Intelligent transportation systems in croatian smart cities

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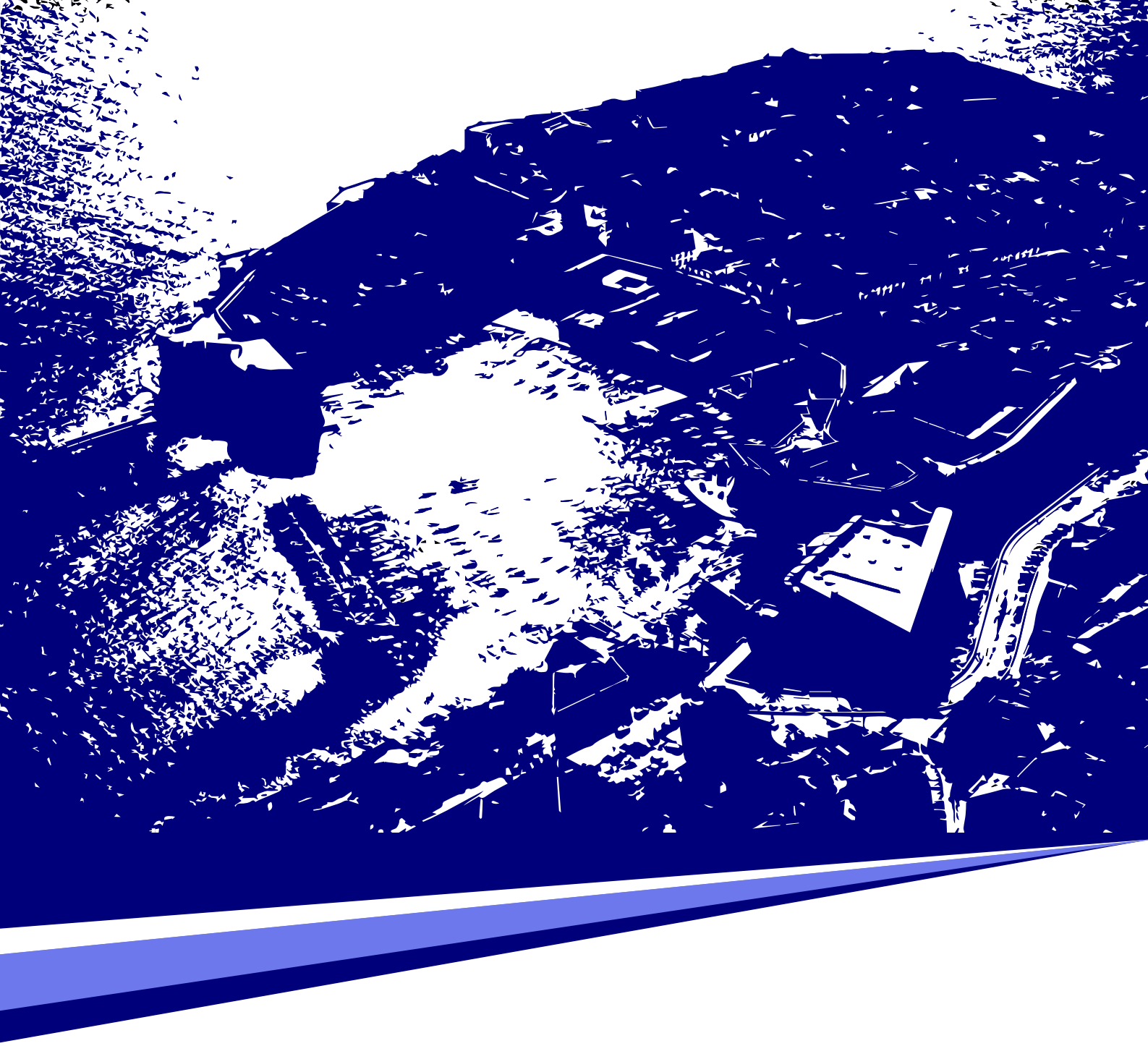

