Relationship among Traffic Intensity, Intersection Geometry, and Users' Behavior

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ABSTRACT

Even though the parts of a road traffic system are interrelated and influence each other, the problems of road safety are directly associated with the geometry and the equipment of streets, particularly in sites where conflicting movements exist, as at intersections. Principles and measures are discussed aiming to decrease the intensity of conflicts in intersections. The examination of accident causes has to be performed in homogeneous parts from various options (geometry of the alignment, pavement condition, traffic conditions, road's equipment and environment, presence of grade intersections and entries in settlements) and not at individual sites. In the city of Xanthi, Northern Greece the number of accidents with victims is not high, due mainly to the behavior of road users, who does not raise the private car in a role of protagonist. The geometry of road network is susceptible to improvements in relatively few intersections; however interventions could be made for the control of its operation with careful signing and recantation of unfavorable impacts from forced signaling choices.

Keywords: traffic, interchange, safety, user's behavior, pedestrian

INTRODUCTION

Road traffic accidents are one of the main causes of both death and permanent disability worldwide. The magnitude of the problem becomes even greater as in road accidents mainly young people are involved, significantly impacting the public health costs as well as the productivity of each country [1].

Three major factors are responsible for traffic accidents all over the world. Namely, vehicle factors, personal or human behavioral factors and road or environmental factors. In this work the road factors will be analyzed mainly in sites with intersections in relation to the traffic volume and the physiological or behavioral reactions of the road system users. The traffic factors should be treated in view of speed limits, traffic density, and flow characteristics.

The study of traffic accidents is a multidimensional process. Road accidents are influenced by three parameters: (a) exposure to risk, which is defined as the total set of operations that expose the person at risk; (b) the likelihood of an accident, which is defined as the probability of a person to cause or participate in a car accident, per unit of exposure at risk and (c) accident severity, which defines the result of the accident, and describes its material consequences as well as its impact on human lives [2].

The level of road traffic safety is determined by characteristics of the road, such as the mode of operation, the alignment, its cross section, technical works and bridges, the presence of cyclists, pedestrian crossings, possible rigid obstacles, other equipment and devices, signs, signals and markings, stops of massive transport means, intersection with railways, the

lighting, the maintenance of greenery, the passive safety facilities, rest and service areas and intersections [3].

There are accidents where the traffic volume is a key factor causing road accidents and accidents where traffic volume does not influence or not the main factor causing accidents [4]. Avoiding unwanted effects can improve both safety and capacity of a section. Moreover, in the case of low-speed roads or in areas with pedestrians lower cornering speeds are needed [5], using smaller turning radii and narrower lanes.

The paper deals with features referring to the driver, to the vehicle, the road network, and the existing codes of driving behavior, since they are all blamed as major causes of road traffic accidents; as such they are targets for preventive interventions.

THE USER AND THE TRAFFIC

Road users behave forced by the degree of security which they consider the intersection design offers them, in view of the lateral visibility, the existence of waiting spaces for pedestrians and cyclists, the signaling, the need to reduce their speed when accessing the site of the intersection.

Pedestrians are walking for at least part of their journey either on foot or using various aids. The walking speed is a critical factor, ranging between 0.8 and 2.0 m/sec, depending on temperature, steepness of grade, time of the day and age. If many elderly people are anticipated, the design walking speed could be assumed as 1.0 m/sec. Other improvements could include minimization of crossing widths, refuge islands in wide intersections, and reflectorized signs [6].

Special pedestrian groups, like the blind, are looking for specific transit routes through the intersection [7]. The necessary infrastructure for the safe operation of an intersection must include the electric lighting devices, the traffic lights, the vertical signs, the drainage installation, any anti-halation provisions, as well as safety equipment (crash barriers, marker posts, etc.) placed in appropriate locations.

