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Roundabouts Contribution in Road Safety Enhancement, Urban Revitalization and Sustainable Mobility Promotion

K. Karagiannis[1], S. Grigoriadis[2], N. Eliou[3]

1. *University of Thessaly, Polytechnic School, Department of Civil Engineering, Road Construction Laboratory. E-mail: karagiannisofficial@gmail.com*
2. *National Technical University of Athens, School of Architects, School of Urban Studies. E-mail: sofgrh@gmail.gr.*
3. *University of Thessaly, Polytechnic School, Civil Engineering Department, Professor, Road Construction Laboratory Director. E-mail: neliou@uth.gr*

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Abstract: Urban areas come up against significant traffic problems which are directly connected to the needs of movement. One of the tools that is used for the resolution of the problems is the redesign and rearrangement of existing infrastructure. The ultimate goal is to form an integrated, safe, sustainable, multimodal transportation system that will both satisfy the need for safe, shorter commutes, and ensure quality living in the center and neighborhoods of the Town.

The implementation of modern roundabouts is part of this direction, which are designed in such a way as to do more efficiently satisfying the traffic flow of urban intersections and at the same time improving the image of the urban environment and the quality of life of citizens and visitors. The object of this work, through the systematic measurements carried out in the City of Volos, is to draw conclusions about the effects of the construction of the roundabouts on parameters such as traffic flow, road safety and accessibility for pedestrians and the PWDs.

Key words: Roundabouts, Road Safety, Accessibility, Sustainable Mobility, Urban Revitalization

1. Introduction

The operation of the road urban transport system affects every day all the mobile citizens who stay in cities, and at the same time it imposes constant and intense pressures in the fields of safety and environmental sustainability. In this context, the upgrading of road safety and the promotion of sustainable urban mobility, have the priority, as at the European direction, as at the corresponding national, regional and local level of action.

The urban areas are against to significant problems of sustainability, which are directly connected to the transportation needs for people and shipments, which affect the environment and the social and economic structure in the Town. The private use of the cars remains increased and dominant for medium and long distance inducing a wide range of negative effects. The target of the urban reorganization and structural restructuring of Municipality is to achieve a whole new sustainable, multimodal, public transport system, ensuring safe and quality living in the neighborhoods and keeping alive the center of the Town. As a consequence, it has to secure the possibility of draining the through flows, mainly on the perimeter of the Town, but also on elongated central arteries that run through the urban fabric, in a safe, comfortable, predictable and at the same time accessible, "smart" and environmentally friendly way.

The configuration of roundabouts is part of this direction, which take the place of typically confluences. The design, the geometry and the total way of their service can provide safe and comfort to the driver but also they can guarantee the possibility of safety crosses to the pedestrians and the PWDs. The aim is to drastically reduce traffic congestion, the levels of noise produced and exhaust emissions, as well as the beneficial contribution to the environmental balance. On every occasion, in overall planning, special care must be taken for avoiding the creation of “vicious cycle”, which is caused by the strengthening of road infrastructure, the subsequent reduction of delays, the corresponding increase in the use of the car which requires the further development of infrastructure, and so on.

The roundabouts are designed to contribute effectively to the traffic flow of urban crosses in the lack of traffic lights. The traffic ability and the road safety are improved because the points of involvement and the chances of severe vehicle collisions are significantly reduced. The speeds of the vehicles are gradually reduced, before, during the entrance but also on the access to the roundabout, providing insurance in case of possible inattention of another vehicle while protecting passing pedestrians and the PWDs.

The advantages of the roundabouts cannot be affected to the area of traffic, but are extended to the area such as urban renewal and revitalization. Because of this, the implementation of roundabouts is classified among the interventions that are friendly to the environment and contributes to the improvement and upgrading of people's quality of life. Their design provokes increasingly the interest of scholars, while the evaluation of their application is the subject of further scientific research.

