PROCEEDINGS OF ELMAR-2020

62nd International Symposium ELMAR-2020

14-15 September 2020, Zadar, Croatia

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Published by: Faculty of Electrical Engineering and Computing, University of Zagreb

Edited by: Mario Muštra, Josip Vuković, Branka Zovko-Cihlar

Front Cover: Painting by artist Mrs Ljerka Njerš

Printed by: Ispis Ltd., Zagreb

Print ISBN: 978-1-7281-5972-0, CFP20825-PRT

XPLORE ISBN: 978-1-7281-5973-7, CFP20825-ART

Printed in Croatia.

62nd International Symposium ELMAR-2020 is organised by:

Croatian Society Electronics in Marine - ELMAR, Zadar

University of Zagreb Faculty of Electrical Engineering and Computing, Department of Wireless Communications

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Welcome speech of the President of Croatian Society Electronics in Marine - ELMAR, Zadar

It is my great pleasure to welcome you to the 62nd International Symposium ELMAR-2020 and wish you a successful work and communication during your stay in Zadar!

Even though we completed only a bit less than one half of the 2020, it can be said that it was one of the strangest in the recent history. Covid-19 disease presented a problem for almost all businesses and activities our civilization relies on. It is not different with the ELMAR, but we are very proud that 62nd ELMAR takes place even in these circumstances.

ELMAR-2020 is organized under the technical co-sponsorship of IEEE Region 8, IEEE Croatia Section, Croatian Academy of Sciences and Arts, Croatian Academy of Engineering, University of Zagreb Faculty of Electrical Engineering and Computing Department of Wireless Communications, University of Zagreb, Faculty of Transport and Traffic Sciences, and University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology.

This year the International Review Committee selected 32 papers written by authors from 9 countries. It is our great pleasure to thank all the authors on their submitted papers and the effort they made while preparing their contributions. We are sincerely grateful to reviewers for their kind help and vast contribution in selection of the papers which showed significant scientific contribution and because of it are accepted for presentation at ELMAR-2020 and publication in IEEE Xplore.

Due to these, a bit different conditions, the program of this year's ELMAR Symposium is divided into 7 regular sessions and one special session. The International Program Committee of ELMAR traditionally invites outstanding experts from fields related to the ELMAR international symposium to present a state-of-the-art in their research fields. As keynote speakers Prof. Dubravko Babić from the Faculty of Electrical Engineering and Computing will give a talk about FERSAT: Characterizing Light Pollution Using a Cubesat; Prof. Edouard Ivanjko from the Faculty of Transport and Traffic Sciences will give a talk about Development of Adaptive Traffic Signal Control Systems for Urban Environments.

I am specially obliged to thank Ministry of the Sea, Transport and Infrastructure of the Republic of Croatia, Ministry of Science and Education of the Republic of Croatia, Croatian Regulatory Authority for Network Industries, Town of Zadar, and County of Zadar, without whom would be impossible to organize this scientific event.

At last, I would like to thank all the members of the Organizing Committee for their efforts in preparing this symposium in these, different than regular, conditions.

Branka Zovko Cihlar

Professor *Branka Zovko-Cihlar*
President of the Croatian Society
Electronics in Marine - ELMAR, Zadar

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Creating A Data-Set For Sustainable Urban Mobility Analysis: Lessons Learned

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***Abstract*—Traffic congestion and resulting pollution affect the quality of life in urban areas. To analyze the correlation between traffic and air pollution, appropriate data-sets containing both traffic and pollution data are needed. Especially since pollution in urban areas has many different sources. This article tackles the problem of creating such a data-set for sustainable urban mobility analysis from the aspect of transport and pollution. Real traffic and pollution data from three intersections in the City of Skopje were collected and statistically analyzed. Obtained first results present a solid foundation for future analysis using an enlarged data-set.**

***Keywords*—Intelligent Transportation Systems; Sustainable Urban Mobility; Air-Quality; Data Science**

I. Introduction

The vitality and the prosperity of a city, to a great extent, depend on the quality of the mobility of people and goods. Sustainable transport contributes to the development of cities, their sustainability, and it can help in creating better living conditions. However, the cities nowadays are more frequently facing serious traffic-related problems, often leading to degradation of the environment. Hence the question: How to model and analyze the transport system from aspects of traffic and air-quality parameters to contribute to sustainable urban development and mobility?

