

# Improvement the urban mobility of the city of Sarajevo through the development of an innovative model for the creation of a low emission zone

Mirzet Sarajlić<sup>1</sup>, Koldo Berasategui Ordeñana<sup>2</sup>, Ahmed Ahmić<sup>3</sup>

<sup>1</sup>Ministarstvo saobraćaja Kantona Sarajevo, Reisa Džemaludina Čauševića br.1. Sarajevo, 71.000, BiH

<sup>2</sup>IDOM Ingeniería y Consultoría S.A. Zarandoa Etorb., 23, Deusto, 48015 Bilbo, Bizkaia, Spain

<sup>3</sup>Fakultet za saobraćaj i komunikacije, Zmaja od Bosne br.8. Sarajevo, 71.000, BiH

## Abstract

This work elaborates a model for the improvement of urban mobility in the city of Sarajevo through the development of an innovative model of urban mobility based on the establishment of low emission zones. Contributing to the development of the city through the establishment of low-emission zones will be a revolutionary move for the Western Balkans region, where not a single city has resorted to such a strategy. The work offers a model of a technical solution for the development and establishment of a low emission zone in Sarajevo, which belongs to medium-sized cities, all with the aim of improving ecologically sustainable urban mobility such as public transport, walking and cycling. . The created model and technical solution can be used as a basis for planning the same or similar solutions in other medium-sized cities. Several scientific methods were used during the creation of the work itself, such as recording, counting, experimental and comparison methods. Mutual connection in different environments similar to the observed city was used as an approximation of the conclusion related to the topic.

**Keywords:** *Low emission zone, urban mobility, electromobility, medium-sized cities, technical solutions.*

## 1 Introduction

According to the report of the European Commission SWD (2022) 336 final [1], Bosnia and Herzegovina (BiH) is at an early stage of preparation in the area of environment and climate change. In this context, the residents of Sarajevo are exposed to some of the highest concentrations of air pollution in Europe.

In terms of sources of GHG emission, the transport sector represents 13.6% of the country, while the energy sector as main GHG emission source generates 70.7% of the total. Working to solve this situation the Canton of Sarajevo started different initiatives to improve public transport services as a way to reduce mobility externalities.

Complementing these actions, implementation of a smart parking management integrated with a LEZ in the City Centre of Sarajevo has been

defined as solution to achieve expected goals in terms of decreasing GHG emission and to discourage the use of private cars.

The establishment of low-emission zones as a measure to preserve the environment represents a significant step for bringing the city closer to European standards. Including the complete traffic policy in that system will together ensure the sustainability of the development of an urban area.

The paper explores the technical possibilities of implementing low-emission zones in one European city, relying on the author's experiences in other European environments. The number of vehicles per hour per day is shown in (Fig.3) clearly shows the variation of daily loads. Scientific works published on the same topic served as a basis for research, and the results of the research can be used for further improvements

and scientific approximations of the topic that the work deals with.

## 2 Objectives and justification of the establishment of low emission zones

### 2.1 Objectives

According to the report “Data Collection Survey on Public Transportation in Sarajevo Canton, Bosnia and Herzegovina” research presented in the working document [2], the modal split of Sarajevo has been estimated resulting the following figure:

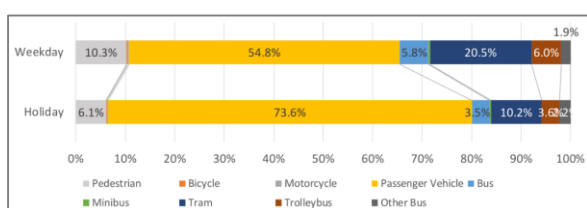


Fig. 1. Estimated modal split (JICA) [3]

This figure shows that sustainable mobility modes (active modes and public transports) represent only 45.2% of the total in weekday and 26.4% in holiday, which are considered low in terms of sustainable mobility. The number of vehicles by day of the week is shown in (Fig. 2.) clearly shows heavy daily loads. Furthermore, this situation is not aligned with European mobility strategy that, supporting the European Green Deal, establishes the goal of achieving a 90% reduction in transport-related GHG emissions by 2050. More specifically, European Commission published in December 2021 the New European Urban Mobility Framework that proposes initiatives to encourage EU countries to develop urban transport systems that are safe, accessible, inclusive, affordable, smart, resilient, and emission-free. The number of vehicles during the day (fig 2.) speaks of the importance of reducing pollution in the city. Key aspects to achieve that objective are the promotion of a strong public transport network and promotion of active mobility, that result in a modal split with low rate of private motorized vehicles.

