters fifty kilometers south-east disturbed Zagreb again. The City and its inhabitants are now facing a long and expensive structural reconstruction. However, as documented by Barbarossa (2020) in his research on local government policies on post-COVID sustainable mobility, these unfortunate events have encouraged a reset in the attitudes of the City administration: this reconstruction will also be utilized for a smoother introduction of new, modern perspectives in addressing most of the transport problems that have been accumulating in the City for years. The creation of the comprehensive Reconstruction Program for the Zagreb historic area started, with the main premise that the quality of life in the Lower and Upper Town will be improved through the regeneration of neglected and unorganized city blocks, planning and construction of new public spaces, and transformation of the area into the "15-minute city", by improving mobility and reshaping transportation system. At the same time, this Reconstruction Program aims to preserve buildings and infrastructure that are part of the identity of the City and to prevent this transformation from becoming a process of gentrification, especially considering that the earthquakes have already dislocated more than 20.000 Lower and Upper Towners.

Urban planning and design, aimed at creating a post-pandemic, climate-proof, adaptive city, resilient to natural disasters, must interface with various disciplines and techniques of engineering and architecture (Moraci 2020). Measures and the timeframe to improve mobility in the City central areas, with the emphasis on cost-effective technical solutions and the integration of zero-emission modes of transport, and green mobility (required by Master Plan), were prepared by the University of Zagreb, Faculty of Civil Engineering, in Urban Mobility Development Program. In the Program, the "superblock" model has been proposed: an innovative land use intervention that aims to reclaim space for people, reduce motorized transport, promote sustainable mobility and active lifestyles, provide urban greening and mitigate the effects of climate change (Rueda, 2018). The "superblock" approach facilitates the development of the "15-minute city", i.e., the development focused on mobility, which promotes denser and mixed development around the public transport service, thus reducing the dependence of residents on personal vehicles (Pozoukidou and Chatziyiannaki, 2021). Most of the ideas and principles that support a "15-minute city" are not new. Zagreb already contains areas that coincide with its principles, even if accidentally, not planned. This paper will present the process and the results of the Zagreb historical center urban transport reprogramming.

2. Methodology

The development of the Program began with the collection and the analysis of all relevant documents (including development strategies and studies, spatial plans, statistical bulletins, preliminary designs, etc.) related to the development of the Zagreb historic center planning. By systematizing 50 documents that were prepared in the last 50 years, the starting points (current situation) in the development of the program were determined. These include spatial planning and strategic determinants, spatial characteristics (from territorial, environmental, demographic, and economic aspects), and characteristics of traffic and infrastructure of all existing transport systems (pedestrian, bicycle, road, railway, public bus, tram, and funicular, and parking) were identified. Based on the collected documents, analysis, and assessment of the current state of transport infrastructure, main characteristics of transport and means of transport, transport supply and demand, traffic safety and security, interoperability, and legislation were conducted, and the main challenges were identified.

According to the Master Plan (2020), strategic goals of City development are (1) competitive economy, (2) human resources development, (3) environmental protection and sustainable management of natural resources and energy, (4) improvement of spatial qualities and functions of the City, (5) improvement of quality of life, and (6) improvement of the development management system. The analysis of these predefined goals indicated the main features of the vision for improved mobility and transport system of the Zagreb historic center. This vision provided an answer to the question of how the transport system affects the achievement of strategic goals of the City's development, i.e., it defined the role of the transport system in achieving these goals.

By systematizing the strategic goals that have a direct impact on the Zagreb historical center, the Program defined a new list of specific goals for the improvement of urban mobility. To meet these goals, the Program offered appropriate solutions - measures. These measures were developed for all transport systems, their organization, management, and infrastructure. Each measure was aimed at achieving one or more transport system development goals. According to Moraci (2020), adaptive planning and sustainable design measures can represent a strategic action in both the short and medium term, while mitigation measures travel over medium-long terms. In this case, the measures were divided according to the possibility of the implementation of the results: short-term measures (until 2030), medium-term measures (until 2040), and long-term measures (until 2050).