This question is crucial today since, with the increase of urban mobility, different forms of traffic congestion (reoccurring and non-reoccurring) appear, while the air pollution resulting from the traffic increases as well. This trend continues to grow with ever more people living in urban areas. To solve these problems, significant efforts are made to improve urban traffic management with an emphasis on the reduction of congestion and pollution using various services from the domain of Intelligent Transportation Systems (ITS) [1]. In order to develop such traffic management systems, it is crucial to test them using appropriate scenarios connecting traffic and pollution parameters. Such tests are performed using simulations based on appropriate data-sets integrating data from several domains. In this particular study, we will observe data from traffic sensors as well as the data from air-quality sensors. This is especially interesting today as the need for sustainable mobility has risen. Sustainable mobility takes into account economic, ecological, and social factors with the goal to maximize passenger throughput, and not just traffic throughput. The result is a mobility-friendly environment for the modern urban area [2].

The creation of different data-sets for the analysis of mobility patterns in urban areas is a very active topic in recent research regarding ITS. They can be used for transport planning, modeling of travel behavior, creation of new road infrastructure, and for studying the connection between traffic congestion and pollution. In literature dealing with mobility services from ITS, the available data-sets are mostly related to urban mobility. For example, in [3] an open data-set for analysis of typical people, mass movements in urban areas were created and evaluated using commercially available traffic data-sets, and survey results. This approach enables the creation of a continuous spatiotemporal movement of persons in urban areas being open to public use. It tackles the privacy issue regarding open data-set, and in this data-set movement of traffic entities cannot be related to the movement of real persons (anonymized data). Another approach to deal with the privacy issue problem is the creation of synthetic data-sets as, for example, the one created in [4] for analysis of the vehicular movement of a large urban area related to the city of Köln, Germany. This synthetic data-set can also be applied for the evaluation of vehicular communication networks, including the spreading performance of the dissemination of important information. The importance of the open data principle is emphasized in [5] were publicly accessible data were used to create origin-destination matrices for the city of Bologna, Italy. Work- and home-ending trips were used for validation reaching a correlation coefficient mostly larger than 0.7 ensuring a good foundation for mobility analysis and transport planning. Large urban areas are also in the focus of the work presented in [6]. Gathered data enabled the creation of a SUMO based open-source simulation model of the municipality of the city of Turin, Italy. The emphasis of the model is on single peak-hour and full-day traffic, with the second giving some less accurate results.

The main anthropogenic sources of air pollutants analyzed in urban areas are mobile and stationary combustion sources [7]. The results presented in [8] show that transportation contributed more than half of the carbon monoxide and nitrogen oxides in the atmosphere during 2013, which makes vehicle emissions significant air pollutants. The gas

978-1-7281-5973-7/20/$31.00

ozone (O_3) cannot be found in vehicle emissions directly, but it can be produced in photochemical catalytic cycles, which involves its persecutor gases (NO_x, CO, and hydrocarbons). The amount of O_3 increases typically from 5 to 15 percent at mid-latitudes in the Northern hemisphere during the summer due to extensive seasonal sunlight and its mentioned persecutor gases that can be found in the vehicle emissions [9]. One of these persecutors is CO known as the common product of all engines with internal combustion. It is noticeably increased in the aging or not properly set engines due to incomplete combustion. The increased NO_2 emissions are characteristic for the diesel engines, and they are also a persecutor of O_3. Furthermore, those emissions can induce smog and acid rains in urban regions [10]. Vehicles mainly emit $PM2.5$ air-born particles directly from the exhaust pipe, while road abrasion mainly increases larger wear particles such as the measured $PM10$ [11]. All mentioned air pollutants can affect the respiratory system, induce hematological problems (especially CO), and cancer. Increased values of the mentioned pollutants are most noticeable in overpopulated-regions with the poorly developed public transport system and increased percentage of older and diesel vehicles. Thus, it is necessary to determine the correlation between the described air pollutants, which can be found in vehicle emissions, and measured traffic load on intersections [12]. The mentioned correlation will show the impact of vehicle emissions at intersections on the surrounding air quality. Intersections, as the nodes of the traffic network, are the places where the vehicles spent a lot of time queuing with running engines, so they are particularly interesting regarding air pollution.

The paper is organized as follows. Following the introduction section, the methodology applied for the analysis of the collected traffic and air-pollution data is described. The third section presents the use case and obtained results with discussion. Conclusion and future work are given in the end.

