Comparing the microsimulated pedestrian level of service with the users’ perception: The case of Thessaloniki, Greece, coastal front

Vasiliki Amprasi, Ioannis Politis, Andreas Nikiforiadis, Socrates Basbas

Abstract

Nowadays, there is a keen interest among societies to improve the quality of life of residents by promoting sustainable means of transport like walking and cycling. Towards this direction, it is important to provide a safe, comfortable and attractive environment for the vulnerable road users (pedestrians, cyclists). This should be reflected both in the objective depiction of the current situation as well as in the subjective viewpoint of the users as it is not unusual that these two dimensions of pedestrian infrastructure assessment (objective vs subjective, calculated vs perceived) differ. Focusing on the abovementioned issue, field measurements were carried out on the coastal front of Thessaloniki, Greece, by filming the actual prevailing conditions at three points of the study area simultaneously, in order to calculate the level of service “before, during and after the peak”. The modelling of these three-time periods was performed using the microsimulation software Viswalk. From the microsimulation, a number of indices were derived which can give an objective estimation of the walking condition in the examined walkway such as the level of service, the average density, etc. In addition, a questionnaire-based survey was conducted to capture the satisfaction and sense of comfort and safety that pedestrians perceive while using the infrastructure. The analysis led to interesting conclusive remarks as, despite the very good level of service that was calculated through the simulation models, a significant percentage of users stated that they feel uncomfortable and unsafe when walking along the coastal front.

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Keywords: Pedestrian microsimulation; Pedestrian level of service (PLOS); Questionnaire survey; PTV Viswalk; Thessaloniki

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1. Introduction

Motorized traffic was predominant in the frame of traditional transport planning approach. Recognizing the deterioration of quality of life that has been caused by this domination, societies are trying to adopt and implement a more sustainable, non-motorized perspective of mobility. Therefore, a clear shift towards a sustainable approach of transport and urban planning is identified nowadays, especially in Europe (COM, 2011). On national and local level, authorities make efforts to promote active transport modes, like walking and cycling, by focusing on providing safe, comfortable and high-quality infrastructure for pedestrians and cyclists in an attractive environment. The prevailing walking conditions as well as the qualitative characteristics of an infrastructure can encourage or discourage people from using it (Babas et al., 2010; Papaioannou et al., 2016). Despite the fact that pedestrianization schemes offer significant environmental benefits (Pitsiava-Latinopoulo and Babas, 2000), the generalized pedestrianization of a city center with the view to protect and ease vulnerable users should not be faced as a panacea, and a holistic traffic management is needed (Taxilitaris et al., 2002).

The abovementioned intended shift to active transport modes results in various environmental, societal and economic benefits and, for this reason, it is an interesting topic for the scientific community. Many researchers, indicatively mentioning Blondiua et al. (2016), Litman (2017), Mulley et al. (2013), have studied the issue and have proven that walking and cycling can benefit people in many aspects of everyday life and can improve their health and their quality of life as well. Other researchers have proven that walking and cycling affect in a positive way the travelers’ subjective well-being and psychology (Friman et al., 2017; Singleton, 2018; Vaitis et al., 2019). As these sustainable means of transport are directly linked to people’s attitude and behavior, they are inevitably influenced by the different emotions developed for the different surroundings and the emotional situation a person is in (Snodgrass et al., 1988; Mody et al., 2009; Hogertz, 2010). Consequently, it is understood that designing a proper infrastructure in which pedestrians and cyclists will exist is more complicated and demanding in relation to the design of vehicles’ infrastructure.

In order to evaluate the pedestrian facilities, the pedestrian level of service (LOS) is used. There are numerous studies in the literature which can be categorized into three types of approaches to assess pedestrian LOS. The first type takes into account quantitative factors such as average available space, motorized and non-motorized traffic characteristics (volumes, speed), width and other variables (Landis et al., 2001; Petritsch et al., 2006; Tan et al., 2007). The second type is based on qualitative criteria for the assessment of infrastructures such as the quality and attractiveness of the environment, safety, comfort, accessibility and others (Jaskiewicz, 2000; Rahaman et al., 2006; Lazou et al., 2015). Finally, the third type combines both quantitative and qualitative factors (Mōri and Tsukaguchi, 1987; Hidayat et al., 2011).

