

Policies for Sustainable Mobility Promotion and Road Safety Enhancement at Urban Intersections

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Abstract: Urban intersections are the most complex points of a road network and the most important road sections to study. The aim of the present work is to develop a complete methodology to redesign the existing urban intersections, based on the principles of sustainable mobility, focusing on the traffic and parking issues and to increase their overall safety characteristics. The work is focused on the design of a sustainable and safe urban mobility system evaluating and redesigning typical intersections of a medium size European city such as Volos which have major problems. Initially, the problems of various types of intersections are recorded and the proposed interventions for a typical urban intersection between secondary roads are then presented. The interventions aim to increase the urban infrastructure, improve road sign placement, replan the parking areas and implement new technologies to create a proper urban intersection.

Keywords: Urban intersections, Sustainable urban mobility, Road safety, Visibility, Accessibility, Smart mobility

1. Introduction

In the central sectors of medium and large cities there are significant traffic and environmental problems, which stem mainly from the long-standing lack of an integrated planning policy for spatial, urban and traffic organization. Existing land uses attract the majority of commuters to city centers. Consequently, there are problems of traffic congestion, illegal parking, unsafe movement of cyclists and limited accessibility for pedestrians and people with disabilities. The image of the majority of today's cities, as it has been shaped over time due to the absence of harmoniously and interrelated combined urban and traffic policies, remains degraded, and it does not meet the requirements of movement of citizens and visitors, causing serious effects on the environment and quality of life.

An urban road network consists of elongated road sections, which enclose building blocks or common areas and are connected by intersections of different forms. Urban intersections are complex points of the network that require more specific study and analysis. They are key points of daily activity, as they serve the distribution of traffic to and from the main and secondary roads, constituting critical points of the transport network. The main goal of intersections is to provide safety, comfort and ease of movement for all those who cross the junction (pedestrians, cyclists, motor vehicles).

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The existing urban planning legislation places greater emphasis on the formation of the building blocks and the way of construction of the building facilities, without approaching evenly the immediate adjacent area of the intersections. In most Greek cities urban junctions are constructed and maintained without a single framework of planning rules, resulting in an illegible road environment for users. The lack of proper design of the intersections is considered equally responsible for the collisions between vehicles, pedestrians and bicycles, as well as the carelessness of the respective users.

Until today, no detailed urban intersection planning guidelines have been established for Greek cities, so that these meeting points ensure the harmonious coexistence of all road users, constituting safe points of approach, continuation or change of direction. This is the weakness that this research seeks to overcome by presenting an integrated approach to the redesign of urban nodes, based on policies in line with the principles of sustainable mobility, with a focus on user safety. The ultimate goal is to formulate as much as possible a standardized procedure for interventions to improve the infrastructure of urban intersections, aiming at the creation of intersections, which will include a basic triptych: Sustainability, Safety, Smart Mobility.

2. The triptych of modern urban mobility

2.1. Sustainable Urban Mobility

In recent years, Sustainable Urban Mobility has been a major challenge for cities and a key concept for the 21st century. The term "Sustainable Urban Mobility", which is now widely used in the transport sector, aims to create sustainable conditions in the transport and movement of people and goods within the city. It includes a series of guidelines for the design of transport systems, so as to provide high quality services in transport, based on the axes of economy, environment and social sustainability (Bakogiannis, 2016).

The directions and planning policies for sustainable urban mobility are shaped according to the needs and problems of each city, adapting to their specific characteristics, their history and their identity. It is therefore understood that the framework of sustainable mobility planning policies is differentiated for each case. However, some of the main guidelines followed in most European cities for Sustainable Urban Mobility are:

1. Unified urban and transport planning.
2. Rational management of urban mobility instruments.
3. Exploitation of new technologies and smart transport systems.
4. Promotion of mild forms of transportation (pedestrians, bicycles, public transport) and reduction of dependence on the car.
5. Improving accessibility for people with disabilities.

2.2. Road safety

In urban areas, a large number of different users (pedestrians, cyclists, car drivers, etc.) are crowded to use the available (usually limited) urban space. The constant interaction between vulnerable users and the urban road network brings about situations in which people are regularly exposed to danger. According to the statistics, around 10,000 people die every year while circulating in urban areas of the EU. In Greece, according to the statistics for the year 2019, 10712 accidents were recorded, of which 8941 were in residential areas and only 1771 in uninhabited areas. The following figures show the accident rates per area, road and means of transport (Hellenic Statistical Authority - E.S.A., 2021).

