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Transportation Research Procedia 45 (2020) 95–102

Transportation Research Procedia

www.elsevier.com/locate/procedia

AIIT 2nd International Congress on Transport Infrastructure and Systems in a changing world (TIS ROMA 2019), 23rd-24th September 2019, Rome, Italy

Pedestrian level of service assessment in an area close to an under-construction metro line in Thessaloniki, Greece

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Abstract

Pedestrian mobility is one of the most sustainable transport alternatives as it offers significant environmental, social and economic benefits. In fact, the non-motorization contributes to the reduction of emissions and at the same time, walking is able to revive purchases and also sociality and communication between people. The present paper focuses on the assessment of a section of a pedestrian area located in the center of the Municipality of Kalamaria, which is one of the biggest Municipalities in the Thessaloniki Metropolitan area, Northern Greece. The pedestrian area which was examined includes the oldest and most important pedestrian street in the Municipality, as it is located in the central business district (CBD) and it serves a large number of pedestrian flows on a daily basis. Also, the construction of a metro station in the area is expected to further increase the pedestrian flows. The analysis of the paper includes the evaluation of the existing situation of the pedestrian street through Viswalk, which is a microscopic software for pedestrian simulation. The aim of the specific evaluation is the identification of variations in the Level of Service (LOS), as the pedestrian composition and flows change. The results of the simulation show that even tripling the pedestrian flow in the pedestrian area will not cause a significant drop in LOS, with the exception of specific sections of the pedestrian street, where bottlenecks are formed.

Keywords: vulnerable users; Viswalk microsimulator; pedestrian street; pedestrians; level of service (LOS)

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10.1016/j.trpro.2020.02.067

1. Introduction

Pedestrian zones also referred as auto-free zones and car-free zones are areas of a city where motorized traffic is prohibited. The process of conversion of a street into an area for the use of pedestrians and cyclists only, by excluding all motor vehicles falls under the term of pedestrianization. This process usually aims to improve accessibility and mobility for pedestrians, as well as the commercial activities in the area or to improve the attractiveness of the local) environment in terms of aesthetics, atmospheric pollution and noise. However, pedestrianization can sometimes lead to impairment of ownership and shifting of economic activity to other areas. Also, in some cases, traffic problems may arise as instead of replacing motorized traffic, there is a shift to nearby areas. Nonetheless, pedestrian area patterns are often associated with significant drops in air pollution, noise levels, accidents, as well as with an increase in retail turnover and property values. Modern cities are investing in this policy in order to improve the built environment and at the same time to bring people back to living in urban areas. Different measures are adopted by local authorities for the creation of pedestrian areas such as the central LTZ (Limited Traffic Zone). Pedestrianization also involves the increase of services to accompany pedestrians during the journey, such as signage, benches and equipped areas. These areas are of great importance for cities with a strong tourist vocation in order to allow groups of tourists to move easily within the city.

The need to study pedestrian safety was born several years after the studies focused on motorized traffic. The issue is in fact quite heterogeneous since pedestrians have a variable behavioral component and they are strongly influenced by the environment. Several studies in the literature show the correlation between pedestrian safety and infrastructure geometry, together with the vehicle flow component. In the literature there are several studies that analyze pedestrians'behavior and safety in various conditions such as:a) unsignalised intersections(Fitzpatrick et al., 2007),b) signalised intersections (Lambrianidou et al., 2013; Paschalidis et al., 2016; Giuffrè et al., 2017; Basbas et al., 2019), c) limited traffic areas (Campisi et al., 2018)and d) shared use sidewalks and pedestrian streets (Nikiforiadis and Basbas, 2019; Basbas et al., 2019), while other works consider how to protect pedestrians taking into account traffic light systems, sensors and new technologies (Pau et al., 2018; Monterde-i-Bort et al., 2019). Other studies focus on the environmental impact of pedestrianization schemes (Pitsiava-Latinopoulou and Basbas, 2000; Taxiltaris et al., 2002), pointing out the positive effect of these schemes to the quality of environment in the near area.