II. Use case and applied methodology

The drawback of the aforementioned data-sets and simulation models is that they do not contain any connections to pollution correlated with traffic. This is a complex topic because different pollution sources contribute to the resulting situation, as stated in [13]. With optimizing different supply options, traffic-related pollution can be reduced [14]. Therefore, the correlation between the traffic and pollution components (such as the gases CO and NO_2, or particulate matter $PM10$) has to be known. The aim of this paper is to tackle this drawback by creating a data-set for urban traffic analysis containing not only travel patterns but also pollution components. In order to create such a data-set, the data from the city of Skopje, North Macedonia were collected for three intersections near air-quality monitoring stations during a two-year period. Gathered data were filtered and statistically analyzed to obtain insight into traffic and pollution-related situation. For traffic-related analysis, the congestion levels, amount of vehicles served on intersections and influence of rush hour traffic on daily traffic were observed, and for pollution-related analysis, the amount of emissions (CO and NO_2, and $PM10$) and the correlation between traffic and emissions related to a particular intersection were considered. Thus, this research provides a solid foundation for examining the traffic and pollution correlation in urban environments, which, due to the lack of appropriate data, was not examined earlier. Moreover, we hope to provide valuable insights on this topic based on the preliminary snippets of data. Thus, reveling lessons learned to process the first amount of available data.

Therefore, in this section, the use case (urban area) for the sustainable urban mobility analysis data-set is presented using data gathered from three signalized intersections and one air quality measurement station located in the city of Skopje, North Macedonia. Following the description of the urban area and gathered data, a detailed description of the methodology used for the creation and analysis of the newly established sustainable urban mobility data-set is given.

A. Analyzed urban area

An analysis of the City of Skopje road network and pollution was done in the author's previous work [15], and in continuation, a brief review is given. Like other urban environments, the City of Skopje is prone to frequent fluctuations in air quality. Skopje is not only the capital but also the country's largest city. Approximately one-third of the North Macedonia's total population are living in Skopje. Daily over $90,000$ people are traveling to Skopje, causing significant traffic demand. Skopje's existing traffic network can be described as a favorable combination of ring roads, including radial and orthogonal infrastructural sub-segments around the city core. The problematic lack of some infrastructural backbone traffic corridors causes unwanted interference, including both transit and non-transit traffic. Combined with the usual inconvenient concentration of administrative and other service activities in the city's center, Skopje is prone to the usual traffic congestion problems of fast-growing and dynamic cities: saturations, bottlenecks, queues, longer travel times, and increased energy consumption and air pollution [16].

The study [17] published at the beginning of 2017 lists Skopje among the 10 most polluted cities in Europe. The pollution often becomes critical during the winter period, because the concentration of $PM10$ particles in the air reaches levels up to 20 times higher than the maximum ones measured in the past. Many sources and causes for the severe air quality problem have already been identified, among which emissions from road transport have a considerable contribution. Road transport emissions depend on multiple factors, including the vehicle category (passenger cars, delivery vehicles for light and heavy goods), vehicle technology (Euro norm of the used engine) quality of the used fuels, etc.

According to the Macedonian Ministry of Interior, in 2014 there were $161,474$ registered vehicles in Skopje [18]. The majority of them (over 40%) are categorized as conventional, with old Euro 1, or Euro 2 norm engines. Such engines have the greatest negative impact on air quality. Also, 31% of delivery vehicles for heavy goods are very old, being categorized as conventional or Euro 1 norm engine vehicles. In terms of $PM10$, the oldest classes of vehicles (conventional, Euro 1, and Euro 2) contribute almost 70% in the total emissions from passenger cars. Regarding CO and NO_X gas pollutants, the class of conventional vehicles is responsible for most of the emissions. In addition, data about the fuel type of vehicles in Skopje were obtained from [19], which shows that 53.18% of vehicles use gasoline fuel, 45.46% use diesel fuel and 0.36% use other types of fuel. Additionally, most of the passenger vehicles in Skopje (65%) use petrol, and about 30% of them use diesel as fuel.

