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A MODEL OF MANAGING THE URBAN MOBILITY PLANNING PROCESS

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Abstract: *The subject of research in this paper is the planning of urban mobility development in the narrow part of Sarajevo using a model based on the growth matrix. The hypothesis of this research is: Based on the analysis of supply and demand of the city traffic system, good practices in sustainable urban mobility and existing strategies and development plans, a model for managing the whole planning process of sustainable urban mobility of the city traffic system in Sarajevo by 2026 can be proposed.*

In accordance with the experience of Europe's main urban mobility observatory (Eltis) and sustainable urban mobility plans (SUMPs), the key elements are defined. The next step, after defining the elements of urban mobility, is to carry out the quantification of elements for 2016. Thereafter, there is a concise explanation of the growth matrix and model of managing the urban mobility planning process is created. In the research results, direct and indirect growth rates were elaborated and analyzed, i.e. the individual and synergic effects of the model. Finally, the synthesis of the research results was presented.

Keywords: *model, growth matrix, sustainable urban mobility, planning process.*

JEL: *R41, R42, R51*

INTRODUCTION

The traffic system and the socio-economic environment are dynamic systems whose mutual action results in mobility. Economic efficiency and the level of development largely depend on the level of mobility in a city. Therefore, urban mobility needs to be constantly and strongly directed not to lag behind the needs of total development, so that it does not become its brake over the time.

The deterioration of traffic conditions associated with the expansion of urbanization and increased motorization has a negative impact on the economy of large cities. The pressures on urban transport systems are increasing as part of the process of growth. Motor vehicle ownership and use are growing even faster than population, with vehicle ownership growth rates of 15 to 20 percent per year common in some developing countries. The average distance travel per vehicle is also increasing in all but the largest, most-congested cities like Sarajevo. This growth exceeds the ability to increase road space, and the major impediment to the efficient working of the urban economies in large-size cities, and particularly in megacities, is the level of road traffic congestion. Travel speeds are decreasing and the travel environment for pedestrians and people-powered vehicles is deteriorating. In the narrow part of the city during the rush hours, traffic speeds are reported to average 20 kilometers per hour (km/h) or less in Sarajevo. Also, traffic congestion has a negative impact on the competitiveness and environment of urban economies; it causes inefficiencies in logistics operations and increases costs. The costs of the 'first' and 'last mile' of supply chains are too high and present a barrier to growth of home delivery. Urban logistics is heavily neglected in city and transport planning.

For that reason, urban mobility planning processes are now essential if we want the transport service of passenger and goods to meet the needs of entrepreneurs and residents of urban/suburban areas. This include enabling social equity, urban accessibility, economically suitable transport costs and enabling tolerable life and development of urban environment by limiting the production of negative aspects of the transport system (congestion, pollution, noise, low level of traffic safety, etc.). In this way, it strives to create the ideal harmony of all supply and demand aspects in order to achieve the urban mobility for all users of city transport services.

The subject of the research is the planning of urban mobility development in the narrow part of Sarajevo by applying a model based on the growth matrix.

The hypothesis of this research is: Based on the analysis of supply and demand of the city traffic system, good practices in sustainable urban mobility and existing strategies and development plans, a model for managing the whole planning process of sustainable urban mobility of the city traffic system in Sarajevo by 2026 can be proposed.

The first thing to do is to define the elements of sustainable urban mobility and carry out an analysis of supply and demand for city traffic services. The next step is to carry out the quantification of elements for 2016 (by adapting the Urban Mobility Index 3.0 for Sarajevo). Thereafter, there is a concise explanation of the growth matrix and model of managing the urban mobility planning process is created. In the research results, direct and indirect growth rates were elaborated and analyzed, i.e. the individual and synergic effects of the model. Finally, the synthesis of the research results was presented.

DEFINING AND ANALYSIS OF SUSTAINABLE URBAN MOBILITY ELEMENTS

The traffic system and socio-economic environment are dynamic systems whose mutual action results in traffic mobility. Economic efficiency and level of total development largely depend on the level of traffic development. Cities are places for the exchange of goods and information which are at the heart of our economy and way of life. For cities to be successful they need to optimise the exchange of goods and information while remaining attractive places to live and work. Therefore, urban mobility needs to be constantly and strongly directed not to lag behind the needs of total development, so that it does not become its brake over the time.

The goal of urban mobility is to create a sustainable transport system in cities by: ensuring availability of jobs and services to all; improvements in safety and protection; reduction of pollution, greenhouse gas emissions and energy consumption; ***increasing efficiency and cost-effectiveness in the transportation of people and goods***; increasing the attractiveness and quality of the urban environment.