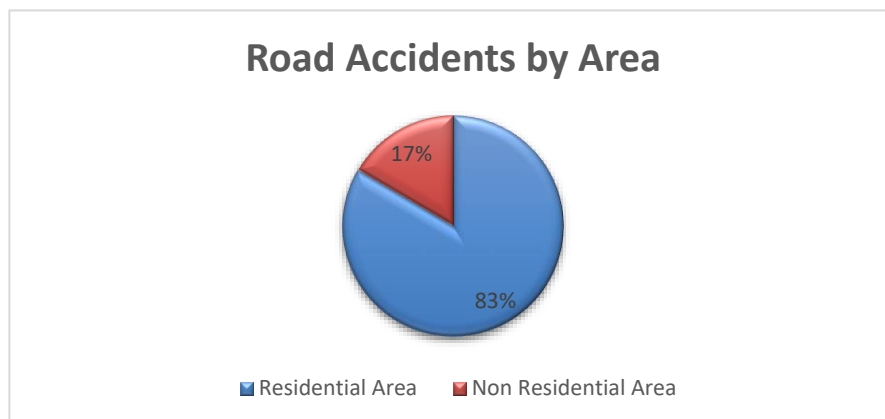


Figure 1: Road Accidents by area

Source: E.S.A., 2021, own processing

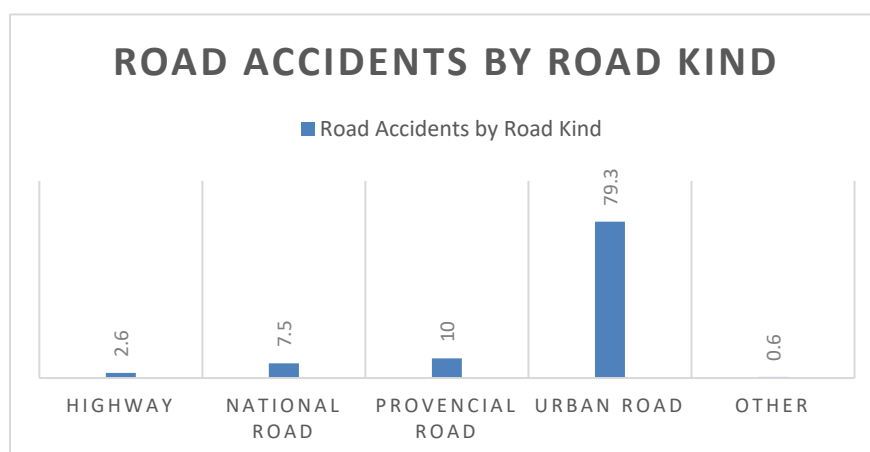


Figure 2: Road Accidents by road kind

Source: E.S.A., 2021, own processing

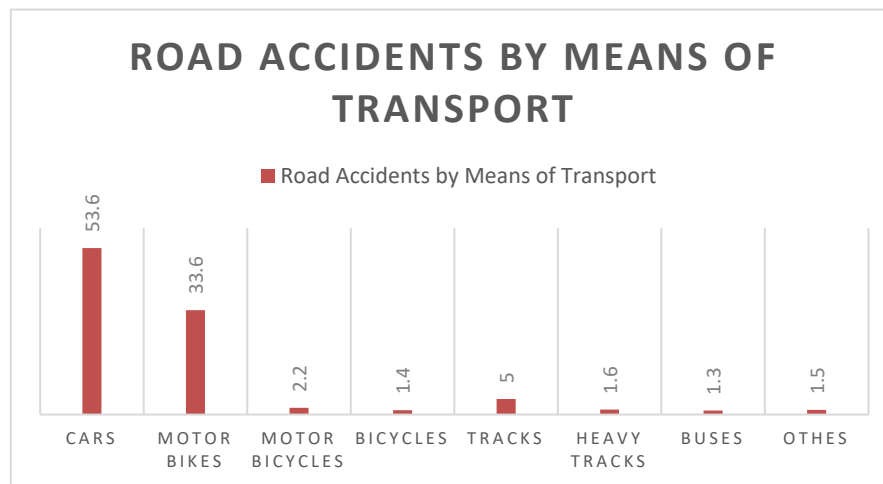


Figure 3: Road Accidents by Means of Transport

Source: E.S.A., 2021, own processing

According to the statistics cited, the largest proportion of road accidents take place in residential areas. This is due to the existence of many successive intersections in urban areas as well as their incorrect geometrical and functional state. Although various measures are in place in some cities to improve road safety, the total number of road accidents remains in a stagnant state as the measures are not a part of a single integrated sustainable urban mobility policy, through which travel will be organised simultaneously in terms of service and safety.

2.3. Intelligent Transport Systems (I.T.S.)

Intelligent transport systems are a combination of information and communication technologies aimed at improving mobility, managing transport work more efficiently and providing services to users to travel in a safer, more efficient and environmentally friendly way. The use of these systems offers real-time information, both to their managers and to road users, contributes to the confrontation of traffic and parking problems, to the improvement of the safe movement of pedestrians and socially vulnerable groups (people with disabilities, the elderly, children, etc.), and contributes to the enhancement of road safety.

3. Urban Intersections – Methodology of research

Urban intersections are complex points of the road network that require more specific analysis and study. Many road safety problems are directly related to the geometry and equipment of urban intersections. The present research, in order to approach the formation of an integrated urban intersection design, evaluates four typical central urban intersections of a medium-sized European city such as Volos. The methodology on the basis of which the subject of the present research was formulated includes both the necessary theoretical part and the useful practical part. The practical part of the research includes the following stages:

1st Stage - Selection of a study area: at this stage the four urban intersections were selected, which were studied with multiparametric criteria.

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2nd Stage - Field research: at this stage, data on urban road infrastructure was collected, through on-site observations and recordings. The data were collected with the help of special Census Bulletins for each intersection and in which the following data were recorded: characteristics of intersection roads, traffic arrangements, signage, accessibility, visibility and new technologies. Converging roads and intersections were captured first photographically and then by design.

3rd Stage - Processing and analysis of findings: at this stage, all the data recorded as well as the problems identified were collected, processed and recorded.

4th Stage - Planning of interventions: in the last stage of the research, a framework of proposals for the redesign of urban intersections was carried out, taking into account all the elements recorded in the previous stages.