Apart from the objective mathematical calculation, many of the existing level of service methods are developed by considering users’ perceptions as the assessing parameters to reflect walking or cycling movement. Thus, the perceived level of service that arises is characterized as a subjective indicator. It is found that important factors which define the perceived LOS are, among others, the social characteristics of the users and their walking experience (Lazou et al., 2014; Lazou et al., 2015; Kang and Fricker, 2016; Tan et al., 2007; Nikiforiadis and Babas, 2019). In addition, it has been found that the presence of bicycles on sidewalks and pedestrian streets has also an impact on the LOS that pedestrians perceive (Kang et al., 2013; Muraleetharan et al., 2003; Nikiforiadis and Babas, 2019).

The aim of this paper is to assess the pedestrian level of service through microsimulation models, as well as to compare it with the users’ perception for the under-study infrastructure. This analysis seeks to identify possible differences between the calculated LOS and the pedestrians’ attitudes and perceptions. Analyses of that type can demonstrate whether a calculation through microsimulation is adequate, or it should be modified and enriched. This way a much more reliable and realistic depiction of the quality of the prevailing conditions can be provided and, therefore, much more informed decisions could be taken by the policy makers regarding the design of new or the management of existing pedestrian infrastructures.
2. Description of the undertaken research

2.1. Study area

The study area is the coastal front of the Municipality of Thessaloniki, located in northern Greece. It constitutes the south-western border of the Municipality and it can be theoretically divided into two segments: a) Palia Paralia and b) Nea paralia waterfront promenades. Although they both operate as shared space areas including pedestrian and bicycle paths, the prevailing conditions and the frequency of events among the users differ significantly due to the different geometry of the two segments. Nea Paralia is a newly restructured area with many green areas and large width. On the other hand, Palia Paralia’s infrastructure is older and considerably narrower. Pedestrian-cyclist segregation is achieved by using a yellow longitudinal line in both infrastructures (see Fig. 1). In the framework of this paper, the under-study segment is the Palia Paralia walkway which appears to be the most problematic regarding the coexistence of pedestrians and cyclists, because of the high flows and the relatively narrow width. The pedestrian street’s width is 3.3-3.5 metres, whereas there are certain spots where the effective width is extremely limited by benches and railings. These spots operate as bottlenecks and they are therefore treated in the same way. The bicycle lane has 2 metres width.

Palia Paralia is an important infrastructure in the city center that connects main attraction poles of the city, such as the port and the White Tower, one of the major touristic attractions. Due to its proximity to the Thermaikos Bay, it is mainly used for recreation purposes or/and exercise by the locals as well as the tourists. For that reason, very high pedestrian and bicycle flow rates are observed during the spring and early summer months, especially on weekends.

2.2. Field measurements

The field measurements were carried out by filming the actual prevailing conditions of the study area with cameras. Increasingly, this method is being used by researchers in the field of pedestrian dynamics for the observation and collection of data about vulnerable users’ movement and behavior. Video has many advantages over direct data collection through observers in the field. (Bloomberg and Burden, 2006) On the other hand, a drawback is that the electronic devices used for the measurements are influenced by the weather (Bloomberg and Burden, 2006; Caramuta et al., 2017). In fact, during this research, a measurement in the field had to stop prematurely due to rain and wind. It was necessarily repeated the next day. Recording at three points of the study area simultaneously and synchronously was required to ensure the successful and reliable extraction of the necessary elements for the research. This need was based on three factors: a) the length of Palia Paralia walkway, b) its elongated geometry and c) the existence of many crosswalks along the way that enable the entry and exit of the users to/from the coastal front. As a result, a recording at only one point would be insufficient or even unacceptable.

