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Critical impact factors of pedestrians traffic combining multiple data sources in Athens

Loukas Strongylis[a], Virginia Petraki[a*], George Yannis[a]

[a] *Department of Transportation Planning and Engineering – National Technical University of Athens (NTUA), Athens, Greece.*

Abstract

The aim of the paper is the investigation of the critical factors affecting pedestrian traffic in Athens Downtown, during the pilot implementation of the Athens Great Walk. Two field surveys were carried out, one on pedestrians travel information through questionnaire, and a second one on pedestrian volume through observations. As for the second one, the modal split was also collected. The database was completed with the land use and road geometric characteristics while Covid-19 pandemic data in Greece was also considered. For the analysis, 3 Poisson regression models were developed to define the correlation between pedestrian traffic and the factors affecting it. Results indicate that the factors affecting pedestrian traffic vary. Areas with stores, increased active modes traffic, reduced heavy vehicles traffic are critical factors that affect positively pedestrian traffic in Athens.

Keywords: pedestrian traffic; sustainable mobility; urban center; land use; traffic volume; poisson regression

1. Introduction

Cities face the challenge to enhance the quality of urban environment reducing traffic congestion, pollution and road accidents. Sustainable urbanization is widely acknowledged as a key global challenge for the 21st century, particularly in developing countries. A way to achieve this sustainability is to promote in urban centres the active travel modes like walking and cycling, upgrading the relevant infrastructure such as sidewalks, cycle paths, parking and crossing facilities, reducing speed limits etc.

A typical example of an urban city, where mobility interventions are required, is the Greek capital, Athens. The need for redesign of the urban space is demonstrated by the traffic and parking saturation within the city center. Urban planning of Athens combined with the increase of moving and parked vehicles aggravate the problem of space narrowness (Bakogiannis, E., et al., 2018). The perennial Greek economic crisis has so far prevented the implementation of policies to promote the sustainable urban mobility. Regarding the center of Athens, due to the high

* *E-mail address:* vpetraki@mail.ntua.gr

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variety of activities and land uses, the increasing traffic problems and the existing environmental burden, the pedestrian traffic need to be promoted in a multimodal transport context that involves additional active travel modes and upgrading of Public Transport.

Today, a Sustainable Urban Mobility Plan (SUMP) is being prepared with the aim of improving the daily lives of citizens, through the promotion of measures that facilitate daily movement, allow access to all parts of the city by citizens and tourists and provide vitality and security to the urban environment (Municipality of Athens). However, the health crisis caused by the COVID-19 pandemic, put the spotlight on the need for immediate interventions in the public space of Athens, in order social distance to be enabled, crowding in the Public Transport to be prevented, and alternative modes of transportation to be promoted.

Since Autumn of 2019, a series of novel traffic and parking interventions for the center of Athens were examined which are part of the new mobility policy of the City of Athens and are harmonized both with the Athens SUMP and the related trends in European cities. The new mobility interventions formed a major urban regeneration plan called the Athens Great Walk. The objective of the new mobility interventions is to create a new quality in urban mobility, promote Public Transport and active travel modes, to achieve safe, green and efficient transport for all. In June 2020, a pilot implementation of a subset of the new mobility interventions was decided, following the example of several cities worldwide on the occasion of the pandemic (Yannis, G., 2021).

The subset of interventions implemented were increase of sidewalks in streets with high pedestrian traffic, exclusive lanes for pedestrians and cyclists, exclusive bus lanes and motorcycle, taxi and disabled parking management (Yannis, G., 2021). The main interventions were the following: Increase of sidewalks in central axes (Panepistimiou St., Filellinon St., Ermou St.), streets free of passenger cars and motorcycles (Olgas Av, Herodou Attikou St.). In the first time period of pilot operation (from 06/14/2020 to 07/31/2020) of AGW, an increase of the sidewalk (9 meters additional sidewalk) and decrease of traffic lanes to three was implemented on Panepistimiou St. In the second period (from 03/08/2020 until today) an additional traffic lane was given to the motorized traffic and therefore the road operated with four traffic lanes (Yannis, G., 2021).