3. Results

3.1. Current situation – analysis and challenge identification

The location of the railway and the Central Railway Station largely determined the existing appearance of both the historic center and the transport system in the Lower Town area. Here, the orthogonal street network is defined by the urban blocks (Fig. 2.). The main street arteries are two longitudinally laid parallel one-way three-lane streets with coordinated traffic lights ("green waves"). The two main transverse streets are multi-lane one-way streets. In the area of Lower Town, more than 70% of motor vehicle traffic is transit, and only a few low-level streets are connected to

settlements south of the railway. Street parking of vehicles is allowed on almost the entire urban road network, a total of about 8 thousand parking spaces, of which approximately 15% are located on “green waves”. Street parking spaces are all metered and mostly longitudinal.

Around the central city square, a pedestrian zone with a total area of 10 hectares is formed. It consists of several interconnected squares, streets, and passages, and the tram network passes through the middle of it. The remaining pedestrian infrastructure of the Lower Town consists of raised sidewalks. Cyclists and, more recently, people on electric scooters often ride on them. In the last few years, the trend is to mark bicycle and pedestrian paths on sidewalks and to introduce joint cycling and motor traffic on the street network with a motor vehicle speed limit of 50 km/h (by alternately marking the so-called “sharrows” and a sign of the recommended speed of 30 km/h and marking “bike-box” areas for stopping cyclists in the intersection zones).

