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Pedestrian Crossing Behaviour in Signalized Crossings in Middle Size Cities in Greece

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1 ABSTRACT

Pedestrian road safety is a key point of the transport road safety policy in urban areas. Pedestrians are vulnerable road users and despite their limited representation in traffic events, pedestrian involved injuries and fatalities are overrepresented in traffic collisions. This paper presents the findings from the examination of the pedestrian crossing behaviour in signalized crosswalks. The study took place in the city of Volos, Greece, in peak traffic hours, during the summer of the year 2010. The target of the study was to count the pedestrian crossing time and velocity for each crosswalk. Furthermore, the target was to identify the illegal pedestrian crossing with red traffic light, criticize their behaviour and propose remedial actions.

More than 1300 pedestrians were recorded using a video camera in twelve signalized crossings located in the center of the city, across main arterials. The pedestrians were categorized according to their sex in men and women and their age in three age groups: 0-20, 20-50 and over 50 years old. The analysis of the pedestrian video data was achieved with the use of a state of the art tool, the Captiv L2100 (TEA). The researcher entered the video data in avi format and created the project, the description protocol and the video configuration. The researcher tested each video, marking each pedestrian crossing in the video sequence window, with great accuracy in a short period of time. After the data analysis and the creation of the post coding file, the results were exported in excel format, where they were following analyzed.

Some of the results of the study were that the 17% of the pedestrians crossed the streets with red traffic light. The velocity of the younger pedestrians was 1,32m/sec and of the older ones was 1,19m/sec. Men walked faster (1,32m/sec), than women (1,25m/sec). Furthermore, the pedestrians walked faster crossing the streets with red traffic light (1,34m/sec), than with green one (1,28m/sec). Finally, this study criticizes the lack of pedestrian road safety education and illegal crossing behaviour.

2 INTRODUCTION

2.1 Pedestrian road safety

Pedestrian road safety is a key point of the transport road safety policy in urban areas. Pedestrians are vulnerable road users and despite their limited representation in traffic events, pedestrian involved injuries and fatalities are overrepresented in traffic collisions. Crosswalks are sites where pedestrians face lower levels of road safety, because they have to cross the street and must be aware of the incoming traffic. Intersections with high vehicle flows should be signalized in order to prevent accidents and raise the level of road safety for both pedestrians and vehicle drivers.

The pedestrian illegal crossing behaviour is a major fact in the road safety issue. The main concerns are the following:

- Pedestrians cross the streets without noticing the incoming traffic, usually because their attention is distracted.
- Pedestrians usually miscalculate the traffic gaps.
- Pedestrians walk across the street, usually due to lack of space on sidewalks.
- Pedestrians cross the streets in midblock location or out of designated crosswalks.
- Pedestrians do not follow the indications of the traffic lights.

2.2 Objective of the study

This study examines the pedestrian crossing behaviour in twelve signalized crosswalks located across main urban arterials in the city of Volos, Greece with the use of a new tool that analyzes video data: Captiv L2100 (TEA). The pedestrians were categorized according to their age and sex. The main questions of the study were the following:

- How much is the pedestrian crossing time.

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- How much is the pedestrian crossing speed.
- Do pedestrians cross the street with red or green traffic light.

3 LITERATURE REVIEW

3.1 Pedestrian crossing behaviour

Many studies have examined the pedestrian crossing behaviour analyzing several factors. Rosenbloom (2008) analyzed the behavior of 1392 pedestrians in signalized crosswalks. The first hypothesis was that pedestrians' behavior waiting to cross the street depends on the factor of being alone or in group. It was expected that the pedestrians would be more optimistic of crossing the street with red traffic light if they were accompanied. Furthermore, the second hypothesis was that he pedestrians would be more optimistic of crossing the street with red traffic light if another pedestrian crossed before him. The first hypothesis did not come true, but the second did so. Moreover, men were more optimistic to cross the street with red traffic light than women. At last, the longer waiting time in red light phase and the less waiting pedestrians increases the possibility of a pedestrian crossing the street with red traffic light.

Hill and Holland (2008), analyzed the factors that influence the pedestrians' crossing behavior. Using video data they checked the crossing decisions of 213 pedestrians. They counted safe or not traffic gaps for every person, according to their walking speed. The most unsafe choices were taken from men and especially the older ones. Factors like the pedestrians' driving experience, their physical skills, walking speed, sex, age and understanding of the traffic characteristics, were important in order to decide where and when to cross the street.