B. Available data

Measurement of traffic flows was done on three signalized intersections in the city of Skopje, North Macedonia. Data were collected using induction loops in 1 hour intervals on all intersection approaches, measuring both the incoming and outgoing traffic flow volume of the intersection. Traffic data were recorded for one week in each month of 2018 and 2019, so the total number of measurements per intersection approach was 8,064, totaling 96,768 measurements for the entire use case. Each measurement consists of the total number of vehicles during 1 hour intervals. From the available data, it was observed that the sum of intersection inputs and outputs deviate slightly, on average 10.67% in favor of intersection outputs. Therefore, in order to calculate the correlation between air pollution and traffic flows, the intersection output records were used since output data are estimated to be more precise due to the larger gap between vehicles. Intersection's and air measurement station micro-locations are depicted in Fig. 1. Intersection I_1 is located 30 m west to the air measurement station, intersection I_2 is located 2.2 km south-east of the air measurement station and intersection I_3 is located 3.4 km south-east from the air measurement station.

Measurements related to air quality were made by using the static air quality station located at the *Rektorat* district in the city of Skopje. Three air pollution parameters are measured: carbon monoxide CO, nitrogen dioxide NO_2, and atmospheric aerosol particles $PM10$. Additionally, the same measuring station has the ability to measure surface O_3 concentration. All listed air quality data were gathered during the 2019 in 1 hour-long intervals. The access to those data is available through the web interface [21] brought by the Ministry of Environment and Physical Planning, Republic of North Macedonia.

C. Applied methodology

The methodology applied consists of four steps (Fig. 2). The first step was filtering the data by detecting and removing outliers, which was done on both traffic and air quality data. Regarding the filtering of traffic data, the first filtering was done manually by eliminating known false data caused by errors in the traffic sensors. After initial filtering, remaining outliers were eliminated if they were farther than three standard deviations from the mean. Outliers in the air quality data were removed using the same methodology.

Figure 1. Intersections (red) I_1, I_2, and I_3, and air-pollution measuring station (blue) AS [20]

To get more information about the traffic behavior, we performed an in-depth analysis regarding traffic flow analysis based on recommendations from [22]. We defined periods of occurrence of peak traffic flow (PHT), Peak Hour Volume (PHV), the coefficient of the variability of the peak hour in relation to the daily average volume (PHHTV), and Annual Average Daily Traffic (AADT) aggregated regarding weekdays, Saturdays, and Sundays, the standard deviation for measured traffic volume during the peak hours (σ_{PHV}), and relative standard deviation of the peak hour ($\sigma_{PHV\%}$).

For graphical presentation of the gathered, filtered traffic and air-quality data, error bar plots were applied to gather also an insight into the variability of data during working and weekend days. To analyze the relation between traffic flow and pollution during 24 hours, both data were used to create a flow-pollutant graph. In it, the change rate of a particular pollutant related to traffic flow can be visualized.

III. Result analysis and discussion

In this section, the results of traffic behavior analyzed, and its correlation with air pollutants are presented and discussed.

A. Obtained results

From the analysis of the traffic data-set, three clusters were formed that correspond to "Work days", "Saturdays" and "Sundays" as shown in Fig. 3. The same was done on corresponding air quality measurements, and these two data-sets are split into three clusters to form the sustainable urban mobility analysis data-set. For each cluster, a mean average model was created to serve as a basis for graphical presentation

