PEDESTRIAN AND CAR DRIVERS' ROAD SAFETY AUDIT IN URBAN ARTERIALS: CASE STUDY "CITY OF VOLOS"

Athanasios Galanis, Department of Civil Engineering, University of Thessaly, Volos, Greece, atgalanis@uth.gr, atgalanis@yahoo.gr

Nikolaos Eliou, Department of Civil Engineering, University of Thessaly, Volos, Greece, neliou@uth.gr

ABSTRACT

Improving the pedestrian walking safety and convenience is an important issue for the promotion of walking as a sustainable transport mode in urban areas. Furthermore, the pedestrian – vehicle drivers' interaction is related with the level of service of the pedestrian urban environment. In this paper, we audited the pedestrians' walkability in the city of Volos, which is a typical medium scale Greek city. The study took place in "Iasonos street", an urban arterial, 860m long, located in the center of the city, during normal traffic flow conditions. The methodology of the walkability audit consisted of four steps. In the first step of the auditing procedure, was the selection and training of the auditors' team. In the second step, the auditors selected data of the existing pedestrian infrastructure of the street and created a detailed drawing. In the third step, the auditors implemented a checklist in the selected road segments and crosswalks of the street. In the fourth step, the auditors counted the pedestrians traffic flow and walking behavior, especially their illegal one walking across the street or midblock crossing the street out of crosswalk. After the data collection and the checklist implementation, the results of specific indicators of the pedestrian infrastructure are presented. The auditors finally graded specific characteristics of a walkable road segment and intersection in terms of walking convenience, road safety, personal safety and aesthetics.

Keywords: Pedestrians, checklist, safety audit, walkability, road segments, crosswalks

INTRODUCTION

Walking as a mode of travel

Walking is a major mode of transportation in urban areas. Trips made primarily by walking are "utilitarian" (destination focused), including travel made for work, education and shopping purposes. There are also non utilitarian walking trips for recreational reasons. Walking is an important connector between different travel modes. While some trips are made entirely by walking, others may involve walking as only one component of a trip, such as walking to catch a bus to school or walking from home to the car on the way to work. Walking trips to transit or between modes are typically not counted as walking trips, but are included in part of trips made by other modes. Consequently, there is a need to accommodate pedestrians safely, providing access and mobility at all types of transportation facilities.

Factors that influence the decision to walk

In urban trips, the decision to walk depends on many factors. Shay et al (2003) refer that the key factors to consider toward the goal of increasing walking and other non-motorized travel among the general population can be split broadly into the two realms of opportunity and motivation. The former includes aspects and features of the built and natural environment – real or perceived – that provide the setting for safe, comfortable and convenient walking for various purposes. Motivation to walk depends on personal and household characteristics, such as age, health status, profession, education and life cycle, as well as from habits, attitudes and preferences. Only in the presence of opportunity do the motivational factors become relevant. Both opportunity and motivation are important to promote walking activity. The decision to walk is based on a complex interaction of factors, including some of the following (Bradshaw, 2000; Hamilton, 2000; Gehl, 1999; Forward, 1998):

1. Distance and access to desired destinations
2. Safety (road and personal)
3. Comfort and convenience
4. Value of time
5. Health
6. Weather

Barriers to walking

Some issues that may discourage people from walking are the following:

1. Physical barriers: These consist of unprotected street crossings, lengthy crossings, interchanges, partial or nonexistent walking paths, poor quality walking surfaces, non existent or inappropriate crossing treatments and high speed traffic.
2. Social and perceptual barriers: These include a perception that motorists disregard or are uniformed of pedestrian rights, that walking is a risk to personal safety or that there is insufficient time to make a walking trip.
3. Organizational barriers: These make walking more difficult by affecting decisions that influence the ease of a walk, including land use patterns that result in long trip distances, greater priority given to other modes (such as intersections) and lack of recognition of the importance of providing pedestrian facilities.

Pedestrian characteristics

Pedestrian cannot be confronted as a homogenous group. They have a wide range of characteristics and needs, such as walking speed, spatial needs, mobility issues and cognitive abilities. Pedestrian age is an important factor in their ability to walk. Sharples and Fletcher (2000) found that the pedestrian behaviour crossing the street differs according to their sex and age. Citizens with lower income are more possible to walk. Furthermore, children from lower income families are more possible to engage in a road accident (Bly et al, 1999). Facilities for a "typical" pedestrian may not accommodate a significant portion of users, including older adults, children and people with disabilities. In order to design and audit the pedestrian facilities, it is important to understand the characteristics of the full range of the population:

1. Walking speed
2. Spatial needs
3. Mobility
4. Vision
5. Cognitive ability
6. Crossing choices and waiting times

Pedestrian road safety

Intersections

In urban areas, limited pedestrian safety is located in conflict points. Such sites are the intersections, where pedestrians need to cross the street facing the incoming traffic. There are some intersection characteristics that mainly impact pedestrian road safety. Pedestrian volume or pedestrian exposure has been found by several studies to be one of the most influential factors in pedestrian crashes (Zegeer et al. 1985, 2005). Traffic volume has also been found to be a major contributing factor to pedestrian crashes. Zegeer et al. (1985) found that traffic volume was the second most important factor in explaining pedestrian crashes. Studies by Brude and Larsson (1993) and Zegeer et al. (2005), also found that the number of incoming vehicles per day at intersections was a significant and positive variable in predicting pedestrian crashes. Crossing width is also an important factor in pedestrian road safety. Narrowing the crossing width has positive effect on pedestrian safety (Davies, 1999). Elvik and Vaa (2004) found that raised pedestrian crosswalks appear to reduce pedestrian accidents. The effect of crosswalk marking on pedestrian safety is ambiguous. Zegeer et al (2005) found that on two lane roads, the presence of a marked crosswalk alone at an uncontrolled location was associated with no difference in pedestrian crash rate, compared to unmarked crosswalk. Further, on multilane roads with traffic volumes above 12.000 vehicles a day, having a marked crosswalk alone (without other substantial improvements) was associated with a higher pedestrian crash rate (after controlling for other site factors) compared to an unmarked crosswalk. Crosswalk illumination can impact pedestrian safety. According to Campbell et al. (2004), there was a significant decrease in nighttime pedestrian crashes before and after the installation of crosswalk illumination. The median refuge island is uncertain whether impacts pedestrian safety. Zegeer et al (2005) found that the presence of a raised median or refuge island was associated with a significantly lower rate of pedestrian crashes on multi-lane roads (compared to no median or refuge islands). This was true both at marked and at unmarked crosswalks. According to Lalani (1977), refuges reduced vehicle crash frequency but increased pedestrian accident frequency at intersections. Pedestrian signal timing is also an important factor in pedestrian road safety. Zaidel and Hocherman (1987) found higher rates of pedestrian crashes at intersections with higher pedestrian and vehicle volumes, as well as more complex intersections (i.e., the most legs or potential points of conflict). The type of signal timing provided for pedestrians had only a slight effect on pedestrian crashes and no effect on vehicle injury crashes, especially where vehicle volumes were low (less than 18.000 ADT). Intersections with exclusive phases for pedestrians had fewer crashes where vehicle and pedestrian volumes were higher. According to Eliou and Galanis (2009) 90% of the car drivers do not give right of way to pedestrians in crosswalks, where pedestrians cross the street with green flashing beacon and car drivers turn right or left with orange flashing beacon, raising the pedestrian risk.