Pedestrian risk decreases as pedestrian flow is also decreased (Leden, 2002). He made that conclusion after studying pedestrian accident data from 300 signalized intersections in Hamilton, Ontario, during the years 1983-1986. Pedestrian safety at semi-protected schemes, where left-turning vehicles face no opposing traffic but have possible conflicts with pedestrians, was compared with pedestrian safety at normal non-signalized approaches, where right-turning vehicles have potential conflicts with pedestrians. Pedestrian safety seems to be affected much more by the traffic pattern (left or right-turning traffic). At low vehicular flows, right turns and semi-protected left turns tend to be equally safe for pedestrians, but right turns are safer for pedestrians than semi-protected left turns at high vehicular flows. If risk for pedestrians is calculated as the expected number of reported pedestrian accidents for pedestrian, the risk decreases with increasing pedestrian flows. One explanation could be increased driver alertness with increasing pedestrian flow. However, an increased pedestrian flow might lead to more pedestrian accidents if promotion is not accompanied by appropriate safety measures.

Ekman (1996) examined 95 non-signalized intersections in Malmo and Lund in Sweden and concluded that the rate of pedestrian conflicts per pedestrian was not influenced from pedestrian flow. According to Ekman the individual pedestrian does not seem to benefit from the presence of other pedestrians. Another explain is that the motorists expect the presence of pedestrians (at least if pedestrian flow exceeds 30 pedestrians per hour. Ekman also found that if risks for pedestrians are calculated as the expected number of reported pedestrian accidents or conflicts for pedestrian, the risk increases as traffic flow is also increased.

Signalized intersections should consider signal phases for pedestrians which do not significantly delay them. Wang et al (2008) concluded that with high delay, pedestrians are likely to violate the signal. From field observations, most pedestrians searched for traffic gaps and crossed the street without following the traffic signal indications. Furthermore, pedestrian intervals should adjust to the vehicle crossing phase, based on the rule that no conflicting phase should be on together.

Pedestrian road safety depends on their exposition on traffic flow. Many studies have concluded that about 25% of the pedestrians cross the streets illegally (Mullen et al, 1990). Keegan and O'Mahony (2003) reported that 35% of the pedestrians cross during the red light phase. Pedestrians usually cross the streets in sites they consider as more convenient or located across their desire route in order to achieve minimum time delay of physical effort.

Many studies have used video data in order to examine the pedestrian crossing behaviour (Hao et al, 2008; Jiangang et al, 2008; Eliou and Galanis, 2009). Some of them use state of the art equipment. Ismail et al (2009) used a real time video data analysis system, which registers vehicle and pedestrian tracks and recognizes traffic conflicts. Relative equipment can examine bicyclists' behaviour. Constant et al (2010) used an "Intelligent Video Analysis System" (IVAS). Connecting an internet protocol (IP) with a video camera in a building above the tested street they could track the bicyclists' route and count their speed.

4 METHODOLOGY

4.1 Data collection

The crosswalks where located across the Benizelou St. and Kartali St, which are main arterials located in the center business district of the city (Fig. 1). The crossing streets were the following:

- Gallias St. (collector arterial)
- 28 Oktovriou St. (collector arterial)
- Dimitriados St. (main arterial)
- Iasonos St. (man arterial)

The data collection took place in June 2010, during peak traffic hours (12:00-14:00). A video camera was put in the opposite of each crosswalk in order to have a complete view of the pedestrians waiting and crossing the street in both sides. The time duration of each video record was 30min for each crosswalk. After the video data collection, certain amount of photos of the crosswalks were collected and the crosswalks' length was noticed in order to count the pedestrians' speed.