If the user has a clear perception not in points, but as the succession of homogeneous sections regarding the geometry of the alignment, the road equipment and environment, the pavement conditions, the traffic conditions etc, then the road accidents in their majority will be preventable [8].

In high speed roads without pedestrians, it is desirable to apply higher speeds for those vehicles turning to leave the stream of straight moving traffic as quickly and safer as possible [9].

In addition to safety, the geometric design of an intersection affects the operating performance for all users of the road. The improvement of the efficiency of an intersection is enhanced by the elimination of the need for lane change and weaving maneuvers, minimizing inhibition factors and the distance required for a person to traverse the intersection.

URBAN SPACE INTERSECTION CONFIGURATION WHICH ENSURES SAFE OPERATION

For intersections and the level of road safety it should be stressed that the control and warrantee of data concerning the geometry, traffic flow, behavior of users (pedestrians, cyclists, bikers, car drivers), and the infrastructure is necessary.

The geometry is governed by design data, such as the cross slope, the grade, the width of the roads which contribute to the junction, the perpendicularity between them, the presence of islets and the presence of shoulders. The quality of traffic flow depends on ensuring good lateral visibility, the existence or not of signaling, the steering of the movement by traffic islands, and the requirement or not for reduced approach speed at the intersection.

The coexistence of an at grade intersection with a curve in horizontal alignment or in the vertical alignment can generate accidents with the same probability with which accidents occur from the commingling of different radii of curvature in the same turn with wrong slope and lack of visibility, the simultaneous creation of sag vertical curve with small radius and of an horizontal curve where the visibility is very low, from turns where the design has imposed to exist a small radius (>180°), large longitudinal slope and wrong slope or by the alignment of a large straight-line segment before a close bend or before the entrance in a housing estate.

When at intersections measures such as the use of traffic islands and raised central islands to prevent erroneous movements, the clear definition of the course of vehicles mainly with delineation in skewed crossings, intersections with many legs, shifted T-type junctions and intersections with very high volumes in turns are applied, then the severity of accidents will be reduced, regardless their cause [10, 11].

The riskiness of a road is a direct function of volume, the composition of the traffic and the speed of vehicles. Also, the increase in number of meeting places with another vehicle in a unit of road length (accesses to adjacent land uses, intersections, etc) leads to increased likelihood of improper handling by the drivers and to accidents genesis [12]. Therefore, for roads of great significance, such as highways, arteries, etc. full or partial access control must be provided, in order to minimize the engagement with incoming or outgoing vehicles.

INTERSECTIONS IN THE URBAN WEB OF THE CITY OF XANTHI

Xanthi is a county city with a population of about 60,000 people according to the National Inventory, 2011. The structure of Xanthi is “compact”, due to the relatively small length of its streets and the fairly level terrain, at least in its central part. The enforcement of bicycle ways allows the reconstruction of main streets in the city. The road network is rather orthogonally organized; still the streets are limited to two lanes in most part of the city.

Accidents at Xanthi's intersections are largely due to high traffic volumes, as well as to geometric features and infrastructure elements (poor visibility, inadequate lighting, plenty of useless and misleading information, horizontal alignment curves, cambers, lack of safety islands). A key factor for the incidence of serious accidents where pedestrians are involved is the lack of organized crossings, along with the road behavior of the pedestrians, since a large number of risky passages are being recorded. The improper maintenance of the pavement is the likely cause of accidents in some road sections, since the driver's attention is distracted. Finally, the problematic management of traffic on main intersections is an operative factor, because points of vehicle involvement are created.

A specific study of riskiness in connection to the design and implementation of urban road projects is proposed in order to provide the necessary input -along with an environmental impact study- for the proper and timely implementation of interventions towards the safety of nowadays black spot positions.

Sidewalks and pedestrian crossings at intersections play a special role. If sidewalks are adequate for the movement of pedestrians -especially in the city's center- then the mentality to use the private passenger car on a daily basis will change. From this point of view, mothers and disabled people are hindered. Therefore, culture imposes to ensure comfortable space and free of barriers movement for all pedestrians in the urban web (Figure 1).