Road segments

In urban areas, pedestrian activity is also taken place in road segments. Pedestrians usually walk along roadway or cross the street in midblock areas. There are some roadway characteristics that impact the pedestrian safety. Presence of sidewalks is a main factor of pedestrian road safety. According to McMahon et al. (2002) and Tobey et al. (1983) sidewalks and walkways can reduce pedestrian crashes, especially "walking along roadway" crashes. In midblock crosswalks, Campbell et al (2004) found that illuminated crosswalk sign showed no benefit to pedestrian crashes. Examining also the installation of pedestrian overpasses at 31 locations in Tokyo, Japan, there was a reduction seen in the occurrence of crashes related to pedestrian crossing events, as well as a greater reduction of day time over nighttime pedestrian crashes. Medians and pedestrian refuges can impact pedestrian safety. Bacquire et al (2001) concluded that overall safety was not helped by the installation of raised pedestrian refuge islands. Cairney (1999) concluded that a study of the crash history of the whole street where pedestrian refuges have been installed would be necessary to determine whether there had been a reduction in pedestrian crashes.

Auditing the urban road environment for pedestrian activity

Studies of the urban road environment and pedestrian activity have evolved over the last years. Early research focused on compliance with supervised exercise programs in relation to proximity to facilities (Dishman, 1982). The next generation of studies examined the impact of the community environment on leisure physical activity in various populations (Sallis et al, 1992). In the same period of time, transportation and city planning researchers were studying the relationship of land-use patterns to walking for transportation, using both survey and GIS measures (Handy et al., 2002). Recently, have been developed better measures of the urban environment. Furthermore, physical activity surveys have become more comprehensive, allowing assessment of walking for both recreational and transportation purposes (Saelens et al., 2003; Hoehner et al., 2005). In order to understand better the impact of the urban environment on pedestrian activity (walkability), it is essential to develop high-quality measures (Sallis et al., 2000). There are three categories of urban environment measures:

1. Interview or self-administered questionnaires (surveys). These measures examine the extent to which individuals perceive access and barriers to various elements of recreation, land use and transportation environment.
2. Systematic observation (audits), to quality objectively and unobtrusively attributes of the urban environment.
3. Data from archival (existing) data sets layered and analyzed with GIS.

Observational measures (audits)

Audit tools allow systematic observation of the urban environment, including the presence and qualities of features hypothesized to affect pedestrian activity (e.g. street pattern, number and quality of public spaces, sidewalk quality). Many characteristics of the urban environment can be measured without direct observation, using existing data, such as GIS or aerial photos. Such "remote" methods may be less labour intensive and therefore less time consuming. Researchers, use audit tools to collect primary data on physical features that are not commonly incorporated into GIS databases (e.g. street trees, sidewalk width). Audit tools are also used to measure physical features that are better assessed through direct observation (e.g. architectural character, landscape maintenance). Not all audit tools are intended for research purposes. Some of them are developed to support local decision making. Such tools engage community members in collecting data that will be used to better understand the needs and opportunities for changing the pedestrian environment in their community. Tools designed for community use are less detailed than those designed for research purposes. Audit tools typically require in-person observation for collecting data, as opposed to videotaping or other methods (Ewing et al, 2006). Researchers walk or drive through a neighbourhood, park or trail, systematic coding characteristics using definitions and a standardized form. For assessing features of the urban environment, street segment is a typical unit of observation. Road segments typically comprise two facing sides of one street block. The audit tool is usually a paper containing close-ended questions (e.g. check boxes, Likert scales) or open-ended questions or comments. Segments are typically sampled because it is not very easy to audit entire neighbourhoods. Sampling is either random or purposeful. Purposeful sampling ensures that rare but important features of the environment, such as parks or corner stores are included. Segments of trails and areas within parks can also be units of observation.

Researchers have developed several audit tools in recent years. Some of the most important are the following:

1. PEDS: Pedestrian Environmental Data Scan (Clifton et al., 2006)
2. SPACES: Systematic Pedestrian and Cycling Environmental Scan (Pikora et al., 2002)

3. I-M Inventory: Irvine Minnesota Inventory (Boarnet et al., 2006a,b)
4. SLU Analytic Audit Tool (Brownson et al., 2004)

Most audit instruments include one or more measures of: land use (e.g. presence and type of housing, retail); streets and traffic (e.g. traffic volume, presence of traffic calming); sidewalks (e.g. presence and continuity of sidewalks); bicycle facilities (e.g. presence of bike lanes); public space/amenities (e.g. presence of street furniture or benches); architecture or building characteristics (e.g. building height); parking/driveways (e.g. presence of parking garages); maintenance (e.g. presence of litter); and indicators related to safety (e.g. presence of graffiti).

In audit instruments, reliability is an important factor. Inter-observer reliability is the primary form of reliability assessed, although test-retest reliability is relevant for assessing stability of observed features. Audit tools that report reliability by item or domain, measures of physical disorder/tidiness/safety-related features tend to be less reliable, compared to measures such as land use and street characteristics.

In person observation is time consuming. Researchers must select sites, define and sample segments within sites, train and monitor observers, collect data and analyze them. Estimates of time required for data collection vary depending on the number of items observed and the type of urban environment (mixed use or residential). Audit tools have recently been developed using personal digital assistant (PDA) devices, such as Palm Pilots, or personal computers (PCs) for data collection. Tools that involve electronic data input save time for data entry. Among audit tools that use paper forms, some have one-page format, which may be easier to manipulate in field.

Relevant skills that are needed for observing the urban road environment include some knowledge of the content area, as well as the ability to carry out the technical methods of the observation. Typically, observers are undergraduate or graduate research assistants from various fields, who are trained to observe detailed features of the urban environment. Often recommended is the combination of classroom and field training. Because many terms and concepts are likely to be unfamiliar to observers, the manual and training must provide clear definitions. Observers should be well trained and inter-observer reliability should be high in order to ensure quality of measures of the study.

METHODOLOGY

Study area

The study area was a main urban arterial in the city of Volos, named "Iasonos St", 860m long (figures 1, 2). The street is parallel to the city's port, allowing traffic flow to pass though the center of the city. Auditing this street was a great temptation as it is consider being a high walkable one. This road is a typical urban arterial located in the center of a typical middle scale Greek city full of shops, banks, public and private sector businesses. Furthermore, this street is considered as a case study itself in a larger scale study auditing the walkability level of selected streets in the city of Volos, conducted from the University of Thessaly (UTh) and the Department of Civil Engineering.