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CONTENT

INTELLIGENT TRANSPORTATION SYSTEMS IN CROATIAN SMART CITIES

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Summary

Cities across the world are trying to develop into so called Smart Cities. Generally, one of the main goals of Smart Cities is an efficient and sustainable transportation. Decreasing traffic congestion, improving mobility and environment preservation are some of the biggest transportation challenges. Non-efficient city transportation, especially when significant congestions occur, impacts nearly all aspects of city functions and its development. To overcome these challenges many city planners are looking to smart public transport solutions, including development and introducing of new transport means, combining different existing means of transport or altering the transport organization using the existing means and infrastructure. More than 40 out of a total of 128 cities in Republic of Croatia use smart transportation initiatives to optimize their public transportation routes, create safer roads, reduce infrastructure costs and traffic congestion. This paper presents an analysis of intelligent transport solutions introduced in Smart Cities across the Republic of Croatia. The main goal is to analyze the efficiency of the smart mobility initiatives and to investigate the importance of information and communication technology in supporting smart mobility actions, influencing on the citizens' quality of life.

Keywords: Smart Cities, Smart Mobility, Information and Communication technology, Republic of Croatia

1. INTRODUCTION

Nowadays, half of humanity or approximately 3.5 billion people live in cities, and in future it is expected that this number will continue to increase [1]. According to data taken form Smart Cities Council, approximately 55% of the world's population lives in cities. The United Nation estimates that in year 2050 the urban population will increase to 6.3 billion inhabitants. Nowadays, in Republic of Croatia about 60% of the population lives in cities across the country and it is expected that 63% of the population will be living in

cities by year 2025 [17]. Although cities occupy just 1% of the Earth's land, they account for 75% of energy consumption and 80% of CO_2 emission [19].

This growth has had a profound impact on the global economy, as approximately 70% of the world economic activity now occurs in urban areas [18]. These trends make it clear that urban areas are the central economic, political, and social hubs of the 21st century. According to aforementioned, cities play a key role in sustainable development so they must be managed in ways that support economic, social and environmental sustainability. The above mentioned could not be fulfilled without use of novel information and communication technologies (ICT). ICT are necessary for transforming traditional city to smart one and to enable the efficient use of infrastructure, services and administrative systems in order to achieve sustainability.

The Republic of Croatia as a member of the European Union puts a lot of effort to make its cities smart. The Republic of Croatia has less than 4 billion inhabitants overall and 17 cities that have the status of a large city (more than 35,000 inhabitants). Most of these cities have the status of a Smart City. Except large cities, there are more than 40 (out of 128 cities in total) that use intelligent solutions for a better management and a better living standard.

In Croatia the development of Smart City infrastructure is at an initial level, but is progressing rather fast. Approximately 50% of Croatian cities have already started the process of implementing one or more smart solution projects [1]. The objective of this paper is to analyze the current situation regarding intelligent transport solutions (Smart mobility) introduced in Croatian Smart Cities.

2. THE SMART CITY CONCEPT

Despite there is some kind of consensus in broad literature that the label "Smart City" represents innovation in city management, it's services and infrastructure, a common definition of this term has not yet been stated. There is a wide variety of definitions of what a Smart City could be.

Today there are several various definitions of the Smart City suggested by different organizations, specialists and scientists from different scientific fields. Hereafter are presented some definitions and explanations of the term as perceived by different authors and institutions:

- A Smart City uses information and communications technology (ICT) to enhance livability, workability, and sustainability [19].
- A Smart City is a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership [8].
- According to the Manchester Digital Development Agency, Smart City means Smart Citizens – where citizens have all the information they need to make informed choices about their lifestyle, work and travel options.
- IBM defines a smart city as "one that makes optimal use of all the interconnected information available today to better understand and control its operations and optimize the use of limited resources.
- The British Standards Institute (BSI) defines the term as "the effective integration of physical, digital and human systems in the built environment to deliver sustainable, prosperous and inclusive future for its citizens".
- The UK Department for Business, Innovation and Skills (BIS) considers smart cities a process rather than a static outcome, in which increased citizen engagement, hard infrastructure, social capital and digital technologies make cities more livable, resilient and better able to respond to challenges.
- According to Mark Deakin and Husam Al Waer Smart City is a city that utilizes ICT to meet the demands of its citizens, and that community involvement in the processes is a necessity for a Smart City. From the definition given by Husam Al Waer and Mark Deakin in their research publication