It has been ascertained that many sidewalk ramps have incorrect orientation and placement creating confusion to their users and driving them outside crossings. Furthermore, pedestrians are not served by ramps with a steep slope and a small length. Several times pedestrians wishing to move towards the opposite sidewalk stand on the pavement next to the sidewalk. This shows that pedestrians would be better served by additional space which may be obtained by extending the sidewalk with suitable protrusions.

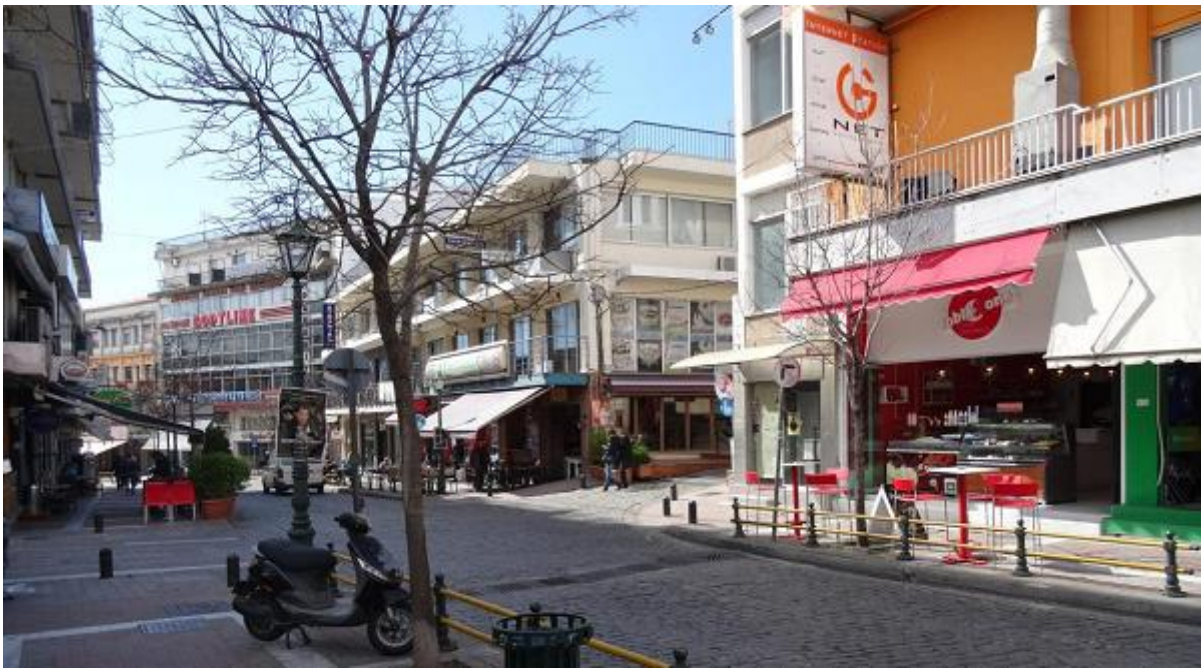

Figure 1 Vehicles have been given the amount of space required for their comfortable passage. This is a proper layout to accommodate pedestrians.

The walkways are not decoration elements. They are the pedestrian crossings; thus, they ought to be smooth, without obstacles and brightly painted. In Xanthi's urban area, it is not an infrequent phenomenon the crossings with faded stripping lines (Figure 2)