In order to determine the values for individual segments of a model of managing the urban mobility planning process (for the Sarajevo area), it is necessary to analyze the current state of supply and demand of certain urban mobility criteria (elements). The demand for the people and goods movement in urban mobility implies total requirements for the movement service that users and entrepreneurs want to achieve at a certain price and at a certain timeframe with an enabled availability across the territory with continuous/additional transportation. Demand for movement occurs in places of habitation and permanent residence, or in touch-points of intercity/international and urban transport which are spatially and temporally distant from the place of daily activities (business, shopping, school, hospitals, recreation, tourist attractions, shopping centers and etc.). The traffic supply considers the offer of the capacity and the possibility of pedestrian movement and various means of passenger transport and all subsidiary means necessary for carrying out the transport process. [Mustafa Mehanović, Nermin Palić, 2018]

According to the experience of Eltis and SUMP, the following elements are defined: **infrastructure, suprastructure, flows of passengers and goods, speed and travel/transport time, traffic safety, urban access regulations, environment impact and organization (integration) of transport services**.

In this paper, research on the traffic system supply and demand services in the area of Sarajevo has been carried out.

INFRASTRUCTURE

High-quality transport infrastructure is the basis of the traffic offer in achieving the best urban mobility. The quality of the traffic offer is characterized by the length and density of the traffic network. Traffic road length is an indicator of the connection between the two ends of the travel, while the network density should enable coverage of the entire urban and rural area of the city in order to obtain a satisfactory coefficient of movement for citizens [Mehanović, Palić, 2018]. In addition to the length and density, it is also necessary to emphasize the infrastructure adaptation for different modes of transport and for all types of users.

The length of the traffic network infrastructure in Sarajevo is 793 *km.* [Federalni zavod za programiranje razvoja (FZPR), 2016:64] If we exclude bus, minibus and trolleybus lines (because they are moving along the traffic network used by personal/commercial means of transport), the total length of the separated infrastructure in the urban public transport (UPT) is 107.1 km (90.8 km – A 44 km, B 46 , 8 km of tram,[Ministarstvo saobraćaja Kantona Sarajevo (MSKS), 2014:6] 14 km of bicycle, [Gradska uprava Grad Sarajevo (GUGS), 2017] 0.14 km of angled elevator [MSKS, 2014:6] and 2.16 km of cable car length [CETEOR, 2017]). The quality of the city's service increases if the network density is bigger, i.e. if the number of network *km* per m^2 of the city surface is higher. Approximately, for the central parts of the city, the network density amounts 3-6 (km/km^2), and outside the central parts of the city about 1,5-3 (km/km^2). The network density for the central parts of Sarajevo is 3,68 (km/km^2), [Mehanović, 2011:308] which according to the standards meets the minimum criteria for coverage of the urban area of the city. Outside the central parts of the city, network density is 1,02 (km/km^2), whereby the minimum coverage of these parts is not met.

The width of the traffic lanes in Sarajevo is 3-3,5 *m*, which is in accordance with Highway Capacity Manual (HCM). At the section Skenderija to Baščaršija, the number of lanes varies from 2-3, where one of them is always in use for the trams, which affects the reduction of the flow rate and the deterioration of the transport service level.

According to existing projects, certain disadvantages in the infrastructure are being sought to compensate by: finalization of longitudinal, transversal and urban highway construction in Sarajevo, extension of the tram network (Ilidža-Hrasnica), reconstruction of the existing tram network and finalization of the planned bicycle route.

Suprastructure

In its property JKP GRAS Sarajevo has a total of 67 trams. It's a pretty outdated fleet: ČKD Tatra K2 (49 for sitting/108 for standing) from the 1970s and 1980s, and several newer compositions were introduced: Düwag, LHB (9G i 10G), Lohner (38 for sitting/73 for standing) and ČKD Pragoimex (Satra II i III). JKP GRAS also has a total of 39 trolleybus: MAN SL 172 HO (38 for sitting/68 for standing), MAN SG 200 HO (50 for sitting/126 for standing), NAW HESS BGT 5-25, NAW HESS BGT 5-25 (2)). [JKP GRAS, 2017] The bus traffic in Sarajevo counts 56 units and 25 minibuses (JKP GRAS). It is also necessary to consider the 45 buses that City of Istanbul and their urban public transport company «IETT» donated to JKP GRAS. [Ministarstvo prostornog uređenja, građenja i zaštite okoliša Kantona Sarajevo (MPZKS), 2017] The number of taxi drivers (TA table, valid driver license, valid vehicle license, valid taxi sign contract) is 908 out of which 813 physical and 95 legal persons, what is more than enough for the Sarajevo area.

It can easily be concluded that in Sarajevo a UPT fleet needs to be modernized: purchase of light rail trams, environment friendly buses, implementation of freight trams, etc.

Flows of passengers and goods

Traffic flow is the interactions between travellers (including pedestrians, cyclists, passengers, goods and vehicles) and infrastructure (including highways, signage, and traffic control devices), with the aim of understanding and developing an optimal transport network with efficient movement of traffic and minimal traffic congestion problems.