"From Intelligent to Smart Cities," the factors that contribute to a city being classified as smart are: the application of a wide variety of digital and electronic technologies to the city and its communities, the application of ICT to uplift life and the working environments in the region, the embedding of such ICT within government systems, the territorialisation of practices that bring the people and ICT together in order to innovate and enhance the knowledge that they offer.

- The use of ICT makes the critical infrastructure components and services of a city – which include city administration, education, healthcare, public safety, real estate, transportation, and utilities – more intelligent, interconnected, and efficient [45].
- A city is smart when investments in human and social capital and traditional and modern communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance [5].
- A smart city is where the ICT strengthens freedom of speech and the accessibility to public information and services [2].

From above examples it can be deducted that most definitions are technologically oriented. It may be assumed that the definition of the Smart City will evolve as different aspects of technology will be developed.

Regarding the Smart City concept there are numerous resources but they all equally define the Smart City concept. Smart City concept contains several axis of a city that relates to (Figure 1) [11,12]:

- Smart Economy – means the use of ICT solution in a business and entrepreneurship sectors
- Smart People – means the use of ICT tools for access to education, to make decision based on appropriate data and to create new products
- Smart Governance – means the use of ICT tools for example web platforms or mobile applications to enable data transparency for different stakeholders.
- Smart Mobility – means ICT supported transport with real-time data
- Smart Environment – means ICT enabled energy grids with monitoring and pollution control
- Smart Living – means ICT- enabled lifestyles which reduce energy and water consumptions.

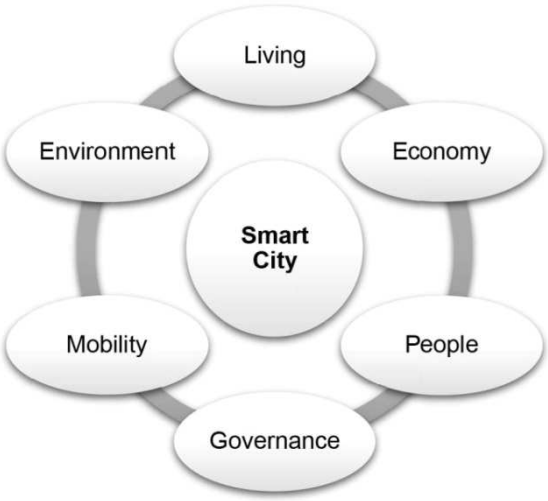

Figure 1 The Smart City concept

Source: Authors, according to [11, 12]

Furthermore, all aforementioned axis of smart city integrates four different networks: Internet of Things (IoT), Internet of People (IoP), Internet of Services (IoS) and Internet of Data (IoD) (Figure 2).

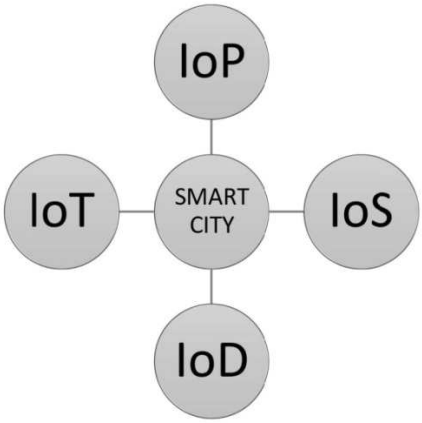

Figure 2 Internet networks in the Smart City

Source: Authors

Internet of Things represents the technology where data are automatically transferred over network without any human interference. Internet of Things refers to different devices, mobile and static sensors and usefully resolves many problems in a city. City collect many real-time data obtained from road sensors, mobile phones, street cameras, drones and other sources, and for example, if there is a car accident or traffic congestion with the help of IoT other car drivers can be directed to another road that is less congested.

