Exploring the TTMS's Impact to the Accessibility of a Long Distance Stretch Using Micro-simulation Approach

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Abstract. Road maintenance is generally analyzed considering complex types of work which must respect two considerable aspects: the first relating to the safety of workers, road users and those who somehow come into contact with the area on the other; the second instead correlated to the reduction of the impacts due to the shrinkage of the superstructure which entails criticalities to the transit vehicle flow. The evaluated parameters are the type of road, the position but also with the duration, visibility, speed and type of traffic. This work focuses on the evaluation of two different construction site layouts related to the TTMS (Temporary Traffic Management Scheme) which are periodically implemented in a medium-high traffic section of a small mountain town. The monitored area is located in one of the main connecting arteries of the city, adjacent to the main areas of attraction linked to the nearby commercial, residential and university areas. The study was addressed through the use of a micro-simulation tool. The results demonstrate how a different extension of the section to be maintained can drastically reduce the level of service (LOS), keeping equal vehicle flow.

This approach is useful for road managers and local Authorities in order to analyze the impacts produced by the construction site in terms of increased congestion of the vehicle flow, evaluating this as the dimensions of the construction site vary. This preventive assessment aims to consider the best solution to be implemented in order not to interfere with other activities as this could further reduce the accessibility of the adjoining places.

Keywords: Accessibility · TTMS · Micro-simulation · Road maintenance

1 Introduction

The road construction site is generally defined like an element of discontinuity and disturbance that cannot be foreseen by motorists and road users. The signals must be suitable and capable of informing users, guiding them and convincing them to behave appropriately for a situation "not habitual" in order to increase the global safety (road users and workers of the building site) maintaining an adequate fluency of traffic demand.

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The necessary precautions must be applied in order to maintain a perfect efficiency and optimal visibility during all time.

The national and local regulation also establishes the procedures for delimiting and signaling construction sites, the feasibility of the day and night visibility of the road workers, as well as the necessary measures for traffic regulation, as well as the procedures for carrying out the works on road construction sites.

The area of the construction site (for example for open manholes) closed to in crossroads or on high-speed roads, are generally prohibited only with the "work in progress" signal without any operational means of coverage.

The elements to be taken into account in a building site are:

- the type of road and its geometric characteristics (number of lanes by direction of travel, presence or absence of emergency lanes or quayside, etc.);
- the interval time (short-term sites present difficulties in preliminary planning of the intervention and require speed of execution and movement of the area affected by the works);
- the importance of the construction site, according to the effects on traffic and the footprint on the road;
- visibility at different conditions (rain, snow, fog, etc.);
- geo-location: urban area, level roads or on works of art, singular points such as intersections or junctions, etc.;
- the speed and the traffic composition (their variability during the life of the construction site can cause chain collisions);
- the execution of works in continuously different and new environments, with variable characteristics and positions that affect safety (schools, hospitals, other services);
- high probability of creating unexpected situations, such as the presence of unknown services.

A traffic management plan was often used to keep workers safe from vehicles and equipment both outside and within roadside worksites [1]. Traffic management plan templates can be used to assess workers' compliance with safety precautions to improve traffic controls, the security of the work area, and general protection of all workers.

In literature different research was focused on the problem of road maintenance considering the efficiency of the construction site layout and temporary traffic management (TTMS) such as the use of narrow aisles or the closure of them [2]. According to [3, 4] it was observed that the narrowing of the lanes shows some important behaviour of the drivers and the presence of heavy vehicles has a significant impact on the reduction of the capacity of the road section. In this work, the effect on traffic performance of various parameters (e.g. vehicle flow, percentage of heavy vehicles, lengths of road work areas and speed limits) was tested and compared considering the Level of Service (LOS). In order to select the better scenario to applied, data of previously implemented construction sites were collected and evaluated. Therefore the same data was used for steps of verification, calibration and model validation processes [5].