Based on PGDS data, the main city road has about 33,000 vehicles per day on average, and the heavily loaded sections are Alipašino Polje, Otoka, Pofalići and M. Dvor. [NTSI-INSTITUT, 2016] The number of passengers transported by UPT in 2011 was about 113 million and in 2015 about 95.9 million. During the analyzed years, the number of passengers transported by UPT is constantly decreasing. [Federalni zavod za statistiku (FZS), 2016] The number of individual vehicles is linearly increasing from 2013 to 2016. (for 126.018 vehicles) justifying the depopulation of UPT. However, if we take into consideration that an individual vehicle transports an average of 2 passengers, a number of trips on the most loaded road section with an individual vehicle are approximately 68.5 thousand passengers, which would amount to about 2.1 million passengers for one month, and for the year around 24.7 million. That is almost four times less than the amount of passengers transported by UPT, and almost twice as much the amount of passengers transported by tram.

When we look at freight transport, 34.000 *tons* of goods were transported in 2016 and the mileage of the vehicles was about 5.8 million *km*, while the *tons kilometers* are around 49.6 million. [FZS, 2016] This amount of passengers and goods flow creates great congestion on all city traffic roads.

There are two organization proposals to reduce the load on the city road that relies on the integration of passengers and goods flow in the existing urban transport systems. First solution is to design a shared public transport network ensuring a shared movement of passengers and goods in urban environment. Second solution is to develop consolidation centers and cross-docks for freight movement and hubs for passenger and freight delivery and collection. [Trentini, Malhene: 2012:807]

There is also a solution that is related to the use of alternative roads based on the application of information technologies and intelligent transport systems. The goal is to relieve main city arteries to ensure safe, uninterrupted and continuous flow of vehicles

Speed and travel/transport time

Speed limit at the main city artery in Sarajevo is 60 *km/h*. During the peak load on the same section, the average movement speed varies from 20 *km/h* to 30 *km/h*, with driving time in relation to the normal traffic load is almost three times longer and the service level becomes F.

When traveling on a tram, the problem occurs in unadjusted tram stop position (before the intersection), then the option of buying a ticket from a driver, whereby the travel time is prolonged, and due to the small distance between the stops and because of the safety reasons, the speed of movement decreases.

Higher speed and shorter travel time can be accomplished by the implementation of public transport priority systems (PTPS). PTPS are an important measure to increase the efficiency of urban traffic management. [Franco, Biora: 2018] It makes public transport more attractive due to service regularity, gain in commercial speed and travel time, reduction of pollution and rational use of energy. The best results of the system priority implementation are expected to be for services operating in protected lanes. Strategies for absolute priority may apply to services operating in reserved lanes, but situations where many services share the same reserved lanes, or where emergency vehicles or taxis can use lanes reserved for public service, have to be handled separately through strategies for high (but not absolute) priority provision. For services which operate in mixed lanes with private traffic, strategies which can reduce the number of stops at traffic signals and the time spent in queues are relevant. In addition to implementing PTPS, the use of ITS and IT systems contributes to increasing speed and shortening the travel time.

Traffic safety

Traffic safety is one of the basic goals of the SUMP. Most often it is reflected by the number of traffic accidents with different consequences: killed, injured and material damage.

The total number of traffic accidents in Sarajevo in 2016 was 11.367, out of which 901 were killed/injured (21 killed, 199 heavily injured and 1.020 slightly injured) and 10.466 with material damage. [BIHAMK: 2016] According to this data, the largest number of traffic accidents in the Federation of Bosnia and Herzegovina occurred in 2016 in the Canton Sarajevo area, with a percentage share of about 38.56%.

In order to improve the road safety situation in Sarajevo, the road safety strategy for the Sarajevo Canton has been adopted for the period 2016-2020 with plans and suggestions for improvement based on the results of Decade of Action for Road Safety 2011-2020.

Urban access regulations

In order to reduce congestion within the city centers and achieve sustainable mobility, an effective traffic control system should be defined when entering the city core area. Local decision makers need to prioritize the use of urban space according to their local needs and circumstances. *The Traffic Regulation Act in the Sarajevo Canton* has briefly defined the traffic restrictions and prohibitions (Article 6). However, this Article is not fully explained, which is why it is not adequately implemented. Another reason for the failure of this Article is that there are no adequate solutions that will offer an alternative to individual and freight vehicle drivers or stimulate them to use public transport/city cargo (for trams).

Solutions which may contribute to the implementation of this restriction measure are the existence of the Park & Ride system and the congestion charging systems for entering the urban center, and also for freight transport, the existence of a city cargo system (for trams). An example of good practice is the finalization of a project for controlling access to the nearby Old Town of Sarajevo. For this purpose, Stari Grad Municipality has set up submersible and fixed pillars to control the traffic of the vehicles.

Environment impact

The continuous increase of vehicle fleet in cities along with the development of road transport networks has resulted in a wide range of negative impacts. It refers to environmental impact, expressed as Greenhouse Gas Emissions, raw materials depletion, energy and fuel consumption or disruption of ecosystem equilibrium, social impact, expressed as the quality of people life, human health, and economic impact, expressed as economic growth.