Internet of People (IoP) represents the mapping of social individuals and their interactions with smart devices to the internet [42]. IoP includes collection, modelling, and ubiquitous intelligence for a wide range of applications which are crowd sourced, internet-based personal information.

Internet of Service (IoS) is a next-generation blockchain technology that provides the network infrastructure to support a service-oriented ecosystem [20]. IoS includes cloud-based solutions, processes, tools and operations.

Internet of Data (IoD) represents linking of open data and data analytics. The aim of IoD is to collect useful information, combine them and deliver them to end users through internet. All aforementioned internets are necessary for providing data transfer and useful information between citizens of a certain city.

3. SMART MOBILITY AS KEY ASPECT OF A SMART CITY

The Smart Mobility integrates citizens and transportation through innovative technologies to improve their mobility [21]. The Smart Mobility as a concept consist of few components which include infrastructure, technology, information and services. Jekkel, H., defined the four components of Smart Mobility [16]:

- Vehicle technology: the basis are new types of vehicles powered by efficient alternative fuels (usually electricity), autonomous, safe and equipped with vehicle dynamics control and car systems assisting drivers.
- Intelligent Transport Systems (ITS): the improved ITS solutions brought a new level of interconnected cars, cooperative adaptive cruise controls, and intelligent traffic management
- Data: the real time data plays significant role in Smart Mobility and includes passengers' information, personalized travel assistance, logistics planning, IT systems matching supply and demand for mobility, Big data, IOT. [3].
- New mobility services: optimal utilization of existing vehicle and truck capacity, carsharing, new biking systems, integration of transport modes, using smartphones for facilitating mobility and ticketing, on-demand ride services, use of individual cars as public transport.

Furthermore, Smart Mobility is one of the key factors enabling sustainability in cities, since the urban transport generates negative impact on environment in cities and also affects the economic and social components of living in the city. The goals of Smart Mobility can be summarized as follows [22]:

- reduce environmental impact,
- improve planning and efficiency of public transport means,
- optimize parking spaces and their management,
- reduce congestions and citizens frustration,
- prioritize the citizens in the mobility,
- improve living quality for the citizens.

The European citizens living in urban areas will count 80% up to year 2050 [9]. E.g., in the Europe 70% of journeys are made by car (private car, taxi or car-sharing) making the road transport a dominant mode. 55% of public transport rides are made by buses [10]. In European cities, over 90% of citizens use a smartphone more than any other device. 57% of Croatian citizens point out the mobile phone as the device they would most likely pay with while 22% citizens already use some variation of mobile payment method [27]. Smartphones and mobile payment methods are very useful to facilitate the Smart Mobility.

Hereafter are presented some Europe cities as good examples in implementing a Smart Mobility concept. The Netherlands is recognized as one of the leading countries in the future of Smart Mobility. The capital Amsterdam is committed to sustainability and citizen-focused modes of travel. Amsterdam has high reliance on bicycles as a key mode of transport (32%) and also on walking (29%). Considering all modes of citizens' transport in Amsterdam, the public transport ratio is 17% while the private mode of transport using cars ratio is 20%. The example of Amsterdam shows how cycling can take prominent role in the future of urban mobility [23].

The City of Helsinki is one of the first cities which implemented the Smart Mobility concept which continuously develops. Their aim is that all citizens do not have a need to own a private car by year 2025 [24]. Furthermore, in Deloitte Study on City Mobility Index, Helsinki is rated as a city committed to innovations such as a self-driving public bus and it is marked as a leader in Future of Mobility concepts such as MaaS (integration of various forms of transport services into a single mobility service accessible on demand). To meet a customer's request, a MaaS operator facilitates a diverse menu of transport options, being public transport, vehicle sharing (ride, car or bike), taxi or car rental/lease (or a combination). In addition, Helsinki has the following transport model ratios of use: 30% of public transport, 21% walking, 8% cycling and 39% private transport by car [25].