The preventive assessment of the possible layouts and related critical issues allows the increase in the phenomenon of traffic congestion with consequent potential increase in CO2 emissions and potential accidents in accordance with [6]. The comparison of maintenance scenarios can also be found in the literature in confined environments or with a narrow pedestrian vocation where they are often compared not only to changing flows but also considering emergency evacuation scenarios [7].

Planning of maintenance and design activities considering IBIM systems can solve some critical issues in terms of costs and safety [8, 9].

This research shows how lengthening a stretch of road construction site on a lane can lead to a reduction in the level of service of a high-flow road axis and therefore generate problems for access to the various neighboring residential and commercial areas.

The comparison of the scenarios was carried out using the micro-simulation tool Cube Dynasim [10] and the process and results were better described in the following paragraphs.

2 Methodology

The study of traffic scenario through the application of microscopic models generally evaluate the action of each single moving vehicle in the traffic network and also allows to investigate the influence between nearby vehicles for each moment and each point in space. After the selection of the parameters, this tool returns a lot of information to the operator, also giving the possibility to observe the movement of vehicles in different circumstances.

In a road section, on average, the speed of the vehicles will be given by a decreasing function of the density of the vehicles: if there is no one, you can go at maximum speed, obviously respecting the limit imposed by the traffic regulation at that point (as in the case study 30 km/h in the city).

The software consider both car following and chance lane model. Through the car following model it is possible to analyse the influence in the presence of other machines and therefore how the speed is affected by them: in fact the closer the vehicles are to each other and the more the scenario will present slowdowns up to the stopping distance. The lane changing model is instead useful to calculate the different parameters that influence possible congestion phenomenon [9]. There are three main factors that were assessed in the decision process are the need, the opportunity and the safety of a lane change respectively. The need or the opportunity to change the lane is determined by calculating, for each driver, a risk factor, which is a function of the relative position of the vehicle with respect to the object that gives rise to the need for a lane change. The study focused on the preventive assessment of maintenance scenarios along the selected stretch of road.

The stretch of road interrupted by two layouts was considered after several observations on the site and monitoring of vehicular flows of the closed intersection through detection systems such as sensors and cameras. Specifically, flow data acquisition campaigns were carried on 2019.

The maximum peak flow generated by the union of the usual traffic component (citizens) with the commuter one (university students) but also the influence made by the closed commercial areas. The composition of the traffic was selected taking into account the data records while the location of the construction site was selected by choosing the lane where major maintenance was recorded and the stretch in which the most critical situations arise due to vehicular currents in the opposite direction and the presence of public transport vehicles that have stops nearby and trucks moving from/to loading/unloading areas and logistics of commercial areas It was hypothesized to study the effect of the lengthening (doubling) of a road construction site located along the same lane in the first instance. The comparison was made through the calculation outputs such as travel speed or the number of stops and the synthetic judgment on the level of service as the TTMS changes was described using the LOS index.

2.1 Microsimulation Tool Description

In the last 10 years, various tools have been developed that allow to study different vehicle and pedestrian scenarios in a preventive way, starting from models that represent vehicular and/or pedestrian actions [11] describing in detail the variations of parameters such as speed, the number of stops and the length of the queues. Over the years, the micro-simulators have proved to be useful tools to mitigate the impacts generated by the increase in flow or to evaluate the critical points (points of conflict) generated by incorrect geometric design [12–14].

This research was carried out implementing 3 scenarios through the use of Cube Dynasim tool [15]. It is a graphical tool that allows you to extract data from a database to create graphs related to vehicle flows and related parameters such as travel time, travel speed, delay, etc.

The software realistically show the interaction among different type of road users (motorised vehicle, bicycles and pedestrians interacting with all the other vehicles and the environment).It is completely interactive 2D and 3D animations. The applied model was stochastic type.

The traffic flow was analysed considering specific matrix O/D and flow composition and the presence of traffic light signs to respect the alternating sense. The comparison can be made between scenarios based on collected data and scenarios based on project hypotheses, thus correlating to future forecasts.