2. Feature Elements of Roundabouts

Roundabouts are specific forms of intersections, where the vehicles can move all the time counterclockwise around a circular islet. This form first appeared and was implemented in the Great Britain (Roundabout) and later in France. Then it was used because of the high-level secure which is provided, especially at areas with increased dangerous. The definition of a roundabout as a circular requires at least three fields. As a rule, in urban areas have from three to eight fields, but in the regional zone the fields cannot be more than six (Mintsis, 2014). In roundabouts all crosses of traffic steams are converted into successive merging and separation maneuvers. In this way, cross-linking is avoided and a region of multiple plexus is created (Frantzeskakis & Giannopoulos, 1986).

2.1 Design Features

The layout of the roundabouts has certain special geometric features which are not presented in other flat roundabouts configurations and other elements that are the same as other types of roundabouts. The most important are:

- Central islet of roundabout
- Node Strands
- Separation islet
- Traffic ring
- Central islet transgressive zone
- Input line
- Crosswalks
- Bicycles’ configurations
- Gardening zone

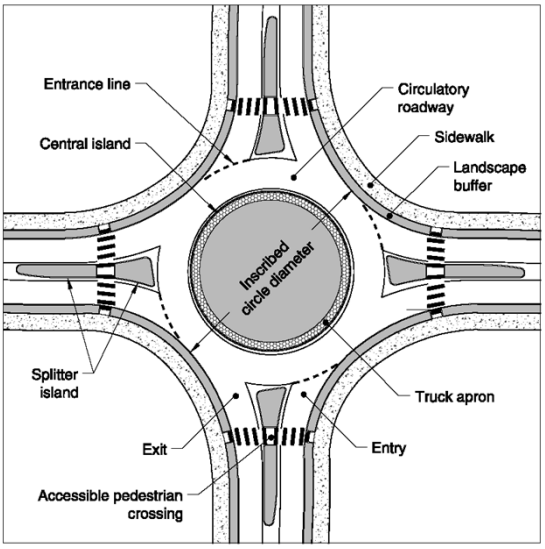

Figure 1: Basic elements of a single lane roundabout

Source: NCHRP & FHWA 2010

2.2 Advantages of roundabouts

The roundabouts are often chosen as a construction solution to regulate traffic at intersections. They present several advantages which are as follows:

- **Road Safety:** The affection of roundabouts on user safety is separated into two main categories, speed effects and effects on potential collision points. The roundabout forces the drivers in reducing their speed and moving in the same direction, resulting the relative speed of the vehicles involved must be sufficiently low in possible collision. Furthermore, at the roundabout the points of engagement between two vehicles are reduced. But in fourth way intersection there are thirty two points of engagement and in a roundabout only eight, that is, there is a reduction of 75% (NCHRP & FHWA, 2010).

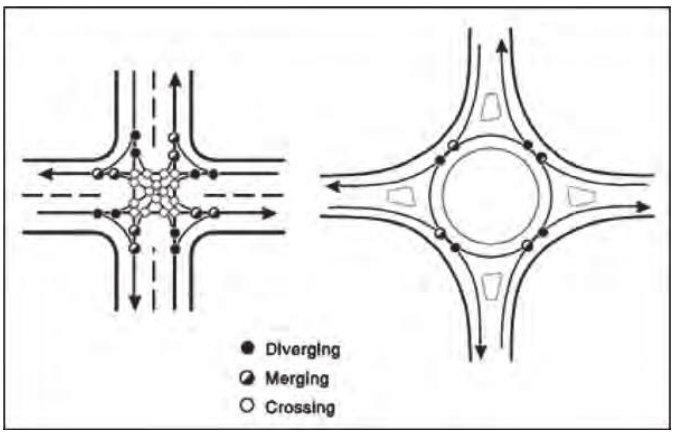

Figure 2: Points of traffic engagement in a standard 4-way and in a corresponding roundabout