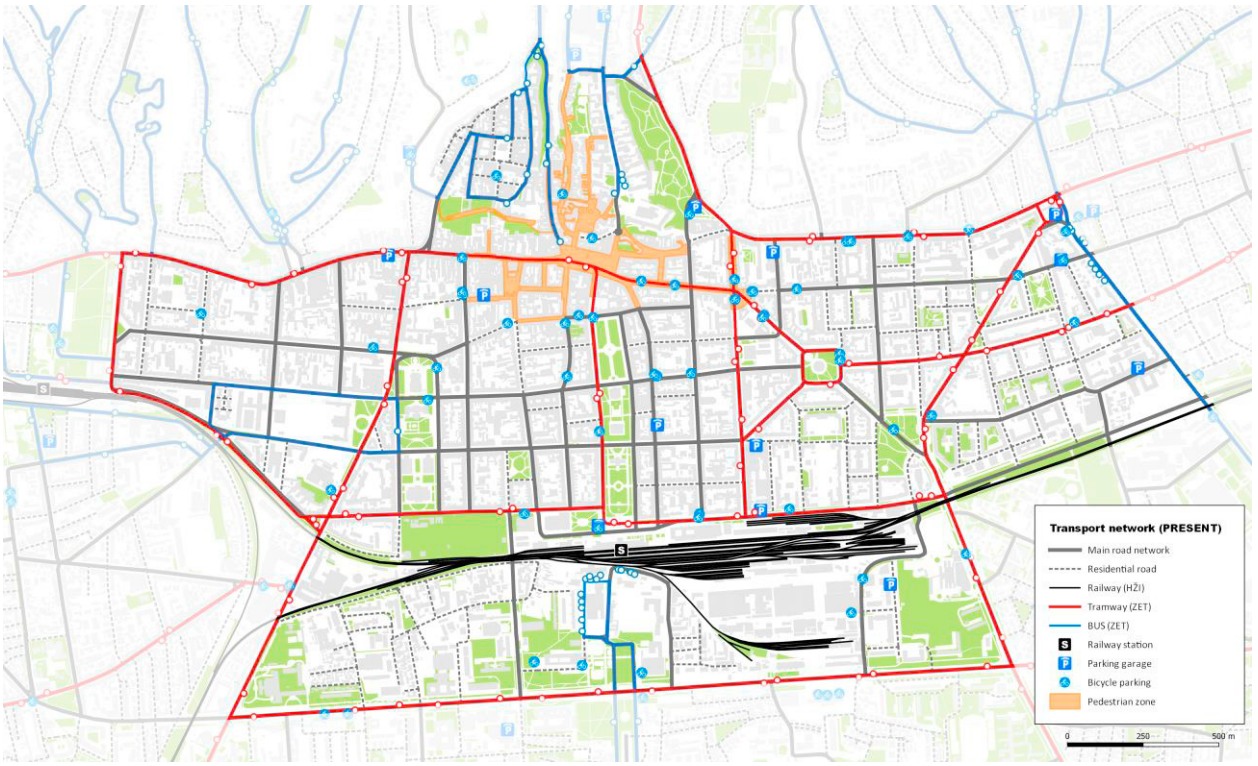

Fig. 2. Lower Town transport network in 2020.

The research results on travel habits in the whole City area published in Master Plan showed that 46% of trips are made by personal vehicle (as a driver or passenger in a car or on a motorcycle) or taxi, while 40% of all trips are made by public transport (bus, tram, or train). Slightly less than 11% of travel is done on foot, while only 3% of travel is done by bicycle. In public transport, as much as 55% of travel is done by tram, 36% of travel is done by bus, while only 4% of travel is done by rail.

Based on this data, it could be concluded that Zagreb has developed a high-quality public transport system, especially a tram system. However, a detailed analysis performed in the Study on the Tram Traffic Development in Zagreb (2020), identified several shortcomings. The main problem with public transport is the lack of its integration. The limiting factors for increasing the operational speed of public transport are the lack of reserved lanes and the lack of priority of the public over individual transport at traffic lights. Also, the insufficient dynamics of tram infrastructure reconstruction resulted in low average traveling speed of trams, high congestion, frequent breakdowns, and accidents. Low quality of infrastructure guarantees decreased passenger comfort. Problems concerning bus and tram stops are a

low number of off-lane bus stops, insufficient platform surface height, and their inadequate adaptation to passengers with disabilities and reduced mobility.

Urban and suburban rail transport, despite its great potential, is used by a very small number of passengers. The main shortcomings of this system are predominantly single-track railway, insufficient electrification of the network, lack of car and bike parking facilities in the vicinity of railway stations and stops, insufficient number of stops on specific parts of the network, inadequate length and height of platforms, poorly resolved access for pedestrians and disabled people, inadequate passenger information systems, lack of integrated timetable and ticketing system, the poorly resolved possibility of transporting bicycles in trains, and insufficient number of rail-road junctions. Finally, there are only a few urban and suburban lines, and existing lines operate well below the designed capacity.

The main issues of the road transport system are the fragmented road network and the lack of ITS. In addition to motor traffic, the Lower Town street network is saturated by stationary and parked vehicles. Pedestrian and cyclist traffic takes place on sidewalks of mostly insufficient widths, which calls into question the safety of users. In addition to insufficient widths, the main lack of cycling infrastructure is the discontinuity of routes. Finally, the only pedestrian zone in the whole Lower Town area is characterized by discontinuity and inadequate landscaping. Some of the streets in this zone appear more like classic streets for motorized traffic, with a carriageway and elevated sidewalks. Also, the tram traffic in the central part of the pedestrian zone greatly restricts the freedom of movement for pedestrians.

As another major issue, it was discovered that there is no systematic collection, storage, and updating of traffic data in a comprehensive historical base at the City level. The traffic model which would perform as a basic tool for qualifying and quantifying the effects of existing and valorization of measures for the planned transport system is not yet established.

3.2. Determining the vision of reprogramming Zagreb into a "15-minute city"

The vision of improving the mobility in the Zagreb historic center implies (1) reshaping the transport system through its reconstruction and (2) the restoration of the identity of the City center through the active participation of citizens. The main features of the Lower Town transport systems in 2050 are described below.