The aim of this paper is the investigation of the critical factors affecting pedestrian traffic in Athens Downtown, during the pilot implementation of the Athens Great Walk (June - October 2020) combining multiple data sources. Athens Great Walk is an urban regeneration plan aiming to create a new quality in urban mobility, promote Public Transport and active travel modes, in order to achieve safe, green and efficient transport for residents and visitors. In June 2020, a pilot implementation of a subset of the new mobility interventions was decided, including the increase of sidewalks in streets with high pedestrian traffic, exclusive lanes for pedestrians and cyclists, exclusive bus lanes, motorcycle, taxi and disabled parking management.

2. Literature Review

A review of the international literature reveals that a plethora of factors affect pedestrian traffic and a variety of sustainable mobility policies are being implemented to promote pedestrians' mobility. Factors such as distance, crowded walkways, accident risk, the lack of public buses and the fact that walking is convenient, fast and is a form of exercise were rated important for one's decision to walk. Moreover, infrastructure elements like stairs, detour, number of crossings and directional signs are all influences upon the decision (Koh, P., P., et al, 2012). In the same vein, another study shows that most of the built-environment variables, such as density, land use, buildings, accessibility, and street design measures, have statistically significant associations with pedestrian volume mainly in residential, but also in commercial or industrial zones. It was, also, found that the most consistent and significant variables regardless of the land-use zone were employment density, accessibility measures and street design measures (Lee, S., et al, 2020). Furthermore, it has been proven that negative traffic perceptions are associated with decreases in walking and bicycling. Interventions, such as traffic calming, constructing trails, closing or restricting use of roads, road user charging, constructing bicycle infrastructure and implementing safe routes to school programs, reduce the danger of traffic to people walking and bicycling and consequently encourage that ways of moving (Jacobsen, P., et al, 2009)

As a consequence of the above, policies are implemented in order to promote pedestrian mobility, in terms of sustainable urban mobility. In London, pedestrian mobility is promoted, as «Legible London», a wayfinding system,

helps pedestrians to navigate within the urban space (Mitchell, D., et al, 2016). In addition, since 2012, in the city of Strasbourg an integrated, multimodal design approach has been developed, where all modes of transport - pedestrians, cyclists, motor vehicles and public transport - are considered at the same level of detail, in order the pedestrian traffic to be improved. Now, in the center of Strasbourg, it is possible for citizens to move safely and quickly, since with the redistribution of public space, pedestrian traffic is not involved in the vehicle traffic and the pedestrian waiting time at intersections was significantly reduced, as the simulation results showed (Compagnie Des Transports Strasbourgeois).

3. Data Collection and Methodology

3.1. Study Area

Athens is the capital and largest city of Greece with a population of 664,046 inhabitants in the central Municipality (Authority-ELSTAT, 2011), and a land area of 38.96 km^2. In Athens dominates an intense mixing of land uses and functions, since trade, handicrafts, offices, universities, leisure areas and sites of archaeological - monumental interest coexist (Aravantinos, A., I., 2007). Residencies correspond to a 35% of the metropolitan area's total land uses, while 7% of that land deals with industrial activities, 6% with administration, 5 % with leisure and 26% with commerce and other activities (Ministry of Environment, Energy and Climate Change, 2014). The existence of a multitude of activities in the same area, therefore, leads to an increase of traffic.

3.2. The Surveys

In the context of the present study, data were obtained from two field surveys which were carried out by NTUA researchers, after the during the pilot implementation of the new mobility interventions of Athens Great Walk. The Survey A is a questionnaire survey on pedestrian travel characteristics, and the Survey B is on pedestrian traffic through observations and volume counts.