Vienna, the capital of Austria made a significant progress in Smart Mobility. Recently the first autonomous or self-driving bus was put into operation, and the first autonomous air taxi in Austria should be ready for series production by year 2020 [26].

In addition to the increasing demand for urban mobility, there are other factors which emphasize the importance of implementation of Smart Mobility solutions: changed travel habits, rise of collaborative mobility, demand for services to increase convenience, speed and predictability and evolving customer expectations towards customization [28].

4. SMART MOBILITY IN THE REPUBLIC OF CROATIA

Smart Mobility concept is still in developing phase in Croatia. The Smart Mobility solutions are concentrated in the capital city of Zagreb and main region cities. There are also several small cities which are aware of benefits of Smart Mobility.

The Department of Urban Transport at the Faculty of Transport and Traffic Sciences has conducted a research regarding the current knowledge and implementation of Smart Mobility and Smart City concepts in

Croatian cities. In cooperation with the Association of Cities, research has been conducted on 23% of all cities in the country (altogether 128 cities). The research has showed the following results [4]:

- 32% of participated cities are involved in the implementation of the Smart City concept; 64% are planning to start;
- The key components of Smart Mobility are ICT technologies (86,2%), smart public transport (65,5%) and smart parking (58,6%);
- The implemented Smart City solutions are: Air quality control (33%), traffic control (22%) and smart parking (11%);
- Smart mobility solutions that the observed cities will be implementing in future are: ICT technologies (60, 7%), smart parking (50,0%), traffic control (39,3%) and smart public transport (32,1%);
- 51,7% of cities are ready to allocate certain financial resources for Smart City and Smart Mobility solutions.

Furthermore, the results showed that there is no systematic collection of data for the indicators of smart mobility level and that the existing data are not harmonized on the national level. For the purpose of measuring the level of mobility, efficiency or sustainability, it is necessary to standardize the collected data into a comprehensive index of indicators at the level of the Republic of Croatia, according to leading European and global trends [43].

The survey on carsharing in Croatia conducted on 183 persons resulted as follows [14]:

- 30,6% of respondents didn't know the meaning of carsharing;
- 50% of respondents who knew the meaning of carsharing used it very rarely;
- 68,3% of respondents showed the interest to use the carsharing in case of possibility.

Table 1 presents the implementation of the state-of-the-art of the Smart Mobility technologies in Croatia as follows: smart parking, smart bus station, e-Bike, e-Scooter, EV charging Stations, carsharing, park and ride, automated traffic management systems, smart travel information applications. To provide a comprehensive analysis the focus is placed on the capital of Croatia - Zagreb, and on the main regional centers Split, Rijeka, Osijek, Zadar, Pula and Dubrovnik.

Table 1 Smart Mobility solutions in Croatian cities

Smart Mobility Technologies	City						
	Zagreb	Rijeka	Split	Osijek	Zadar	Pula	Dubrovnik
Smart parking	X	X	√	X	X	X	√
Smart bus station	X	√	X	X	X	X	X
e-Bike	√	√	√	X	√	√	√
e-Scooter	√	√	√	X	√	√	√
EV charging station	√	√	√	√	√	√	√
Carsharing	√	√	√	√	√	√	√
Park and Ride	√	X	X	X	X	X	X
Automated traffic management system	X	√	X	X	X	X	X
Travel info apps	√	√	√	√	√	√	√

Source: Authors

The capital of Croatia, Zagreb, is the only city in Croatia with implemented Park and Ride system. Located near the main railway station Park and Ride offers citizens the possibility to combine the use of parking and city transportation [29]. Via tickets citizens are able to park for unlimited time and continue their transport using bus or tram. Furthermore, Zagreb has a well-developed network of EV charging stations which are mainly available in public garages and shopping malls. Zagreb is also intensively developing e-Bike services since cycling is becoming continuously more popular in Zagreb [30]. E.g. the e-Bike Zagreb company

offers simple online bike booking in range of hour to weekend booking [30]. Zagreb has introduced carsharing e.g. via Spin City Application. After the registration and payment, a user is able to unlock the car using the application and use it. All cars are eco-friendly (currently 30 cars) which are available at all times, and users have may freely use the parking places around the city [31].