Field measurements were conducted between July 23, 2018 and July 27, 2018. They were implemented in different time periods of each day to examine the escalation of the peak phenomenon. It was an attempt to collect the data of pedestrian and bicycle flow rates that represent the situations “before, during and after the peak” in order to evaluate the walking conditions and calculate the level of service of the aforementioned periods. Table 1 presents the observed results. It is noted that, despite the low densities occurred, pedestrians’ speed does not increase proportionally with the increase of the available space. This is explained by the recreational travel purposes of the

Fig. 1. (a) Palia Paralia; (b) Nea Paralia
users (AlGadhi et al., 2002). Also, the relation among the average speeds of the different categories of pedestrians, such as individuals who walk faster than groups, coincide with the relation found in the literature (Crociani et al., 2018; Rinke et al., 2017; KONE Corporation, 2016)

### Table 1. Field measurements results.

<table>
<thead>
<tr>
<th></th>
<th>Before the peak</th>
<th>During the peak</th>
<th>After the peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average pedestrian flow</td>
<td>13.5</td>
<td>36</td>
<td>17.5</td>
</tr>
<tr>
<td>Average bicycle flow</td>
<td>2.1</td>
<td>2.7</td>
<td>0.9</td>
</tr>
<tr>
<td>Average pedestrian speed</td>
<td>1.41</td>
<td>1.21</td>
<td>1.39</td>
</tr>
<tr>
<td>Average pedestrian speed</td>
<td>1.26</td>
<td>0.97</td>
<td>1.09</td>
</tr>
<tr>
<td>Average pedestrian speed</td>
<td>3.29</td>
<td>2.95</td>
<td>3.12</td>
</tr>
<tr>
<td>Average bicycle speed</td>
<td>6.84</td>
<td>4.20</td>
<td>4.36</td>
</tr>
</tbody>
</table>

**2.3. Questionnaire-based survey**

In order to understand the perceptions of the pedestrians when walking alongside Thessaloniki’s coastal front, as well as to compare their perceptions with the results of the simulation, a face to face questionnaire survey was carried out. The survey lasted 1 month and more specifically from May 10, 2014 to June 10, 2014. It should be highlighted at this point that no interference has been made at the geometry, coating materials or equipment of the coastal front since 2014. Also, no changes have been identified in pedestrians and cyclists flow. Thus, it is assumed that pedestrians’ perceptions haven’t changed through these years. During this 1-month survey, 300 valid questionnaires were completed using the random sampling method. This number is considered satisfactory for a city with a population of about 1 million. Of the 300 questionnaires, half were completed along the Palia Paralia (section to which the simulation models refer) and the other half along the Nea Paralia. The distribution of the questionnaires in the two infrastructures allows the identification of differences in pedestrians’ perceptions due to the different abovementioned characteristics of the infrastructures. For the purposes of this research, an initial questionnaire was structured, which was significantly modified after the implementation of a pilot survey, in which 30 questionnaires were completed. The final questionnaire consists of the following 3 parts:

- **pedestrians’ social and economic characteristics**: this section includes elements such as gender, age, income, etc.
- **pedestrians’ mobility characteristics**: this section attempts to recognize respondents’ mobility patterns (e.g. walking frequency, frequency of using the under-study infrastructures), as well as information on their specific trip at the time of the interview (e.g. trip duration and purpose).
- **pedestrians’ perceptions**: in this section of the questionnaire, pedestrians assess the comfort and safety of the under-study infrastructures, state their main concerns and they also report ways to make these infrastructures more attractive.

**3. Simulation results**

To obtain an objective depiction of the current walking conditions in the examined area, micro-simulation models were developed based on the analysis of the field measurements results. The models were developed for the three time periods “before, during and after the peak” using the microsimulation software Viswalk, which is based on the social force model for pedestrian dynamics (Helbing and Molnar, 1995). Emphasis was given to the calibration and validation of the models.

So, before the models of this research were able to produce satisfactory results, they were calibrated by adjusting appropriately a number of parameters and making other necessary adjustments to the core of the model. Visual calibration was performed by watching carefully the behavior during the simulation run and sensitivity analyses were conducted considering speed and flow as measures. The aim was to achieve the most natural behavior of pedestrians and cyclists. After many trials and simulation runs, the final calibrated parameters concerning pedestrians’ walking behavior were selected and they are presented in Table 2.
Table 2. Pedestrian walking behavior parameters.