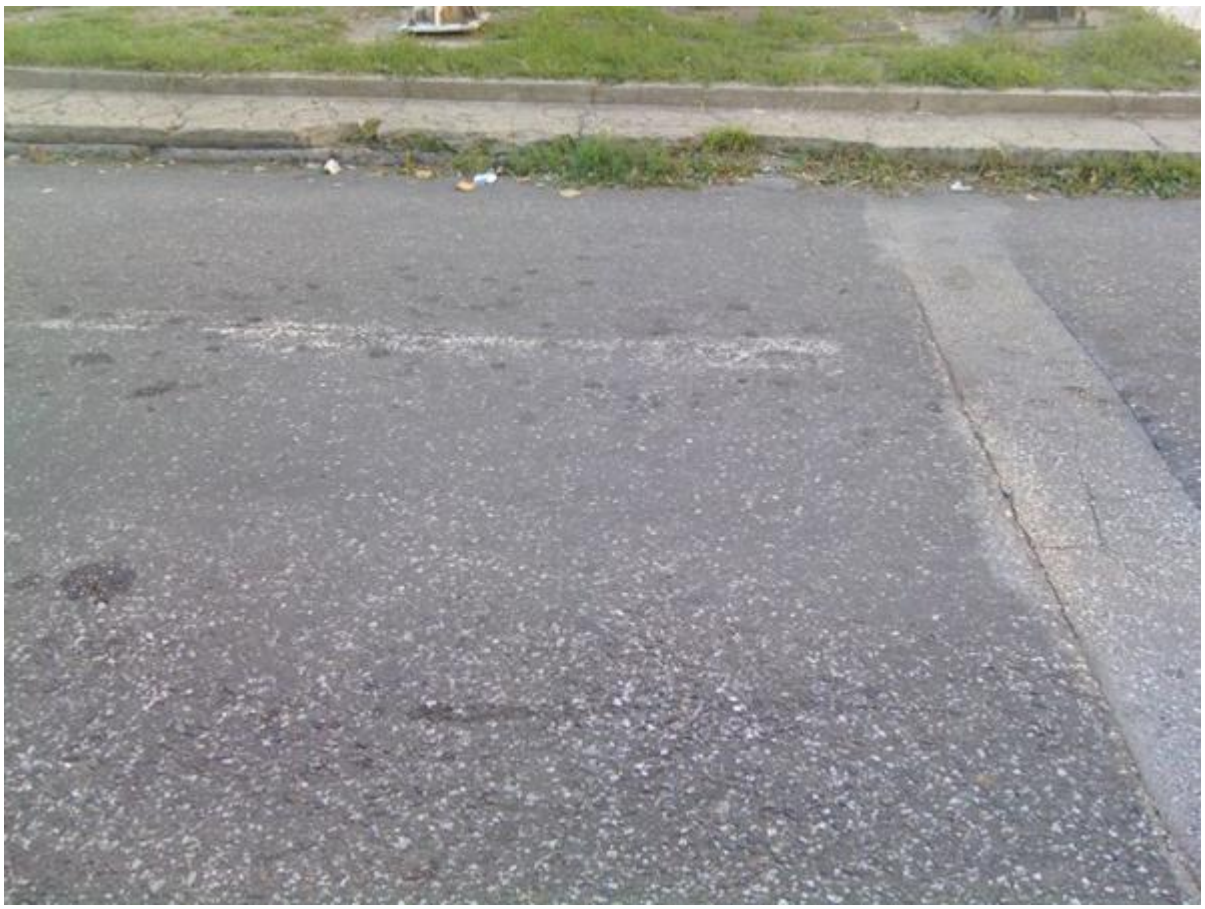

Figure 2 Marking lines are almost invisible in this site.

In the case of narrow streets, the removal of all parked vehicles could offer a safe solution. Great improvement in the safety of pedestrians and the intersection as a whole would be brought about by the widening of sidewalks at the street corners and by the allowance of space just for a parked car. With suitable planting, the projections formed in this way could upgrade the intersection aesthetically and provide added control and safety to the movement of vehicles.

On sidewalks both car and bicycle parking should not be allowed, since they do not only obstruct walkers, but literally a barrier. Placing deterrent devices for the rise of vehicles on the sidewalk (e.g. metallic columns of low height) and changing the attitude of drivers would yield the sidewalks to those for which they were created.