The present paper aims to compare different scenarios in order to evaluate the level of service in a pedestrian street, which serves various commercial activities. From the modification of the pedestrian flows (composition and O/D matrices) and through the geometrical-functional analysis of the area, it is possible to express a synthetic judgment through the evaluation of the LOS. The evaluation of the LOS has been validated through the calibration of the Viswalk pedestrian traffic simulation software. This tool is based on the behavioral model of Helbing according to (Helbing and Molnar, 1995) which pedestrians are attracted to each other as if there were gravitational forces. Three different scenarios have been evaluated in order to understand if the under-study pedestrian area is passable by all users including a percentage of disabled people. Pedestrian behaviors have been studied and calibrated in the tool focusing on the parameters of the Helbing model mentioned above and therefore inserting in the input phase the tendency of the pedestrians to mutually modify the trajectories. The evaluation of the LOS was followed by a comparative evaluation of the various scenarios implemented through the Viswalk tool (PTV Group, 2011) in order to be able to evaluate in advance some of the measures that will be implemented in the future.

2. Description of the undertaken research

2.1. Study area

The study area is the center of the Municipality of Kalamaria, which is located in the eastern part of the Thessaloniki Metropolitan Area, Greece. According to the results of the national census of 2011, the population of the Municipality is 91270 inhabitants and the population density is 14258.71 inhabitants/km^2. Kalamaria constitutes the largest Southeastern part of Thessaloniki's conurbation, contains several formal public spaces but also a large number of informal open spaces. In the study area, there are two main pedestrian streets, namely Komninon and Metamorfoseos, where the one pedestrian street is the continuation of the other. This paper focuses in Komninon

pedestrian street (see Fig. 1), which is the oldest one and it is characterized by the large number of coffee bars and retail stores, thus attracting a large number of visitors on a daily basis. Komninon is also connected to the central square of Kalamaria and as a result it is used by many people for leisure purposes. It is designed to provide pedestrians a high comfort level, having many benches and green areas. The basic idea behind the present paper was the increasing interest on soft mobility in this area and the expected extra increase in walking trips due to the future operation of a metro station in close proximity.

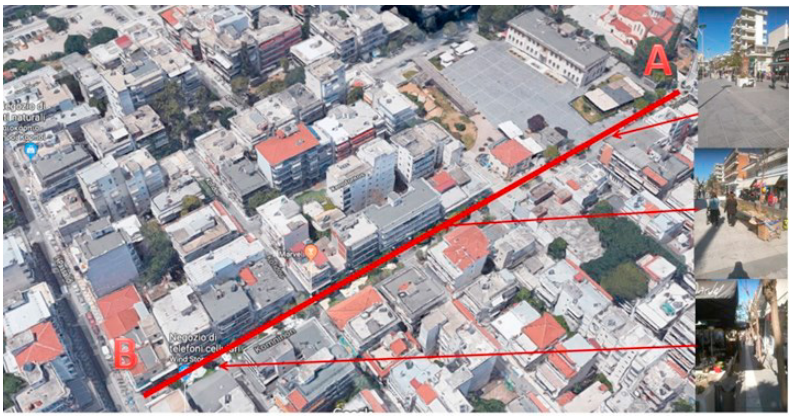

Fig. 1. Komninon pedestrian street in Kalamaria, Greece (Source: Google, n.d.).

2.2. Field measurements

The field measurements were carried out through observers in the field. According to the Florida Department of Transportation, the use of observers in the field leads to the exportation of reliable results and allows the researchers to become familiar with the operational conditions of the infrastructure and the general environmental conditions of the study area (Florida Department of Transportation, 2014). The measurements were carried out during February 2019, in typical weekdays (not weekends), morning hours and under fine weather conditions. The measurements were related to the pedestrian flows, the composition of pedestrians (e.g. gender) and their speed. The results from the field measurements are presented in Table 1.

Table 1. Komninon functional and geometric attributes.

Variables	Komninon
Length [m]	270
Effective width [m]	9.4 (minimum 2m)
Average pedestrian speed [m/sec]	1.35
Pedestrian flow [ped/h]	Max flow: 900peds/h, Average flow: 640peds/h
Pedestrian mix (gender)	56% female and 44%female
Pedestrian mix (age)	<18: 12%; 18-65: 60%; ≥65: 28%
Pedestrian mix (type)	Alone: 75%; Group: 12%; Cart: 11%; Mom and kid: 2%

3. Evaluated and perceived Level of Service

The evaluation of the LOS was introduced for the first time in motorized traffic in the 60s in the Highway Capacity Manual (HCM, 2010). The calculation of the LOS is based on the assumption that drivers perceive that the low traffic volumes have a higher quality and therefore a higher LOS. To determine the LOS, the operating speed and the volume/capacity ratio were used. Based on these criteria, six levels were distinguished, from A to F.