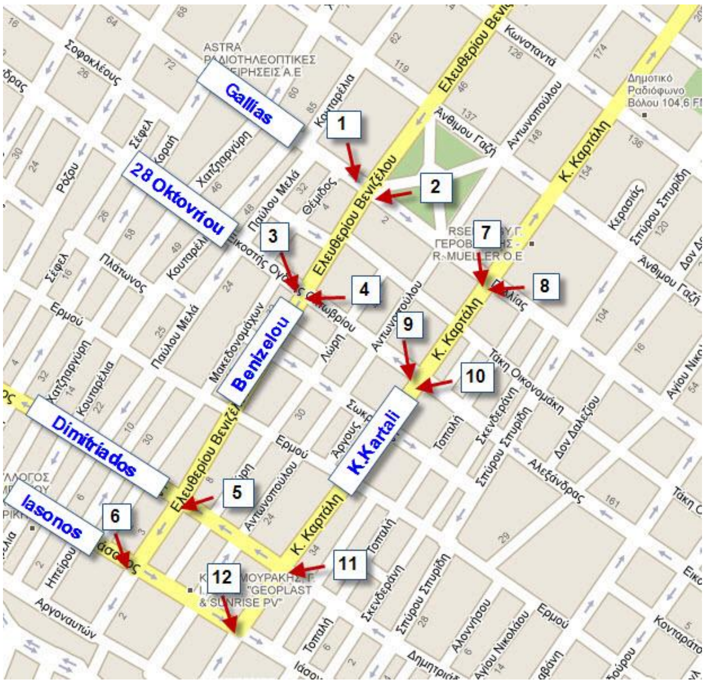

Fig. 1: Study area

4.2 Data analysis

After the video data collection, the video was exported from the camera to the pc in avi format in order to be compatible with the Captiv L2100 software. The first step of the analysis was the creation of the project in the site: C:\Program Files\Captiv L2100\Project. The second step was the formation of the "Description Protocol", which is the most important step of the analysis because the researcher forms the coding (Fig. 2). The pedestrian crossing behaviour was analyzed according to their sex and age. The columns of the description protocol were the following:

- Code: 020mrs (abbreviation of the characteristic)
- Coding: 020 man red start (analytic presentation of the characteristic)
- Class: 1man
- C: Color of each code

12 classes and 24 codes were formed because in order to notice the time when the pedestrians start and finish crossing the street. So, the coding "020 man red start" describes a pedestrian in the age group of 0-20 years old who starts crossing the street with red traffic light and the coding "020 man red stop" describes the pedestrian in the age group of 0-20 years old who stops crossing the street with red traffic light. For each coding line a proper colour was selected. With red color was marked the coding referring to pedestrians who crossed the street with red traffic light and with green colour the ones who crossed with green traffic light. Darker colours referred to men and brighter to women.

Code	Coding	Recoding	Class	Init	P	C
020mrs	020 man red start	020 man red start	1 man			
020mrt	020 man red stop	020 man red stop	1 man			
2050mrs	2050 man red start	2050 man red start	2 man			
2050mrt	2050 man red stop	2050 man red stop	2 man			
50mrs	50 man red start	50 man red start	3 man			
50mrt	50 man red stop	50 man red stop	3 man			
020mgs	020 man green start	020 man green start	4 man			
020mgt	020 man green stop	020 man green stop	4 man			
2050mgs	2050 man green start	2050 man green start	5 man			
2050mgt	2050 man green stop	2050 man green stop	5 man			
50mgs	50 man green start	50 man green start	6 man			
50mgt	50 man green stop	50 man green stop	6 man			
020wrs	020 woman red start	020 woman red start	1 woman			
020wrt	020 woman red stop	020 woman red stop	1 woman			
2050wrs	2050 woman red start	2050 woman red start	2 woman			
2050wrt	2050 woman red stop	2050 woman red stop	2 woman			
50wrs	50 woman red start	50 woman red start	3 woman			
50wrt	50 woman red stop	50 woman red stop	3 woman			
020wgs	020 woman green start	020 woman green start	4 woman			
020wgt	020 woman green stop	020 woman green stop	4 woman			
2050wgs	2050 woman green start	2050 woman green start	5 woman			
2050wgt	2050 woman green stop	2050 woman green stop	5 woman			
50wgs	50 woman green start	50 woman green start	6 woman			
50wgt	50 woman green stop	50 woman green stop	6 woman			

Fig. 2: Description Protocol (Captiv L2100)

After the formation of the description protocol, was formed the "Video Configuration" file (Fig. 3). This file was created when the videos were entered in the project. Each video was characterized from its description name, the file where it was saved, the start and end time and its duration (about 15min).