Significant influence on air quality in Sarajevo has the traffic sector. The reasons for increased traffic air pollution are: a large number of vehicles, insufficiently strict regulations for car control, inadequate vehicle maintenance, poor quality inspection of vehicle emissions, unstructured infrastructure, lack of efficient traffic regulation on existing traffic routes (traffic jam emits a higher amount of polluting substances), inadequate UPT, lack of parking spaces, low-quality fuels etc.

Today the regulations limit the emission of the following components: carbon monoxide (CO), nitrogen oxides (NOx), uncombusted hydrocarbons (HC), carbon black (particles) and smoke in diesel engines and sulfur dioxide (SO_2).

According to the available data, the emission of exhaust gases in the Sarajevo

Canton is: SO_2 15 tons/year, NO_X 2.935 tons/year, CO_2 744.263 tons/year, CO 37.737 tons/year and PM10 220 tons/year. [MPZKS, 2015]

The number of registered vehicles in Sarajevo is 126.018, of which 27.222 are older than 15 years, 39.781 are 11-15 years old, 28.703 are 6-10 years old, 9.295 are 3-5 years old, 2.789 are from 1-2 year old and 2.798 are only 1 year old. From this age structure, it is easy to conclude that in Sarajevo runs a large number of old vehicles that release large amounts of exhaust gases. [FZS, 2016]

The Traffic Regulation Act in the Sarajevo Canton has shortly defined the traffic restrictions and prohibitions (Article 6), which also includes a traffic ban to reduce emissions of harmful gases.

There are some efforts to reduce the negative impacts of traffic on the environment, such as: the ban on the import of used vehicles (EURO standards), the proper implementation of "eco-testing" on vehicle technical inspection, the restriction of entry into the core of the city and promotion of other modes of movement (use of UPT, bicycles or the use of ecofriendly vehicles - urban gas buses and implementation of car sharing system).

Organization (integration) of transport services

The integration of transport services is a way of coordinating the use of several types of public mass transport carried out by various operators (including the connection to individual automobile transport) in order to ensure the purposed and cost-effective traffic coverage of the desired area from the point of view of the economic and non-economic needs of persons and institutions covered by the system. It is also necessary to point out the organizational integration (e.g. coordinated timetables; metropolitan tickets for different transportation modes) and economic integration focused on introduction of different measures supporting sustainability and efficiency of the public transportation systems (e.g. integrated tariffs). There are many different modes of urban transport: bus, tram, trolleybus, metro etc. Companies most often work independent of one another, they are even often in competition, as is the case in Sarajevo (JKP GRAS and Centrotrans Eurolines) since 2013.

The prices of transport are aligned with all modes of UPT in the city under a unique tariff system. Ticket validation is not harmonized and there is no unique ticket for all modes of transport.

The arrangement of the terminus and stops is made so that it is possible to change the line or the mode of transport, for example: Ilidža (bus/tram), Dobrinja (city bus/trolley/public bicycle /international flights), Otoka (city bus/tram/ trolley/public bicycle/taxi), railway-bus station (city bus/minibus/tram/intercity bus/train/taxi), Skenderija (tram/trolley/public bicycle), Park stop (city bus/minibus/tram/public bicycle) and Ciglane market (city bus/minibus/trolley).

The timetables are aligned so that in most of the urban areas there is no waiting time of more than 10 minutes. The exceptions are the bus and train station (waiting time is 12-25 minutes), on the peripheral parts of the city and suburban settlements (waiting time is 30 min-1h) and at the airport (waiting time is about 1 hour).

In Sarajevo increasing road space to accommodate greater car usage is not an option. Optimising the efficient use of existing road space is therefore a key principle to appraise the requirements of competing users. The first thing to do is to integrate urban transport operators to complement each other, and not to be a competition. The coordination of cycling and walking with public transport in Sarajevo needs to be done. The benefits are mutual, encouraging more bicycling and walking as well as more public transport use. The more popular is the implementation of car sharing services. This new mobility solution is not going to cover the main part of the citizen's trips, but it will provide the key to less car ownership and in aggregate less car use.

Also, several solutions have been mentioned in the section 1.3., which refers to the integration of passengers and goods flows in the existing urban transport systems.

FORMULATING A MODEL OF MANAGING THE URBAN MOBILITY PLANNING PROCESS

In this paper, for modeling, we have chosen the growth matrix. [Stojanović, 1988] The reasons for the application are multiple, and mostly because of the inability to show the relations between the growth of elements through direct growth rates. Based on direct growth rates, it is not always possible to prove exactly which element is developing faster in absolute and relative terms, given the different initial values. Therefore, it was necessary, in addition to direct, also to introduce indirect growth rates, through which we can observe more complex relations between elements, i.e. more precisely to determine the absolute and relative growth rates as well as the relationships between the mobility elements.