Source: NCHRP, 2010

- **Pedestrian Safety:** The great safety for pedestrians is achieved at the roundabouts which are due to the shorter transverse distances traveled, at the low speeds which the vehicles move and the one-way direction of the vehicles. Possible accidents with enmeshed pedestrians are happened at a speed not exceeding 25-40 km/h, which means that the possibility of survival to be 90% (NCHRP & FHWA, 2010).
- **Efficiency:** It has been estimated that roundabouts can handle 30-50% more traffic than a conventional intersection (NCHRP & FHWA, 2010).
- **Access Management:** The roundabouts give the possibility to the vehicles for any direction even the possibility of inversion, eliminating left turns and bypass lanes.
- **Environmental Benefits:** Because of the mode of operation, roundabouts reduce the stopping time of passing vehicles and prevent sudden decelerations - accelerations which have positive benefits on fuel consumption, air pollution from emissions and noise (WDT, 2008).
- **Esthetic Improvement:** Because of the central islet but also the bypass space that exists at the roundabouts, they are an attractive option and upgrade the image of the area, creating small landmarks (Birlon, 2011).

3. Roundabouts in City of Volos

The research presents the results which are recorded, with measurements system, before and after the implementation of the first four modern roundabouts in City of Volos: Roundabout “Dimini” (City Entrance), Roundabout “KTEL” (Bus Station), Roundabout “Customs” (Port Customs) and Roundabout “City Hall”.

Figure 3: The first four new roundabouts in the City of Volos

Source: Own processing

The roundabouts under evaluation are the following:

- «Dimini» roundabout: It is located at the west entrance in the Town of Volos, at the intersection of Larissis, Dervenakion & Botsari streets. It is a four-way roundabout with four entrances and four exits, with two traffic streams, a dividing islet and the capability of serving movements without entering the roundabout.

Figure 4: "Dimini" roundabout before, during the construction phase and in its final form

Source: Private Archive

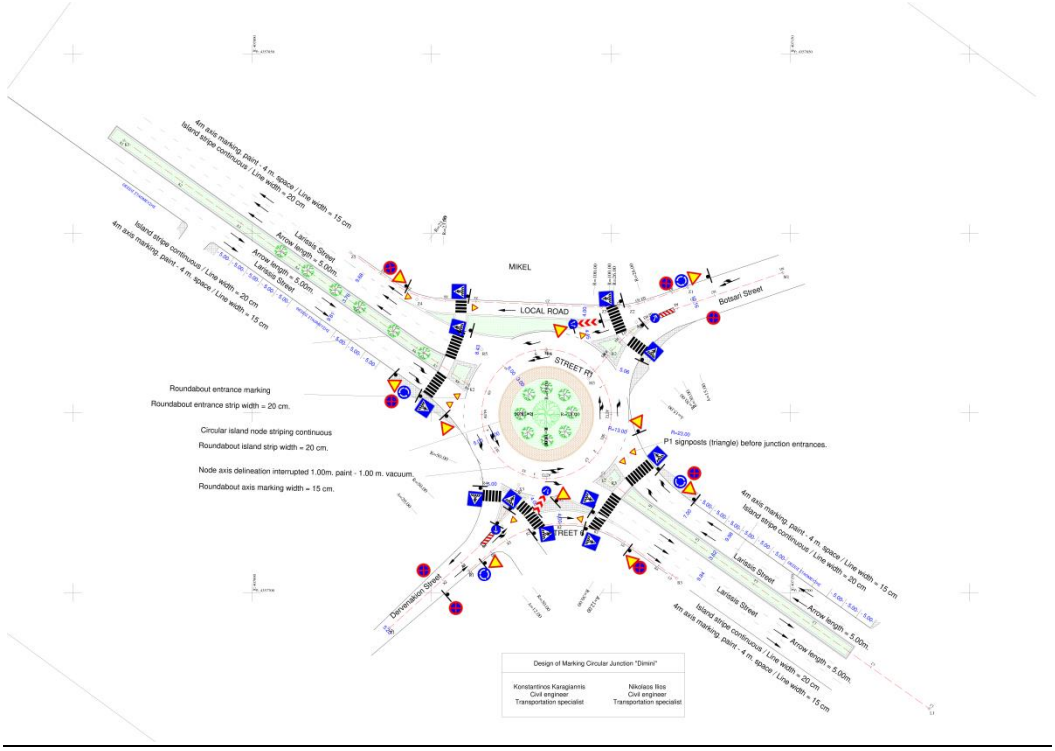

Figure 5: "Dimini" Roundabout Plan

Source: File of Sustainable Mobility Directorate of Volos Municipality

- **«KTEL» roundabout:** It is located at the intersection of Lambraki, Sekeri, and Lachana streets, in the straight vicinity of Bus Terminal (KTEL). It is a five-legged roundabout with three entrances and four exits, with two traffic streams and a dividing islet. There is no capability of serving movements without entering the roundabout.