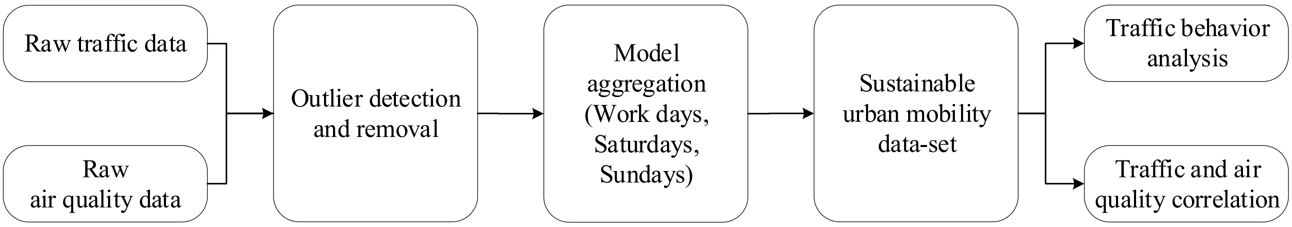

Figure 2. Data processing steps

TABLE I. Summary of traffic behavior on chosen intersections

Parameter	I_1			I_2			I_3		
	Work day	Saturday	Sunday	Work day	Saturday	Sunday	Work day	Saturday	Sunday
PHT [hh - hh]	08 - 09	13 - 14	14 - 15	16 - 17	14 - 15	19 - 20	16 - 17	12 - 13	19 - 20
PHV [veh/h]	$4,939$	$3,824$	$2,888$	$4,472$	$3,512$	$2,502$	$3,488$	$2,777$	$1,975$
PHHTV	1.66	1.63	1.55	1.91	1.73	1.67	1.81	1.72	1.61
AADT	$71,522$	$56,263$	$44,688$	$56,275$	$48,853$	$35,899$	$46,245$	$38,719$	$29,438$
σ_{PHV}	$1,275$	$1,045$	$1,073$	449	315	584	654	634	473
$\sigma_{PHV\%}$ [%]	25.82	27.34	37.14	10.04	8.94	23.33	18.76	22.82	23.96

TABLE II. Pearson correlation coefficients for all intersections

Pollutant	I_1			I_2			I_3		
	Work day	Saturday	Sunday	Work day	Saturday	Sunday	Work day	Saturday	Sunday
$CO\ [mg/m^3]$	0.49	0.78	0.81	0.53	0.76	0.81	0.52	0.79	0.79
$NO_2\ [\mu g/m^3]$	-0.09	-0.24	-0.33	-0.16	-0.39	-0.39	0.04	-0.21	-0.30
$O_3\ [\mu g/m^3]$	0.52	0.60	0.38	0.46	0.44	0.36	0.63	0.62	0.40
$PM10\ [\mu g/m^3]$	-0.31	-0.24	-0.27	-0.30	-0.42	-0.35	-0.10	-0.22	-0.24

and correlation analysis to compensate for many missing values and noise in the gathered raw data. The summary of recorded traffic data is shown in Table I.

Figs. 3 and 4 present the characteristic change of traffic flow and CO concentration during working and weekend days. Depicted standard deviation from the mean value denotes the variability contained in the gathered data. It is most evident during the day where the daily activity of people significantly affects traffic and air-quality.

The correlation analysis was performed between traffic flow and pollutants. The calculated Pearson correlation index for each case can be seen in Table II. A strong correlation is observed for CO with all three intersections during Saturday and Sunday, with moderate correlation on work days. Fig. 5 shows the relation plot for the case with the strongest correlation between CO concentration and traffic flow on intersection I_1. The arrows in Fig. 5 denote the progress of time during corresponding days. From this analysis, it can be observed that the correlation between CO and the traffic flow varies during the day. Moderate correlation is observed for O_3 concentration. The results show that there is no evident correlation between NO_2 and $PM10$ concentration with the traffic flow.

B. Discussion

Analysis of traffic behavior at the chosen intersection shows that the traffic follows a typical daily routine with morning and afternoon peak hours during work days. Saturday peaks tend to occur midday and in the late afternoon or evening on Sundays as travelers return home. Large σ_{PHV} indicates that the mean model might not properly represent the traffic flow. The probable cause of this are the seasonal changes in the traffic flow. To alleviate this problem, traffic flow data should be split into several segments corresponding to seasonal variations in the traffic flow.

The results show a moderate to the high correlation of traffic flow and CO concentration, with the highest concentration of CO present in the afternoon peak hour. The reason for that may be the higher number of vehicles within traffic, which uses petrol engines and old diesel engines (Euro 1 or Euro 2). It is also observed that for work days there is a rapid increase in traffic flow in the morning with no imminent increase in CO concentration. However, immediately after the morning peak hour, there is a sudden increase in CO concentration, which could still be explained as the delayed effect of the morning rush hour. Thus, cross-correlation should be explored in the continuation of this research. Also, shorter time windows for traffic flow and air-quality correlation could show increased correlation coefficient value in characteristic daily periods such as during the morning and afternoon rush hours.

In [23], the relation between speed and exhaust emissions is explained. As the speed gets higher, the more CO is being polluted in the case of petrol engines. This could be the reason for the higher pollution of CO during the Sunday (Fig. 5) since traffic volume is lower compared to other cases, and higher average speed can be achieved across the examined intersection. Additionally, on Sunday, there is only a minimum number of delivery vehicles using diesel engines. Due to that fact, further correlation analysis is needed regarding traffic speeds and emissions. The correlation of traffic flow and O_3 is also moderate, even while O_3 is not directly emitted by vehicles. Lack of correlation of traffic flow with NO_2 and