3.1. Characteristics of the intersections under study

The intersections studied include the four most common types of secondary road junction found in a typical urban center, with the exception of those controlled by light-signalling or served through roundabouts. These are four-legged level intersections with basic function the access to roadside residential and commercial land uses. Specifically, the intersections studied are the following:

a) *Intersection of Glavani & Gallias streets*

Intersection of a secondary road of a traffic stream (Glavani) with a secondary priority road of a traffic stream (Gallias).

b) *Intersection of Deligiorgi & Polymeri streets*

Intersection of a secondary road of a traffic stream (Deligiorgi) with the main priority road of two single-lane traffic streams (Polymeri).

c) *Intersection of Mavrokordatou & Analipseos streets*

At the intersection of a secondary road of a traffic stream (Mavrokordatou) with the main priority road of two-lane traffic streams and an islet (Analipseos).

d) *Intersection of Hatzimichali-Ypsilantou & Larissis streets*

Intersection of a two-lane secondary road (Hatzimichali-Ypsilantou) with a three-lane main road and an islet (Larissis).

3.2. Description of the main problems of cross-checks

The problems recorded during the on-the-spot investigation at the above cross-checks are similar in all cases and the main ones are the following:

a) *Insufficient width of pavements*

One of the main problems identified at the studied intersections concerns the width of the existing pavements. In most cases, the available pavement width is insufficient, preventing the free routing of pedestrians resulting in forced movement of pedestrians on the roadway. For people who have difficulties in moving, the situation is more unfavorable as they do not have the ability to move comfortably and safely.

b) *Irregular siting of urban equipment*

In several parts of the existing pavements there are scattered and irregular planted trees, which sometimes cover the existing signage. In several places the trees have been placed on pavements of limited width, creating problems in the free routing of pedestrians and people with disabilities. The incorrect placement of waste

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bins, on the corners of the building blocks, creates another problem, as the visibility of the drivers is significantly reduced.

c) Incomplete horizontal and vertical signage

The existing vertical signage was evaluated as incomplete / not visible / not maintained / incorrectly placed, thus hindering the visibility of drivers and the unhindered movement of pedestrians and people with disabilities and creating a gap in the correct information of drivers. As far as horizontal signage is concerned, in many cases the markings of the crossings and the protograms for the interruption of the course or the granting of priority were either absent or were poorly maintained.

d) Absence of pedestrian crossings

At the intersections under consideration, there was no markings - pedestrian crossings, a fact that significantly hinders the accessibility of pedestrians and especially of vulnerable groups (people with disabilities, the elderly, children, etc.).

e) Illegal parking

Another problem that was recorded with various negative effects, was illegal parking and abusive occupation of common areas, such as sidewalks. Illegal parking creates serious problems for the safe passage of pedestrians and people with disabilities. The remaining road surface available for the passage of vehicles often becomes marginal (<2.00 m) and there are often bumps of vehicle mirrors. In areas with more intense commercial traffic, problems are created in the operation of the road network due to the absence of special locations that serve basic needs of the supply chain, such as the loading and unloading of goods. Similar problems are created due to the absence of the design of suitable parking spaces for two-wheeled motorbikes and for micromobility vehicles, as well as for buses. Finally, particularly the illegal parking that takes place at the junction points of the intersections (complete circumvention of the parking ban provided by the Traffic Code at a distance of 5.00m from the Building Line) dangerous is as the visibility of the driver is significantly limited for the safe passage of the vehicle.

f) Lack of planning for vulnerable social groups

At the intersections under consideration, the absence of sound and comprehensive planning for vulnerable users (people with disabilities, the elderly, new parents with strollers) was characteristic. There was also a lack of local downhills through ramps for people with disabilities as well as a driver for the blind on the pavement, as well as a lack of special places for parking disabled vehicles on the roadway.

4. Analysis of the intersection of Glavani & Gallias streets

For the purposes of this research, it was chosen to analyze more extensively one of the four intersections examined, namely the intersection of Glavani & Gallias streets. Initially, the current situation and the problems identified are depicted and then the proposed redesign guidelines are listed.

4.1. Recording of the current situation

The intersection of Glavani & Gallias is a four-legged central urban junction of the city of Volos to which a secondary road of a traffic stream (Glavani Street) contributes and with a secondary priority road of a traffic stream (Gallias street). In the context of recording the characteristics of the current situation, a detailed survey was made of a) the geometrical characteristics of the intersection, b) the existing urban equipment, c) the vertical signage d) the horizontal signage, e) the traffic and parking conditions.

The main characteristics of the roads are presented in the following table:

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Street	Street Category	Direction of Traffic	Priority	Road Width (m)	Pavement Width (m)	Speed (km/h)
Gallias	Secondary	One Way	Yes	6,50	1,00	50
Glavani	Secondary	One Way	No	6,00	3,00	50

Table 1: Current situation - Road characteristics

Source: Own processing

The following cross sections depict the basic characteristics of the two Roads:

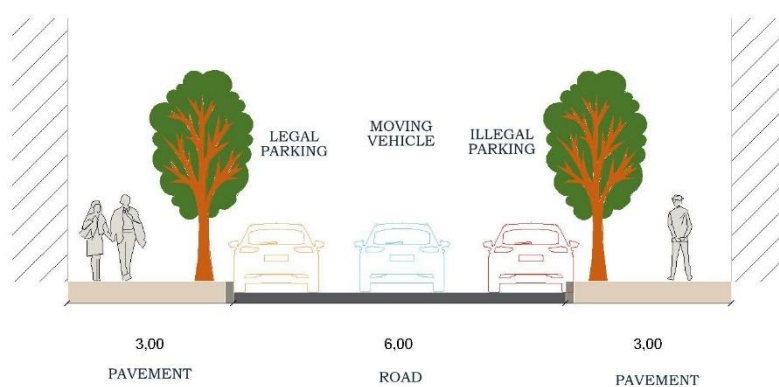


Figure 4: Glavani Street Width

Source: Own processing

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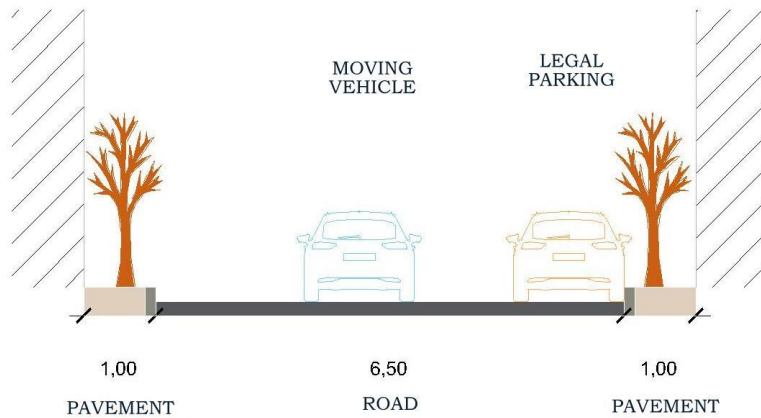


Figure 5: Gallias Street Width

Source: Own processing

4.2. Recording of main intersection problems

The problems recorded at the intersection of Glavani & Gallias streets are depicted in Figure 6 and are detailed in Table 2.