3 Description of the Undertaken Research

3.1 Study Area

The monitored area is located in the district named Enna Bassa. It has undergone several transformations from an urban and infrastructural point of view in the last ten years. In fact, this area has been enhanced as a craft area with the inclusion of various commercial activities such as supermarkets and workshops. The road intersection is also one of the major access points to the city for those coming from the west of Sicily.

Recently the infrastructure has been installed undo a traffic light intersection with a sloping roundabout that connect the commercial areas located in the South and East (that include low-cost MMR and a multi-brand shopping center) with the other areas. This area is also considerable because it is the main connection between the University area with the new Campus and therefore during weekdays it is crossed by a stream also composed of an aliquot of university students as well as commuters and inhabitants.

The hub is characterized by the presence of local bus stops with a frequency of 30–35 min crossing this area facilitating travel from the upstream part of the city with a tourist and tertiary vocation with the downstream one with a residential/commercial vocation (Fig. 1).



Fig. 1. Monitored area before and after roundabout execution (Image source: Google Earth 2019)

The images also show an enhancement of the neighboring residential areas and the presence of several workshops and a nursing home. The North-South direction allows access to the city from the other neighbors while the East-West direction let the connection between the part a upstream and downstream of the city.

The arms of the roundabout and relative flow directions were respectively named (Table 1):

The traffic flows directed to/from the cities bring the names of Enna Alta (EA) and Enna Bassa (EB) with flows in the North-West direction and vice versa and the city of Caltanissetta (CL) with the flows to and from Enna in the South-North direction and vice versa. The transit flows between the two cities are characterized not only by vehicular traffic but also heavy traffic and suburban buses. The commercial areas have been identified with the MMR code instead the residential one with the letter D. Finally

Table 1. Traffic flow direction of monitored road network

Direction ID	Details	Flow composition
MMR_R	MMR area_Roundabout	LV-HV
EA_R	Enna Alta_Roundabout	LV-HV-LocalBUS
R_EB	Roundabout_Enna Bassa	LV-HV-Locla BUS-ExtraBUS
CL_R	Caltanisetta_Roundabout	LV-HV-ExtraBUS
CL_EB	Caltanissetta_Enna Bassa	LV-HV-ExtraBUS
EB_CL	Enna Bassa_Caltanissetta	LV-HV-ExtraBUS
D_R	Residential area_Roundabout	LV-HV-LocalBUS
EB_R	Enna Bassa_Roundabout	LV-HV-LocalBUS-ExtraBUS

where
LV = light vehicle (car, van, sport utility….)
HV = heavy vehicle (truck, cement mixer, ambulance…)

the traffic flows entering and leaving the roundabout report the node R. The peak flow monitored by cameras and sensors, measured at peak time between 8:30 and 09:30 is equal to 1250 veh/h.

The composition of traffic is equal to: 90% light vehicles, heavy vehicles 5% and bus 5%. In the North South direction, extra-urban buses run with a frequency of 1 bus every 50 min. In the North-West direction, minibuses and city buses pass frequently. In the areas surrounding the roundabout there are stops for the city bus. The stretch of construction site is located in the lane that connects the node EB with the roundabout R and is characterized by the presence of vertical and traffic light signs with an extension of 50 m in the first layout and 100 m in the second as shown in Fig. 2.