Thus, the matrix allows all relations within the urban mobility system to be included at the same time.

It is assumed that the sustainable urban mobility system consists of n mutually dependent elements. With y_{it} and $y_{i,t-1}$ is marked the value of the element (i.e., input, parameter, etc.), of the i element (i = 1,.....,n) in the period t and t_{-1}.

The growth input value of the i urban mobility element is:

$$\Delta y_{it} = y_{it} - y_{i,t-1}$$

where is:
y_{it} and $y_{i,t-1}$ the value of the i element of urban mobility (i = 1,.....,n) in the period t and t_{-1}

The indirect growth rate of the i element of urban mobility in relation to the j is defined as the ratio of the input growth of the i element of urban mobility, Δy_{it}, and the values of the j element of urban mobility in the period t, respectively:

$$r_{ijt} = \frac{\Delta y_{jt}}{y_{jt}} \quad i,j = 1,\ldots, n. \quad y_{i,t-1} \neq 0$$

Indirect growth rates can be expressed in the form of matrix growth of the urban mobility elements:

$$R_t = \begin{matrix} r_{11} & r_{12} & \ldots & r_{1nt} \\ r_{21} & r_{22} & \ldots & r_{2nt} \\ \ldots & \ldots & \ldots & \ldots \\ r_{n1t} & r_{n2t} & \ldots & r_{nnt} \end{matrix}$$

$$t = 1,\ldots, T.$$

where the elements on the main vertical indicate direct ($i = j$) and the other ($i \neq j$) indirect growth rates.

Elements in i line indicate the inputs growth in the i element of a model of managing the urban mobility planning process compared to the inputs in other elements. The elements in i column mark the growth of the inputs values in all the elements of the model in a relation to the input of the i element in the period t.

From above mentioned it can be concluded that each element in growth matrix is represented in one row and one column, with elements expressing indirect or relative growth relations. Thus, for example, in the first row, the input the growth of the model first element in relation to the other elements is indicated, and in the first column, the growth of other elements in relation to the input of the first element. The other rows and columns match the other elements of the model of managing the urban mobility planning process.

The growth matrix can also be determined by the external vector of the model elements. This method is useful for practical calculation of the growth matrix. The growth vector of the model of managing the urban mobility planning process:

$$\Delta y_{it} = (\Delta y_{it}, \dots \Delta y_{m,t})$$

and vector of reciprocal values of the elements of the model of managing the urban mobility planning process:

$$\frac{1}{y_t} = \left(\frac{1}{y_{1t}}, \dots \frac{1}{y_{nt}}\right) \qquad i,j = 1,\dots,n$$

The external growth vector of the model elements coefficients and vector of reciprocal values defines the growth matrix model of managing the urban mobility planning process.

$$R_{pt} = \Delta y'_t \left(\frac{1}{y_t}\right) = \begin{bmatrix} \Delta y_{1t} \\ \Delta y_{mt} \end{bmatrix} \left(\frac{1}{y_t}, \dots, \frac{1}{\Delta y_{nt}}\right)$$

$$R_{pt} = \begin{bmatrix} \dfrac{\Delta y_{1t}}{y_{1t}} & \dots & \dfrac{\Delta y_{1t}}{y_{nt}} \\ \dots & \dots & \dots \\ \dots & \dots & \dots \\ \dfrac{\Delta y_{mt}}{y_{1t}} & \dots & \dfrac{\Delta y_{m1t}}{y_{nt}} \end{bmatrix} = \begin{bmatrix} r_{11t} & \dots & r_{1nt} \\ \dots & \dots & \dots \\ \dots & \dots & \dots \\ r_{m1t} & \dots & r_{mnt} \end{bmatrix}$$

Quantification of criteria (elements) for evaluation

Quantification of the model of managing the urban mobility planning process arises from the analysis of supply and demand, good practices in sustainable urban mobility, future strategies and development projects and other qualitative researches, by transforming the qualitative values of mobility elements into a numerical form (1 to 100).

Evaluation of model elements takes in consideration the synergistic effect of the following aspects:

- aspects of good practice for individual model elements,
- the values of the model elements in the period analyzed in the research (actual situation in 2016). The analysis is based on the following sources: The Directorate for Roads in Sarajevo Canton, Federal Bureau of Statistics, Federal Institute for Development Programming, Sarajevo Canton Planning Department, Ministry of Spatial Planning, Construction and Environmental Protection of Sarajevo Canton, Ministry of Transport of Sarajevo Canton and others;
- the assumed values 2021., when certain activities from the adopted strategies, that include the key urban mobility principles, are expected to be completed (such as the Traffic Safety Strategy for the Sarajevo Canton 2011-2020, Transport Strategy of the FBiH, Strategy for the Development of the City of Sarajevo 2012-2020), along with the second phase of IPA funds[1] and BiH gaining EU candidate status,
- the assumed values 2026. (when negotiations between BiH and EU are expected to be completed and the Treaty of accession is expected to be signed. The projects significant for urban mobility are also expected to be finalized in 2026 (such as harmonization of existing FBiH legislation with EU directives, final construction of bypass roads in major cities, implementation of road safety strategy, stimulation of new and more environmentally friendly vehicles in urban transport, development of information systems for passengers and transport companies etc.)).