Figure 6: "KTEL" roundabout, before, during the construction phase and in its final form

Source: Private Archive

Figure 7: "KTEL" roundabout plan

Source: File of Sustainable Mobility Directorate of Volos Municipality

- **«Customs» roundabout:** It is located at the intersection of Lambraki, Papadiamanti & Pirassou streets, between the establishment of Train Main Station and Volos Port. It is a five-legged roundabout with four entrances and five exits, with two traffic streams and a dividing islet. There is no capability of serving movements without entering the roundabout.

Figure 8: "Customs" roundabout, before, during the construction phase and in its final form

Source: Private Archive

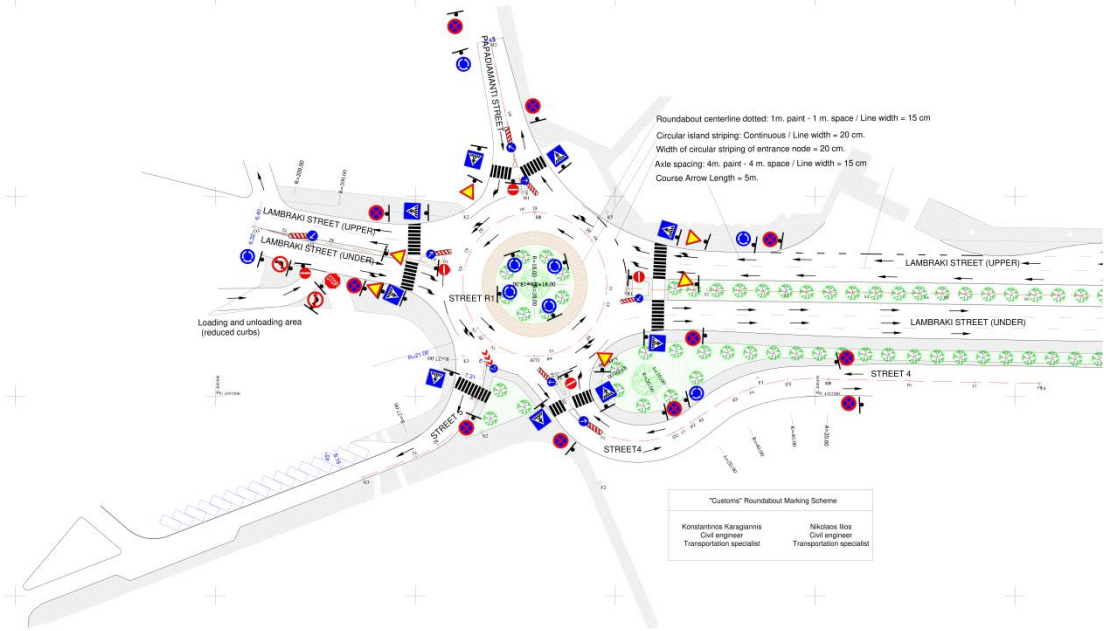

Figure 9: "Customs" roundabout plan

Source: File of Sustainable Mobility Directorate of Volos Municipality

- **«City Hall» roundabout:** It is located at the intersection of Dimitriados, Borel, Lambraki & Iasonos streets in front of one of the most important landmarks of Volos, the City Hall (work of the Architect Dim. Pikionis).