The Survey A was conducted over 6 days, for two consecutive weeks on the three focal points of the main roads of the intervention Panepistimiou St., Athinas St., and Vas. Olgas Str. The origin, the destination and the purpose of the travel, as well as the parking spot, in case of a motorized commute are some of the parameters that were collected for 2829 movements that were observed. The gender, the age and the travel mode of the respondent were also recorded through visual assessment.

In the context of the Survey B, the hourly traffic volume of pedestrians and motorised transport modes: private passenger cars, taxis, trucks, buses, motorcycles, bicycles, scooters, was collected for the examined time period and the modal split was calculated. That survey lasted 18 weeks (6/12/20-3/23/21), the first week was before the pilot implementation of the new mobility interventions. Thursday was chosen as the typical day for the field measurements. The points selected as research sites are located within Athens area, both in the center roads and in the ring roads. The survey points of both surveys, as well as Athens Great Walk interventions appear on Figure 1. The final database was completed with additional data, for other sources as presented in the following table.

Table 1. Additional Data

Factor	Values	Source
Land use	0: without land use / road 1: stores 2: services / square 3: grove	On-site autopsies; Google Maps
Covid-19 cases	Covid-19 cases during the examined period	Greek Government
Covid-19 deaths	Covid-19 deaths during the examined period	
Traffic regulations	0: without traffic regulations 1: lockdown; AGW interventions; protests	Greek Government; On-site autopsies
Traffic lanes	Number of traffic lanes in the Survey B examined road axes	On-site autopsies; Google Maps
Bus lanes	Number of bus lanes in the Survey B examined road axes	
Sidewalk width	Width (m) of the sidewalk in the Survey B points	On-site autopsies; Google Maps
Month	Month of field measurements	

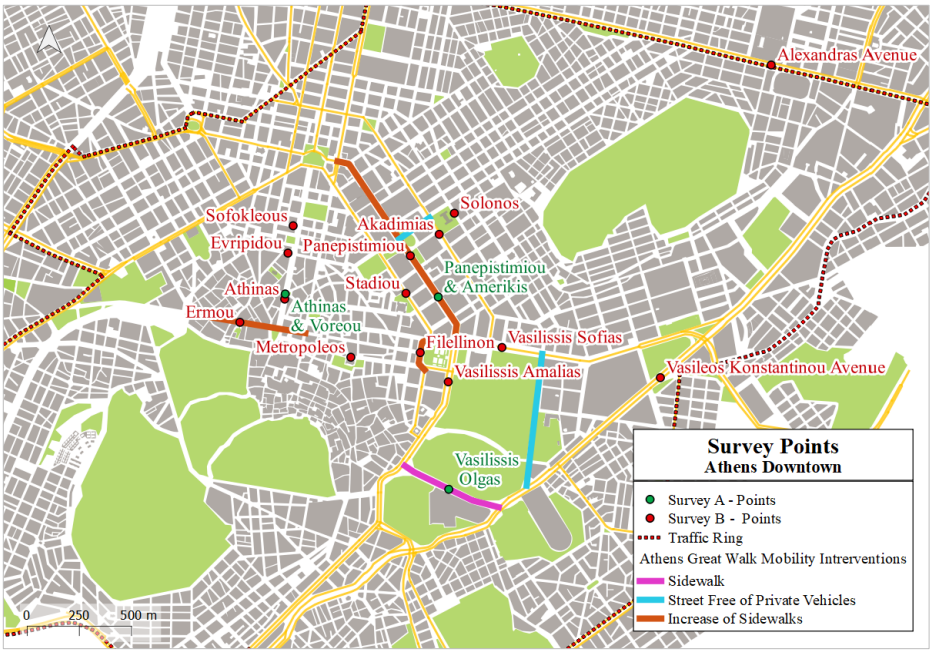

Fig. 1. Survey Points in Athens Downtown

3.3. Theoretical Background

In the statistical analysis the data obtained by the Pedestrian Traffic Survey (Survey B) for the development of statistical models, with the hourly pedestrian traffic per meter of pavement width as a dependent variable. Generalized Linear Models (GLMs) were implemented with a Poisson data distribution, because it is known to be used when describing completely random discrete events (Kokolakis, G., Spiliotis, I., 2010).