The basic goals of establishing low emission zones are reflected in the following:

- Improvement of air quality and thus the living conditions for residents of urban areas,
- Favoring public transport as a means of urban mobility,

- Favored use of environmentally sustainable modes of transport such as bicycles, walking, etc.
- Reduction of noise pollution,
- Reduction in the number of traffic accidents,
- More efficient management of the traffic system in the city.

Aspects that contribute to this modal split and GHG emission rate are the current situation of public transport services, high level of motorization with an important increasing evolution and the open offer of parking slots.

With the main objective of improving Sarajevo wellness, the project intends to decrease the number of polluting private vehicles transferring commuters to public transport services that should be improved by the Canton considering following key aspects:

- Integrated mobility management, saving the value that data represents in mobility management.
- Seamless mobility promotion, in terms of avoiding obstacles that could penalize pedestrian access as well as looking for a potential future door to door mobility service.
- Accessibility, looking for inclusive solutions in terms of sex, age, financial or technological inclusion.

### 2.2 Basis for establishing a low emission zone

For the purposes of this research, certain counts of traffic were made on a characteristic cross-section of the planned coverage of the low emission zone.

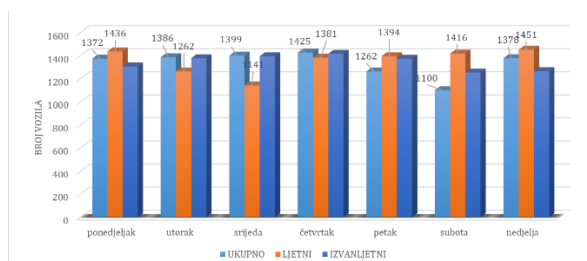
The results of the measurements are given below, and the data are the basis for the importance of the establishment of zones.

In the center of the zone at the Obala Kulina bana location, the following data were recorded using the continuous number method (Table 1.).

**Table 1.** Average number of vehicles on the cross section of the road [author's result]

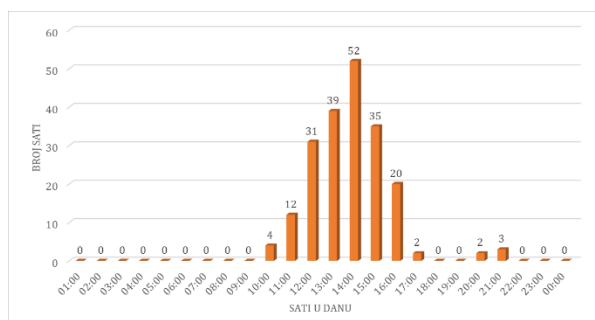
|                                           | MJESEC |         |       |       |       |       |       |        |           |         |          |          |
|-------------------------------------------|--------|---------|-------|-------|-------|-------|-------|--------|-----------|---------|----------|----------|
|                                           | JANUAR | FEBRUAR | MART  | APRIL | MAJ   | JUNI  | JULI  | AUGUST | SEPTEMBAR | OKTOBAR | NOVEMBAR | DECEMBAR |
| PROSJEK                                   | 30573  | 31855   | 32153 | 34108 | 33675 | 33419 | 32821 | 33098  | 32287     | 32234   | 31713    | 32758    |
| Average annual daily traffic (PGDS) 32558 |        |         |       |       |       |       |       |        |           |         |          |          |

Average hourly traffic in the days of the week is recorded and presentet in next dijagram:



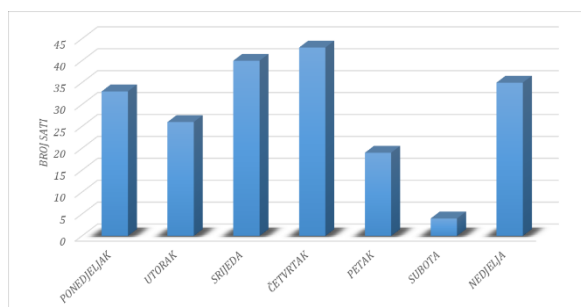
**Fig. 2.** Average hourly traffic in the days of the week [author's visualization]

The breakdown of traffic density by typical hours of the day is given in the following diagram:



**Fig. 3.** Traffic density by typical hours of the day [author's visualization]

The schedule of traffic density by day of the week is shown below:



**Fig. 4.** Schedule of traffic density by day of the week

The indicators presented refer to the year 2023, considering that at the time of writing the current year is in progress. The data clearly speak of the need to reduce motor traffic in the inner-city core, which is the basis for innovation and development of measures to establish low-emission zones.