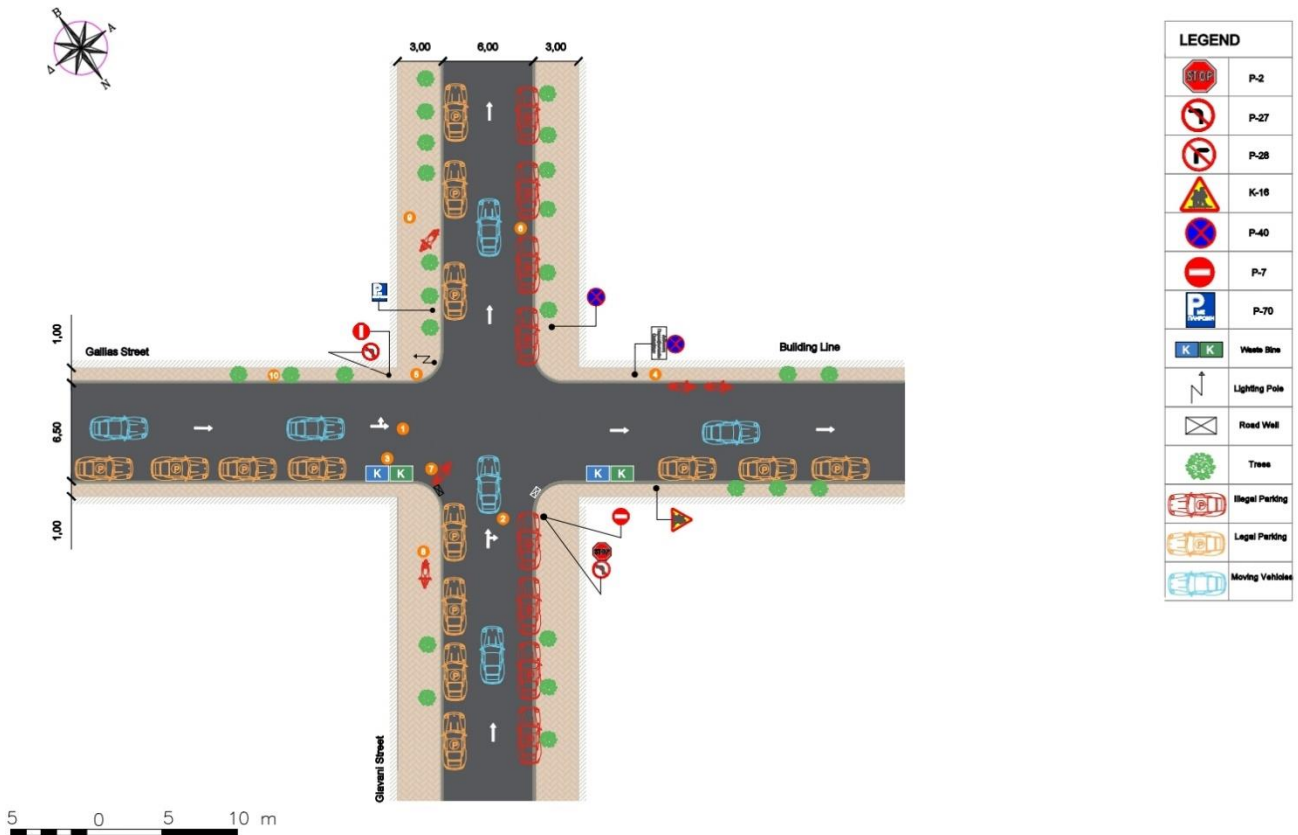


Figure 6: Glavani Str. & Gallias Str. Intersection – Recording Major Problems

Source: Own processing

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List of intersection major problems	Photographic Documentation
<p><u>1. Absence of pedestrian walkways:</u></p> <p>The accessibility of pedestrians and especially of vulnerable users (people with disabilities, the elderly) is significantly reduced and their safety is endangered.</p>	
<p><u>2. Absence of horizontal marking of mandatory stoppage (STOP gel):</u></p> <p>The existing regulation of mandatory stoppage of vehicles is not sufficiently understood.</p>	
<p><u>3. Installation of waste bins in an unsuitable position:</u></p> <p>The visibility of drivers is prevented for the safe passage of vehicles through the intersection.</p>	
<p><u>4. Insufficient pavement width:</u></p> <p>The free routing of pedestrians is prevented, resulting in the mandatory movement of pedestrians on the roadway.</p>	
<p><u>5. Absence of sidewalk landings through an inclined level (ramp) of a disabled crossing:</u></p> <p>The movement of disabled people is difficult.</p>	

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<p><u>6. Illegal two-sided parking:</u></p> <p>The available width of the road surface for the movement of vehicles is limited. Illegal parking also occupies part of the already narrow pavement, thus preventing or making impossible the movement of pedestrians and people with disabilities on the sidewalks.</p>	
<p><u>7. Illegal parking at the junction points of the junction:</u></p> <p>The driver's visibility is prevented for safe passage through the intersection.</p>	
<p><u>8. Illegal moto parking on the pavement:</u></p> <p>The unhindered movement of pedestrians and people with disabilities is hindered.</p>	
<p><u>9. Absence of a guide for the blind on the sidewalks:</u></p> <p>It is not possible to move blind people.</p>	
<p><u>10. Installation of urban equipment elements and afforestation in an inappropriate position:</u></p> <p>The movement of pedestrians and people with disabilities is prevented.</p>	

Table 2: List of Gallias Str. & Glavani Str. intersection major problems

Photos Source: Private Archive

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The concept of safety at an intersection is inextricably linked to the concept of visibility. Ensuring visibility enables vehicle users to make correct decisions, after evaluating the traffic data prevailing in the area. At most urban intersections, visibility conditions are characterized as particularly unfavorable, as the urban landscape is quite densely built and many times the existing urban configuration, combined with the problems mentioned above, make it even impossible to ensure the minimum requirements of lengths – fields of visibility (Mintsis, 2014). The figure below shows the surface – field of visibility of the driver who moves on Glavani Street and approaches the intersection.

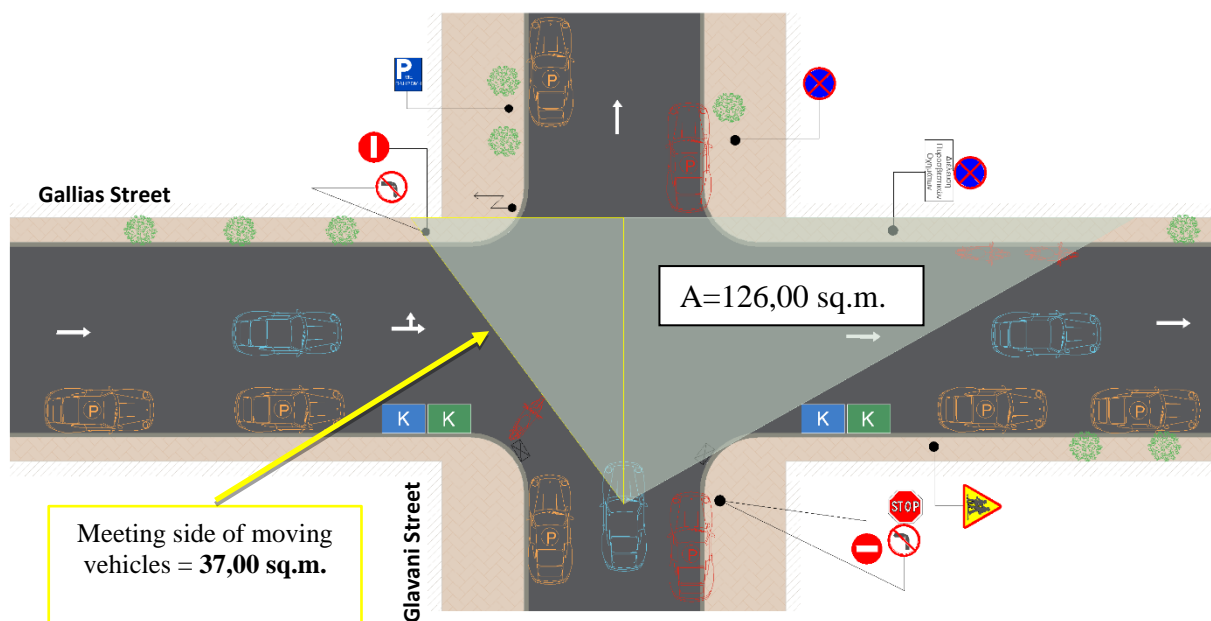


Figure 7: Driver Visibility while crossing the intersection

Source: Own processing

As shown in Figure 7, the Area – field of visibility is estimated at 126.00 sq.m., of which only 37.00 sq. m. are on the meeting side of the moving vehicles. The obstacles at the junction points of the intersection (illegal parking and rubbish bins) significantly limit the visibility of the driver travelling on Glavani Street, who cannot perceive in time the vehicle moving with priority on the Gallias Street.