In the case of Poisson regression, the general mathematical equation used is as follows:

$$\log(y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n \quad (1)$$

Where: y is the dependent variable, x are the independent variables and β are the fixed-effect parameters

In addition, using the measure of elasticity, as well as the sign of the coefficient of each independent variable, it is feasible to compare the influence that each independent has on the dependant value. Elasticity (e) refers to the relative influence and is usually expressed as the percentage change of the dependent variable caused by the 1% change of the independent variable and is calculated by the following mathematical equation where x is the independent variable and β is the coefficient.

$$e_i = \beta_i \cdot x_i \quad (2)$$

4. Results

4.1. Descriptive Analysis

Regarding the Survey A, as targeted, the percentage of men (49%) who answered the questionnaire is approximately equal to the percentage of women (51%). The following figures capture the travel patterns of pedestrians and the trip purposes on Vas. Olgas St. and Panepistimiou St., during the afternoon. It is observed that the main purpose of trips within the center of Athens is leisure, especially in the afternoon. Although, in Panepistimiou and Athinas streets, where various activities are developed (trade, services, etc.) there is a variety in terms of mobility purposes, in contrast to Vas. Olgas St.

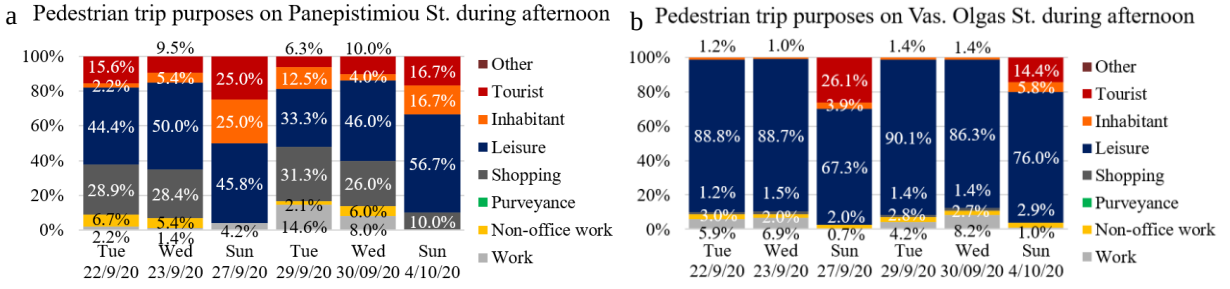

Fig. 2. (a) Pedestrian trip purposes on Panepistimiou St. during afternoon; (b) Pedestrian trip purposes on Vas. Olgas St. during the afternoon

Table 2. Origin-Destination Table of Pedestrians on Vas. Olgas St. during the afternoon

Vas. Olgas St. Afternoon		Destination						
		North	**East**	**West**	**South**	**Athens**	**Center**	**Total**
Origin	**North**	0.0%	0.0%	0.0%	0.3%	2.8%	0.0%	**3.1%**
	East	0.0%	0.2%	0.0%	0.0%	2.8%	0.2%	**3.1%**
	West	0.3%	0.2%	0.0%	0.0%	7.0%	0.0%	**7.5%**
	South	0.0%	0.0%	0.0%	0.0%	8.9%	0.8%	**9.8%**
	Athens	0.8%	0.7%	1.0%	1.8%	35.4%	8.3%	**48.0%**
	Center	0.0%	0.0%	0.0%	0.5%	26.0%	2.1%	**28.6%**
	Total	**1.1%**	**1.0%**	**1.0%**	**2.6%**	**82.9%**	**11.4%**	**100.0%**

According to Table 2. it is clear that the commuters on Vas. Olgas street have as origin mainly the center and the wider area of Athens and as destination the wider area of Athens. Vas. Olgas street, with its pedestrianization in the context of AGW, has attracted more pedestrians who aim mainly at leisure.