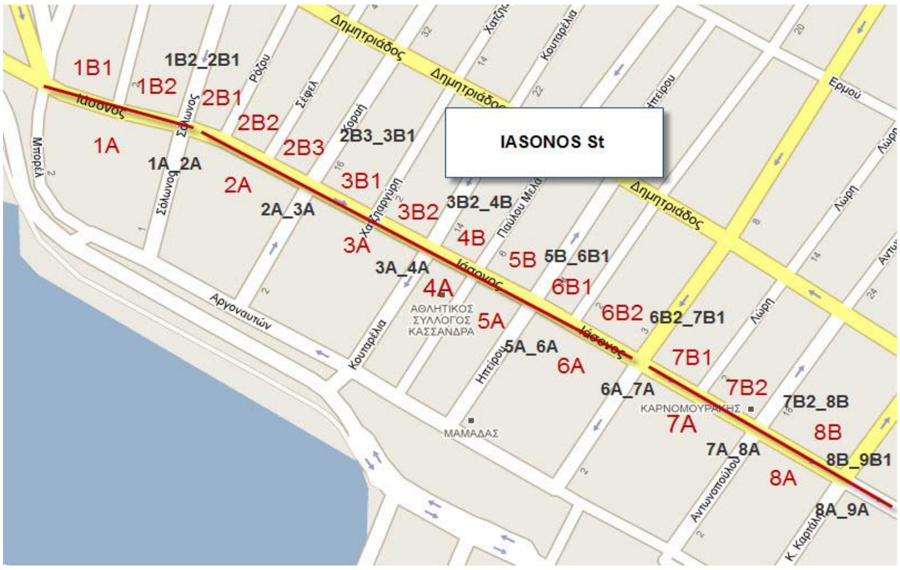

Figure 1 – Study Area, "Iasonos St", Part A

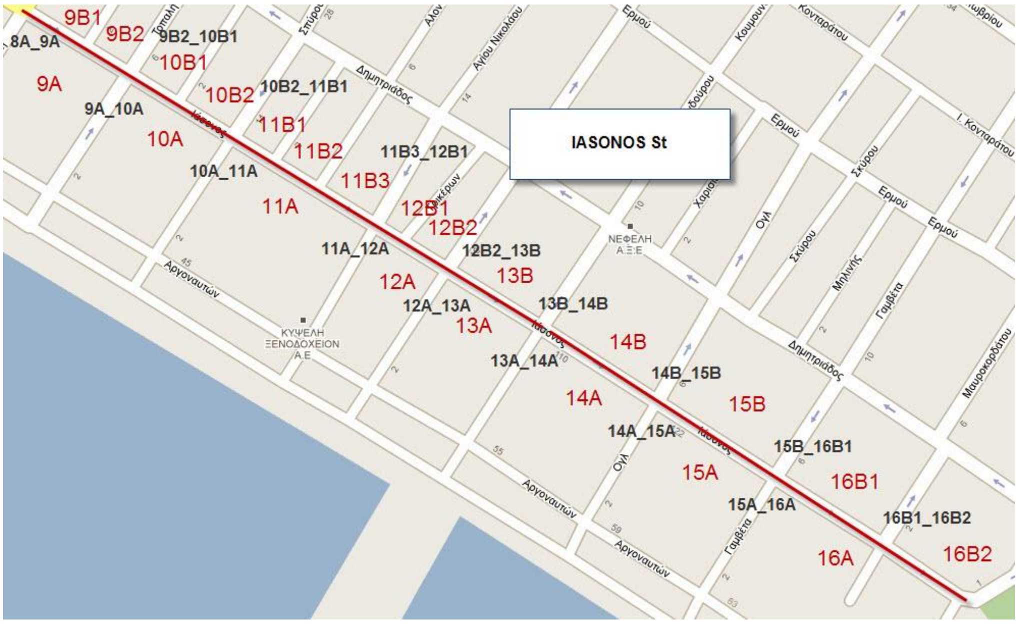

Figure 2 – Study Area, "Iasonos St", Part B

Audit tool: Checklist

The target of the study was to evaluate the pedestrians' road safety and walkability across the pedestrians' desire line in both sides of the street and their conflicts with vehicles' drivers. In order to achieve that goal, the study implemented a proper checklist in the selected road. The checklist consisted of two parts: the road segments one (23 questions) and the intersections one (14 questions regarding the crosswalks). In order to implement the checklist was important the identification of each road segment and intersection with a unique code (figures 1, 2). The street was separated in two sides: "Side A" (the right one according to the vehicles flow heading) and "Side B" (the left one). The side A consisted of 16 road segments (1A – 16A). The side B consisted of 16 main road segments and more sub segments leading to a total number of 28 ones (1B1 – 16B2). Except the road segments, the crosswalks were also identified as e.g. "1A_2A" from the road segments name they connected.

An important issue in the conduction of the study was the selection of the auditors and their training on the implementation of the checklist. Three auditors, one PhD student (leader) and two other university students participated. The leader of the team explained every question of the checklist and the overall goal of the study to the other two auditors. This training procedure took no more than two hours. After that, the team was able to conduct the audit procedure in the field.

Before the final conduction of the study, the auditors inspected the street conducting a pilot implementation of the checklist in one typical road segment and one typical crosswalk. The target of this process was the auditors to become more familiar with the procedure. The auditors quickly understood the procedure and the implementation of the checklist.

Data collection: Street topography

One part of the data collection was the topographic charting of the street pedestrian infrastructure in a drawing format. The auditors' team visited the street in Sunday morning when the pedestrians' activity was limited in order to take data like the dimensions of the sidewalks, crosswalks, signs, signals, trees and the rest of street furniture. Furthermore, the absence of activity helped the auditors to take clear pictures of the road infrastructure and permanent obstacles for the pedestrians' movement. It is important to mention that the methodology of the study aimed to describe the permanent obstacles of the pedestrians' movement into the drawing and the mobile ones into the checklist. After the data collection, the auditors' team created a drawing of the street pedestrian infrastructure using the Autocad software, being able to counter specific indicators as will be following presented.

Checklist implementation

After the pedestrian infrastructure data collection, the auditors continued with the checklist implementation. The auditors' team used the following tools:

- Street map with identification codes of the street urban segments and crosswalks.
- Checklist forms
- Pencils, pens
- Camera

The checklist implementation took place during peak hours 10:00 – 14:00 under good weather and normal traffic conditions. The three auditors walked together across the street, answering separately the checklist for each road segment and crosswalk, as they were previously identified. The aim of the checklist implementation was to achieve a quickly assessment of the pedestrian urban infrastructure.

In table 1, the results of the checklist implementation are presented. In side A, there are 16 road segments and in the side B, 28 ones. In the "yes" column the average of the "yes" answers of the three auditors is presented and in the right column the rate of the "yes" answers of each characteristic. In the checklist question No 1 (table 1) we concluded that the main activities in the street were business, offices, services and also houses. The results verify the character of the street as a central arterial of the city. Examining the pedestrian infrastructure we concluded that in both sides of the street existed sidewalk for the pedestrians' movement. This was the first sign of the walkability level of a street and Iasonos St as a high walkable one in this sector. The location of the sidewalk was next to the road, which is not positive for the pedestrians' road safety as they walk very close to the vehicles' traffic. In every road segment for both sides of the street the sidewalks' slope and grade were flat or gentle. Furthermore, the sidewalks' surface was made of concrete slabs. The sidewalks' condition and smoothness was good in all road segments and also continuous without braking points that force the pedestrians to walk in the street. So far (checklist questions 2-7, table 1) we concluded that the urban infrastructure is sufficient for the pedestrians' movement.

In question 8, we examined the obstacles on the pedestrians' desire line. It was a critical question because it could give us a first indication of the walking convenience of the pedestrians' path. In side A, there were permanent obstacles in 31% and mobile obstacles in 38% of the road segments. In side B, there were permanent obstacles in 18% and mobile obstacles in 25% of the road segments. In question 9, we examined the presence of road furniture in the sidewalks. In side A there were traffic signs, signals, lighting poles and trees in all road segments. On the contrary, in side B there were traffic signs and signals only in 25% of the road segments, but trees in all of them.

The traffic flow across the street was one way, with two traffic lanes available. The auditors counted the pedestrians' traffic flow for every road segment and crosswalk of the street for a time period of 15 min as far as their illegal walking behaviour. In the checklist question 12 (table 1) the average pedestrian flow which is almost the same for the two sides of the street is presented. It was a clear indication that there were not important factors that force the pedestrians to choose a side of the street in order to walk. Furthermore, their illegal behaviour was limited, as only the 5% walked across the street and 10% crossed the street from midblock out of the crosswalks.

In all the road segments for both sides of the street there was a vehicles' parking restriction. Nevertheless, in 90% of side A and in 10% of side B of the road segments the auditors noticed parked vehicles. In side A, in all the road segments and in side B, only in 7% of them, there were motorcycles parked on the sidewalk hampering pedestrians' movement. Bicycles were locked on trees or traffic poles in 50% of the road segments in side A and in 10% in side B. As a result, more mobile obstacles existed in side A than in side B. In side A there were also driveways in 25% of the road segments comparing to none in side B. This results as a safer walking path in the side B.