- Planning and development of the transport system is based on statistical data describing the social and economic activity of the area, spatial data describing the transport offer and traffic indicators describing the traffic demand collected continuously in an integrated, publicly available, historical database.
- By encouraging environmentally, economically, and energy-friendly transport solutions, improved mobility and the transport system based on the principles of transport integration and sustainability are achieved. The continuous introduction of innovative and high-tech solutions has ensured an optimal (quality, efficient, sustainable, accessible, and safe) transport system. This has been achieved through the application of modern transport solutions and the integration of modes of transport with zero emissions. These solutions continuously ensure the provision of economical transport services, reducing harmful emissions, and the development of alternative forms of transport.
- All parts of Lower Town are connected, and the use of cars is reduced in favor of the public, pedestrian, and bicycle traffic. Walking and cycling have become essential forms of mobility, reducing the pressure on the individual motor and public transport. Investing in walking and biking provides benefits for local businesses, creating space for venues like shops, restaurants, and other pillars of the local economy.
- The public transport system (timetables, ticketing/toll, and passenger information) is integrated. The construction of the freight railway bypass enabled lowering the tracks underground (Fig. 3.). Now, only modern passenger trains run through the City center. The railway is the backbone of the entire transport system and connects historic Zagreb, the outskirts of the City, and satellite settlements. The lowering of the railway revealed the space for the development of the street network integrating the Lower Town. The level of service of all forms of traffic and quality of life along the railway corridor is increased, and the problems of safety and reduced capacity at rail-road junctions are solved. The tram network is supplemented with new tracks that intertwine through the urban fabric and form a unique functional whole. With the reorganization and introduction of new tram lines, more settlements are interconnected. City bus lines complement suburban rail and tram lines throughout the City.
- The main street network is forming so-called "superblocks", thus improving the availability and quality of public spaces. The primary street network is placed at the edges of "superblocks". The street network within a single

"superblock" is a residential street network used by pedestrians and cyclists (Fig. 3.). Here, access and motor vehicle speed are limited. Within the "superblocks", street parking spaces are replaced by parking spaces in garages reserved mostly for the domicile population.