Moving on to the descriptive analysis of the Survey B, a number of figures and tables were developed, for the better understanding of the database.

Table 3. Land uses count of position

Count of Position		Left land use			
		Without land use / Road	**Stores**	**Services / Square**	**Grand Total**
Right land use	**Stores**	3	2	3	**8**
	Services / Square	0	2	1	**3**
	Grove	2	1	0	**3**
	Grand Total	**5**	**5**	**4**	**14**

Regarding the land uses, it is observed that most of the streets are dominated by shops, followed by streets that combine shops with services and a square. The list of uses is completed by a grove, the coexistence of services and a square, as well as the coexistence of shops and a grove.

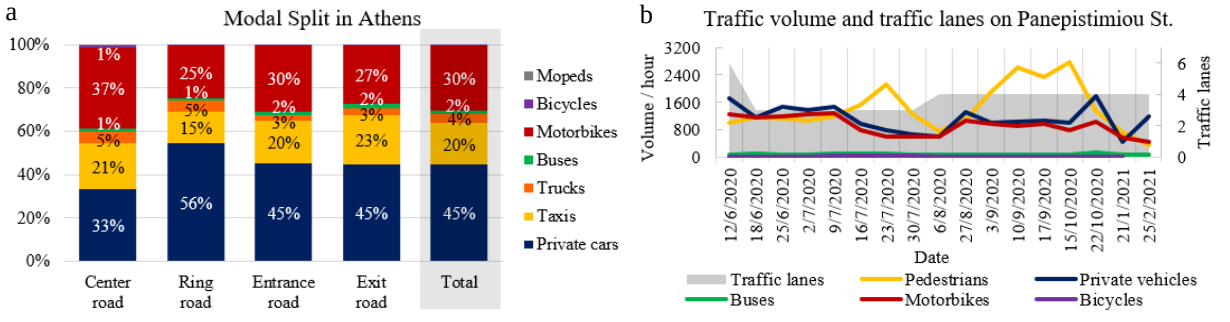

Fig. 3. (a) Modal Split in Athens; (b) Traffic volume and traffic lanes on Panepistimiou St.

As for the modal split in the city of Athens, it is understood that the largest percentage of vehicles are private

passenger cars (average 45%) as well as motorcycles (average 30%), while the percentage of taxis is also high (average 20%). They are followed by heavy vehicles (average 4%) and buses (average 2%), while skates and bicycles have almost zero percentage of traffic.

Considering the interaction between Traffic and traffic lanes in Panepistimiou St., there is a declining trend in the traffic load of passenger cars and motorbikes during the first phase of the pilot implementation of the "Great Walk", when 3 traffic lanes were in use. During this phase, pedestrian traffic increased significantly, as there was more available space, but there was also probably increased interest in observing the new image of the area. Finally, when the number of traffic lanes increased to 4, on August 6, 2020, the load of vehicles increased too, while there is a further increase in pedestrian traffic, by mid-October 2021. This increase may be due to the return of residents from the summer holidays and also, the fall at the end of the year may be a consequence of traffic restrictions due to pandemic.

Finally, it is noticed that in the central streets the hourly pedestrian traffic per meter is higher compared to other streets, which indicates the strong presence of pedestrians in the city center in combination with the existence of smaller sidewalks there.

4.2. Statistical Model Results

For the statistical analysis, three Poisson regression models were developed to define the correlation between pedestrian traffic in the center of Athens and the factors affecting it. The first statistical model analyzes the pedestrian traffic in the wider area of the center of Athens and takes into account all the Survey B points, the second in the center of Athens and the third in the entrance axes in the center of Athens. Table 4 shows the result summary of the mathematical models.