In both sides and all road segments of the street, the auditors noticed that there were trees of medium size that were aligned in order not to hamper pedestrians' movement either horizontally or vertically. Referring to the weather protection, in both sides the auditors concluded that trees cannot protect pedestrians but only the building facades. In the side A, there are street lighting poles in all road segments, but in side B only in 18% of the road segments. On the contrary, street lighting from the buildings was available. Examining the aesthetics of the street, the auditors noticed that there was no garbage in the sidewalks, but only graffiti in one road segment. Furthermore, the auditors did not notice any dangerous people or dogs in the street, improving the feeling of personal safety.

Table 1 – Checklist results (road segments)

Iasonos St		Side A		Side B	
Characteristics		Yes	Rate	Yes	Rate
	Road Segments	16		28	
1	Land Use				
	Housing	6	0,38	20	0,71
	Business - Office	16	1,00	26	0,93
	Educational	3	0,19	1	0,04
	Service	9	0,56	12	0,43
	Empty buildings	1	0,06	1	0,04
	Petrol stations	1	0,06	0	0,00
	Else	0	0,00	0	0,00
2	Pedestrian infrastructure				
	No sidewalk	0	0,00	0	0,00
	Sidewalk	16	1,00	28	1,00
	Footpath	0	0,00	0	0,00
	Shared path	0	0,00	0	0,00
3	Path location				
	Next to the road	16	1,00	28	1,00
	Within 1m of kerb	0	0,00	0	0,00
	Between 1-2m of kerb	0	0,00	0	0,00
	More than 2m from kerb	0	0,00	0	0,00
4	Path slope				
4a	<u>Slope</u>	0	0,00	0	0,00
	Flat or gentle slope (1-2%)	16	1,00	28	1,00
	Moderate slope (3-4%)	0	0,00	0	0,00
	Steep slope (>5%)	0	0,00	0	0,00
4b	<u>Grade</u>	0	0,00	0	0,00
	Flat or gentle grade (1-2%)	16	1,00	28	1,00
	Moderate grade (3-4%)	0	0,00	0	0,00
	Steep grade (>5%)	0	0,00	0	0,00
5	Path material				
	Earth, grass	0	0,00	0	0,00

	Continuous concrete	0	0,00	0	0,00
	Concrete slabs	16	1,00	28	1,00
	Bricks	0	0,00	0	0,00
	Under repair	0	0,00	0	0,00
	Else	0	0,00	0	0,00
6	Path condition & smoothness				
	Poor (lot of cracks & holes)	0	0,00	0	0,00
	Moderate (some cracks & holes)	0	0,00	0	0,00
	Good (very few cracks & holes)	16	1,00	28	1,00
7	Sidewalk continuous				
	Continuous sidewalk	16	1,00	28	1,00
	Non continuous sidewalk	0	0,00	0	0,00
8	Obstacles in the pedestrians' desire line				
	Permanent obstacles	5	0,31	5	0,18
	Mobile obstacles	6	0,38	7	0,25
	No obstacles	6	0,38	16	0,57
9	Street furniture on pedestrians' path				
	Traffic sign, signal pole	16	1,00	7	0,25
	Street lighting pole	16	1,00	5	0,18
	Trees	16	1,00	28	1,00
	Bench	0	0,00	0	0,00
	Litter basket	9	0,56	12	0,43
	Bus stop with shelter	3	0,19	0	0,00
	Bus stop only with sign	0	0,00	0	0,00
	Kiosk	3	0,19	0	0,00
	Else	1	0,06	0	0,00
	None	0	0,00	0	0,00
10	Traffic heading				
	One way direction	16	1,00	28	1,00
	Two way direction	0	0,00	0	0,00
11	Traffic lanes				
	1 lane	0	0,00	0	0,00
	2 lanes	16	1,00	28	1,00
	>4 lanes	0	0,00	0	0,00
12	Pedestrian flow - 15min				
	Pedestrians walking across the sidewalk - path	45	0,86	47	0,84
	Pedestrians walking across the street	2	0,05	3	0,05
	Pedestrians crossing the street from midblock	5	0,09	6	0,11
13	Traffic flow - 15min				
	Cars	183			
	Tracks - buses	9			
	Power two vehicles	37			
	Bicycles	13			
14	Vehicle parking condition				

	Parking restrictions	16	1,00	28	1,00
	Parking control	0	0,00	0	0,00
	Free parking	0	0,00	0	0,00
	Parking out of street	0	0,00	0	0,00
	Parking vehicles across the street kerb	14	0,88	3	0,11
	Parking vehicles on the sidewalk - path	0	0,00	0	0,00
15	Power two vehicles parking condition				
	Parking control area	0	0,00	0	0,00
	Parking vehicles across the street kerb	0	0,00	1	0,04
	Parking vehicles on the sidewalk - path	16	1,00	2	0,07
16	Bike parking condition				
	Bike locker or enclosure	0	0,00	0	0,00
	U rails	0	0,00	0	0,00
	Rack or stand	0	0,00	0	0,00
	None	16	1,00	28	1,00
	Parking bicycles on trees, poles etc	8	0,50	3	0,11
17	Driveways				
	Building parking driveways	4	0,25	0	0,00
	Building driveways (rest)	1	0,06	0	0,00
	None	12	0,75	0	0,00
18	Trees				
	Trees horizontal obstacle (free space < 1m)	0	0,00	0	0,00
	Trees vertical obstacle (free space < 2m)	0	0,00	0	0,00
19	Trees height				
	Small (<2m)	0	0,00	0	0,00
	Medium (2-3m)	16	1,00	28	1,00
	Large (>3m)	0	0,00	0	0,00
20	Weather protection (sun, rain)				
	Trees	0	0,00	0	0,00
	Building facades	15	0,94	24	0,86
	Else	0	0,00	0	0,00
	None	0	0,00	4	0,14
21	Street lighting				
	Street lighting poles	16	1,00	5	0,18
	Street lighting (buildings)	16	1,00	28	1,00
	None	0	0,00	0	0,00
22	Cleanliness				
	Litter	0	0,00	0	0,00
	Paper, glass	0	0,00	0	0,00
	Graffiti	1	0,06	0	0,00
	Else	1	0,06	0	0,00
23	Road users				
	Normal citizens	16	1,00	28	1,00
	Drop out, dangerous people	0	0,00	0	0,00
	Stray dogs	0	0,00	0	0,00

The second part of the checklist referred to the pedestrian crosswalks across the pedestrians' desire line in both sides of the street. In side A, the auditors examined 14 crosswalks and in side B, 15 ones. In side A, there were only two zebra crossings which were controlled with traffic signals. The crosswalks pavement material was asphalt in 57% of the crosswalks in side A and 67% in side B. In the rest crosswalks the pavement was made of bricks, which is a material that advises the drivers for the existence of a pedestrians' crosswalk. In both sides, the condition of the crosswalks surface in terms of smoothness and maintenance was good with very few cracks and holes. The surface coverage of the crossing lines was moderate (50%) and limited (50%) in side A and good (50%) and limited (50%) in side B. The 14 crosswalks in side A are equivalent to 28 corners and the 15 ones in side B are equivalent to 30 corners. In side A, in 4 corners the connection between sidewalks and crosswalks was made with kerbs and in the 24 corners with ramps or walkable kerbs. In side B, in 6 corners the connection was made with kerbs and in 24 ones with ramps or walkable kerbs. In side A, all the ramps were located across the pedestrians desire line, but in side B, only in 8 of them. The auditors checked the presence of obstacles in the corners. In side A, there were street lighting and sign poles only in 4 corners. They noticed the same in side B. Generally, there were not obstacles blocking pedestrians' movement in the corners of the crosswalks.

Auditing the pedestrians' road and personal safety during the night, the auditors noticed that the crosswalks were illuminated from street lighting poles and buildings. In side B, street lighting poles were present only in two crosswalks, and the rest ones were illuminated from street buildings. In all crosswalks the auditors noticed that the lighting covered the entire surface. In all corners, the pedestrians' sight of incoming traffic was good when they were standing on the sidewalk or in the street level of the crosswalk.