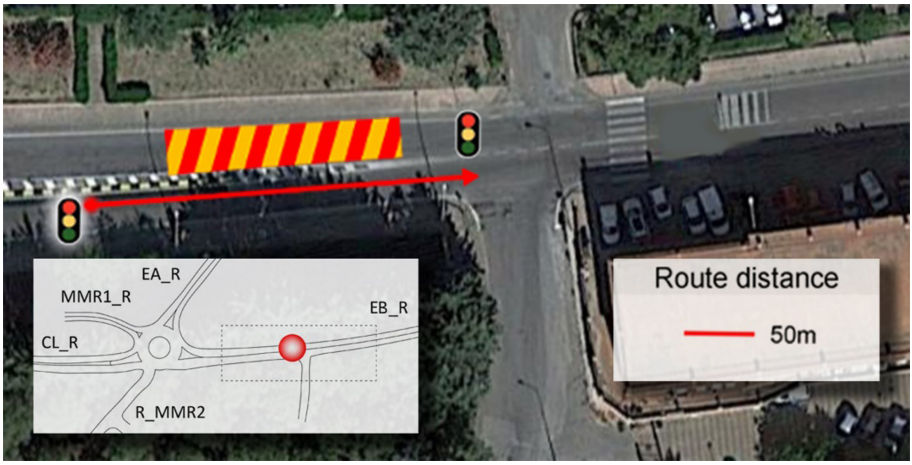


Fig. 2. TMMS1 layout and relative route distance (Image source: Google Earth 2019)

This traffic direction is characterized by single lane for motorized vehicle and a sidewalk for pedestrian located to the right of the lane (width about 1.50 m).

In particular, TTMS1 layout (with extension of 50 m) placed on the right lane (direction EB_R) allows alternate transit along the direction indicated in Fig. 3.

The micro simulation layout can help in understanding the alternating flows in the adjacent lanes as shown below.

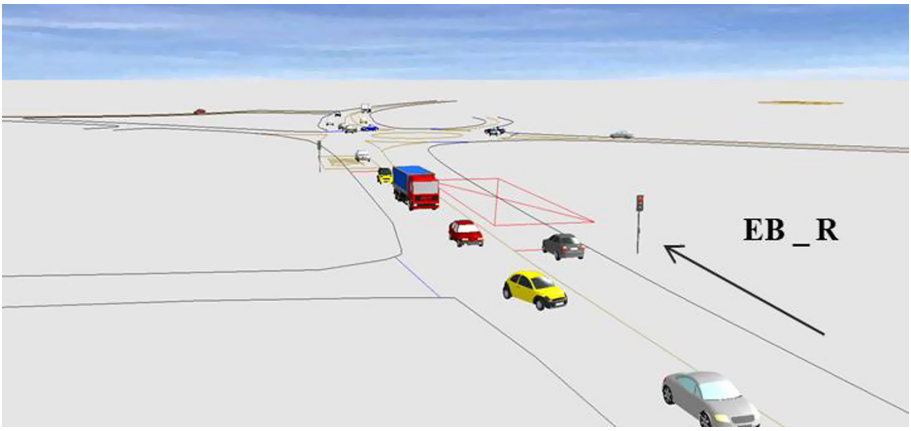


Fig. 3. Microsimulation results with increasing of traffic queue for TMMMS1

The TTMS2 layout (with extension of 100 m) is placed in the same direction allows alternate transit along the directions considering the route distance indicated on figure below (Fig. 4).

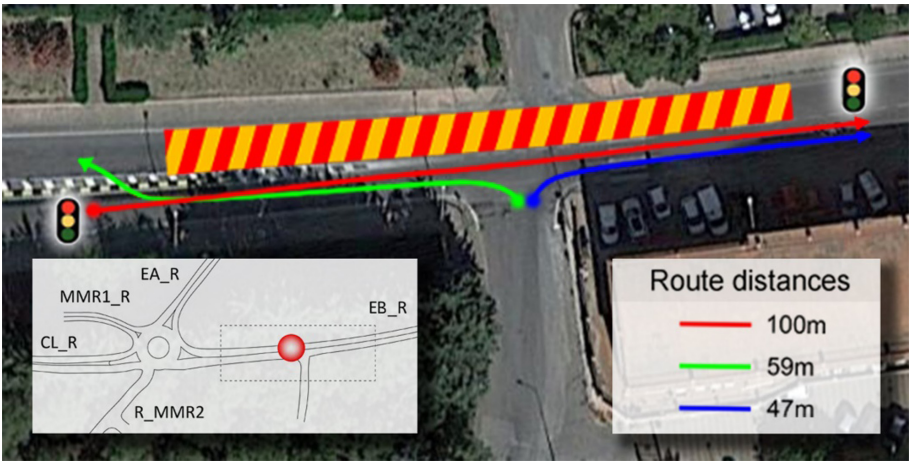


Fig. 4. TMMS2 layout and relative route distances (Image source: Google Earth 2019)

In this case, the construction site interferes with the flows exiting the secondary road located to the EAST, generating greater congestion problems as shown in Fig. 5.