Figure 10: "City Hall" roundabout, before, during the construction phase and in its final form

Source: Private Archive

Figure 11: "City Hall" Roundabout Plan

Source: File of Sustainable Mobility Directorate of Volos Municipality

4. Research Methodology

The present research is implemented based on extensive observations - field measurements carried out by Volos Municipality / Directorate of Sustainable Mobility / Traffic & Transportation Department, Furthermore, data obtained from the University of Thessaly were also used. The observations took place, in a period of four months, weekdays and weekends at the whole time of the day. For the needs of extracting qualitative

characteristics, questionnaires were also used that were answered in the field in a total sample of one thousand people (drivers and walkers) per node. The numbers that are recorded are about the traffic flow, the level of service, traffic accidents, driving behavior and the accessibility for pedestrians and the PWDs.

5. Research Results

5.1 Traffic Flow

The traffic flow is about the traffic of vehicles or pedestrians on a street. It is specified from the traffic flow quantities such as traffic load, speed time and density. At first, before the implementation of roundabouts, the average time required for a vehicle moving at the permitted speed (limit 50 km/h) was recorded for each intersection (which was controlled with the help of light signaling) and for each separate access, in a total length of 200m at different times of the day. Subsequently and after the construction of the roundabouts, the corresponding average transit time was recorded again.

According to comparative results of measurements, **the roundabouts have helped to improve the traffic flow (reducing actual average transit time) by 42% to 58%**.

Specifically, at the City Entrance «Dimini» roundabout the transit time is reduced by 51% on the main accesses and by 54% on the secondary accesses, at the Bus Station «KTEL» roundabout the transit time is reduced by 46% on the main accesses and by 49% on the secondary accesses, at the Port Customs «Customs» roundabout the transit time is reduced by 53% on the main accesses and by 58% on the secondary accesses and at the City Hall roundabout the transit time is reduced by 42% on the main accesses and by 47% on the secondary accesses.

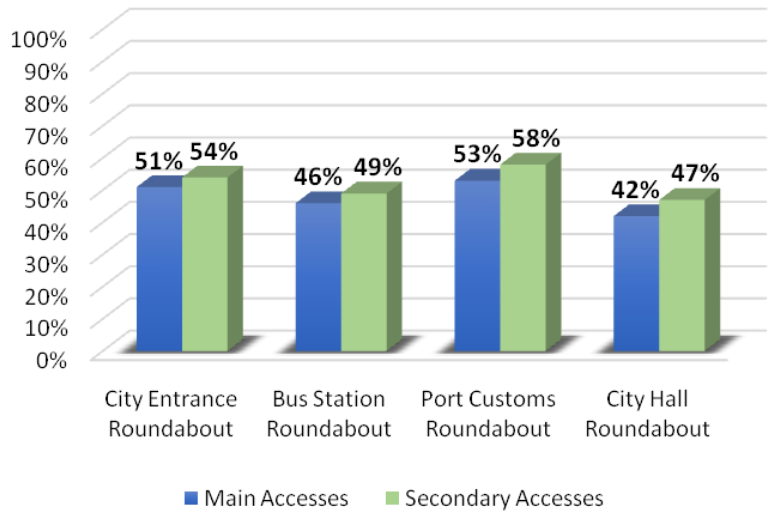

Figure 12: Rates of reduction in average transit time at roundabouts

Source: Own processing

5.2 Level of Service

The Level of Service (LoS) constitutes a qualitative quantity which reflects the prevailing operating conditions in a traffic stream as perceived by drivers and passengers. Operating conditions are the result of different parameters such as speed, the road interruptions, travel time, freedom of maneuver, driving comfort, road safety and running costs. According to the USA Highway Capacity Manual, six levels of service have been established which are characterized by the elements from A to F and they cover all the possible operating conditions, from the best A (free flow), until the worst F (saturation) (Frantzeskakis & Giannopoulos,1986).

The levels of service which are presented in the case study are A, B, C and D and they convey the following operating conditions in the roundabout (Frantzeskakis & Giannopoulos,1986).

Service Level A: Free flow conditions with low traffic load and high speeds. The traffic density is small and the speeds are defined only by the wishes of the drivers, the set speed limits and the prevailing road conditions.