The auditors counted also the pedestrians' traffic flow and crossing behaviour for a time period of 15 minutes in the two signalized crosswalks for each side of the street. They noticed that 25% of the pedestrians crossed the street with red traffic light and 10% crossed outside the crosswalk lines. Furthermore, the drivers' behaviour of giving right of way to pedestrians was good or moderate.

Table 2 – Checklist results (intersections)

Iasonos St		Side A		Side B	
Observation point		Yes	Rate	Yes	Rate
Crosswalks		14		15	
1	Type of crossing				
	Zebra	2	0,14	2	0,13
	Traffic signal	2	0,14	2	0,13
	Median crossing	0	0,00	0	0,00
	Bridge/overpass	0	0,00	0	0,00
	Underpass	0	0,00	0	0,00
	None	12	0,86	13	0,87
2	Crossing control				
	Traffic signal - separate phase	2	0,14	2	0,13

	Traffic signal - one phase	0	0,00	0	0,00
	Pussbuttons	0	0,00	0	0,00
	Stop sign	2	0,14	5	0,33
	Priority sign	0	0,00	0	0,00
	Chicanes, chokers, kerb extensions	0	0,00	0	0,00
	Speed humps or ramps	0	0,00	0	0,00
	Roundabouts	0	0,00	0	0,00
	None	10	0,72	7	0,47
3	Crosswalk material				
	Asphalt	8	0,57	10	0,67
	Bricks	4	0,29	5	0,33
	Earth	0	0,00	0	0,00
	Else	2	0,14	0	0,00
4	Crosswalk condition & smoothness				
	Poor (lot of cracks & holes)	0	0,00	0	0,00
	Moderate (some cracks & holes)	0	0,00	0	0,00
	Good (very few cracks & holes)	14	1,00	15	1,00
5	Crosswalk surface lines cover				
	Good (>75% surface)	0	0,00	1	0,50
	Moderate (50%-75%)	1	0,50	0	0,00
	Limited (25%-50%)	1	0,50	1	0,50
	Bad (<25%)	0	0,00	0	0,00
6	Sidewalk - crosswalk connection	28		30	
	Kerb	4	0,14	6	0,20
	Ramp, walkable kerb	24	0,86	24	0,80
	None	0	0,00	0	0,00
7	Sidewalk - crosswalk continuity				
	Ramp across the pedestrian desire line from the sidewalk	24	0,86	8	0,27
	Ramp leading pedestrians inside crosswalk	0	0,00	0	0,00
8	Obstacles in the corner of sidewalk - crosswalk				
	Street lighting poles	4	0,14	4	0,13
	Sign poles	4	0,14	2	0,07
	Signal poles	0	0,00	0	0,00
	Litter basket	0	0,00	0	0,00
	Trees	0	0,00	0	0,00
	Parking vehicles	0	0,00	0	0,00
	Parking power two vehicles	0	0,00	0	0,00
	Else	0	0,00	0	0,00
	None	24	0,86	24	0,80
9	Lighting				
	Street lighting poles	14	1,00	2	0,13
	Building lighting	14	1,00	15	1,00
	None	0	0,00	0	0,00
	Lighting covering all crosswalk	14	1,00	15	1,00

	Lighting covering part of the crosswalk	0	0,00	0	0,00
10	Pedestrian sight from the waiting point on the corner				
	Good	28	1,00	30	1,00
	Moderate	0	0,00	0	0,00
	Limited	0	0,00	0	0,00
11	Pedestrian sight from the waiting point inside crosswalk				
	Good	28	1,00	30	1,00
	Moderate	0	0,00	0	0,00
	Limited	0	0,00	0	0,00
12	Pedestrian flow 15min - Traffic signal	2		2	
	Pedestrian crossing with green traffic signal - legal	10	0,72	11	0,78
	Pedestrian crossing with red traffic signal - illegal	4	0,28	3	0,22
	Pedestrian crossing inside crosswalk - legal	13	0,92	12	0,85
	Pedestrian crossing outside crosswalk - illegal	1	0,08	2	0,15
13	Pedestrian flow 15min - Traffic sign	0		0	
	Pedestrian crossing inside crosswalk - legal	0	0,00	0	0,00
	Pedestrian crossing outside crosswalk - illegal	0	0,00	0	0,00
	Pedestrians crossing in one move	0	0,00	0	0,00
	Pedestrian conflicts	0	0,00	0	0,00
14	Drivers behaviour				
14a	Drivers giving right of way to pedestrians	0	0,00	0	0,00
	Good	2	1,00	1	0,50
	Moderate	0	0,00	1	0,50
	Limited	0	0,00	0	0,00
14b	Vehicle drivers aggressive behaviour	0	0,00	0	0,00
	Power two vehicle drivers aggressive behaviour	0	0,00	0	0,00

RESULTS

Road segment indicators

Using data from the topographic charting of the street we calculated indicators for the road segments that are presented in figures 3 to 6. The first indicator (figure 3) was: "sidewalk surface". From the diagram we concluded that in side A there are less road segments than side B, leading to larger sidewalk surfaces. This indicator is more useful to compare the same number of road segments between two sides. The second indicator (figure 4) was: "min/max unobstructed sidewalk width". For each road segment we counted the sidewalk width where there was permanent street furniture or obstacles. It is a useful indicator as we can identify walking black spots in road segments. In side A, we counted that the index was equal to 0.35 – 0.20 in road segments 2, 5, 7, 11 and 12. In figure 6 we resulted that in these road segments there were bus stop shelters and kiosks minimizing the pedestrians' walking width. Same indications resulted for the side B, in road segments 3, 5 and 9. In figure 6, we resulted that in these road segments there were also bus stop shelters and kiosks. The third indicator (figure 5) was: "surface percentage of street furniture in sidewalk". In side A, the index reached its higher values in road segments 2, 5, 7 and 12 (0.10 – 0.20). In side B, the index reached its higher values in road segments 1, 3, 5 and 9. The fourth indicator was (figure 6): "surface percentage of street furniture except kiosks and bus stop shelters", in order to estimate the outlier influence of these factors.

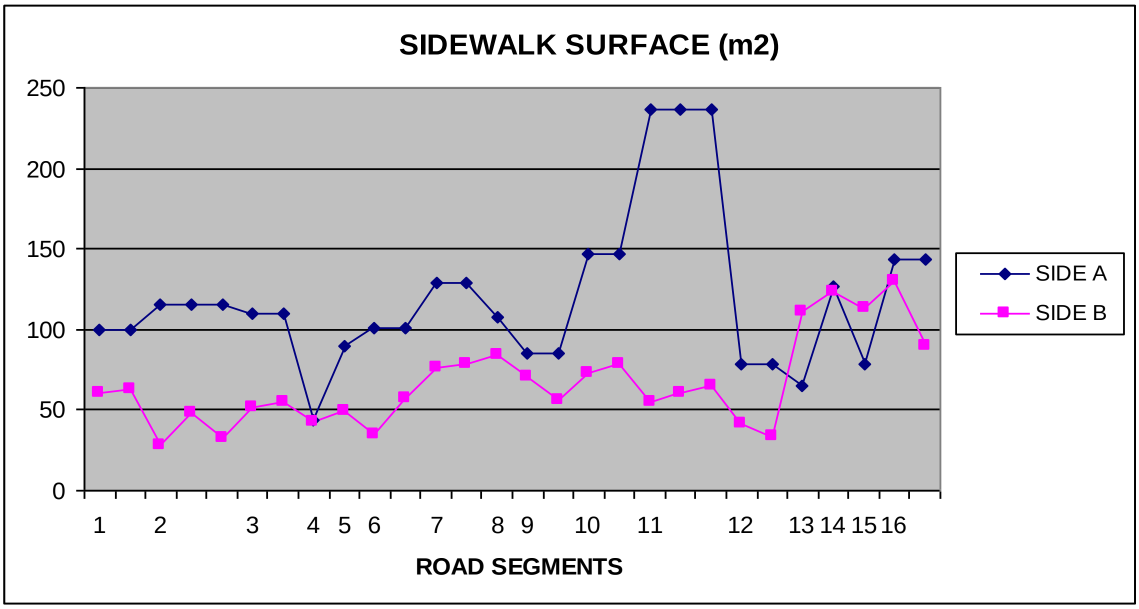

Figure 3 – Sidewalk surface (m2)