The City of Rijeka is one of the most prominent city in Croatia in terms of Smart City concept with a clear strategy for development of Smart Mobility. In 2015, the City of Rijeka established the ''Smart RI'' center which acts as a cluster manager linking business entities and research institutions to develop projects for smart cities. Partners have conducted six researches and developed two projects in Smart Mobility field from which: SmartCity.Trans and SmartCity.Surinmo. The SmartCity.Trans (Traffic Management and Internet of Things) is aimed at advanced analytic solution for increased security, advanced algorithms for detection of traffic anomalies, incidents and dangerous situations. The SmartCity.Surinmo aims at development of platform for connected, energy efficient and shared urban mobility. In detail, through the project it will be developed the e-Roaming platform for e-vehicle charging, carsharing, digitalized parking and public transport. Furthermore, the system of E-signs will provide safety and information as well as the redirection of transport. The E-crossing is a part of Surinmo focused on integration with Smart City Platform [32].

First smart bus stations in Croatia are implemented in Rijeka in 2017. The implemented Automated Traffic Management System in Rijeka aims to optimally manage traffic under the given conditions. Modern traffic management technology allows the management of light traffic signaling, depending on the prevailing traffic loads in the traffic network [33]. The system is modular and can be easily adapted to new traffic conditions. Rijeka still lacks of Park and Ride system although there has been the initiative to organize it. Smart Parking is still not implemented in Rijeka.

The City of Split is one of the first cities in Croatia which implemented the Smart Parking. The citizens use Smart Split parking application which is considered as one of the best applications in Croatia of that kind. The system uses sensors to detect whether the parking space is free or busy, and the application user sees the current situation on his/her mobile phone. The parking availability is visible in the form of a pin on the map, which contains numerical information about free parking spaces. The application also offers the user the ability to navigate to the nearest free parking space. In application, free parking spaces for persons with disabilities are emphasized. The system enables reduced crowds, better driving experience and eco-effect in the form of lower polluting emissions [34].

The City of Osijek has provided EV charging stations, carsharing and smart travel information applications for citizens. Other systems and technologies are in process of development through various EU projects in which Osijek is especially active.

The City of Zadar and the City of Pula are continuously developing their e-Bike and e-Scooter capacities mainly in order to improve their touristic offer. The Tourism Office Pula provides e-Bikes at one spot. To use this service tourists or citizens must show one personal document and after data acquisition they may rent an e-Bike [35]. Behind various companies Zadar provides e-Bike through Nextbike Smart Bike Renting System. Once registered with bike sharing system it's possible to rent bikes at different locations. The rent and return of the bikes are possible by phone, online, via smartphone application or at one of rental terminals [36].

The City of Dubrovnik is becoming the smartest city in Croatia in the sector of Smart parking. Although Smart parking already exists few years, Dubrovnik is investing in Smart parking by development of sensor network and technology introducing 1.900 new sensors based on IoT network [37]. The system already provides the similar service as the city of Split, offering the information on parking space availability. Dubrovnik also has the first smart street in Croatia, developed in partnership with the telecommunication operator T-Com. The street has a multifunctional sensor network installed with public lighting, wireless high-speed Internet connection, cameras that monitor traffic violations, smart parking with contactless payments, and environmental conditions control.

