19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Smart Parking Management System: Architecture Design and Technologies Issues

DANIELA KOLTOVSKA NECHOSKA, SONJA CHALAMANI,TOME DIMOVSKI, ILIJA HRISTOSKI

Abstract Smart parking solutions are one of the most popular systems and devices in smart cities due to the availability to detect parking space in real-time, reducing fuel consumption, and traffic emissions. Various types of smart parking systems, such as parking guidance systems, smart payment systems, e-parking, etc., have been deployed worldwide. The experiences of Intelligent transport system application in the Republic of North Macedonia are modest and most of the deployed systems and services are from the area of Real- time Travel Information Service and Urban Traffic Management. The problem issues related to parking demands are present and they have a significant impact on traffic congestion on the city's road network. Specific objectives of the research are to identify and access the most promising, pertinent technology and systems for the design of an integrated, highly functional solution for a smart parking management system for the Macedonian capital city. To meet these objectives, a two-phase research approach has been suggested. In the first phase a comprehensive approach that identifies analysis and selection of smart parking infrastructure and its architecture design are presented. In the second stage development of the new attractive and effective web application (as part of hardware and software components of the proposed system) will be presented. As a crucial component of the overall traffic system, the proposed smart parking management system will play an important tool for municipality authorities in providing effective digital services that will improve traffic customer's needs.

Keywords: • Intelligent Transport Systems (ITS) • Smart Parking • Systems and Services • Architecture Design and Technology

CORRESPONDENCE ADDRESS: Daniela Koltovska Nechoska, PhD, Sonja Chalamani, PhD, St. Kliment Ohridski University – Bitola, Faculty of Technical Sciences, Department of Traffic and Transport Boulevard 1st of May B.B., Bitola 7000, Republic of North Macedonia, e-mail: daniela.koltovska@uklo.edu.mk, e-mail: sonja.chalamani@uklo.edu.mk, Tome Dimovski, PhD, St. Kliment Ohridski University – Bitola, Faculty of Information and Communication Technologies Boulevard 1st of May B.B., Bitola 7000, Republic of North Macedonia, e-mail: tome.dimovski@uklo.edu.mk; Ilija Hristoski, PhD, St. Kliment Ohridski University – Bitola, Faculty of Economics Boulevard 1st of May B.B., Bitola 7000, Republic of North Macedonia e-mail: ilija.hristoski@uklo.edu.mk

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

The concept of a smart city refers to the application of information and communication technology for the more efficient functioning of the city services in the provision of public services, to raise the quality of life of citizens, productivity and efficiency, as well as achieve savings.

A smart city is also defined as a city that meets all the needs of its citizens fully and efficiently following the goals set by local, national, and international sustainability standards. All services and needs, which are included in this concept are traffic management, education, air pollution, internet, and open data, smart health, smart homes and buildings, public safety, smart street lighting, smart parking, smart waste management, smart energy use, etc.

The metropolises, such as London, Paris, Berlin, New York, and others, have been at the top of the list of smart cities due to their innovative solutions and approaches that are integrated into various spheres of everyday life of citizens including the field of stationary traffic.

Why is parking an important segment in the overall concept of a smart city?

In many cities, more and more time is wasted while the vehicles "wander" on the roads looking for a free parking space. The location of the bigger, well- maintained parking lots is not always visibly marked, and then, there is a lack of information regarding their occupancy. Drivers often complain about increased travel time and that when they reach their destination, there is not an available parking space on the parking lot. Therefore, intensive work is being done to improve the process of parking management, which refers to the creation of various policies and programs in creating solutions for more efficient use of parking resources.

Effective programs in parking management in combination with advanced technologies could reduce travel time, as well as the time needed/wasted while looking for a parking space by up to 20-40 % compared to conventional solutions, providing an increase in economic, social, and environmental benefits.

In his comprehensive implementation guide, Littman states that the solutions that are proposed in the process of traffic management tend to be better than the conventional offer expansion (standard increase in the number of parking spaces) because the management supports more strategic goals, such as reduced development costs and increased availability, improved user options and quality of services, etc. [1].