Service Level B: Constant flow with speeds which start to be limited by traffic conditions. The drivers have still the ability, in logical margin, to choose their speed and the traffic lane.

Service Level C: The level C is still in the constant flow zone but the speed and the maneuvers are more controlled by the highest traffic flows. The freedom of choose speed, change traffic line and overtaking are limited for the most drivers. The operation speed is still in decent level.

Service Level D: The level D approaches the destabilize flow, but tolerant speeds are still maintained. Changes in traffic flow and temporary limitation can provoke important fall on speeds. The drivers have less freedom of maneuver and the driving quantity is small. These circumstances are tolerable for limited time periods.

In the case study, according to the observations made, it was recorded that **the level of service at all roundabouts was upgraded from C to B in the main accesses, from D to C in the secondary accesses and from C or D to A where it was possible to serve movements without entrance to the roundabout** ("Dimini" & "City Hall" roundabouts).

5.3 Road Safety

It is observed that the road safety in the roundabouts is particularly increased because of the reduced speeds and the fewer points of convergence. Indeed, during on field measurements, the level of road safety was recorded to have increased significantly. While on average every year and according to the available data at the points where interchanges are currently operating, there were 16 to 20 traffic accidents with significant property damage (among which two were fatal) per year, these have now been reduced to 4 to 6 minor property damage per year from the start of operation of the nodes.

Specifically, **City Entrance "Dimini" roundabout, recorded reduction of accidents from 16 to 4, Bus Station "KTEL" roundabout, recorded reduction of accidents from 18 to 4, Port Customs "Customs" roundabout, recorded reduction of accidents from 19 to 5, "City Hall" roundabout, recorded reduction of accidents from 20 to 6**.

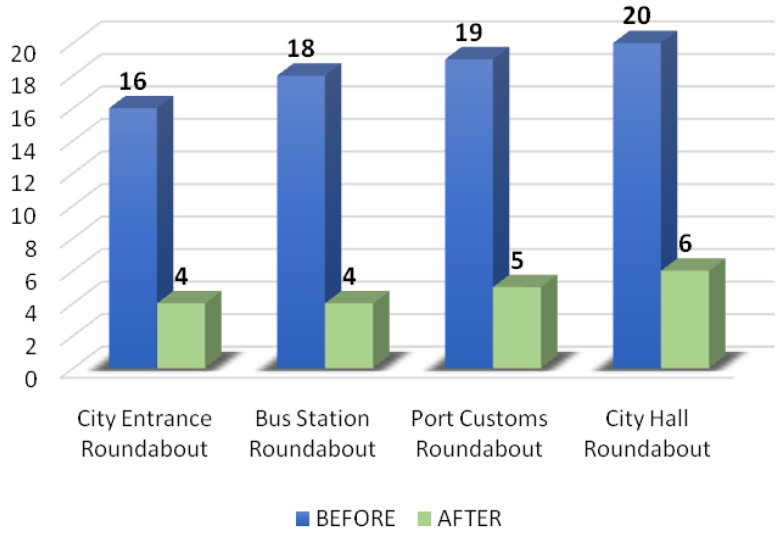

Figure 13: Accidents before and after the construction of roundabouts

Source: Own processing

5.4 Driving Behavior

Another important element that was recorded was the driving behavior under the new traffic data. Three basic elements that were imprinted were: **the harmonization of drivers with the intended correct course of movement within the roundabout**, as it is prescribed when entering, staying and leaving it, **the understanding and respect of the priority by the drivers and the essential possibility of safe & unhindered crossing of pedestrians & PWDs people.**

In the first case, **the harmonization rate** of drivers with the predicted correct course of traffic at the roundabout **reached 82% at the City Entrance "Dimini" roundabout, 84% at the Bus Station "KTEL" roundabout, 86% at the Port Customs "Customs" roundabout & 85% at the "City Hall" roundabout.**