## 2.3 Model for the creation of a low emission zone

Technological solutions support the implementation of a mobility management policy in an efficient way. The design of Smart Parking and LEZ has also included the definition of the business rules of both systems in terms of sustainable mobility management. Defined rules are based on the following key topics:

- Parking spots availability prioritized for residents as a way to limit the parking availability for visitors vehicles and consequently reducing entrances to the City Centre.
- Define roles avoiding visitor vehicles with seasons tickets to promote rotation and reduce entrances to the City Centre.[3]

These consideration result in the definition of different parking sectors:

- Residential sector.
- Low rotation sector.
- High rotation sector.

Additionally, they limit the duration and re-entry time of parking for visitor vehicles as a way to demotivate them and consequently reduce entrances to the City Centre.

## 2.4 Systems design

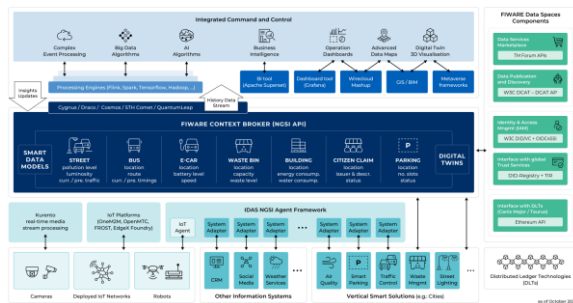
According with the European Commission, smart city is defined as follows [4]:

“A smart city is a place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of its inhabitants and business.

A smart city goes beyond the use of digital technologies for better resource use and less emissions. It means smarter urban transport networks, upgraded water supply and waste disposal facilities and more efficient ways to light and heat buildings. It also means a more interactive and responsive city administration,

safer public spaces and meeting the needs of an ageing population.”

This general vision should be considered in the implementation of solutions for cities, identifying the role of each of the digital tools to be implemented. In any case, a critical element is the Smart City platform with the purpose of integrating available information to generate indicators that allow an efficient and inclusive management of the city by high managers. (Fig. 5.) The following image, it is an example of the role of Smart City Platform and how it works in collaboration with the digital tool of integrated services:



**Fig. 5.** FIWARE Smart Cities Reference Architecture (FIWARE) [2]

As the architecture shows, the mission of the Smart City platform is the integration of data generated by:

- Vertical Smart Solutions that support operational management of specific municipal services. This is the case of parking, LEZ, traffic lights, lighting, public transport...
- External Information Systems that could be managed by other entities. This is the case of Meteorological monitoring developed by national entity, Social Networks, Public Media...
- Complementary sensors. That correspond with elements installed out of integrated system to complement data gathered from existing Vertical Smart Solutions and required in order to comply with stated objectives and indicators.

As a consequence, Smart Parking system and LEZ control system are designed to obtain those indicators from the Smart City platform in the general architecture.

## 2.1 LEZ control system

The general architecture of the LEZ system includes all the required subsystems to detect and identify vehicles with permission to enter the

LEZ, as well as the management subsystem necessary to initiate the enforcement and fraud control once an unauthorized vehicle has been detected.

Regarding the system operation, it is characterized for being a hybrid ALPR system combining fixed and mobile control units. On one hand, there will be fixed cameras installed at the entry and exit points of the LEZ to capture images or videos of the passing vehicles.

On the other hand, there will be on-board cameras installed in the mobile units. These elements and the necessary physical components to be deployed on the street, allow the identification of vehicles circulating within the LEZ by the LPN. An OCR software analyses the images to extract and recognize the license plate number of each vehicle and the license plate information is compared against a database containing details about permitted emission levels for each vehicle.

This solution aims to reduce the cost and time to install fixed points in each of the access streets presenting the following pros and cons:

- ↑ The investment required for the implementation is not especially high for big areas.
- ↑ The efforts to control can be regulated.
- ↑ Electrical light vehicles can be used as mobile units.
- ↑ The extension of the solution to other areas can be contracted.
- ↑ Mobile units do not suffer vandalism.
- ↓ 100% of vehicles are not controlled.
- ↓ Restrictions based on permanence cannot be implemented.
- ↓ There should be considered drivers for mobile units.

Once the vehicles are detected, the information from the different sources is collected, so that the central system can decide whether a vehicle is punishable, the type of infringement and the amount to be charged.