Obstacles to be removed from the sidewalks to maximize the safety of an intersection, besides the vehicles, are fixed objects such as bus-stop shelters, protrusions for mounting garbage containers, sizable trees on narrow sidewalk, lighting poles, kiosks etc. Another type of obstacle for the pedestrians is the safety rails in front of the entrance of schools, combined with signs or other arbitrary structures (Figure 3).

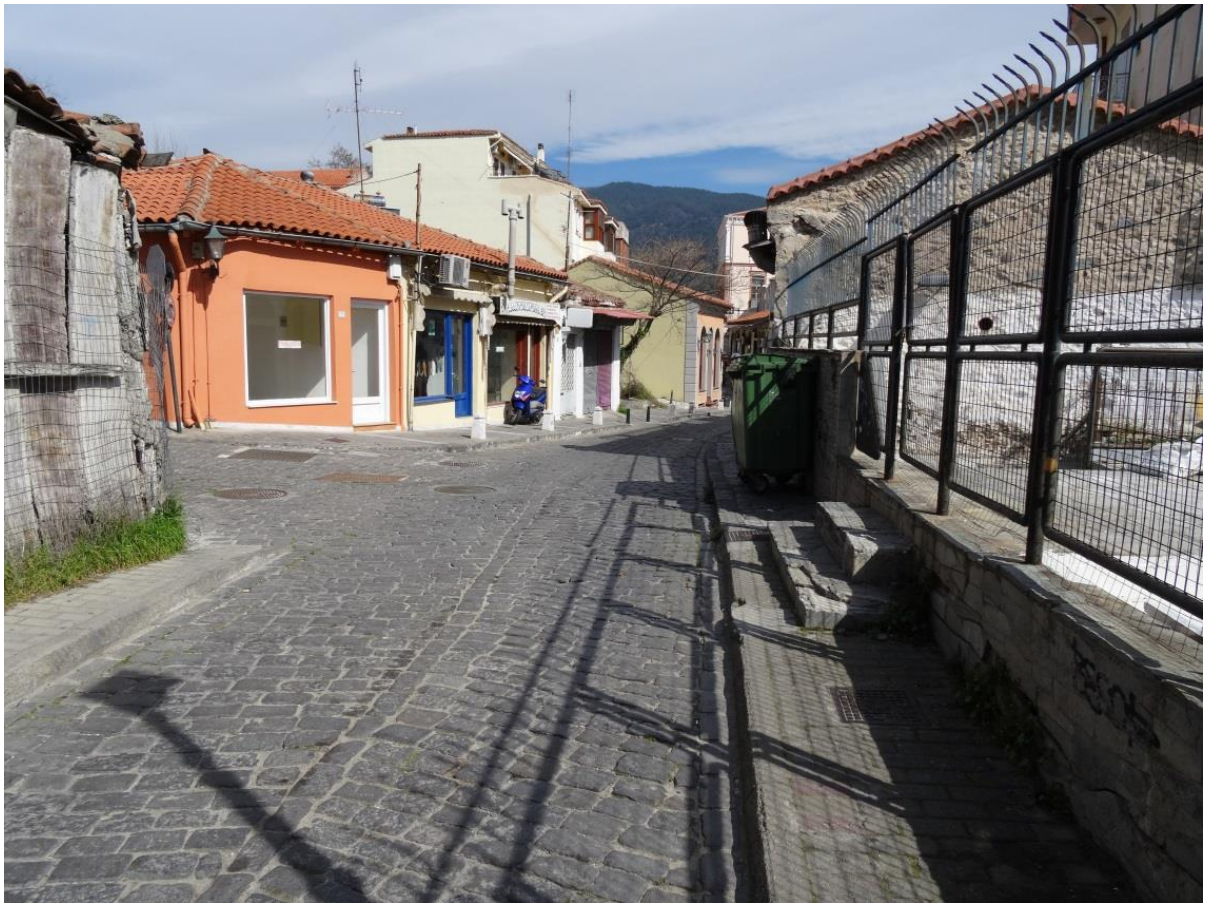

Figure 3 Sidewalks occupied by trash cans, constructions, scooters. This T-type intersection could be safer after the placement of underground trash buckets, the reconstruction of various elements and the demolition of ramshackle buildings.