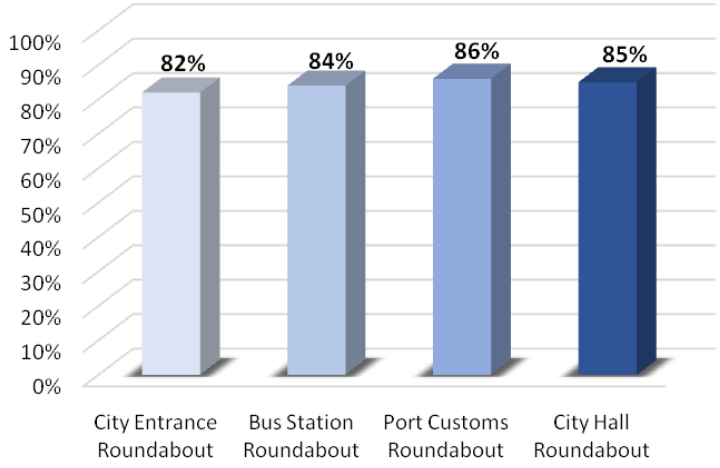

Figure 14: Rates of alignment of drivers with the correct course of traffic at the roundabout

Source: Own processing

In the second case, **understanding and respect for the priority during traffic at the roundabout were found in percentages amounting to 90% at the City Entrance "Dimini" roundabout, 94% at the Bus Station "KTEL" roundabout, 92% at Port Customs "Customs" roundabout and 91% at the "City Hall" roundabout.**

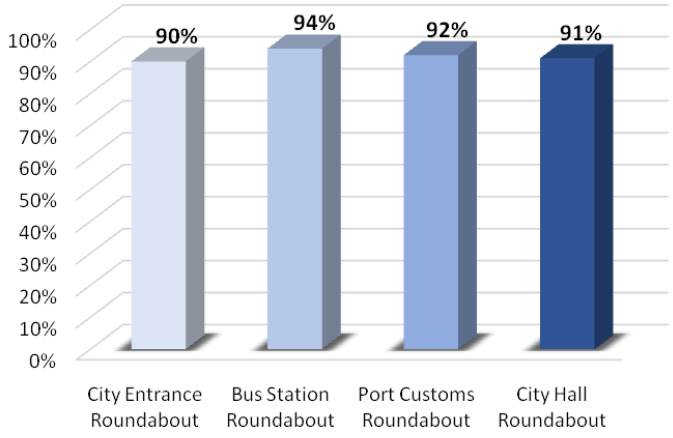

Figure 15: Rates of respect for priority when driving at the roundabout

Source: Own Processing

In the third case, an attempt was made to capture the **possibility of safe and unimpeded crossing of pedestrians & PWDs** with the findings being particularly encouraging, while, with limited exceptions, the stopping of vehicles in sight of pedestrians & PWDs who were waiting to cross the existing pedestrian crossings was recorded. **The respective percentages of vehicles stopping in view of pedestrians & PWDs amount to 78% at the City Entrance "Dimini" roundabout, 82% at the Bus Station "KTEL" roundabout, 84% at the Port Customs "Customs" roundabout and 86% at the "City Hall" roundabout.**

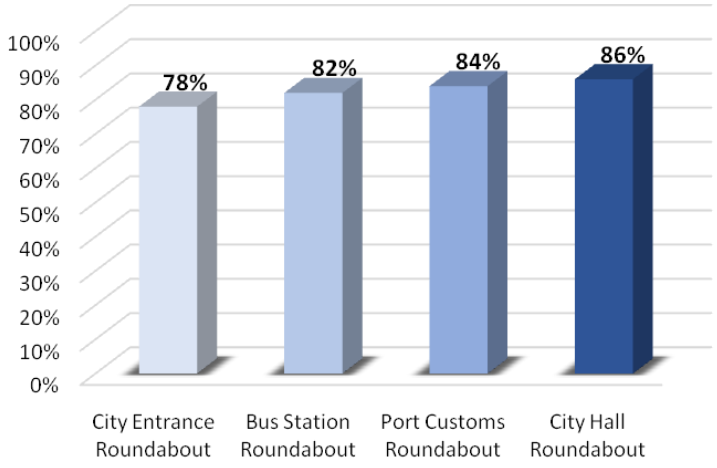

Figure 16: Rates of stopping vehicles in view of pedestrians & PWDs at the roundabout