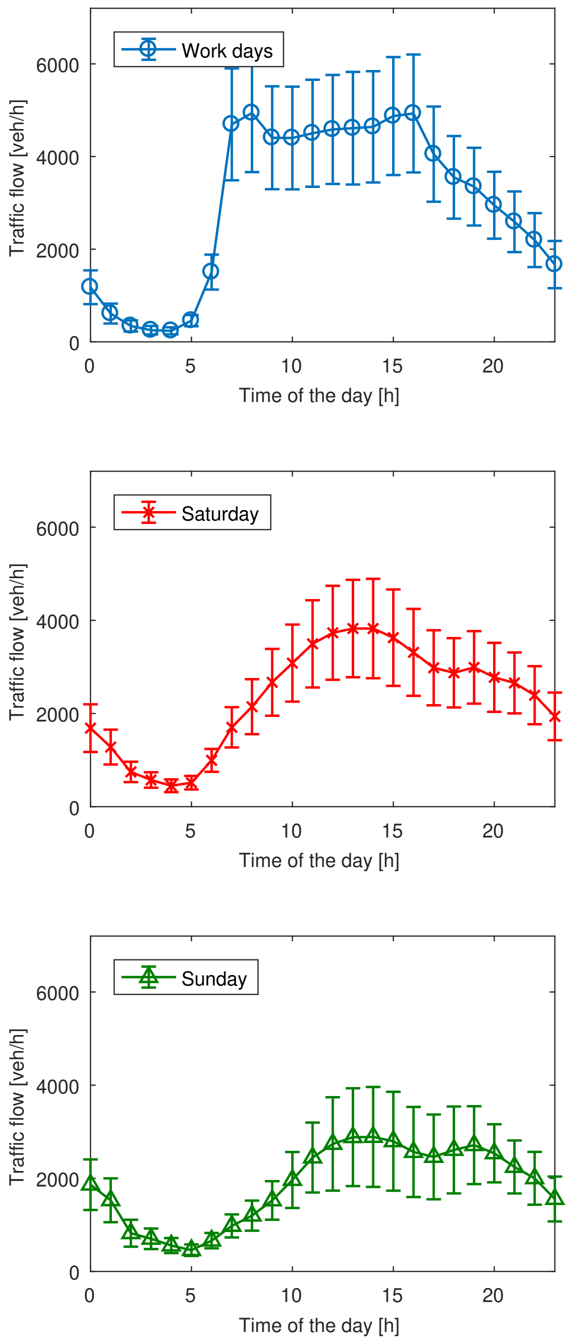

Figure 3. Characteristic behavior of traffic flow with error bars showing the standard deviation of the hourly data for work and weekend days