<table>
<thead>
<tr>
<th>Pedestrian parameters</th>
<th>Default</th>
<th>Calibrated</th>
<th>Pedestrian parameters</th>
<th>Default</th>
<th>Calibrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>React to N</td>
<td>8</td>
<td>9</td>
<td>Dynamic potential</td>
<td>Not</td>
<td>Checked</td>
</tr>
<tr>
<td>Tau</td>
<td>0.4</td>
<td>0.4 (before and after peak) / 0.3 (peak hour)</td>
<td>Impact of dynamic potential</td>
<td>-</td>
<td>100% (before and after peak) / 15% (peak hour)</td>
</tr>
<tr>
<td>Lambda λ</td>
<td>0.176</td>
<td>0.2</td>
<td>AssocMean</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>VD</td>
<td>3</td>
<td>22</td>
<td>BsocMean</td>
<td>2.8</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Multiple successive simulation runs were realized for each examined time period. The average of their quantitative results was compared with the corresponding observed field data. The comparison between the simulated results and the original data set is essential in order to check the level of convergence between them and to validate the model. Achieving small discrepancies confirms the realistic depiction of the prevailing walking conditions in the software and ensures that the model is able to predict properly the behavior of pedestrians. The pedestrian flow and the pedestrian speed were used as validation parameters. The GEH values for modeled and observed results were found around 1 or less for the periods “before, during and after the peak”. These values were much less than 5 which shows that the models are significant (TRB, 2014). All the discrepancies of the modeled and observed measurement results were less than 10%.

Table 3 and Table 4 presents the indices that the micro-modeling of this study produced. Thus, an objective estimation of the walking conditions in the study area can be created for the three periods. It is clear that early in the afternoon and late at night, meaning before and after the peak hour respectively, the measured pedestrian level of service is excellent, and the density is low. During these periods of the day, pedestrian and bicycle flow is free with a stable speed profile and without many conflicts among the users. During the peak hour, the increased flow leads to increased average density as well as lower speeds. The density is more than tripled in relation to the other periods, however it is still in the limits of the first rate of the level of service scale (A-F). Although it is measured as LOS A for the study area as a whole, it is found that at the bottlenecks where the effective width is very limited, the level of service degrades for two rates and becomes LOS C with a significantly increased average density. Generally, during the peak, pedestrians were able to develop their desired speed and had enough space to avoid other users. At the bottlenecks, the possibility for conflicts among the users was higher.

Table 3. Quantitative simulated results for the evaluation of LOS of Palia Paralia.

<table>
<thead>
<tr>
<th>Period</th>
<th>Average density [pedestrians/m²]</th>
<th>Level of Service</th>
<th>Color display in Viswalk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before the peak</td>
<td>0.04</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>During the peak</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Whole study area</td>
<td>0.14</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>- Bottlenecks of the study area</td>
<td>0.31</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>After the peak</td>
<td>0.05</td>
<td>A</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Simulated results for the average speed of the different categories of pedestrians and bicycles.

<table>
<thead>
<tr>
<th>Average speed [m/s]</th>
<th>Before the peak</th>
<th>During the peak</th>
<th>After the peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average pedestrian speed – individuals</td>
<td>1.32</td>
<td>1.13</td>
<td>1.34</td>
</tr>
<tr>
<td>Average pedestrian speed – groups</td>
<td>1.22</td>
<td>0.91</td>
<td>1.06</td>
</tr>
<tr>
<td>Average pedestrian speed – runners</td>
<td>3.09</td>
<td>2.75</td>
<td>2.93</td>
</tr>
<tr>
<td>Average bicycle speed</td>
<td>6.34</td>
<td>4.09</td>
<td>4.77</td>
</tr>
</tbody>
</table>
4. Pedestrians’ perceptions

This section seeks to understand the perceptions of pedestrians about the environment of the coastal front and to identify any differences with the results of the simulation. For this reason, the 150 questionnaires completed in the Palia Paralia, that is to say the simulation section, were initially used. The Palia Paralia sample is well distributed in terms of gender, with 53.3% male and 47.7% female. However, it does not exist the same for age, as about 85% of the respondents are younger than 40 years old. Regarding trip purpose, 91% of the respondents use the coastal front for leisure and recreation. Respondents were asked to state whether they feel comfortable and safe when walking on Palia Paralia. Although the simulation results find out an extremely good level of service, from the questionnaire survey it is found that 38% of the respondents feel unsafe and 45% of them uncomfortable. Of a number of factors reported to respondents as potential causes of unsafety and limited comfort, the most important problem according to the pedestrians is the large number of conflicts with bicycles. It is therefore understood that the interaction of pedestrians and cyclists is extremely important and should be taken into account when determining the objective level of service. The inadequate geometry was also found to be a crucial issue for the users. As a result, one of the most important improvements that the respondents expect is the widening of the effective space available for pedestrian movement. Also, the overwhelming majority of pedestrians (98%) prefer the segregated type of infrastructure between cyclists and pedestrians (as it is today on the coastal front), rather than the mixed type of infrastructure. Pedestrians’ preference for segregated infrastructures has been also found in previous studies (Delaney et al., 2016; Nikiforiadis and Basbas, 2019).