Video configuration

Description	File	Start time	End time	Duration	Fps	Top synchro	C
16_06_01	G:\VIDEOS_PHD_1\16_06_01.	27/11/2010 08:12:52.671	27/11/2010 08:27:56.991	00:15:04.320	25		
16_06_02	G:\VIDEOS_PHD_1\16_06_02.	27/11/2010 08:13:21.562	27/11/2010 08:28:32.481	00:15:10.919	25		
16_06_03	G:\VIDEOS_PHD_1\16_06_03.	27/11/2010 08:13:21.921	27/11/2010 08:28:30.200	00:15:08.279	25		
16_06_04	G:\VIDEOS_PHD_1\16_06_04.	27/11/2010 08:13:22.281	27/11/2010 08:29:03.401	00:15:41.120	25		
16_06_05	G:\VIDEOS_PHD_1\16_06_05.	27/11/2010 08:13:22.687	27/11/2010 08:29:26.807	00:16:04.120	25		
16_06_06	G:\VIDEOS_PHD_1\16_06_06.	27/11/2010 08:13:21.156	27/11/2010 08:29:52.476	00:16:31.320	25		
21_06_01	G:\VIDEOS_PHD_1\21_06_01.	27/11/2010 08:13:47.031	27/11/2010 08:28:50.550	00:15:03.519	25		
21_06_02	G:\VIDEOS_PHD_1\21_06_02.	27/11/2010 08:13:47.375	27/11/2010 08:28:52.215	00:15:04.840	25		
21_06_03	G:\VIDEOS_PHD_1\21_06_03.	27/11/2010 08:13:47.859	27/11/2010 08:29:50.859	00:16:03.000	25		
21_06_04	G:\VIDEOS_PHD_1\21_06_04.	27/11/2010 08:13:48.234	27/11/2010 08:28:58.434	00:15:10.200	25		
21_06_05	G:\VIDEOS_PHD_1\21_06_05.	27/11/2010 08:13:48.703	27/11/2010 08:28:55.303	00:15:06.600	25		
21_06_06	G:\VIDEOS_PHD_1\21_06_06.	27/11/2010 08:13:46.625	27/11/2010 08:29:05.024	00:15:18.399	25		

Video configuration | Options

Fig. 3: Video Configuration (Captiv L2100)

The next step was the formation of the "Video Sequence" file, which was the basic tool for our analysis (Fig. 4). Each button referred to a coding and its one colour (Fig. 2). We run the videos and marked each pedestrian start and stop time, based on our coding. We were able to stop the video (pause), play it back or synchronize it in a selected time when a pedestrian crossed the street. All the registrations were saved in a "Post Coding" file, which refers to the start and stop time of the pedestrian crossing according to the coding.

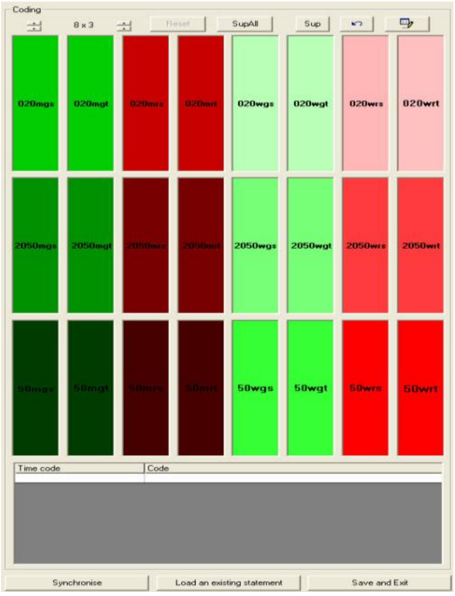

Fig. 4: Video Sequence (Captiv L2100)

After the creation of the post coding file, all the data were exported in the excel software for further analysis. The basic benefit of this analysis procedure was the speed, convenience and reliability of the process, comparing to the manually video analysis.

5 RESULTS

5.1 Pedestrian and traffic flow

The first result of the data analysis was the counting of the traffic flow (Table 1). The highest traffic low were noticed in crosswalks No5-6 and No11-12, located in Iasonos St and Dimitriados St, which are main urban road arterials.

The traffic flow is those streets was about 300% higher than the other crosswalks No1-4 and No7-9, located in Gallias St and 28 Oktovriou St, which are collector arterials. The duration of the traffic signal phases in each crosswalk is presented in Table 2. Higher percentage of green traffic light was noticed in the crosswalks located across the collector streets.