4.3 Proposed Interventions

The proposed interventions to improve crossovers are based on the principles of sustainable mobility, aiming to solve traffic problems and enhance the safety of all users. Until today, no specific specifications for the design of urban intersections to which secondary roads contribute have been established, the measures proposed are the product of a synthesis of international standards and specifications, existing legislation, good practices, as well as experiences collected by experienced Executives of Technical Services of Local Government Organizations.

The measures proposed concern:

- the improvement of the infrastructure of intersections,

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- the implementation of soft traffic measures,
- the organization of parking,
- planning for pedestrians and bicycles, planning for people with disabilities,
- the provision of micromobility systems,
- the regulation and clear identification of priorities, with the aim of ensuring maximum visibility and restoring accessibility for all users. In this way, the creation of a safe environment is achieved in which pedestrians, people with disabilities, cyclists and drivers of various types of vehicles have clear visual contact, clearly perceive each other and can share equally, fairly and effectively the public space. The interventions proposed to smooth the problems of the junction of Glavani & Gallias streets are the following:

1. Implementation of pedestrian crossings

The route of pedestrian movement at an intersection should have as few discontinuities and detours as possible and follow, as far as possible, a continuous flow. It is necessary to have crossings inside the intersection, which will facilitate the safe and unhindered flow of pedestrian movement. The minimum width of the crossings applied is three (3) meters. Their length should be as short as possible and this is achieved by the extension – local widening of the pavements at the junction points of the intersection.

At the intersection of Glavani & Gallias streets, three different crossing design solutions are proposed (level crossings, elevated crossing, elevated junction), as depicted in Drawings 8, 9 & 10.

Elevated crossings and elevated intersections are measures of mild traffic, which help reduce speed, attract the attention of drivers and ensure accessibility.

2. Widening of pavements

The geometrical characteristics of the pedestrian movement corridor directly affect their smooth movement as well as their sense of security and comfort. The width of the pavement must meet the requirements for safe and unhindered pedestrians and people with disabilities. Through their widening, the reduction of vehicle speeds is ensured at the same time, as the width of the road surface of the traffic current is reduced. The design of the widenings is done in such a way as to ensure a walkway of a net width of 1.50 meters for free routing of pedestrians.

3. Extension of the pavement at the point of convergence of the intersection

The extension - local widening of the pavement at the intersection, is a simple, effective and attractive means of improving the safety and overall accessibility of the junction. It is not a measure suitable for every case but it offers several benefits, the most important of which are:

- Improve the visibility of drivers and pedestrians.
- Prevent illegal parking of vehicles near the intersection.
- Reduction of vehicle speeds as the width of the road surface is limited.
- Increase of the pedestrians' living space for control and safe passage.
- Reduction of the distance crossed by pedestrians, which is particularly important for people who slowly cross the intersection such as the elderly and people with disabilities.

The extension – local widening of the pavement is designed at such a width as to achieve the minimum width of the road for a traffic stream (3.25 meters) and at such a length as to prevent the parking of vehicles at a distance of 5.00 meters from the point of junction of the intersection.

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4. Removal of elements that hinder the visibility and passage of pedestrians

The elements of urban equipment that obstruct the visibility of users at an intersection may be garbage bins, tree plantings, utility poles, lighting poles, advertising boards, information signs and vertical signage. The measures proposed to ensure visibility and safe passage of pedestrians are:

- Removal of vertical signage and any element of urban equipment from the area of the junction of the intersection. Especially in the area formed by the extensions of the building lines to the adjacent curbs, it is forbidden to install any element that prevents visibility.
- Installation of vertical signage and urban equipment along the pavement, at a distance of 0.40 meters internally from the curb, ensuring the required 1.50 meters of free route for pedestrians and people with disabilities.
- Creation of recesses on the pavement for the placement of waste and recycling bins, away from the crossings and the junction.
- Siting of low vegetation to improve aesthetics at the critical points of the junction, in order to ensure adequate and ample visibility.

5. Organization of parking

The organization of parking is a simple but basic measure of safety and functionality. It is necessary to take into account both the needs of the residents and the needs of the provision of roadside use for loading and unloading. By placing the parking of vehicles at a sufficient distance from the crossings and the junction, visibility for all users is improved. The available parking spaces are demarcated so as not to interfere with the smooth movement of vehicles. Focusing on sustainable mobility, it is also proposed to locate parking spaces for electric and micromobility vehicles.

6. Planning for people with disabilities

When planning intersections, provision should always be made for people with disabilities, applying the appropriate infrastructure. The measures adopted against the design of the crossing under consideration are the following:

- Observance of 1.50 meters of free pedestrian routing along the pavements, free from any obstacle.
- Construction of a local demolition of pavements with ramps for people with disabilities at all crossings.
- Construction of a Guide for the Blind, along the pavement that ensures continuous and unhindered flow of movement.
- Provision for the creation of a parking space for people with disabilities.

7. Design for bicycles

Designing in accordance with the principles of sustainable mobility, emphasis is placed on the safe movement of bicycles. For this reason, it is proposed that Gallias and Glavani roads should be converted into roads where bicycles coexist with the rest of the vehicles, i.e. roads with mild traffic, with a speed limit of 30 km / h.

8. Setting priorities with appropriate horizontal and vertical signage

One of the most important elements at an intersection is the correct and clear horizontal and vertical signage, through which traffic arrangements and priorities are depicted. In the case under consideration, appropriate labelling is used so that users are informed in a timely and clear manner.