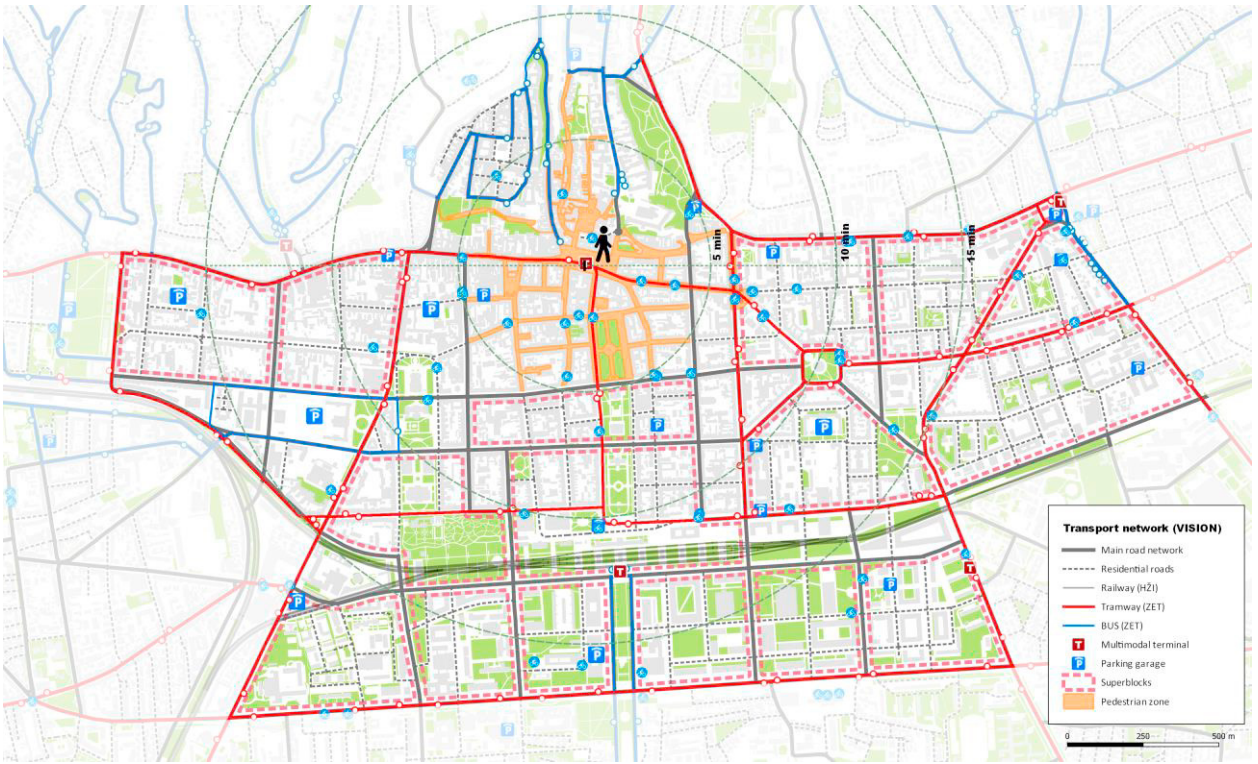

Fig. 3. Lower Town transport network in 2050 (vision).

3.3. Mobility improvement measures

Considering the vision of improved mobility, five goals for the development of the transport system in the Zagreb historic center have been identified: (1) economic sustainability, (2) environmental sustainability, (3) safety, (4) accessibility, and (5) mobility. A total of 27 measures have been proposed for the implementation of these goals. These measures include the development of a historical database on traveling patterns, traffic models, regulations and guidelines, programs, studies, and ultimately project documentation. This documentation precedes the implementation of the proposed transport infrastructure upgrade: lowering the railway underground, expansion of pedestrian and bicycle network, the establishment of intermodal terminals, construction of underground garages for residents, etc. All measures are ranked as equally important and their implementation needs to start immediately so that the solutions they envision can be implemented in a defined period (until 2030, 2040, and 2050).

It should be emphasized that the Program does not prohibit the possible ad-hoc solutions if these solutions can improve mobility. The reason for this approach is the fact that certain problems of the transport system of the historic center can only be solved by planning the wider area of the City. Therefore, measures proposed by the Program also cover the areas outside the Lower and Upper Town limits. Ad-hoc solutions that could be implemented immediately include construction of cycling and pedestrian infrastructure, the introduction of calm traffic zones, construction of new public bicycle parking infrastructure, reorganization and integration of public transport lines, and integration of ticketing systems for public transport and parking.

4. Conclusions

Common development issues in historic city centers are dense urban blocks (with buildings that do not follow modern construction standards), narrow traffic corridors, and low mobility of pedestrians and cyclists. When it comes to the abovementioned issues, the historic area in Croatia's capital Zagreb, with residential and commercial buildings and infrastructure dating from the beginning of the 20th century, is no exception. Following a series of strong earthquakes that struck the City in 2020, severely damaging the historical center, a program for the complete reconstruction of this area, containing the Urban mobility development program, was created.

This Program aimed to identify sustainable transport solutions that would promote public and non-motorized transport and provide quality and sustainable mobility. The performed research has shown that the City needs to invest primarily in its infrastructure and intermodality between motorized forms of transport, and then in the promotion of green forms of travel. To popularize public transport as the main form of transport, it is necessary to upgrade existing intermodal hubs, convert parking areas into pedestrian and bicycle green corridors and provide alternative parking to the domicile population. Through the regeneration of neglected and unorganized block interiors and the construction of new public spaces, the quality of life in Lower and Upper Town could significantly improve. An important step in the implementation of the Program is the establishment of an information system, digital database, and data exchange services, and the implementation of continuous individual and periodic public traffic surveys. It is necessary to develop a mesoscopic multimodal traffic model for the entire City. The model needs to be continuously upgraded and periodically updated, available to the public, and it must be used in the development of proposed measures.

Finding technical solutions for a particular measure proposed by the Program must be considered comprehensively, with all other types of traffic. Therefore, the implementation of the Program will require the engagement of numerous experts from different professions and their continuous cooperation as well as upgrading their competencies in planning, design, implementation, and management of urban structural and infrastructural resources to realize the vision of Zagreb as an adaptive, resilient, decarbonized, 15-minute city.

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