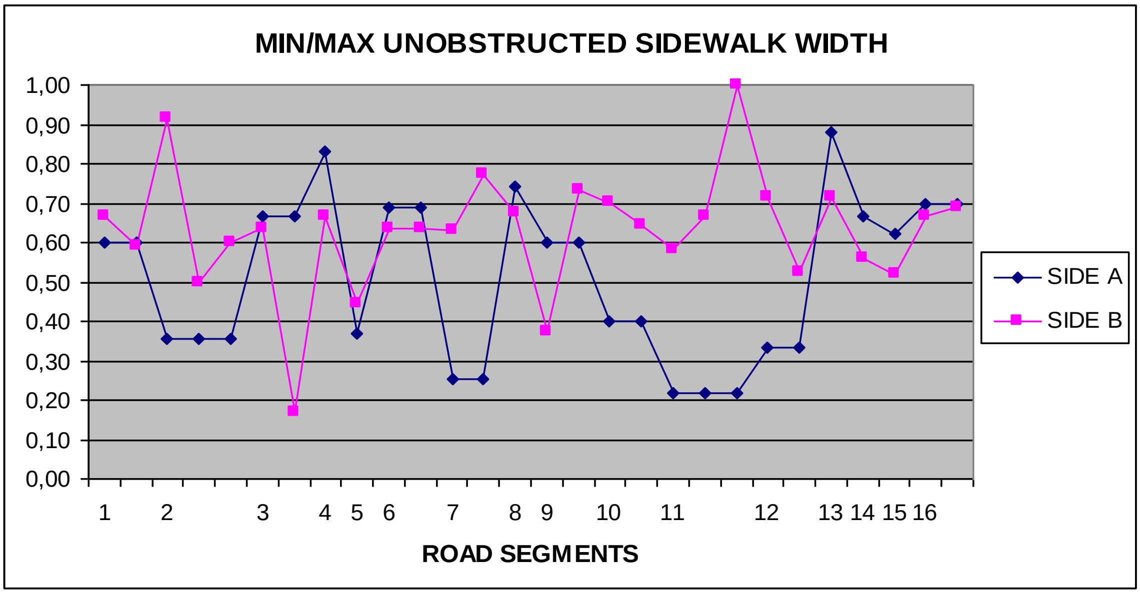

Figure 4 – Min/max unobstructed sidewalk width

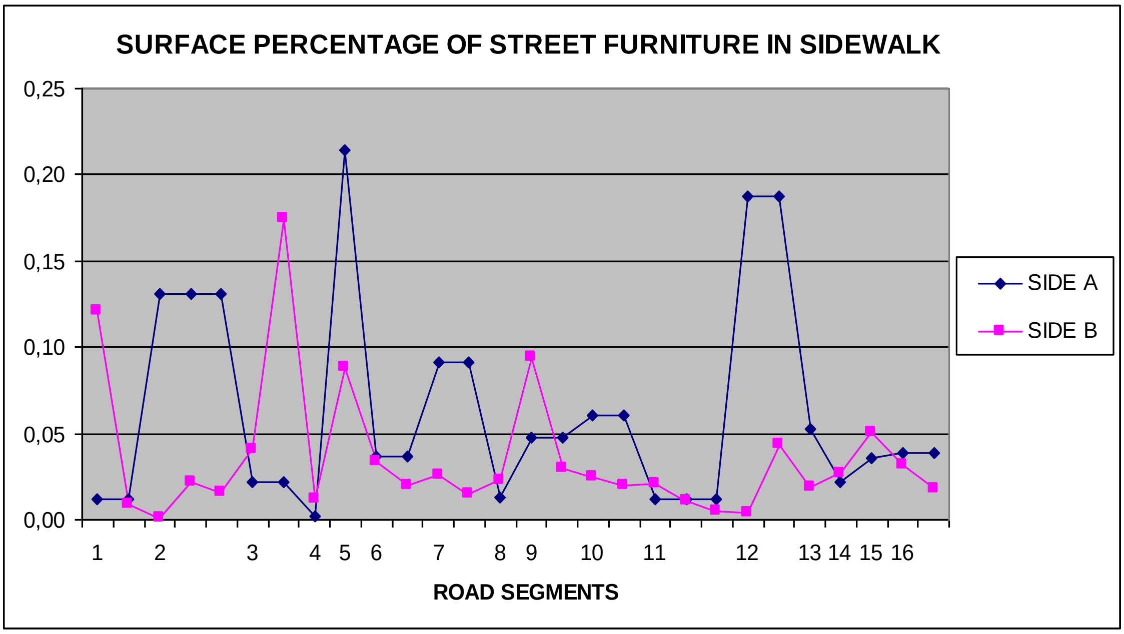

Figure 5 – Surface percentage of street furniture in sidewalk

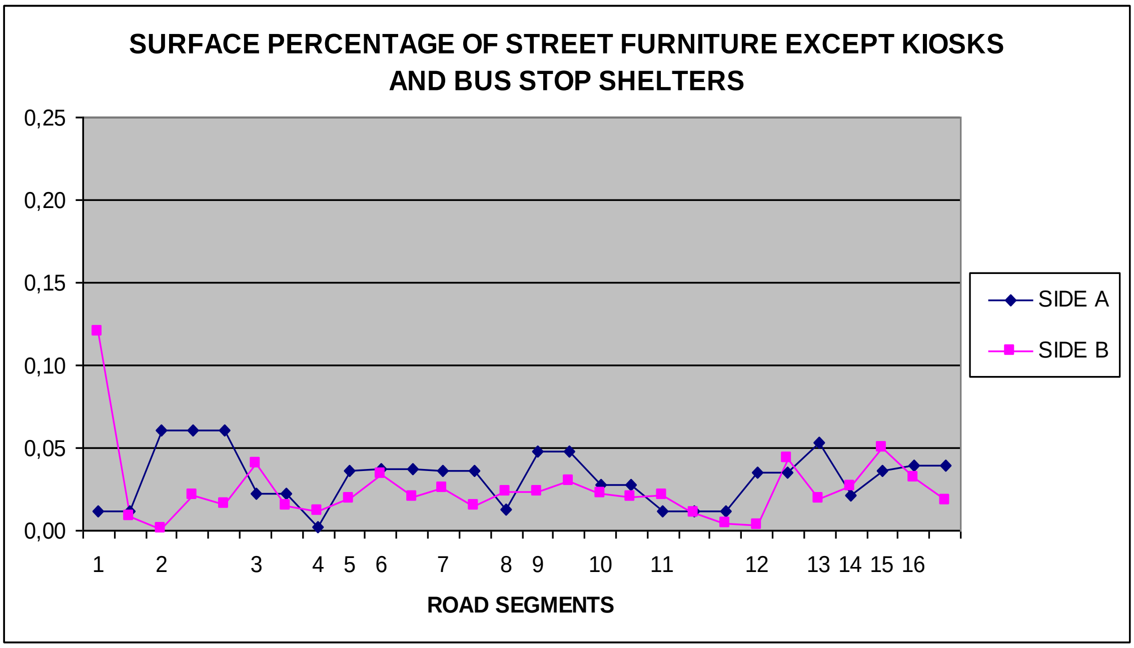

Figure 6 – Surface percentage of street furniture except kiosks and bus stop shelters

Crosswalk indicators

Using data from the topographic charting of the street we calculated indicators for the crosswalks that are presented in figures 7 and 8. The indicators were the following:

- Corner surface
- Street furniture surface
- Ramp surface

In both sides of the street, we concluded that in all corners the existence of a ramp covered a high percentage of the corners' surface. The contribution of street furniture like traffic signs, signals and street lighting poles was almost close to zero.