*Figure 8: Suggested interventions at the intersection of Glavani & Gallias streets
with road and pavement same bottom level crossings*

Source: Own processing

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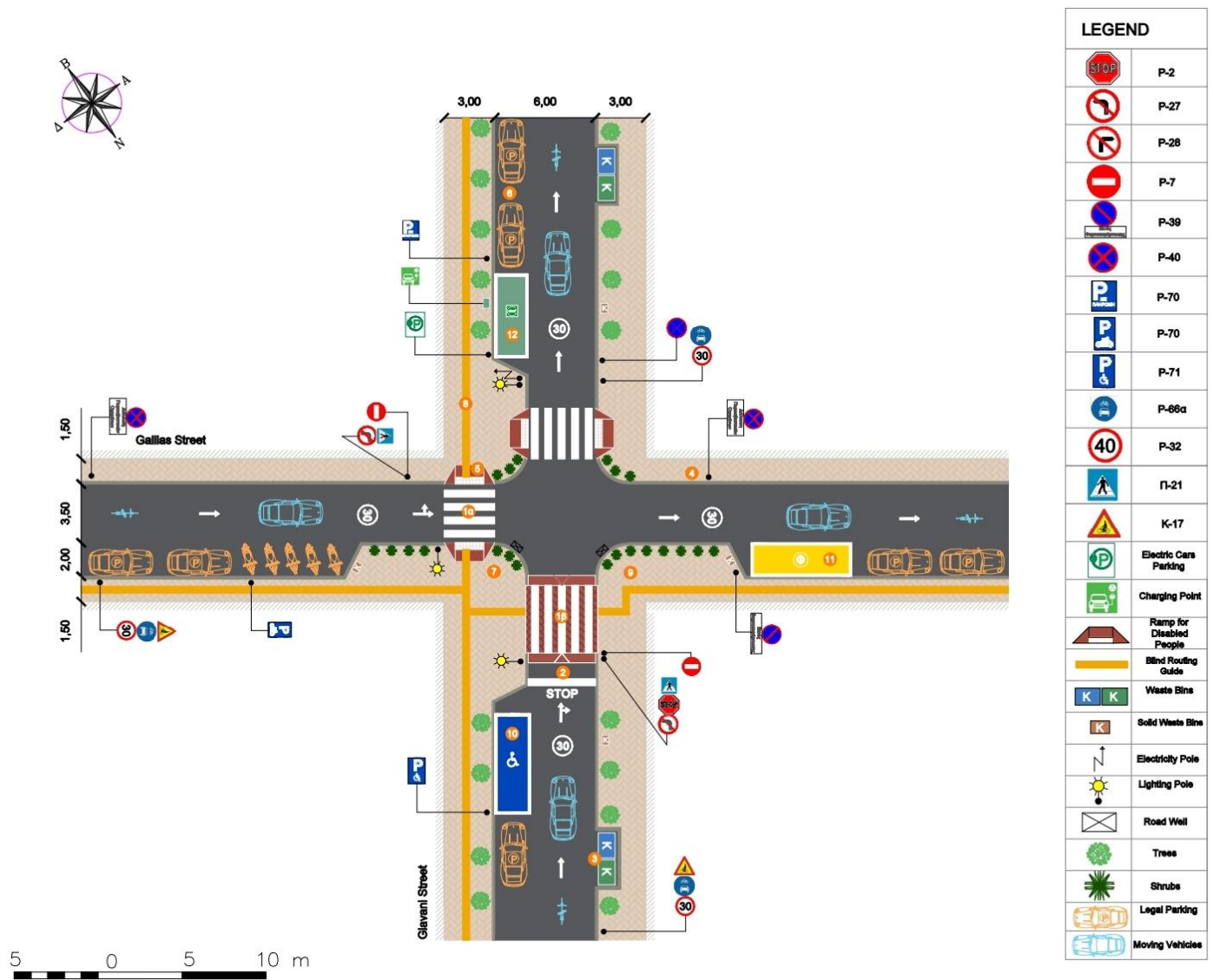


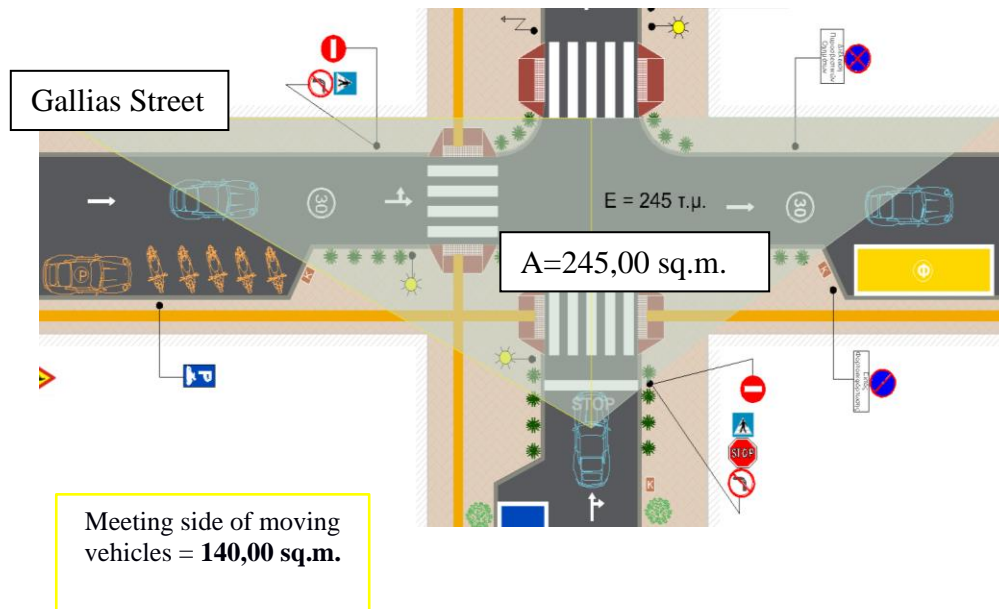
Figure 9: Suggested interventions at the intersection of Glavani & Gallias streets
with one elevated crossing
Source: Own processing