Traffic (1hr)	1	2	3	4	5	6	7	8	9	10	11	12
Vehicle	360	348	108	168	1176	924	312	288	384	408	1044	1212
Motorcycle	180	120	120	108	576	240	96	180	60	48	468	456
Bicycle	24	36	12	12	36	24	24	36	12	24	12	24
Bus	0	0	0	0	48	60	0	0	12	12	48	72

Table 1: Traffic flow data (1 hr)

Time (sec)	1	2	3	4	5	6	7	8	9	10	11	12
Green	45	45	45	45	30	30	50	50	30	30	35	25
Red	25	25	25	25	40	40	25	25	25	25	35	45
Sum	70	70	70	70	70	70	75	75	55	55	70	70
%Green	0,64	0,64	0,64	0,64	0,43	0,43	0,67	0,67	0,55	0,55	0,50	0,36
%Red	0,36	0,36	0,36	0,36	0,57	0,57	0,33	0,33	0,45	0,45	0,50	0,64

Table 2: Traffic signal phase (sec)

In Table 3, are presented the pedestrians who crossed the streets during the data collection time (30min for each crosswalk) and their percentages according to their age, sex and traffic light (Table 4). The crossing behaviour of 1322 pedestrians was analyzed. Separating them by age, 304 pedestrians were under 20 years old (23%), 664 between 20 and 50 years old (50%) and 353 over 50 years old (27%). Separating them by sex, 529 were men (40%) and 793 women (60%). Analyzing their crossing behaviour, 185 pedestrians crossed the street during the red traffic light phase (15%) and 1137 during the green traffic light phase

(85%). The highest illegal crossing behaviour was noticed in collector streets (8%-28%) and the lowest in main arterials (4%-16%).

Pedestrians in the age group of 20-50 years old were more optimistic to cross the street with red traffic light (55%) and also women (63%) than men (37%), (Table 5), comparing to the sample percentages (Table 4).

N	1	2	3	4	5	6	7	8	9	10	11	12	SUM
0-20	36	8	12	24	21	11	16	39	19	59	28	31	304
20-50	38	51	28	52	67	57	42	70	42	77	96	44	664
50+	21	38	13	29	23	36	24	20	23	46	58	22	353
Men	34	40	19	46	37	50	36	36	38	74	87	32	529
Women	62	57	34	59	74	54	46	93	46	108	95	65	793
Red	8	27	14	23	9	17	13	18	18	23	11	4	185
Green	88	70	39	82	102	87	69	111	66	159	171	93	1137
Sum	96	97	53	105	111	104	82	129	84	182	182	97	1322

Table 3: Pedestrian sample (30min)

N%	1	2	3	4	5	6	7	8	9	10	11	12	AV
0-20	0,38	0,08	0,23	0,23	0,19	0,11	0,20	0,30	0,23	0,32	0,15	0,32	0,23
20-50	0,40	0,53	0,53	0,50	0,60	0,55	0,51	0,54	0,50	0,42	0,53	0,45	0,50
50+	0,22	0,39	0,25	0,28	0,21	0,35	0,29	0,16	0,27	0,25	0,32	0,23	0,27
Men	0,35	0,41	0,36	0,44	0,33	0,48	0,44	0,28	0,45	0,41	0,48	0,33	0,40
Women	0,65	0,59	0,64	0,56	0,67	0,52	0,56	0,72	0,55	0,59	0,52	0,67	0,60
Red	0,08	0,28	0,26	0,22	0,08	0,16	0,16	0,14	0,21	0,13	0,06	0,04	0,15
Green	0,92	0,72	0,74	0,78	0,92	0,84	0,84	0,86	0,79	0,87	0,94	0,96	0,85
Sum	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Table 4: Pedestrian sample (%)

Red%	1	2	3	4	5	6	7	8	9	10	11	12	AV
0-20	0,63	0,00	0,21	0,30	0,00	0,24	0,08	0,44	0,44	0,17	0,18	0,00	0,23
20-50	0,25	0,59	0,5 7	0,35	0,56	0,53	0,85	0,44	0,44	0,57	0,45	1,00	0,55
50+	0,13	0,41	0,21	0,35	0,44	0,24	0,08	0,11	0,11	0,26	0,36	0,00	0,22
Men	0,25	0,37	0,36	0,52	0,44	0,71	0,31	0,22	0,22	0,39	0,45	0,25	0,37
Women	0,75	0,63	0,64	0,48	0,56	0,29	0,69	0,78	0,78	0,61	0,55	0,75	0,63
Sum	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Table 5: Pedestrians crossing with red traffic light (%)