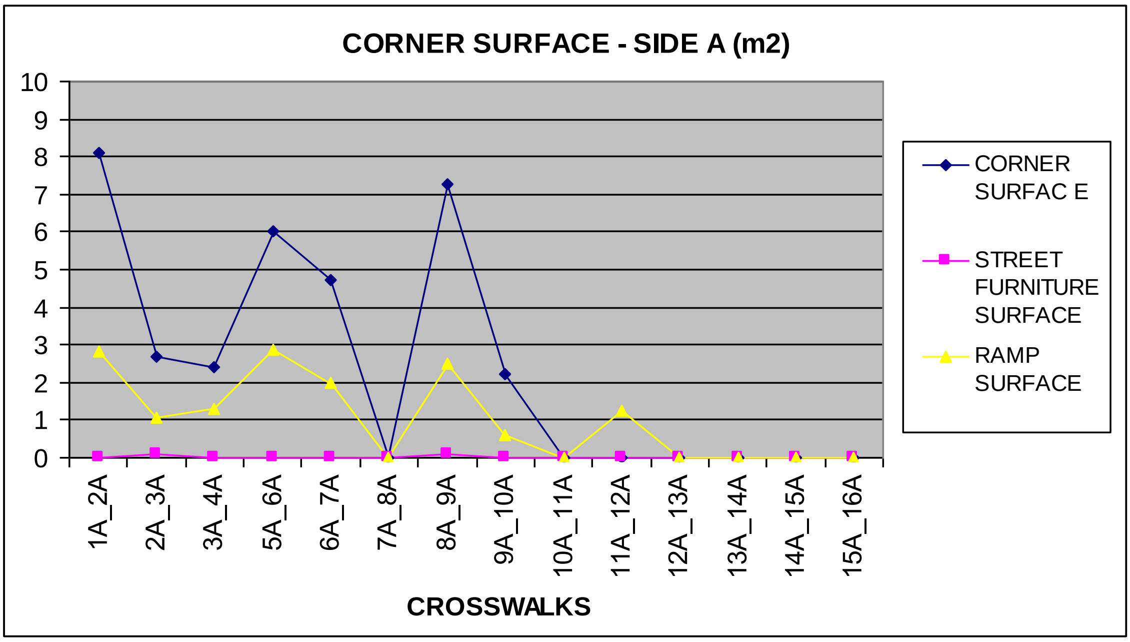

Figure 7 – Corner surface, Side A

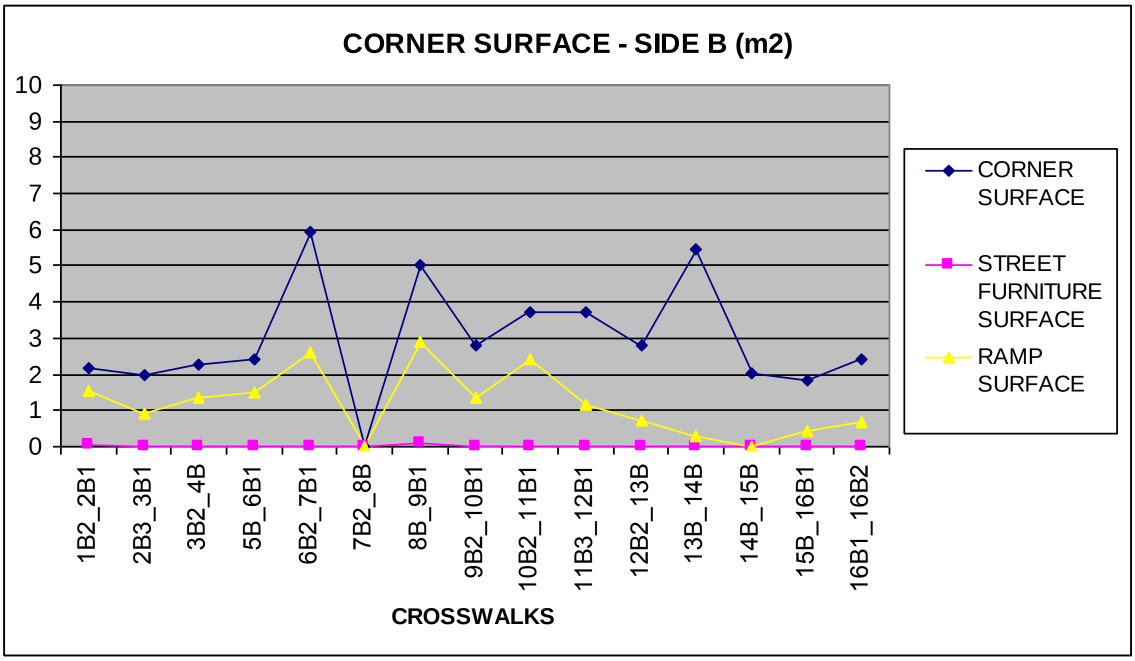

Figure 8 – Corner surface, Side B

Pedestrian behaviour

The auditors counted the pedestrian flow and walking behaviour for every road segment using three indicators:

- Pedestrians walking in the sidewalk
- Pedestrians walking across the street
- Pedestrians crossing the street from midblock (out of crosswalks)

In figure 9, we concluded that the pedestrians' illegal behaviour walking across the street was located in road segments 9, 10 and 12. Pedestrians' crossing the street from midblock points was located in almost half of the road segments in 10% of the pedestrians' total traffic flow. The higher rates of the index were located in road segments 1, 5, 10, 12, 14 and 16. In road segments 1, 5, 10 and 12 this can be explained due to the existence of bus stops and in the segment 16 due to the existence of a University Department building entrance.

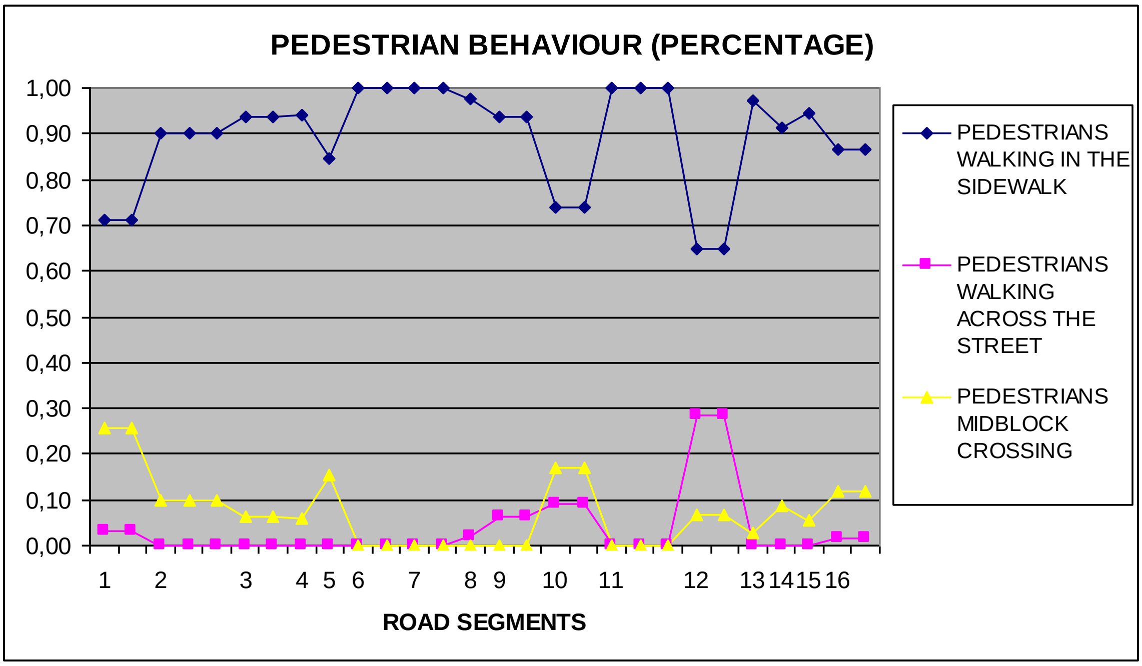

Figure 9 – Pedestrian behaviour (percentage)