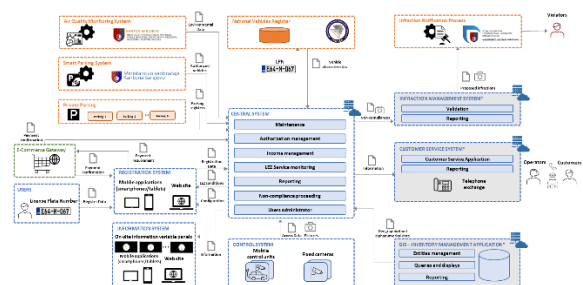
Complementarily to those elements to control the access of vehicles and due to existing Air Quality Monitoring System of the Canton only has seven (7) station located out of the area of the LEZ, the system includes sensors to monitor the air quality in restricted area in order to evaluate the effect of restrictions. [7]

As in the case of the Smart Parking system, the design of the architecture has considered the synergies between different mobility services supported by the Ministry of Traffic of the Canton, distributing required functionalities in subsystems in order to deploy independent applications for those functionalities that can be used by other mobility services. In this way, LEZ system is composed of the following subsystems:

- Vehicles are authorized in the system to enter the LEZ by the registration of the vehicle license plate number in order to identify which vehicles are allowed to enter the LEZ or which ones are exempted.
- Registration system involves the subscription of the license plate of vehicles so as to interact with the central system. (Fig. 6.) In case an infraction is detected the central system verifies if the vehicle has an exemption or the necessary registration data to process the infraction.
- Control system embraces fixed cameras strategically located along the LEZ equipped with automatic number plate recognition systems, and mobile units equipped with portable on-board automatic number plate recognition systems to detect and identify vehicles driving inside LEZ.
- Information system involves the distribution of information. On one hand, on-line channels such as mobile application and data services to inform the user about the LEZ restrictions. On the other hand, on-site elements such as variable panels in order to notify about special environmental events that might change the restrictions for the LEZ.
- Air Quality Sensor system helps to analyze air quality complementing the information provided by the Air Quality Monitoring system supported by the Ministry of Environment of the Canton of Sarajevo. These sensors are located inside the LEZ, providing information about air quality magnitudes (CO<sub>2</sub>, NO<sub>2</sub>, PM...).
- Central system is the central application to store, manage, process and disseminate the information captured by the external physical infrastructure, as well as to monitor and control the traffic, manage the authorizations and sanctions, and review the proposals.
- In case of a non-authorized vehicle, potential infraction should be reviewed before being reported to be processed by the Ministry of

Interior of Sarajevo Canton according to established process to notify misdemeanour orders.

- Customer service encompasses a range of tools in order to provide general assistance for various needs such as complaints, claims questions and service inquiries both in presential and non-presential manner. Although the aim is to prioritize a non-presential customer service, the customer presential service is maintained for those users less integrated with the digitalization.
- GIS-Inventory management system entails the necessary tools for the registration of the alphanumeric and geographical data such as geographical scope and on-site elements that involve entities related to the LEZ.
- Electronic payment methods are prioritized in order to reduce fraud and operational costs, although cash remains, which is in line with the rate of financial inclusion of BiH. Electronic payment gateway is integrated as a service that incorporates tools to control bank transactions from the clients.



**Fig. 6.** Architecture for LEZ control system [author's visualization]

In the previous image, the elements in grey are those subsystems that are in common with Smart Parking system so they do not have to be developed twice.

### 3 Conclusion

Defined solutions will be implemented by the Canton in the following years complementing already developed improvement of cantonal tramway system, new Automatic Traffic Management System in execution and scheduled bus service fleet update.

Solutions, aligned with international best practices and customized for cantonal administrative organization and social

characteristics, represent an important improvement for the Canton in terms of mobility management allowing to:

- Access to reliable mobility data related with driving fleet and their characteristics.
- Access to reliable data about parking demand in Sarajevo.
- Improve the efficiency by the use of technological solutions.
- Deploy solutions like GIS and Infraction Management Application that can be used for other services supported by the Canton, in order to advance in automatic process.
- Implement parking regulation to unencouraged the use of private car.
- Promote electronic payment methods to advance in intermodality and seamless experience for commuters.

Supporting Bangkok Urban Living in 2030,” MDPI Journal, vol. 14, no. 1, pp. 120-138, 2022.

## References

- [1] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Ministry of traffic and communications Canton Sarajevo, City of Sarajevo “*Sustainable Urban Mobility Plan for City of Sarajevo (SUMPs)*”, 2020.
- [2] European Commission, “Accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions”, Commission Staff Working Document. Bosnia and Herzegovina, Brisel, 2022.
- [3] JICA and NIPPON KOEI company “*Data Collection Survey on Public Transportation in Sarajevo Canton, Bosnia and Herzegovina.*”, 2020.
- [4] European Commission “*Smart Cities and Communities*”, 2022.
- [5] APDS “*Alliance for Parking Data Standards. Overview. Version 4.0 Release*”, 2022.
- [6] T. Sobral, T. Galvão and J. Borges, “Visualization of urban mobility data from intelligent transportation systems,” *Sensors* (Switzerland) (2019), vol. 15, no. 1, pp. 88-99, 2019.
- [7] N. Gerdri, K. Sivara, C. Chatunawarat, S. Jaroonjitsathian and K. Tundulyasaree, “Roadmap for Future Mobility Development