At thirteen studied intersections the recorded data have shown the picture appearing in Table 1. There are a very high number of dangerous violations of the STOP sign, meaning that the responsibility of drivers in this type of accidents is almost exclusive. Another risky attitude of drivers in Xanthi's urban area is the trend to disobedience to traffic lights. It is true that all lights are not necessary, but this cannot explain the behavior of drivers. For each accident in Xanthi, the following information has been recorded:

a. Accidents with injured persons
   1. Accident's location
   2. Information about the incident (time, date, type, maneuver, right of way violation, excessive speed, uncontrolled pavement crossing by pedestrian, fatal accident or not, number of vehicles involved).
   3. Information on the victim persons (number of victims: dead, injured, quality of victim: driver, passenger, pedestrian).
   4. Information for those involved in the accident (genre, age, if he/she is a victim the severity of injury, alcotest results).

b. Accidents with material damage
   1. Accident's location
   2. Information about the incident (time, date, type of incident, number and type of vehicles involved, vehicle movement direction).
   3. Information about the drivers (genre, age, alcotest results).
   4. Street features (existence of signing and traffic lights).

Unfortunately, in many cases of accident records not all of the above information is mentioned. These cases have not been rejected in the processing phase because they have been judged exploitable regarding the rest of the received information.

Table 1 Causes and number of accidents in several Xanthi's intersections (in ascending order, recording period 2012)

Cause of accident	Number of accidents
U-turn	1
Slippery pavement	1
Pothole on the pavement	6
Leaving a parking space	22
Traffic sign violation (signs forbidding the entrance to all vehicles, the left turn, the right turn, stopping, stopping and parking, and signs about obligatory yield of right of way)	23
On a one-way road opposite movement	25
Parking maneuver	35
Traffic light violation	42
Illegal parking	74
Reverse	164
STOP sign violation	1040

Table 2 Number of road traffic accidents in Xanthi during the three last years

Traffic Accidents		Year		
		2013	2014	2015
Total Number of traffic accidents		72	65	82
Fatal accidents	Number	6	7	7
	Victims	6	8	8
Accidents with serious injuries	Number	11	9	6
	Victims	12	13	6
Accidents with slight injuries	Number	55	49	69
	Victims	92	73	106

Different types of accidents as a function of persons involved are shown in Table 2 for the city of Xanthi during the years 2013, 2014 and 2015. The accident rates are similar in this

time interval, emphasizing the need for preventive measures. Some of them are described in the following sections.

At the intersection of Anatolikis Thrakis and Andrianoupoleos streets, the traffic is controlled with a pulsating yellow light as well by directory and prohibitive signs. For the recorded accident, the responsibility is fully on the driver's side because he had driven his private car on the opposite way. However, despite both streets serve one way movement, the site frequently is the theater of accidents due to reduced visibility (Figure 4).