Walkability grade

The auditors had to put a grade on the questions 1 to 10 (tables 3, 4) in order to characterize the pedestrians' walkability and safety in the selected road segments and intersections. The presented grades in tables 3 and 4 are the average of the three auditors for all road segments and intersections. The grading scale was the following:

- Bad = 1
- Many problems = 2
- Moderate, some problems = 3
- Good = 4
- Very good, excellent = 5

Table 3 – Grading walking characteristics for road segments

Road segments	Average	
Questions	Side A	Side B

1	Sidewalk, path width (existence, efficiency)	4,6	4,9
2	Pedestrian convenience in sidewalk, path (obstacles)	3,6	3,7
3	Pavement surface quality (maintenance)	3,6	3,9
4	Road environment (aesthetics, trees, litter)	3,8	4,0
5	Weather protection (sun, rain)	4,0	4,0
6	Street furniture	3,6	3,9
7	Personal safety (dangerous people, dogs)	4,0	4,0
8	Pedestrian road safety	4,0	4,0
9	Street lighting	3,9	4,0
10	Total walkability grade	3,7	3,9

In table 3, the auditors had to grade road segment characteristics that referred to a walkable street. In the question No 1, they examined the sidewalk or path width (existence, efficiency). Putting a grade close to 5 (very good), resulted that existed a sidewalk with efficient width in order the pedestrians to walk. This grade can be matched with the checklist question No 2 (table 1), where the auditors referred that there was sidewalk in 100% of the road segments.

In the question No 2, the auditors graded the convenience of walking on the sidewalk. They resulted that there were some problems due to the street furniture, bus stops and kiosks and the mobile obstacles like parked vehicles. This grade can be matched with the checklist questions No 4a and No 4b (table 1), where the auditors referred that the slope and grade of the sidewalks was 100% flat or gentle. Also with the checklist question No 7, where the sidewalk was 100% continuous and the checklist question No 8, where there were permanent and mobile obstacles in about 50% of the pedestrians' route. Furthermore, the indicator "min/max unobstructed sidewalk width" was close to 0.60, indicating moderate walking conditions.

In the question No 3, the auditors graded the pavements' quality and maintenance. They resulted that the pavement surface condition was good with some problems. This grade can be matched with the checklist question No 6, where the auditors referred that in all the road segments the path condition and smoothness is good, with very few cracks and holes.

In the question No 4, the auditors graded the aesthetics of the road environment, according to the presence of trees, building facades and litter. They resulted that the aesthetics of the road environment was good. This result can be matched with the checklist question No 9, where the auditors referred that there are trees in all road segments. It can also be matched with the checklist question No 22, where the auditors referred the absence of litter or glasses and the presence of graffiti only in one road segment.

In the question No 5, the auditors graded the weather protection of the pedestrian. They resulted that the protection was good. According to the checklist question 20, the pedestrians were protected from the building facades, as the noticed height of the trees was medium (checklist question No 19).

In the question No 6, the auditors graded the existence of street furniture as good but with some problems, mainly due to the absence of benches and litter baskets (checklist question No 9).

In the checklist question No 7, the auditors graded the pedestrians' personal safety. They resulted that they were safe enough, as in the street walked mainly normal citizens and not drop out, dangerous people or stray dogs (checklist question No 23).

In the question No 8, the auditors graded the pedestrians' road safety walking across the road segment. Again, they resulted that they were safe enough, as they were not forced to walk in the street or did not face other road users walking in the sidewalk. As we presented in figure 9, the pedestrians' percentage walking in the street facing the traffic flow was very low.

In the question No 9, the auditors graded the level of lighting in the street as good in all road segments. This grade can be matched with the checklist question No 21, where the auditors referred that there were street lighting poles in the majority of the road segments and street lighting from building facades in all the road segments.

Finally, in the question No 10, the auditors graded the walkability level of the road segments. This grade was the overall aspect of the walking ability in the street. They graded, as previously, each road segment separately. In table 3, the average of their grade is presented which is good in side B but good with some problems in side A (all the previous indicators have higher grades in side B than side A).

Table 4 – Grading walking characteristics for crosswalks

Crosswalks		Average		Average		Average	
Questions		Side A		Side B		Side A	Side B
		Start	End	Start	End		
1	Crosswalk access across the pedestrians desire line	4,70	4,50	4,30	4,60	4,60	4,45
2	Corner pavement smoothness - maintenance	4,00	4,00	3,86	3,93	4,00	3,93
3	Crosswalk pavement smoothness - maintenance	3,29	3,57	4,00	3,93	3,43	3,79
4	Pedestrian road safety in crosswalk	3,71	4,14	4,07	4,07	3,93	4,11
5	Street lighting in crosswalk	4,14	3,86	4,14	4,14	4,00	4,00
6	Total walkability grade	3,86	4,14	4,07	3,93	4,00	4,11

In table 4, the auditors had to grade crosswalk characteristics that referred to a walkable street. In question No 1, they graded the crosswalk access across the pedestrians' desire line as very good in all the audited crosswalks. It means that in zebra crosswalks, the pedestrians faced the crosswalk across their desire line as they walked in road segments. In the rest crosswalks, they could simply walk straight from the road segment in the street. Furthermore, it means that there were limited obstacles in the corner of sidewalk – crosswalk. This result can be matched with the checklist question No 8 (table 2), where the auditors referred that there were obstacles in their desire route only in 10-15% of the corners.

Additionally, with the checklist question 6 (table 2), where the auditors referred that there were ramps or walkable kerbs in 85% of the corners and also the checklist question No 7 (table 2), where the ramps are across the pedestrians' desire line.

In question No 2, the auditors graded the smoothness and maintenance of the corners' pavement. They graded it as good without problems. This result can be matched with their answer in the grading question No 3 for the road segments (table 3) referring to the pavement surface quality (maintenance).

In question No 3, the auditors graded the smoothness and maintenance of the crosswalks' pavement. They graded it as good but with some problems. This result can be matched with the checklist question No 4 (table 2) where in all the crosswalks the pavement was good.

In question No 4, the auditors graded their road safety in the crosswalks as good. This result can be matched with the checklist questions No 10, 11 and 14 (table 2). The auditors could see the incoming traffic in all the corners standing in the sidewalk. Furthermore, the vehicle drivers' behavior towards pedestrians was good.

In question No 5, the auditors graded the level of lighting in the crosswalk as good. This result can be matched with the checklist question 9 (table 2), where they referred that lighting covered all the crosswalks.

Finally, in question No 6, the auditors graded the walkability level of the crosswalks. They graded, as previously, each crosswalk separately. In table 4, is presented the average of their grade which is good in both sides of the crosswalks.

The final result of the study was that "Iasonos St" is a "good" one for walkability terms of road safety and walking convenience in the tested road segments and intersections. Implementing this methodology into more roads gives as the ability to compare the road safety and walking convenience.

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