Lan and Shih in their research found that in areas, such as Los Angeles, vehicles looking for a parking space produce more than 730t carbon dioxide (CO_2) and consume about 47 000 liters of gas [2]. The inconvenience created by the need to find a free parking

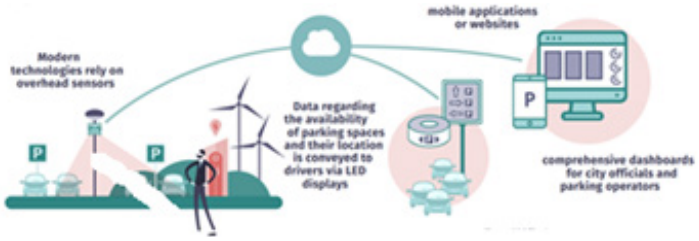
space, not only contributes to increased carbon dioxide emissions, but also causes drivers to park in unmarked parking zones, commit offenses for illegal parking, and most of all, further affect the creation of traffic congestion. Currently, there are numerous parking applications (EasyPark, BestParking, ParkingPanda, Parkopedia, Parclick, ParkMan, Parkomat, PayDo, SplitParking) offering different services.

In addition to the mobile application, as part of the Intelligent Transportation System (ITS) and the Advanced Traveler Information System (ATIS), we can also mention the Parking Guidance and Information (PGI) system. Countries that have implemented the Parking Guidance and Information system in their major cities are Finland, France, Japan, the Netherlands, Germany, Norway, USA, Sweden, UK.

The technology that is behind the smart parking systems can be fully automated, relying on hardware and software. Hardware, such as sensors and traffic signs with variable content, are set up locally – the first to monitor the occupancy of the parking lot and to collect data on the size of the available space and the number of parked vehicles, and the second to transmit parking information and navigation instructions to the free parking spaces.

Smart parking solutions enable city authorities and parking space owners' collection and analysis of input and output data including the availability status, parking duration, as well as parking revenue. In addition to real-time data, historical data and analysis are available to enable optimization of resource and staff planning (Fig. 1).

Figure 1. Parking solutions for Smart Cities



Source: Clever city; The Ultimate Guide to Smart City Parking 2021

Parking operators are expected to significantly increase their investment in the short term through the many benefits offered by smart technologies in this field. Parking operators are already spending more than 3 billion US$ a year on parking management globally, and these investments are projected to grow by 15 % annually by 2025.

Research problem

Skopje is the capital city of North Macedonia with approximately 600 000 inhabitants (one-third of the total population). The City of Skopje has been existing as a center of social life and carrier of the economy within the course of history. Available funding

is very restricted and limited, and the space available has become a major obstacle.

The estimated number of people traveling daily to Skopje exceeds 90 000 passengers, causing significant traffic congestion [2]. The concentration of administrative, cultural, political, economic, and educational services further increases the problem not only with the dynamic but also the stationary traffic [2].

The imbalance between the need for parking and the capacity, the pressure on the traffic network from the local traffic due to circling around parking lots, are just a few of the identified problems. Therefore, the research will especially emphasize the need for a comprehensive analysis of parking in the city, to create solutions for the introduction of modern ways of parking management following the example of the European and the world's cities.

The main goal of the analyses and studies that have been done so far is the financial analysis of the toll system, and the intelligent and modern solutions to the parking problem are rarely mentioned by anyone.

In recent years, to assist the movement of people and goods, there has been a general call that "something has to be done".

Therefore, the idea of this research is to improve the management of stationary traffic and parking services by creating modern and "smart" solutions.

METHODOLOGY APPROACH

The city of Skopje is to be understood to work as an organic whole. Thus, we come to the term of sustainability. The management process rooted in sustainability should represent the interests of future generations.

The strategic objective is to develop a transportation system that maintains or improves human and ecosystem well-being together - not at the expense of the other.

Data analysis

According to the analysis of the current GUP (General Urban Plan) for Skopje, in the city center alone there is a need for 15 000 parking lots, but currently there are only 5 000. The prognosis given in the existing GUP is that in the center of the city, by 2020 the need for parking lots will be between 18 000 and 31 000. The existing GUP for Skopje does not provide an overview of the impact of parking on achieving the defined goals of traffic policy and its importance in choosing a means of transport in realizing daily mobility. The IDOM survey shows that the total number of declared parking lots in the City of Skopje (including parking garages and outdoor parking) is 165 914 lots, 103 371 of, which are private garages (Table 1) [3].

Table 1. Number of parking lots

	Classification/parking lots				
Municipalities	**On street/ sidewalks**	**Parking zones**	**Private parking garage**	**Rented parking garages**	**Total**
Center	3846	5934	6152	123	16 054
Kisela Voda	2795	4094	15336	86	22 310
Aerodrom	1177	15049	11727	73	28 026
Butel	986	1293	9950	0	12 230
Gjorche Petrov	1129	1760	14427	0	17 316
Karposh	6345	4216	14717	42	25 320
Chair	4635	3031	4824	45	12 535
Saraj	156	50	6903	50	7159
Gazi Baba	2119	3251	18395	0	23765
Shuto Orizari	182	77	939	0	1 198
Total	23370	38 755	103371	419	**165914**

Source: IDOM, 2009.