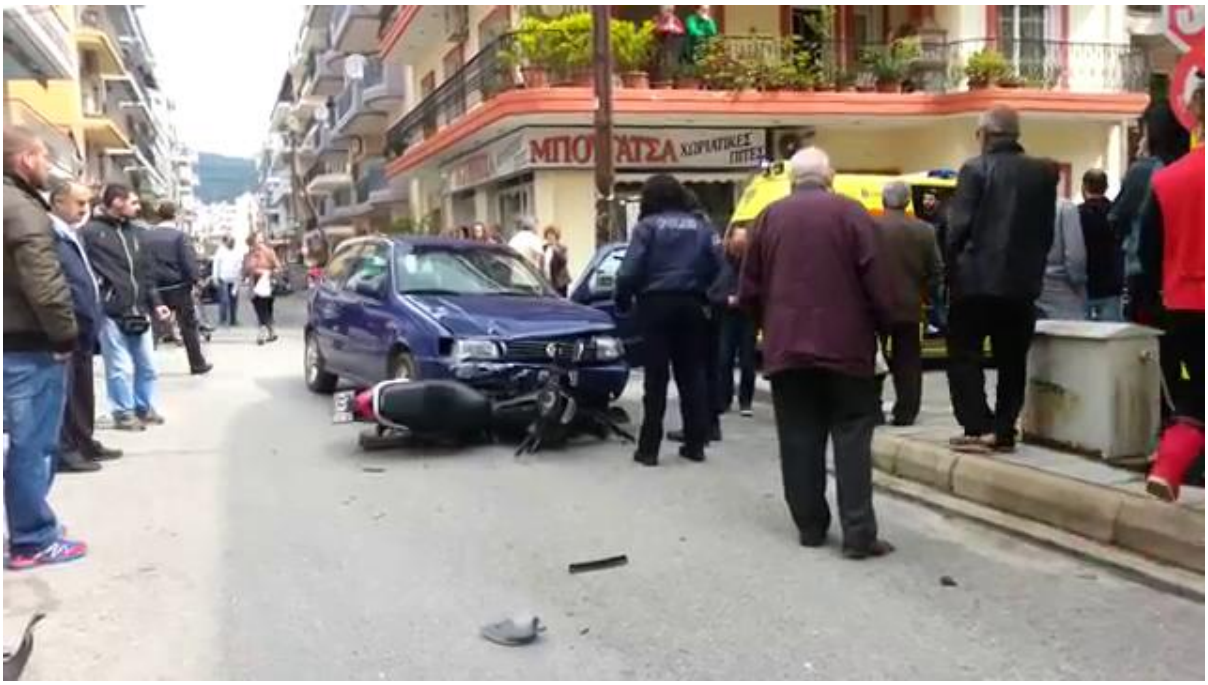

Figure 4 Accident at an intersection. The responsibility is on the elderly car driver.

Two circular intersections have recently been created (Figure 5) while another one already existed in the urban web. Hence, the experience could not be considered as sufficient. However, it can be said that the number of accidents in the existing junction is very limited.