In addition, for the Palia Paralia database, possible correlations between the characteristics of the pedestrians and their perceptions were investigated. From the statistical tests applied, statistically significant correlation was found only in two cases. It has been found that the impact of conflicts with bicycles and the lack of resting areas on the comfort and safety of pedestrians varies based on age. In particular, the elderly are more annoyed by the conflicts with bicycles (p-value < 0.05) and they are more affected by the lack of resting areas (p-value < 0.05). Recognition of the needs of specific groups of pedestrians (e.g. the elderly) is of great importance and in many cases is ignored during the simulation process.

The perceptions of the pedestrians on Palia Paralia are compared with those of the pedestrians in Nea Paralia, in order to investigate whether the upgraded environment and the larger effective width of Nea Paralia affects the perceptions. Using the appropriate statistical tests, it has been found that pedestrians in Nea Paralia perceive considerably better comfort and safety (p-value < 0.001) as well as adequate geometry (p-value < 0.001) (see also Fig. 2). On the other hand, no statistically significant difference found for the “conflicts with bicycles” variable, indicating that a problematic coexistence between cyclists and pedestrians also exists in Nea Paralia, despite the improved geometry.

![Fig. 2. (a) Assessment of comfort and safety in Nea Paralia and Palia Paralia; (b) Assessment of the effect of inadequate geometry in pedestrians’ perception about comfort and safety in Nea Paralia and Palia Paralia.](image-url)
5. Conclusions

In the frame of this paper, PTV Viswalk microsimulation software was used to calculate the objective pedestrian level of service based on quantitative factors and, at the same time, face to face questionnaires were completed to reveal the subjective pedestrians’ perception based on, mainly, qualitative factors. The aim was to evaluate the pedestrian level of service and to compare it with the users’ perceptions. The purpose of this comparison was to identify possible differences and additional points that need to be taken into account in the process.

The level of service for the three periods “before, during and after the peak” is measured as excellent for the whole study area of this paper, even though during the peak the density is more than tripled in relation to the other two examined periods. However, at the existing bottlenecks along the study area the level of service deteriorates to C during the peak hour, due to the limited effective width and the increased flow rates. The results of the analysis show that pedestrians perceive the prevailing conditions in a different manner compared to the level of service that emerges through the microsimulation software. Despite the fact that the calculated results, which are based on quantitative indicators, find out a very good level of service, a significant percentage of respondents feel uncomfortable (38%) and almost half of them feel unsafe for the same infrastructure (45%). The conflicts with cyclists and the inadequate geometry are the two most crucial issues identified. In addition, pedestrians’ perception is found to be affected by their age. More specifically, the impact of qualitative factors like pedestrian-bicycle coexistence and lack of resting areas affect more the elderly in relation to the younger users.

The abovementioned results indicate the importance of taking pedestrians’ perceptions into account when designing a pedestrian or/and a shared-use infrastructure. It can be concluded that the calculated and perceived assessment should be combined in order to achieve a truly reliable evaluation of the quality of services provided. Also, the interaction between pedestrians and cyclists, as well as the different needs of specific groups of users are two important aspects and they should be integrated in the process of assessing the objective level of service. Transport planners and decision makers should be particularly careful and pay more attention in pedestrians’ comfort and safety feeling in order to promote walking as a preferred transport mode.

This paper has two limitations, which will be further investigated in the future: a) the impact of cycling in pedestrians’ objective LOS was not examined adequately, b) the period of realization of the field measurements does not coincide with the seasons when there are the highest flows on Palia Paralia and consequently when the most significant problems are identified.

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