According to Oeding (1963) a first evaluation of the qualitative pedestrian LOS is defined with 4 quality levels that take into account walking alongside or overcoming others in more or less overcrowded areas. Several years later, Fruin developed his concept of LOS (Fruin, 1970).Fruin's LOS levels are still used as benchmarks in many

applications today. Following Fruin, the concept of LOS for pedestrians was further developed and adapted to different situations. Pushkarev and Zupan studied platoons of pedestrians and the right time range (15-30 min) in which to determine their value (Pushkarev and Zupan, 1975).Several publications focused on the transfer of the concept in different cases (Polus et al., 1983; Tanaboriboon and Guyano, 1989). Schopf (1985) studied the spatial need for space in various walking situations and proposed another methodology for the evaluation of LOS, based on the number of conflicts.

The analysis of pedestrian areas is now customary to include the evaluation of the PLOS. This assessment is done through methodologies that influence the planning, design and operational aspects of transport projects, as well as the allocation of limited financial resources in competing transport projects. The evaluation of the PLOS requires the acquisition of geometric-functional data characterizing the infrastructure, such as the length, width, pedestrian density and flow rate.

Other researchers are focused on the evaluation of alternative parameters such as delay time or the number of conflicts with other types of traffic as a measure of quality rather than density (Kretz, 2011; Milazzo II et al., 1999; Basbas et al., 2019).The perceived quality does not depend only on the restrictions imposed by other pedestrians. In order to take this into account, other quality concepts have been developed that are widely applied today including the attractiveness of the surroundings, the volumes of motorized traffic, the safety aspects as network parameters (Mōriand Tsukaguchi, 1987; Sarkar, 1993; Stangl, 2012; Christopoulou and Pitsiava-Latinopoulou, 2012; Kadali and Vedagiri, 2016).

This branch of the LOS schemes overlapping with the idea of walkability (Saelens and Handy, 2008), which focuses more on the quality of the walking experience. In recent years, researchers have increasingly focused on developing a multimodal service level (Dowling et al., 2008; Scherer et al., 2009).

Several LOS assessment approaches based on pedestrian density can be found in the literature. Table 2 presents two of the most widespread, that is the Highway Capacity Manual (HCM, 2000) and Fruin's model (Fruin, 1970).

Table 2. Level of service values comparison.

	LOS					
	A	B	C	D	E	F
Period (1970)			**FRUIN**			
space (m^2/ped)	>3.20	2.3-3.2	1.4-2.3	0.9-1.4	0.5-0.9	<0.5
flow rate (ped/min/m)	<23	23-33	33-49	49-66	66-82	variable
Period (2000)			**HCM**			
space (m^2/ped)	>4.80	3.54-4.8	1.74-3.54	1.14-1.74	0.59-1.14	<0.59
flow rate (ped/min/m)	<16	16-23	23-33	33-49	49-75	variable

In 2013, a perceived LOS analysis was carried regarding Komninon pedestrian street (Lazou et al., 2014; Lazou et al., 2015). The results demonstrated that male pedestrians tended to evaluate better the pedestrian street ($r=-.133$, $p<0.05$) and elderly people perceived higher LOS than younger ($r=.157$, $p<0.01$). Also, frequent users perceived higher LOS compared to rare users ($r=-.293$, $p<0.001$). The analysis also showed that the respondents perceived the provided LOS in a different manner compare to the LOS as it is calculated by the Highway Capacity Manual 2010.

4. Microsimulation approach

The evaluation of the under-study area was conducted through Viswalk. This tool is based on the gravitational model of Helbing according to which people move by attracting each other and causing a certain disturbance to trajectories. Pedestrian traffic data were collected through observers in the field and it was possible to trace the pedestrian composition in terms of age (12% younger than 18.60% between 18 and 65.28% older than 65).Also, through the observations it was possible to identify the typology of the users who mostly use the pedestrian area (75% move alone, 12% in a group and the rest part is formed by mothers with children or pedestrians who carry an object). Through the conduction of a survey, it was found that almost 60% of the interviewed population moves in the Komninon pedestrian street for leisure while the remaining part to go home or for work purposes. Over 20% of the sample uses the under-study pedestrian area at least once a day. Moreover, pedestrian flow measurements in the

peak hour were carried out and the flows were equal to 700-900 peds/h (at 12:00-13:00) of access or exit respectively from the initial and final part of the segment. Finally, the speed of pedestrians derived from 100 counts and it was found equal to 1.35 m/s but a reduced speed has been considered for the elderly as well as for mothers with children and wheelchairs.