Figure 10: Suggested interventions at the intersection of Glavani & Gallias streets
with a fully elevated junction

Source: Own processing

By applying the above interventions at the intersection, we achieve a significant increase in the visibility area of the driver, in a total percentage ranging from $207/126 = 64\%$ to $245/126 = 94\%$ and in an individual percentage (to the side of the cross-movements) ranging from $121/37 = 227\%$ to $140/37 = 278\%$ as shown in the following Figures.



***Figure 11: Visibility surface at the intersection of Glavani & Gallias streets
with road and pavement same bottom level crossings***

Source: Own processing

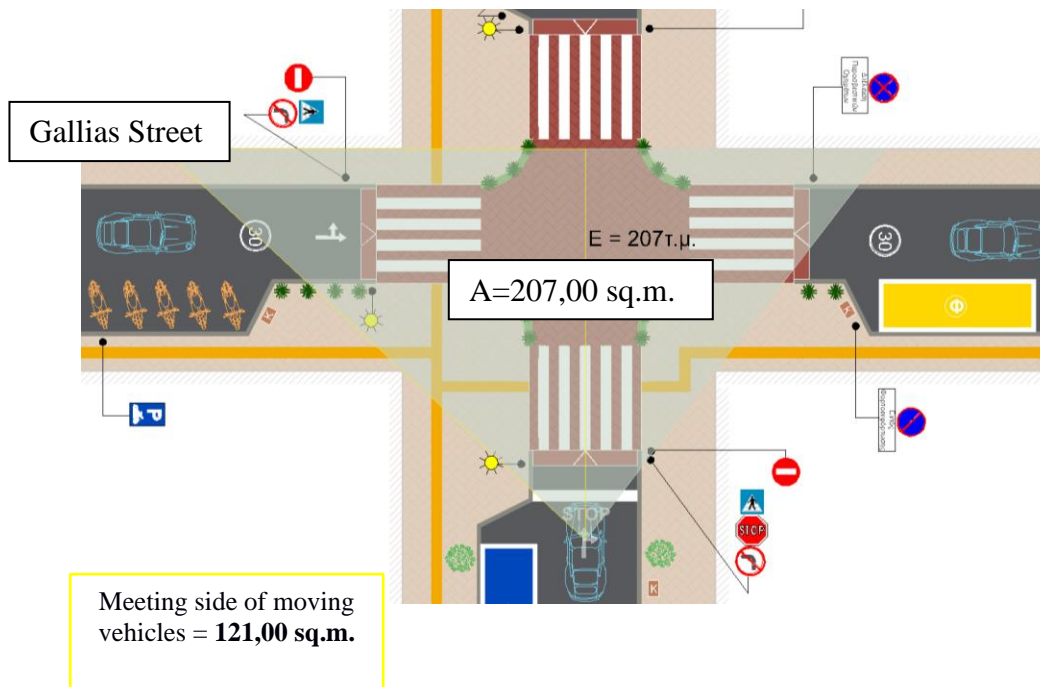


Figure 12: *Visibility surface at the intersection of Glavani & Gallias streets
with fully elevated junction
Source: Own processing*

5. Conclusions

Urban intersections are the most complex and dangerous parts of the urban road network. These are the sections in which most road accidents are recorded. The highly densely built urban fabric, the existing urban configuration of the site and the often incorrect geometric and functional design of the intersections, create adverse visibility conditions, resulting in a degraded level of road safety. The main problems recorded at the intersections are: the incomplete, incorrect, invisible or unsupported vertical and horizontal signage, the limited geometrical characteristics and the poor workmanship of the road and the pavements, the non-existence of pavement downhill through access ramps for people with disabilities and drivers for the blind, the disorderly siting of urban equipment, illegal parking, poor visibility and the layout of the intersection. These problems combined with speeding, priority violations and the carelessness of drivers and pedestrians compose a dangerous landscape in which every moment lurks the risk of an accident. The lack of an integrated framework for the application of rules and specifications for the design and restoration of urban intersections, exacerbates the above problems.

The proper design of urban intersections should be implemented with a holistic standardised approach that respects the needs of all users, including drivers and pedestrians, who do not know the area in which they are moving, are elderly, or have limited motor skills. The proposed interventions that are reflected in this research concern the improvement of the infrastructure and equipment of urban intersections, under the basic triptych:

1. Strengthening road safety
2. Promoting sustainable mobility
3. Implementation of intelligent transport systems

The basic view is that by applying this design triptych, the creation of a safe environment is achieved in which pedestrians, people with disabilities and drivers of various types of vehicles have clear visual contact, clearly understand each other and can share equally, fairly and effectively the public space.

The results of this research can be used to enrich other research projects on enhancing safety at urban intersections as well as taken into account by the competent Authorities and Services for policy formulation and planning of new projects and infrastructures in the context of promoting sustainable urban mobility.

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