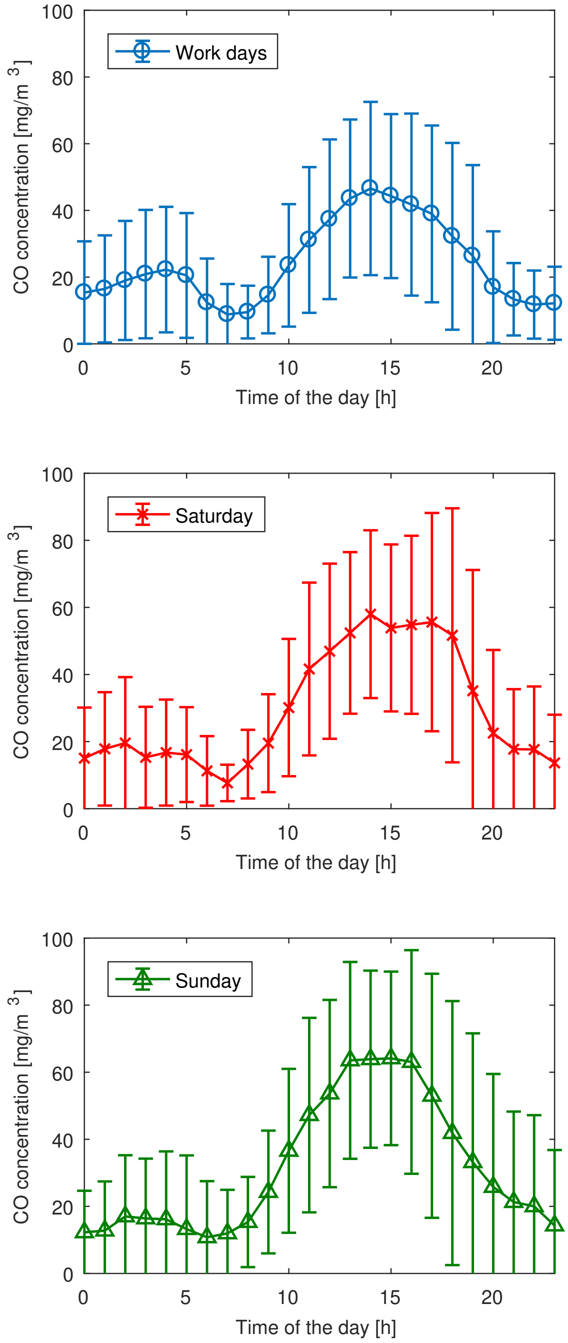

Figure 4. Characteristic behavior of CO concentration with error bars showing the standard deviation of the hourly data for work and weekend days

$PM10$ suggests that in Skopje, several other large polluters are responsible for generating these pollutants. The second reason may be the average age of the vehicles (19.2 years), where older diesel engines produce low emissions of NO_2.

IV. Conclusion and Future Work

A data-set for the analysis of sustainable urban mobility was created using combined traffic flow and air quality data. This data-set was used to perform traffic behavior analysis and correlation analysis between traffic flow and air pollutant concentration. Traffic flow data show a significant difference between intersection in- and out-flow what requires further in-depth analysis. The analysis of the relationship between the hourly concentration of air pollutants and traffic flow shows a moderate correlation to CO and O_3, and negligible to a low negative correlation between traffic flow to NO_2 and $PM10$. The presented methodology can be an effective tool for adding air-quality measures into traffic management decision support systems needed to deliver sustainable mobility in urban areas.

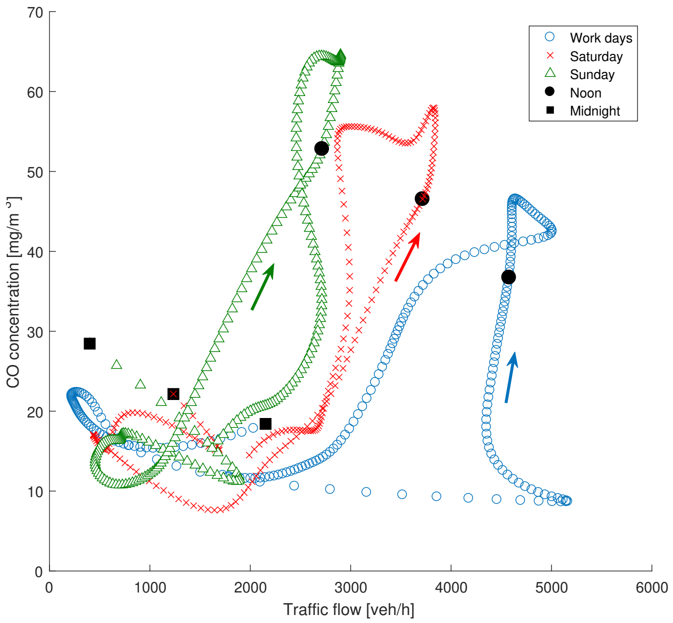

Figure 5. Relation between CO concentration and traffic flow for intersection I_1 during 24 hour period

Further work on this problem and created data-set should include its augmentation with data for additional time periods, the analysis of seasonal changes during the year, adding additional traffic flow performance indicators such as speed and occupancy and weather data. Especially since incorporating the influence of forecasting pollution and traffic flow behavior into urban traffic management is an important topic for ensuring sustainable mobility.

Acknowledgment

The authors would like to express their appreciation to the Traffic Management and Control Center of the city of Skopje & Roads and Street Public Company - Skopje, for supporting this research by providing relevant traffic data. This work has been partly supported by the University of Zagreb and Faculty of Transport and Traffic Sciences under the grant "Innovative models and control strategies for intelligent mobility", it was also supported in part by the Croatian Science Foundation under the project UIP-2019-04-1737, and by the European Regional Development Fund under the grant KK.01.1.1.01.0009 (DATACROSS). This research has also been carried out within the activities of the Centre of Research Excellence for Data Science and Cooperative Systems supported by the Ministry of Science and Education of the Republic of Croatia. The author Daniela Koltovska Nečoska received COST and CEEPUS, and author Edouard Ivanjko received ERASMUS+ mobility grants that enabled the research presented in this paper.

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