In Table 6, is presented the pedestrian crossing time in each crosswalk according to their age, sex and crossing behaviour. Due to the difference of the crosswalks' length it was better to count the pedestrian crossing speed (Table 7). The pedestrian crossing speed was analyzed according to their age (Fig. 5), sex (Fig. 6) and traffic light (Fig. 7). It is clear that pedestrians under 50 years old cross the streets faster (1,30m/sec) than pedestrians over 50 years old (1,18m/sec). Furthermore, men walked faster (1,31m/sec) than women (1,25m/sec). Finally, pedestrians realize the danger for their road safety and cross the streets faster during the red traffic light phase (1,35m/sec) than during the green traffic light phase (1,26m/sec). The speed profile was relative smooth and steady in all categories (Fig. 5, 6 and 7).

Time (sec)	1	2	3	4	5	6	7	8	9	10	11	12	AV
0-20	4,51	5,00	3,59	3,69	6,73	7,72	3,72	4,24	3,27	3,44	5,68	6,08	5,63
20-50	4,61	4,44	3,71	3,56	6,57	7,62	4,17	4,43	3,50	3,57	6,44	6,76	5,48
50+	5,06	4,89	4,41	4,06	7,04	7,80	5,54	4,87	3,82	3,90	7,21	7,61	6,16
Men	4,47	4,41	1,22	3,64	6,91	7,39	4,40	4,24	3,43	3,48	6,53	6,83	5,37
Women	4,77	4,83	1,20	3,80	6,60	7,98	4,55	4,52	3,62	3,69	6,60	6,69	5,87
Red	4,34	4,27	1,25	3,62	6,00	7,43	3,75	4,16	3,67	3,56	6,97	5,38	5,65
Green	4,70	4,81	1,19	3,76	6,76	7,75	4,62	4,49	3,50	3,61	6,54	6,8	5,64

Table 6: Pedestrian crossing time (sec)

L (m)	5,5m	5,5m	4,5m	4,5m	9m	10m	5,5m	5,5m	4,5m	4,5m	9m	9m	
V (m/sec)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**AV**
0-20	1,26	1,14	1,26	1,25	1,37	1,31	1,36	1,32	1,39	1,29	1,46	1,36	1,31
20-50	1,24	1,29	1,25	1,31	1,39	1,38	1,24	1,27	1,33	1,34	1,32	1,23	1,30
50+	1,13	1,20	1,06	1,16	1,32	1,31	0,98	1,17	1,25	1,31	1,19	1,11	1,18
Men	1,28	1,31	1,22	1,29	1,34	1,42	1,23	1,34	1,38	1,33	1,32	1,25	1,31
Women	1,19	1,20	1,20	1,23	1,39	1,28	1,16	1,25	1,28	1,26	1,27	1,24	1,25
Red	1,29	1,33	1,25	1,29	1,55	1,44	1,36	1,34	1,27	1,31	1,32	1,49	1,35
Green	1,22	1,21	1,19	1,25	1,36	1,33	1,16	1,26	1,34	1,29	1,30	1,23	1,26

Table 7: Pedestrian crossing speed (m/sec)

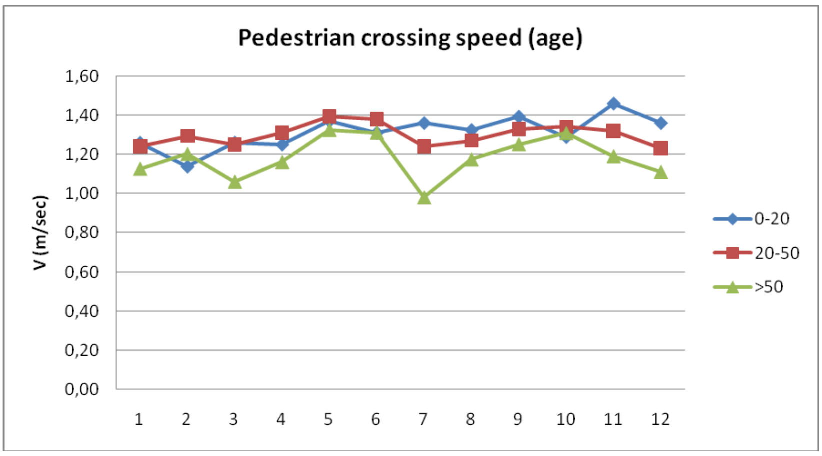

Fig. 5: Pedestrian crossing speed (age)