Source: Own processing

5.5 Acceptance of new roundabouts

As part of research which was accomplished for the traffic conditions in the Municipality of Volos, an important finding emerged from the collection of opinions on the design and implementation of the new roundabouts. A questionnaire was used in a sample of 1,000 people per node of which 740 were men (74%) and 260 women (26%). In terms of age groups, 340 (34%) belong to the 18-39 group, 410 (41%) belong to the 39-59 group and 250 (25%) belong to the 60+ group. Regarding their mode of transportation, 650 (65%) were drivers while 350 (35%) were walkers. To express the opinion of the respondents, a Likert scale was used, from 1-5 (1: completely negative, 2: negative, 3: either positive or negative, 4: positive, 5: completely positive).

A total of 85% of those interviewed appeared satisfied, recognizing, on the one hand, the successful traffic intervention, on the other hand, the aesthetic urban upgrade that has been achieved through the integrated scientific planning.

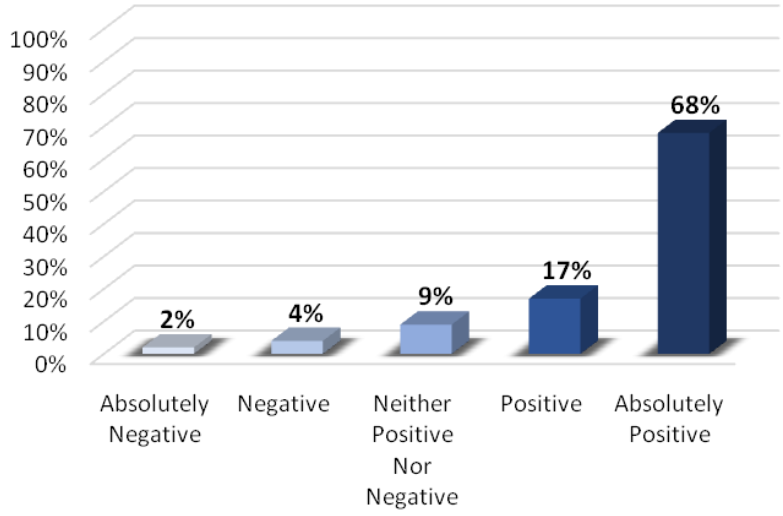

Figure 17: Percentages of views on the design and implementation of the new roundabouts

Source: Own processing

6. Conclusions

The first four modern roundabouts, that were manufactured in the Municipality of Volos, according to the research that was held, turned out that they have a special positive imprint, such as in traffic conditions, as in the image of the urban environment. The creation of new roundabouts changed radically the traffic model of the city, effectively constituting a special point of reference, with a special appeal, both inside and outside "borders". It is indicated that the circular “City Hall” roundabout, with the mythical "Argo" placed on a water base located in its center, it is one of the most frequented and recognizable landmarks of the city.

The results obtained from the collection and processing of 1000 samples on drivers and pedestrians, concerned the improvement of the traffic flow in percentages, from 42% to 58%, the increase of the level of service, the significant reduction of road accidents with material damage and the elimination of corresponding accidents combined with impacts on human life. The harmonization rates of drivers with the right course of traffic at the roundabout ranged from 82% to 86%, the understating and the respect on the priority when moving to the roundabout ranged from 90% to 94%, while the respective percentages of vehicles stopping in view of pedestrians & PWDs ranged from 78% to 86%. In total the 85% of those interviewed appeared satisfied with the traffic interventions, recognizing at the same time the aesthetic urban upgrade that has been achieved through integrated scientific planning.

The results of the research can be used to enrich other research projects related to the strengthening of road safety through the formation of road safety through the formation of modern roundabouts as well as to be taken into account by Local Authorities and Public Services for policy-making and the planning of new projects and infrastructures in the context of promoting sustainable mobility.

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