Table 4. Result summary of mathematical models

	Independent Variables	Model 1 - Athens wider area				Model 2 - Athens Center				Model 3 - Entrance axes			
		Reference variable	β	z value	Relative influence ei*	Reference variable	β	z value	Relative influence ei*	Reference variable	β	z value	Relative influence ei*
	Constant factor	-	4.538	-	-	-	5.291	-	-	-	6.593	-	-
Discrete variables	**Month**												
	February	January	-1.616	-13.590	59.945	-	-	-	-	-	-	-	-
	March	January	-3.334	-13.541	402.077	-	-	-	-	-	-	-	-
	June	January	0.630	11.476	-6.944	-	-	-	-	-	-	-	-
	July	January	0.625	11.710	-6.910	-	-	-	-	-	-	-	-
	August	January	0.180	4.416	-2.452	-	-	-	-	-	-	-	-
	September	January	0.531	15.037	-6.122	-	-	-	-	-	-	-	-
	October	January	-0.065	-2.426	1.000	-	-	-	-	-	-	-	-
	Road type												
	Ring road	Center	-0.482	-16.684	9.213	-	-	-	-	-	-	-	-
	Entrance road	Center	2.365	30.223	-13.468	-	-	-	-	-	-	-	-
	Exit road	Center	2.033	24.944	-12.918	-	-	-	-	-	-	-	-
	Land use												
	Services - Squares	Stores	-0.157	-7.774	2.532	Stores	-0.404	-15.296	1.000	-	-	-	-
	Grove	Stores	-3.198	-42.939	349.060	-	-	-	-	-	-	-	-
	Stores & Services - Squares	Stores	-0.679	-36.424	14.452	Stores	-0.629	-40.950	1.760	-	-	-	-
	Stores & Grove	Stores	-3.483	-40.631	469.068	-	-	-	-	Grove	-0.315	-6.638	1.000
Continuous variables	**Covid-19 cases**	-	0.001	11.463	18.351	-	-0.0002	-23.674	1.938	-	-0.0004	-8.507	-5.476
	Private cars volume	-	0.0003	12.409	9.321	-	-	-	-	-	-	-	-
	Taxis modal split	-	1.074	11.428	7.903	-	1.122	12.243	-4.987	-	-6.047	-4.992	-39.984
	Trucks volume	-	-0.003	-18.274	-6.785	-	-0.003	-15.860	2.888	-	0.002	3.349	4.440
	Buses volume	-	-0.007	-16.967	-6.289	-	-0.002	-6.787	1.000	-	-0.007	-2.441	-11.226
	Motorbikes volume	-	-	-	-	-	-	-	-	-	-0.001	-4.549	-16.704
	Bicycles volume	-	0.003	4.219	1.000	-	-	-	-	-	-0.008	-1.965	-3.196
	Mopeds volume	-	0.021	13.750	1.694	-	0.035	19.931	-1.829	-	0.012	2.043	1.000
	R^2 McFadden:		**0.601**				**0.309**				**0.360**		

The final models were evaluated considering the common statistical tests (R^2, t- test etc.) but also based on the logical explanation of the results. Also, the correlation of variables was examined to select the best-fitting mathematical model. The final models have an adjustment factors R^2 from 0.3 to 0.6, which are considered adequate. Variables are considered statistically significant at the typical 95 % level.

5. Discussion

The present research aimed to explore the critical factors affecting pedestrian traffic in Athens Downtown, during the pilot implementation of the Athens Great Walk. Two field surveys were carried out, one on pedestrians travel information through questionnaire and a second one on pedestrian volume through observations. For the analysis, 3 Poisson regression models were developed to define the correlation between pedestrian traffic and the factors affecting it. The first statistical model analyzes the pedestrian traffic in the wider area of the center of Athens, the second in the center of Athens and the third in the entrance road axes in the center of Athens. Results indicate that the factors affecting pedestrian traffic in Athens vary. Land use, active modes, motorized traffic, the month and Covid-19 pandemic are critical factors that affect pedestrian traffic in Athens.