5. FUTURE PERSPECTIVE OF SMART MOBILITY IN THE REPUBLIC OF CROATIA

The City of Rijeka, City of Split and City of Dubrovnik are the leading cities in Croatia using different Smart Mobility technologies and generally in Smart City concept. The Park and Ride, smart parking and smart bus stations are the technologies which cities lack the most. Other technologies vary from city to city. The analyzed cities are aware of importance of Smart Mobility technologies to improve the quality of transport service for citizens and to contribute to sustainability goals and thus are implementing strategies, plans as well as concrete projects.

E.g., the City of Zagreb prepared the smart city Strategy up to 2030 ''Zagreb Smart City'' in which one of the strategic goals is Sustainable Urban Mobility, including:

- integrated passenger transport on the basis of a unique modernized integrated transport system with mobile application and a non-contact card (actual mileage / cell payment).
- Passenger information system and travel planning and video surveillance system for public passenger transport.
- Introducing a system of free information on free capacities at parking lots (or free parking spaces), a navigation system for free street and off-street parking spaces, a system for the remote reservation of parking spaces (including electric vehicle charging stations).
- Continuous development of Park and Ride systems (residents who live on the boarders of the city or outside the city can freely park their vehicles on the tram turnaround and continue the route by public transport).
- System and application solution for cyclists (info about cycling trails, bike sharing, route planning and travel time, traffic, shipping, pollution, etc.).

The City of Osijek is currently developing electric carsharing system under the EU project ''I-SharE LIFE''. The aim of the project is to reduce the number of conventional vehicles in use, thus reducing the emission of pollutants. The City of Osijek started pilot activities to implement 8 electric cars with a special focus on the development of electric vehicle distribution models, the integration of IT solutions of shared electric vehicles and public transport operators, and related modelling of future services for different user groups [40].

ThCity of Rijeka adopted the Strategic plan "Rijeka Smart City 2019-2020" where Smart Mobility takes an important part. Some of the current and future project of Smart Mobility in Rijeka are: ECOMOBILITY – ecologic support to sustainable traffic management in coastal areas using intelligent systems (City of Rijeka), Sustainable urban Mobility plan (City of Rijeka), Smart traffic lights (Rijeka promet), Solar tricycle for waste collection (Rijeka promet), Strengthening the public transport system (Autotrolej) [13].

The City of Dubrovnik has adopted the strategy ''Smart City Dubrovnik 2020'' which aims at: Promoting the development and implementation of sustainable and urban transport; introducing e-vehicles and filling stations for the same in the city; encouraging the use of sustainable forms of transport, reducing CO_2 and toxic gas emissions; developing the integrated transport system (Airport and the suburban and interurban bus station with Port of Gruž) [7].

6. CONCLUSION

Nowadays half of Earth population lives in cities, so the cities have the key role in sustainable development in general. The Republic of Croatia as a member state of European Union is trying to transform the traditional cities' management to smart ones respecting the principles of sustainable development. Currently there are 40 Smart Cities in Croatia and some of them have developed solutions in the Smart Mobility domain. Smart Mobility is a key element of Smart City closely related to the Smart Environment and Smart Living. Without the Smart Mobility any city cannot be categorized as Smart. According to the conducted analysis in the cities across Croatia it can be concluded that Smart Mobility solutions are mostly concentrated in the capital city

and capital cities of regions and that the concept of Smart Mobility is still in development phase. The City of Rijeka, City of Split and City of Dubrovnik are the leading cities in Croatia in Smart Mobility. The City of Rijeka is the only city in the Republic of Croatia which developed the Automated Traffic Management System for optimal traffic management while the City of Split and City of Dubrovnik are the only cities where the smart parking based of IoT network is implemented. The capital city, City of Zagreb is the only city with implemented Park and Ride System. This technology all other cities lack the most. The growth of transport solutions including ticket management, guidance systems, parking and traffic management could increase the demand in the smart city market. Changing travel habits, the rise of collaborative mobility, the demand for services to increase convenience, speed and predictability, as well as evolving customer expectations towards customization, will require more intelligent infrastructure able to cope with these demanding mobility requirements.

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