The quantification of the model elements is based on the adaptation of the Urban Mobility Index 3.0 [Centre for Economics and Business Research (Cebr), 2017] for Sarajevo. The index scores cities using 27 indicators to assess mobility in urban areas according to 'maturity' (includes indicators such as modal split, transport infrastructure and existing transport initiatives that aim to improve mobility), 'innovativeness' (looks at transport sharing schemes, mobility-as-a-service platforms and autonomous vehicle initiatives) and 'performance' (considers, among other things, air quality, accident rates and travel time to work or transport time to final consumer). [Van Audenhove, Rominger, Korn, Bettati, Steylemans, Zintel, Smith, Haon, 2017] Quantification results are given in Table 1.

[1] Instrument for Pre-Accession Assistance (IPA) with at least EUR 314.9 million intended for Bosnia and Herzegovina in the period 2018-2020.: <http://europa.ba/?p=58190>

Table 1: Quantification of sustainable urban mobility elements

SUSTAINABLE URBAN MOBILITY ELEMENTS	Input y_{it}			Growth
	2016.	2021.	2026.	$\Delta y_{i,2026}$
Infrastructure	50	70	90	40
Suprastructure	40	50	70	30
Flows of passengers and goods	40	60	80	40
Speed and travel/transport time	40	50	80	40
Traffic safety	30	40	80	50
Urban access regulations	20	50	50	30
Environment impact	30	50	70	40
Organization (integration) of transport services	20	40	70	50

Source: Authors

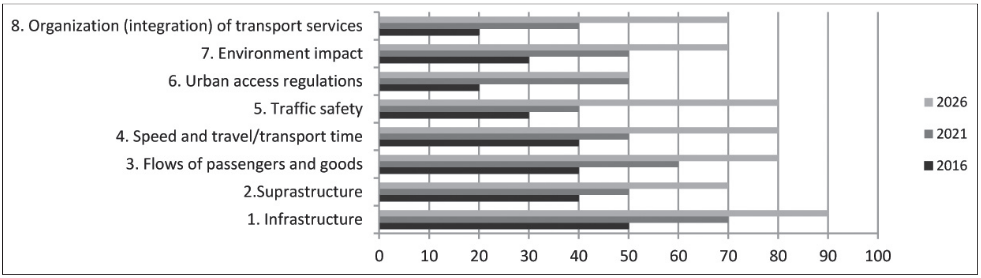

Chart 1: Display of elements of the model of managing the urban mobility planning process

Source: Table 1.

When we look at Table 2 and Chart 1, the growth vector of sustainable urban mobility is interpreted as an external vector $\Delta y_{i,2026}$. The product of external vector $\Delta y_{i,2026}$ and reciprocal values predicted for 2026 $1/y_{2026,}$ determines the growth matrix of sustainable urban mobility in relation to the current state.

Evaluation results (direct and indirect growth rates)

After implementation of the growth matrix model procedure, we get the model growth rates in the observed area (Table 2). Model elements are mutually dependent and their trends should be viewed simultaneously through direct and indirect growth rates. The matrix of growth is characterized by the expression of the relationships of different elements through the corresponding rows and columns in which the synergic effects of the model are shown. Each row or column of the growth matrix express the relation of one element to the other elements, including the parameters (outputs) that express the direct growth rates, i.e the individual effects of the model.

Table 2: Matrix – growth rates of the model of managing the urban mobility planning process

	Infrastructure	Suprastructure	Flows of passengers and goods	Speed and travel/ transport time	Traffic safety	Urban access regulations	Environment impact	Organization (integration) of transport services
Infrastructure	44%	57%	50%	50%	50%	80%	57%	57%
Suprastructure	33%	43%	38%	38%	38%	60%	43%	43%
Flows of passengers and goods	44%	57%	50%	50%	50%	80%	57%	57%
Speed and travel/ transport time	44%	57%	50%	50%	50%	80%	57%	57%
Traffic safety	56%	71%	63%	63%	63%	100%	71%	71%
Urban access regulations	22%	29%	25%	25%	25%	40%	29%	29%
Environment impact	44%	57%	50%	50%	50%	80%	57%	57%
Organization (integration) of transport services	56%	71%	63%	63%	63%	100%	71%	71%

Source: Authors

This model introduce a new theoretical approach that encompasses the relative changes of the elements and connects the elements of the model of managing the urban mobility planning process into a complete dynamic motion system. Evaluation of these elements resulted in direct rates for the period 2016-2026. (Chart 1.). Due to the limited space, only one indirect growth rate will be elaborated in this paper.