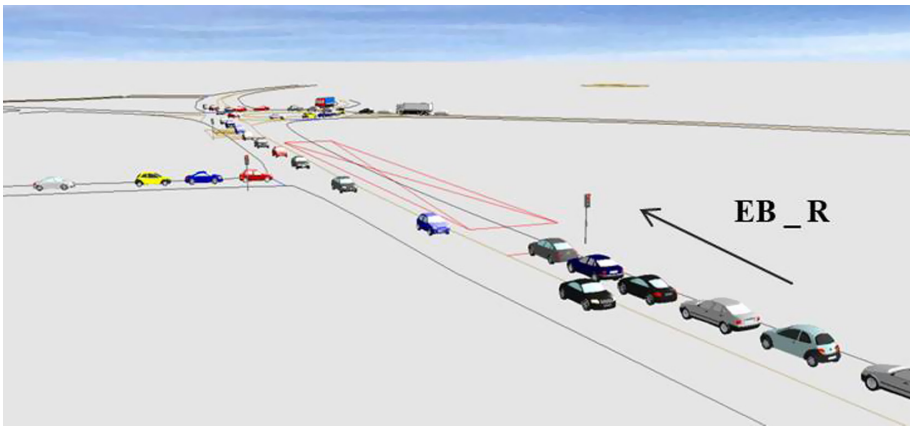


Fig. 5. Microsimulation results with increasing of traffic queue

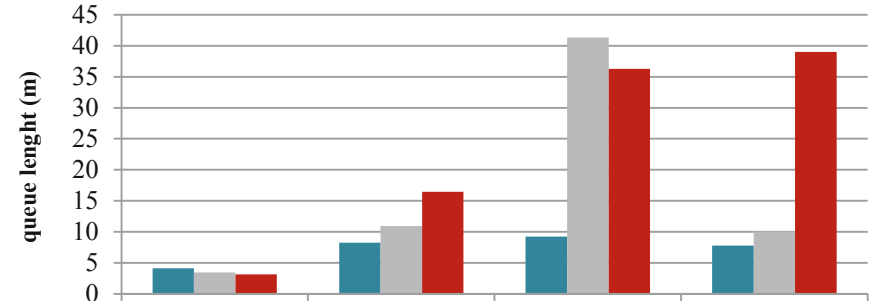
The comparison between the different scenarios was calculated considering the main parameters that describe the fluidity of vehicular traffic, i.e. the length of the queues and the number of stops and subsequently estimating the level of LOS service.

4 Microsimulation Results

4.1 Comparison of Scenarios

The TTMS layouts were implemented considering a traffic flow setting by a traffic light system with total traffic cycle of 80 s on TTMS1 (with respectively 26 of green and 4 of yellow) and with 110 s on TTMS 2 (with 24 s of green and 4 of yellow).