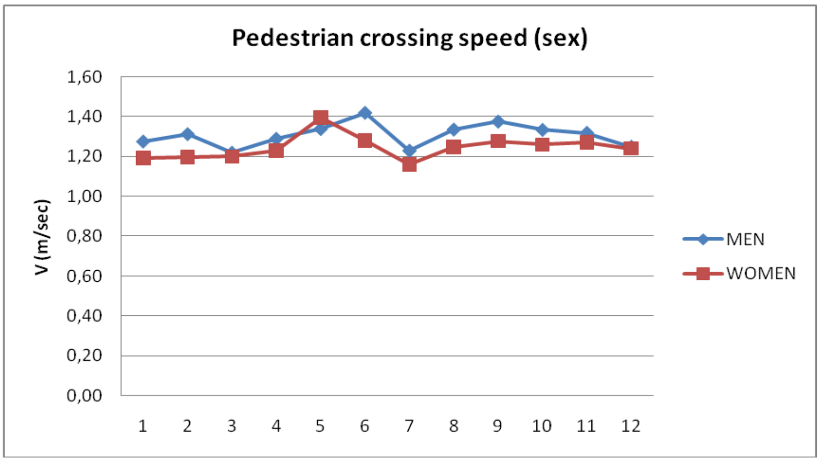

Fig. 6: Pedestrian crossing speed (sex)

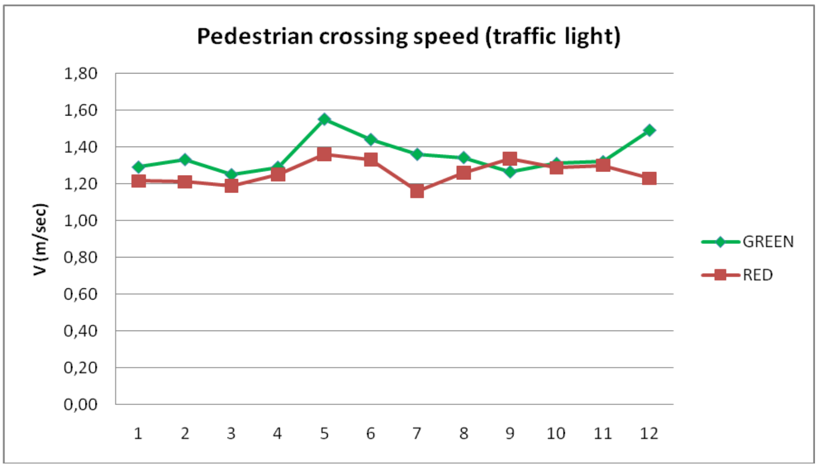

Fig. 7: Pedestrian crossing speed (traffic light)

6 CONCLUSION

The implementation of the Captiv L2100 (TEA) software was a very useful tool to analyze the pedestrian crossing behaviour with convenience, reliability and speed, using video data. The main conclusions of our study were the following:

- The quantum of pedestrian data collection using this age scale was representative. The 50% of the pedestrians were aged between 20-50 years old, 23% under 20 years old and 27% over 50 years old.
- The 60% of the pedestrian sample was women and 40% men. We noticed a significant dominance of women walking in the center of the city during morning time.
- The 85% of the pedestrians crossed the streets with green traffic light and only 15% with red traffic light. More pedestrians crossed the streets illegally where the traffic flow and speed are lower.
- Older pedestrians crossed the street with lower walking speed (1,18m/sec) than pedestrians 20-50 years old (1,30m/sec) or under 20 years old (1,31m/sec).
- Men crossed the streets faster (1,31m/sec) than women (1,25m/sec).
- Pedestrians walked faster when they cross the streets with red traffic light (1,35m/sec) than green traffic light (1,26m/sec).
- The highest walking speed (1,55m/sec) was noticed when the pedestrian crossed main arterials during the red light phase when the traffic flow gaps are minimized.
- The most illegal crossing behaviour was noticed in women and pedestrians 20-50 years old.
- Pedestrians usually respect the traffic light indications, crossing the street when they judge that there is a safe traffic gap, according to their physical skills and traffic road safety education.

The conclusions of our study can help engineers and local authorities to understand better the pedestrian crossing behaviour and promote remedial actions in urban road network. Furthermore, we propose the implementation of a road safety training program to older citizens in order to improve their walking behaviour.

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