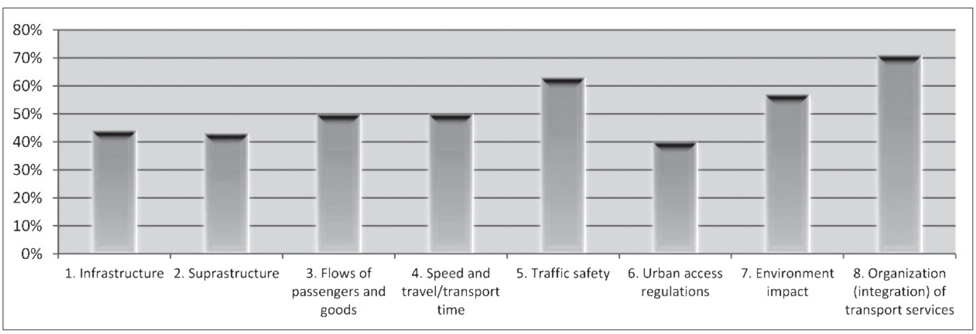

Chart 2: Display of the direct growth rates of the model in 2026 (%)

Source: Table 2.

Observing Chart 2, the direct growth rate shows that the value of infrastructure in creating better mobility of passengers and goods in urban areas in the period from 2016 by 2026, show growth of 44%, which is primarily related to the finalization of the longitudinal, transversal and city highways in Sarajevo, and also the planned implementation of bicycle infrastructure.

By comparing the growth values of the selected elements in Table 1 and direct growth rates in Table 2, it can be seen that the variables are greater in direct growth rates of the model of managing the urban mobility planning process, due to the effects of the remaining seven elements on each individual element.

When we take into consideration indirect growth rates, comparing the infrastructure respecting to other elements of mobility in the period 2016-2026 from Table 2 we can see the growth rate of 57% in relation to the superstructure, the environmental impact and the organization (integration) of transport services.

Compared to flows of passengers and goods, speed and travel/transport time and traffic safety, the development of infrastructure would be 50%, while in relation to the urban access regulations it would be even 80%.

If we compare the indirect growth rate of other model elements in relation to infrastructure construction, we can see that the superstructure will have a growth rate of 33%, while flows of passengers and goods, speed and travel/transport time and reduction of negative environmental impacts will increase by 44%. The growth rate of traffic safety and organization (integration) of transport services will have a growth rate of 56% in relation to infrastructure. The minimum growth rate regarding infrastructure will be for urban access regulations.

This analysis for indirect growth rates is valid for other elements of the model of managing the urban mobility planning process.

We can conclude that the basic hypothesis (based on the analysis of supply and demand of the city traffic system, good practices in sustainable urban mobility and existing strategies and development plans, a model for managing the whole planning process of sustainable urban mobility of the city traffic system in Sarajevo by 2026 can be proposed) of this work has been proved by direct growth rates.

CONCLUSION

The planning of the traffic system is constantly changing, which is caused by aspiration of enabling better life and work performance of citizens, which is greatly contributed by sustainable urban mobility. In order to evaluate the state of mobility in urban areas, the valorization of mobility elements was carried out. In light of SUMPs and the experience of Eltis, the criteria (elements) for the valorization of sustainable urban mobility were defined, which rely on transport supply and demand: infrastructure, suprastructure, flows of passengers and goods, speed and travel/transport time, traffic safety, urban access regulations, environment impact and organization (integration) of transport services.

The estimated inputs for selected elements in 2016 are relatively low because they reflect the current state of the mentioned elements, ranging from 20% to 50%. The reason for the low input values is inadequate investment in traffic infrastructure, outdated suprastructure, limitation and reduction of public transport passenger flows, low speed (passenger cars, city buses and trolleybuses) and longer travel time (in peak load and long wait times at the places of transferring from one mode of transport to another), a large number of traffic accidents, absence and non-implementation of the law on limitation of access to the city center and very basic integration of transport services. In order to achieve European standards of sustainable urban mobility (COM(2013) 913 final – Together towards competitive and resource-efficient urban mobility) and on the basis of existing strategic plans of the city, as well as regulatory, spatial and urban plans for the Sarajevo Canton, business plans of city and intercity/international transport service providers operating in Sarajevo area, the state of these elements will improve in the following period. That is the reason why all these values in 2026 are rated higher.

The growth matrix can focus the sustainable urban mobility planning process in Sarajevo, because it is possible to calculate the growth matrix of the model of managing the urban mobility planning process, based on the values of quantified model elements for 2016. and expected element values in 2021 and 2026. Useful information in comparative analysis can be obtained by matching appropriate growth rates for different periods.

By researching, analyzing and evaluating elements, we obtain the following: direct growth rates ranging from 40% to 71%, which show the growth of one element independently of the growth of other elements; and direct growth rate ranging from 22% to 100% which determine the growth structure of elements and express all relations over the growth matrix in the in total management of the urban mobility planning process.