Specifically, in commercial areas with stores high pedestrian traffic is observed while in areas where stores coexist with other land uses such as services and squares the pedestrian traffic is reduced. The commuting within the central area of Athens mainly originates from the southern suburbs and the city center and has as main destination the wider central area of Athens. The purpose of the commuting in the center of Athens is mainly related to leisure and shopping, while in the morning there is also trips with the purpose of working. The leisure as a main purpose of commuting, is confirmed by the existence of many stores within the city center of Athens.

Also, the active modes traffic such as bicycles and mopeds have a positive impact on the pedestrian traffic in the central area of Athens. So, it can be concluded that in the areas where cycling is promoted, pedestrian traffic also seems to be promoted. Considering motorized traffic, the pedestrian traffic increases by increasing the taxi share and private car volume, while pedestrian traffic decreases by increasing trucks and buses traffic. Usually in areas where encourages pedestrian traffic, there are no heavy vehicles, while buses absorb traffic from pedestrian traffic.

Regarding motorized traffic, passenger cars and motorcycles dominate in the city center of Athens, while a significant share of taxis is found. Buses are a small percentage of the modal split, while active modes, bicycles and mopeds, it is found that they are not observed as means of daily commuting of an Athenian citizen. Pedestrian traffic is significant in Athens, especially in the central areas of the city, where the hourly traffic is high and the sidewalks are narrow indicating the need of increasing the width of sidewalks there and promote the pedestrian.

Regarding the three main roads of AGW area of interventions, where either the geometry of the road was changed or new traffic regulations were imposed, the following conclusions emerge. On Panepistimiou St., during the first operation phase, there is a declining trend in the traffic volume of passenger cars and motorcycles, while pedestrian traffic increased significantly. In the second phase, when an additional traffic lane was given to the motorized traffic, the vehicles volume increased, while there was a further increase in pedestrian traffic, until mid-October 2021. On Filellinon St., there is no particular change in the traffic conditions considering both pedestrians and vehicles. Moreover, the pedestrianization on Vas. Olgas St. led to a significant attraction of pedestrians commuting mainly for leisure.

Furthermore, regarding the wider area of the center of Athens there is a reduced pedestrian traffic on the ring areas in relation to the central areas, while at the exits and entrances from/ to the city center, the pedestrian traffic is increasing. In terms of land uses, the largest pedestrian traffic is observed on roads with shops, while on the streets with mainly services-shops-squares there is a slightly reduced traffic.

It is worth noticing that the months February - March 2021 and October 2020 there is a reduced hourly pedestrian traffic compared to January 2021, while in the months June - September 2020 the hourly pedestrian volume is increased. This may be explained by the fact that during the summer months outdoor activities are favored as well from the imposition of traffic restrictive measures on travel during the winter.

It must be noted that there is a significant correlation between pedestrian traffic and Covid-19 pandemic cases in Greece. Covid-19 pandemic is a factor that seems to have determined the movements within the center of Athens,

since in times when the number of Covid-19 cases was increased and traffic restriction measures were implemented, the pedestrian and motorized traffic fluctuated. More specifically, in the center and at the entrance of the center, the increase of Covid-19 cases is associated with the reduction of pedestrian traffic, while in the wider area of the center it was combined with a small increase of pedestrians.

The pedestrian mobility and generally active modes mobility are a key component of the development of a sustainable transport system in urban centers. Athens is a city with significant pedestrian traffic, mainly on central areas, which indicates need to upgrade the sidewalks and generally the active travel modes facilities. The pilot implementation of Athens Great Walk is the first but very important step towards the pedestrian promotion in the city of Athens. It is considered appropriate to present a series of proposals, which can improve the conditions of movement within the center of Athens, emphasizing on improving pedestrian traffic. The following policies are therefore proposed: the reconstruction of the public space, with widening of the existing sidewalks, the expansion of the pedestrian areas, the creation of green paths, as well as the configuration of the crossings in an appropriate way in order the pedestrians to have the traffic priority. Additionally, it is proposed the maintenance and expansion of the benches within the urban environment, the creation of a unified network of bicycle lanes and the invigoration of Means of Transport.

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