This shows that approximately 63 % of the parking lots are privately owned garages, 23 % are in the parking zones and 14 % are on the streets and the sidewalks.

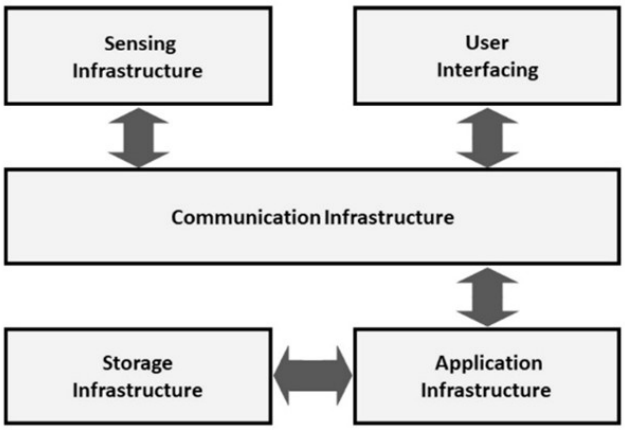
According to the analysis of the current GUP for Skopje, there is a need for 15 000 parking lots in the city center alone, and 5 000 of them have been registered. The forecasts given in the existing GUP are that by 2020 the demand for the Center will be from 18 000 to 31 000 parking lots.

The city authorities need to start solving the parking problems in a systematic approach. The parking policy has to meet the vision and add a vision that underscores prospective scientific, technological, and societal trends. Decisions on the development of the parking systems and activities involve a number of different actors (universities, governments, transport planners, businesses, citizens) and are influenced by factors related to environmental concerns, prices and quality of services, the availability of modal choices, travel time and the organization of economic and social life.

A model of a parking system

The model of the parking management system we propose is based on the implementation of five subsystems schematically depicted in Figure 2.

Figure 2. Parking solutions for Smart Cities



- Sensing Infrastructure

Sensing nodes are hardware sensors that collect parking location status data and send the acquired data to the application infrastructure using the communication infrastructure. Hardware sensors are installed on each parking location to detect the presence of a vehicle and to send the current status to the application infrastructure.

- Communication Infrastructure

The communication infrastructure is used to connect different constituent subsystems of the parking management system and to allow their mutual communication. The communication infrastructure can be built on different communication technologies, such as Wi-Fi, Bluetooth, infrared, NFC, etc.

- Application Infrastructure

The application infrastructure consists of software modules, a WebAPI (Application Programming Interface), and a Web-based application, used to monitor the status of parking locations, to display and share their status, as well as to access and store data to the storage infrastructure. Besides, it can be used for communication and data sharing with the user interface, Web-based or mobile applications, and also to fulfill other requirements of the parking management system, e.g., parking location reservations, payments, etc.

- Storage Infrastructure

The application infrastructure stores the data received from the sensing infrastructure to the storage infrastructure, which consists of an SQL database server and a file server that are both used for storing, processing, and analyzing data.

- User Interfacing

The user interface, as a part of the parking management system, consists of a user Web application, as well as a user mobile application, both using sensed information to provide parking information to drivers. It also offers an interface for making parking location reservations and payments. Both the user Web application and the user mobile application obtain the needed information from the application infrastructure.

CONCLUSIONS

If we point out that we live in the XXI century where the Internet, the comprehensive wireless coverage, smartphones, sensors, detectors, the continuous development in the information and communication technology is something normal and expected, then, the development and the application of the concept of "smart cities "is quite necessary.

Despite sufficient funding available, it is very likely that the problems still exist because the classical approach of building more roads and parkings makes it difficult for political, financial, social, and environmental reasons. Therefore, the challenge is to identify or develop ways and means to alleviate traffic-related problems without building new roads and parking lots. The two principal ways are through the application of innovative traffic management measures and the development of new smart parking technologies.

In this paper, a comprehensive approach that identifies analysis and selection of smart parking infrastructure and its architecture design are presented.

This paper proposes a new model of parking management system to satisfy the needs of the Macedonian capital city.

To implement the intelligent solution pattern, the local government is going to be a valuable partner in this research, since the local transport policy decision-makers should back up and direct smart solutions when sustainable urban development is their ultimate goal. Therefore, it is expected that the outcomes of the research will have a positive impact on the urban transport policy decision-makers who will put valuable input into the course of advanced traffic parking management system policy.

ACKNOWLEDGEMENT

The authors would like to express gratitude to Aleksandra Angelkovska Ognenovska for her collaboration during her master thesis and for this research.

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