The analysis and evaluation of individual model elements and the obtained growth rates were intended for scientific purposes to formulate the results of the research, according to examples of good practices of the development of sustainable urban mobility by 2026.

The basic hypothesis of this paper was proved by the direct growth rates of the aforementioned model elements: Based on the analysis of supply and demand of the city traffic system, good practices in sustainable urban mobility and existing strategies and development plans, a model for managing the whole planning process of sustainable urban mobility of the city traffic system in Sarajevo by 2026 can be proposed.

This model contributes to the multidisciplinary research necessary for the planning of sustainable urban mobility, and there is a possibility for its practical application as well. By showing direct and indirect rates, it is possible to monitor changes in the intensity of growth of individual elements (key factors that need to be developed in order to achieve better urban mobility), as well as their structural relations.

In this paper, it has been found that in order to create better urban mobility for passengers and goods, there is a significant growth of organization (integration) of transport services is expected for 71%, traffic safety 63%, and environment impacts of 57%, which is also logical, because, together with infrastructure, they represent the foundation for a quality and safe urban mobility. On the other hand, the infrastructure records almost equal growth with elements that are mutually dependent (suprastructure, flows of passengers and goods, speed and travel/transport time), which shows the direct connection of certain activities in creating better urban mobility (by covering the area with adequate infrastructure network and more modern fleet will enable the growth of traffic connection, flows of passengers and goods, movement speed and reduce the travel time). Urban access regulations have a direct growth rate of 40%.

The performed evaluation contributes to a more complete understanding between elements and position of individual elements in an effort to provide the best possible mobility in the future. The model shows that only adequately built, optimally structured and organized movement system in cities, based on synergic effect of all relevant elements of supply and demand, can influence the development of mobility in urban areas.

What remains interesting to do is cost-benefit analysis of cost-effectiveness of investment in the implementation of specific activities for individual elements of sustainable urban mobility.

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MODEL UPRAVLJANJA PROCESOM PLANIRANJA URBANE MOBILNOSTI

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Abstract: *The deterioration of traffic conditions associated with the expansion of urbanization and increased motorization has a negative impact on the economy of large cities. The pressures on urban transport systems are increasing as part of the process of growth. The average distance travel per vehicle is also increasing in all but the largest, most-congested cities like Sarajevo. This growth exceeds the ability to increase road space, and the major impediment to the efficient working of the urban economies in large-size cities, and particularly in megacities, is the level of road traffic congestion. Also, traffic congestion has a negative impact on the competitiveness and environment of urban economies; it causes inefficiencies in logistics operations and increases costs. The costs of the 'first' and 'last mile' of supply chains are too high and present a barrier to growth of home delivery. Urban logistics is heavily neglected in city and transport planning.*

For that reason, urban mobility planning processes are now essential if we want the transport service of passenger and goods to meet the needs of entrepreneurs and residents of urban/suburban areas. Urban transport and other innovative solutions (such as bicycle, car sharing, city cargo etc.) that are of great importance for the economic and ecological development of cities are becoming significantly important ways of ensuring mobility and accessibility within urban centers. Achieving urban mobility is also one of the most important goals of the European Union (EU) member states in creating a traffic policy, which requires a multidisciplinary approach and cooperation of all participants. According to the European Commission, the main goal of the sustainable urban mobility plan is to improve the accessibility of urban areas *and to ensure mobility and high-quality traffic to the city area and within it. Proper planning of sustainable urban mobility should be based on a detailed analysis of the present and future design of the urban traffic system and people behavior.*

The subject of research in this paper is the planning of urban mobility development in the narrow part of Sarajevo using a model based on the growth matrix. The hypothesis of this research is: Based on the analysis of supply and demand of the city traffic system, good practices in sustainable urban mobility and existing strategies and development plans, a model for managing the whole planning process of sustainable urban mobility of the city traffic system in Sarajevo by 2026 can be proposed.

In accordance with the experience of Europe's main urban mobility observatory (Eltis) and sustainable urban mobility plans (SUMPs), the key elements are defined: infrastructure, suprastructure, flows of passengers and goods, speed and travel/transport time, traffic safety, urban access regulations, environment impact and organization (integration) of transport services. The next step, after defining the elements of urban mobility, is to carry out the quantification of elements for 2016 (by adapting the Urban Mobility Index 3.0 for Sarajevo). Thereafter, there is a concise explanation of the growth matrix and model of managing the urban mobility planning process is created. In the research results, direct and indirect growth rates were elaborated and analyzed, i.e. the individual and synergic effects of the model. Finally, the synthesis of the research results was presented.

According to the model, the proper order of funds investment into aforementioned elements will contribute to the perfect harmony of all aspects of supply and demand of urban mobility services, and hence the economic development of the city.

Keywords: *model, growth matrix, sustainable urban mobility, planning process.*

JEL: *R41, R42, R51*