In order to evaluate the LOS of the pedestrian area, 3 different scenarios were analyzed, considering the measured flow and an increasing percentage of flow. The increase of pedestrian flow in this pedestrian street is highly anticipated, as a metro station will operate in a short distance and it will connect the CBD of Kalamaria with Thessaloniki's CBD. Despite the fact that there are no available data about the expected demand in the specific station, it is anticipated that the pedestrian flows to/from the station will increase significantly since there is a high demand for trips from Kalamaria to Thessaloniki CBD.

Table 3 presents the pedestrian flows for the examined scenarios, as well as the nodes used in the analysis. The beginning and the end of the pedestrian area are marked with letters A and B respectively. The letter C corresponds to the neighboring square. The other secondary nodes (from D to I) correspond to the secondary roads that join the Komninon.

Table 3. Q1 matrix with monitored flow (entrance in the network) (Source: Google, n.d.).

Q1	Scenario 1st	Scenario 2nd	Scenario 3rd
A	678	1356	2034
B	906	1812	2718
C	54	108	162
D	84	168	252
E	54	108	162
F	144	288	432
G	66	132	198
H	102	204	306
I	78	156	234
TOT.	2166	4332	6498

The simulation model was appropriately calibrated considering the different parameters relating to the presence of different pedestrian users and their mutual attraction / disturbance during walking due to the different speeds assumed or due to the presence of area narrowings (bottlenecks) or due to movement priorities. It was considered appropriate not to use the default values that Viswalk provide, but to calibrate the model considering the field measurement results and the lifestyles of the interviewed population.

5. Results

The micro-simulation allowed to compare the scenarios assessing pedestrian speed and density and as a global parameter the level of service (LOS). Table 4 presents the LOS values for the three scenarios per segment. It can be seen that in the current situation, Komninon pedestrian street offers an extremely high LOS in all segments. The LOS will remain high in all segments in case of doubling the pedestrian flows in the pedestrian area. According to the simulation results Komninon can also serve the three-fold pedestrian flow of the existing situation, with problems only in very specific parts of the pedestrian street. These problems are identified between nodes G and H, where bottlenecks are formed due to the existence of tables from cafes and bars. Fig. 2 facilitates the supervision of the segments that are characterized as more problematic. These segments are mentioned with yellow and red colour.

It is also useful to note how the pedestrian speeds reduce in the narrower segments, especially in the case of the third scenario. Taking into account the fact that the average pedestrian speed varies between 3.6 and 5.4 km/h, it is possible to see that in scenarios 1 and 2 the transition from the beginning to the end of the pedestrian street can be

made easily and unhindered, while there are significant speed reductions at the narrowings of the pedestrian area in scenario 3 (see Fig. 3).

From the global evaluation of the results it is possible to affirm that the pedestrian area of Komninon has been designed in an effective way and it will be capable for serving the higher flows, which are expected due to the operation of the metro station.

Table 4. LOS values per segment in the three scenarios.