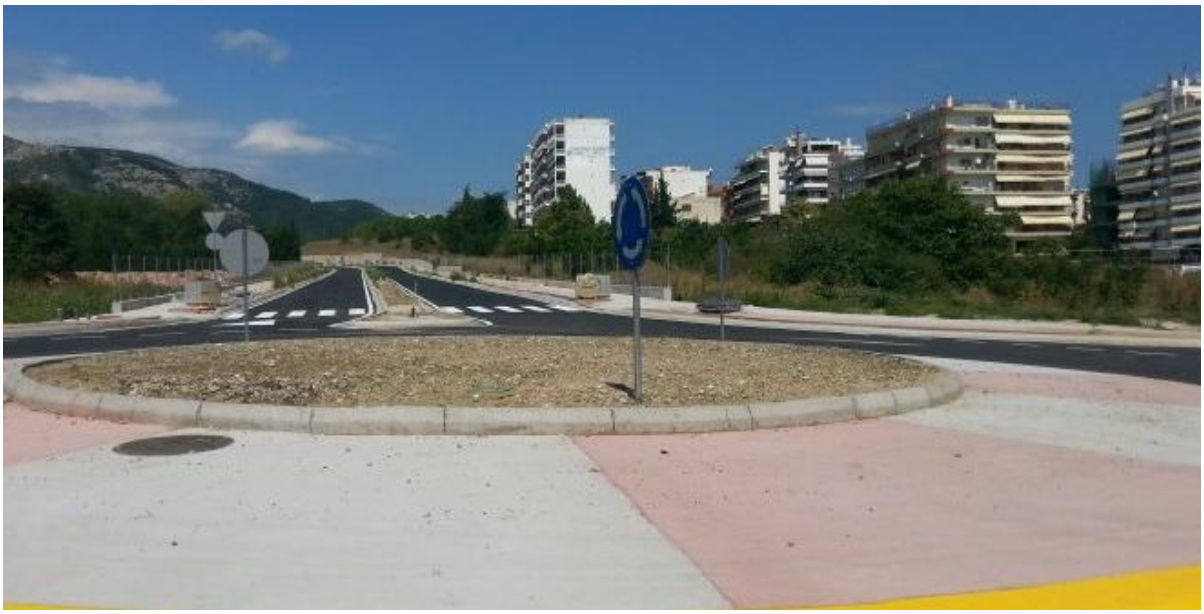

Figure 5 The circular intersection has been opened to traffic in December 2014

The decision to install a circular intersection in order to improve safety should be based on a well documented safety problem which can be corrected. It is essential for a study of accident reports to be preceded and a full record of crashes to be completed. A circular intersection could resolve safety problems like high rates of incidents, high severity of collisions possibly reduced due to low speed imposed by such an intersection, visibility difficulties reducing the efficiency of a STOP sign, and the inadequate splitting of movements, especially in one-lane ramps.

In residential areas, what is needed is the wide application of "30" (maximum speed 30 km/h) zones and the structural configuration of the road networks in traffic calming networks. Disciplining to the signs almost does not exist; the only solution is the physical design that makes the road friendly to vulnerable users and shields it from arbitrary drivers' behavior.

Finally, despite the labyrinth-like form of the roads in the Old Town, no accidents involving persons are recorded, due to the low volumes and low speeds developed in the streets which are paved with stone blocks (cobbled roads).

CONCLUSION

The safety in road intersections is a complex public health issue which cannot always be solved by making changes to traffic lights and signals, but it can be enhanced by a comprehensive national effort of improved management of safety for vehicles and pedestrians in the intersection. Reliable marking, improved lighting, the vehicle maintenance, systematic policing of speed limits, of traffic oncoming and of alcohol consumption, are short-term and low-cost measures. Changing driving behavior, respect of road safety rules, reducing aggression and tolerance to other drivers consist long-term performance measures, which - while have low cost- they require systematic information, continue and realization that road safety is everyone's concern.

Design concepts for major urban intersections refer to clear, unobstructed view at an adequate distance to all road users, irrespective of the weather conditions or the time of the day, 30 km/h maximum speed differences between users of the road, and the adjustment of traffic flows to reflect the best possible visibility and the predicted behavior of road network users.

In the city of Xanthi, the number of accidents with victims is not very high because of the behavior of people traveling on the road network, which is based on attitudes that do not exalt the private car in the role of protagonist. The geometry of the road network can be improved in relatively few intersections, but there may be interferences controlling its operation by carefully marking and moving in refutation of adverse effects of hasty signaling options.

Transportation managers and road designers should alter their perception that it is adequate to study only dangerous points where a critical number of accidents has been recorded. This idea does not lead to an improvement of the level of road safety on the particular road section, because accident causes are usually shifted to neighboring points. So, the level of road safety of this road section gets worse, while on the same time dead-end thoughts are created for solutions that can improve the situation.

A specific risk study of risk in connection with the design and implementation of urban road projects is proposed. In such a way, along with an environmental impact assessment study, the necessary supplies for a proper and timely implementation of interventions on the side of safety in nowadays black spots in the city of Xanthi will be provided.

The choice of intersections with cyclic paths requires finding enough free space. If this is the case, it is preferable to construct roundabouts. It is expected that the newly formed circular intersections will offer the chance to examine the conditions for a road accident.

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