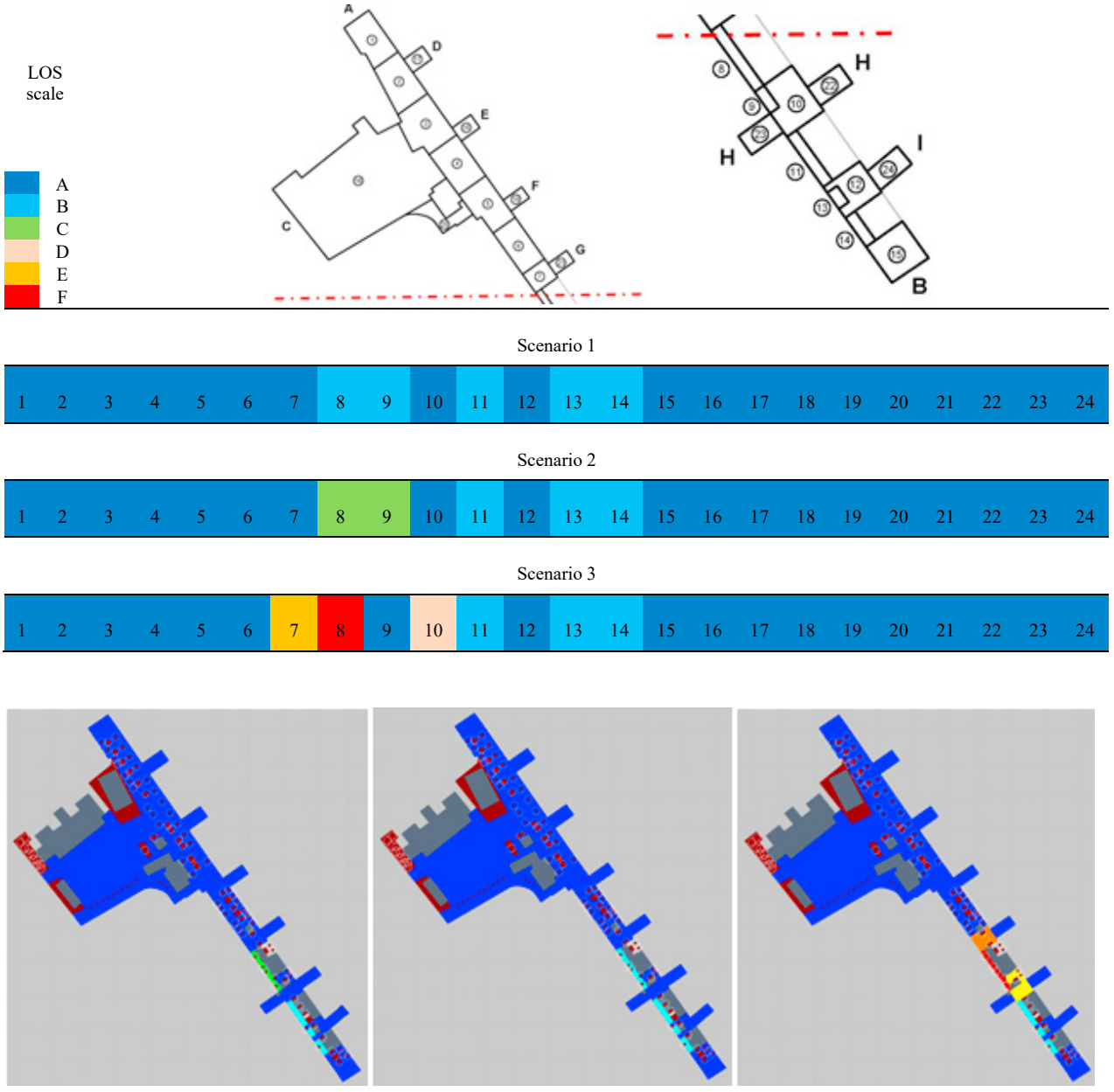

Fig. 2. Comparison of the LOS values among the three scenarios.

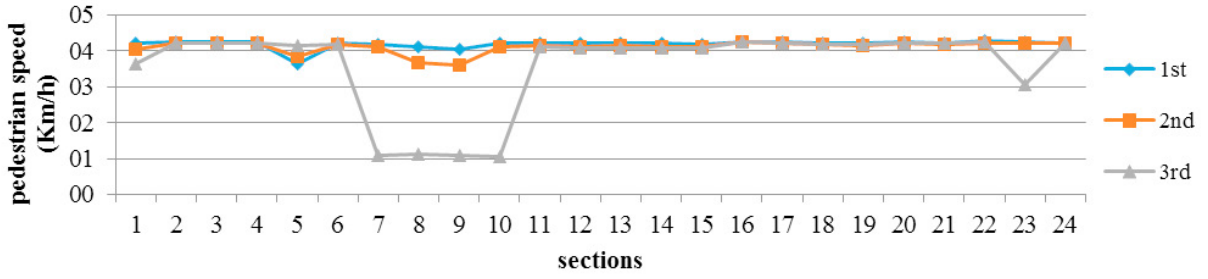

Fig. 3. Pedestrian speed variation in the three scenarios.

6. Conclusion

Sustainability in the field of transportation can be an incentive to spread pedestrian-type areas, allowing vulnerable road users to use them in a comfortable and safe way. The construction of a metro station near the Komninon road will be detrimental to the use of private vehicles, for foot and underground transport, reducing congestion and pollution. In order to be able to assess whether the pedestrian area will be able to serve the vulnerable road users in the future situation, the LOS value can be used. Pedestrian micro-simulation tools allow evaluating the LOS in different segments, considering different mixes of pedestrians and various pedestrian flows. The present work therefore shows that in the case of Komninon, doubling or tripling the existing pedestrian flows does not deteriorate significantly the provided LOS, but problems can be caused in some segments of the Komninon street. These problems are found in bottlenecks that are formed, due to premises and equipment of cafes and bars that are located along the pedestrian street. These aspects should be also taken into consideration when studying an area in terms of evacuation scenarios or cases of maintenance. Thus, future research includes the examination of different scenarios in order to investigate the ability of pedestrian areas to serve the users in case of emergency events or in case of maintenance works.

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