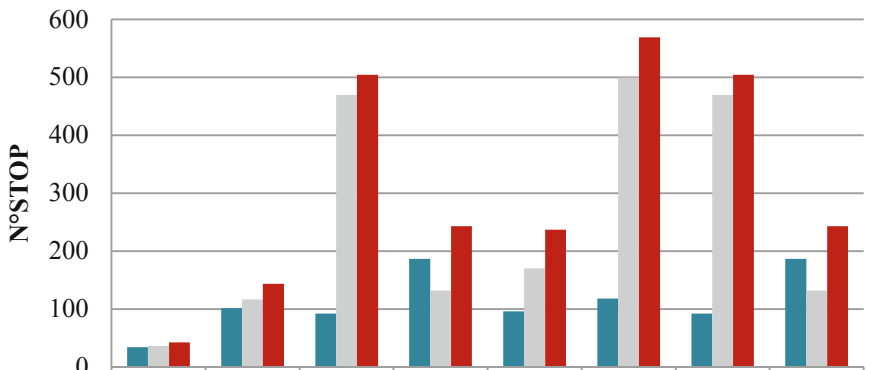
The tool made it possible to count the vehicles that pass through selected points of the sub-network during a predetermined time interval. The case study focused on the territory of Enna where a 4-arm sloping roundabout was recently built. The vehicular flow saturation hypothesis was studied for each arm by evaluating the variations of 4 distinct variables. From the point of view of the length of the queues, the direction D_R has the highest increasing value, passing from the standard scenario to the maintenance scenario TTMS2, instead the direction CL_R changing to standard to TTMS1 as described in Fig. 6.



	MRR_R	EA_R	D_R	CL_R
R	4.1	8.2	9.3	7.8
TTMS1	3.5	10.9	41.3	10.0
TTMS2	3.2	16.4	36.3	39.0

Fig. 6. Comparison of queue length(m) considering different scenarios

The STOP number is considered as another evaluation criterion and considers vehicles in a stopped state. The value depends on two threshold speeds (lower and upper) respectively. In fact, a vehicle is in a stopped state if, when it entered the subnet, its speed was lower than the minimum limit and since then it has not reached a speed higher than the maximum limit or if, because it has slowed down or has not reached or exceeded the upper limit. In terms of STOP number, proximity to congestion is further confirmed along EB_R direction (lane where is placed the TTMS) as described in Fig. 7 for both TTMS layouts.



	MRR_R	EA_R	D_R	CL_R	CL_EB	EB_R	D_R	CL_R
R	34	101	92	187	96.2	118	92.1	186.7
TTMS1	36	116	470	132	169.95	499	469.7	132.1
TTMS2	43	144	504	243	236.8	569.1	504	242.8

Fig. 7. Compariosn considering N°stop for different scenarios

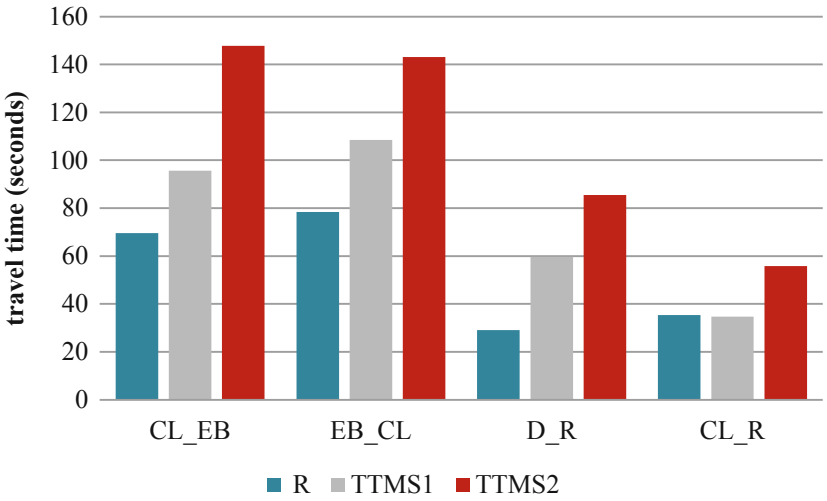
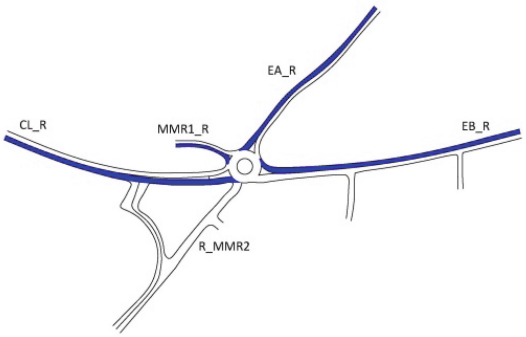
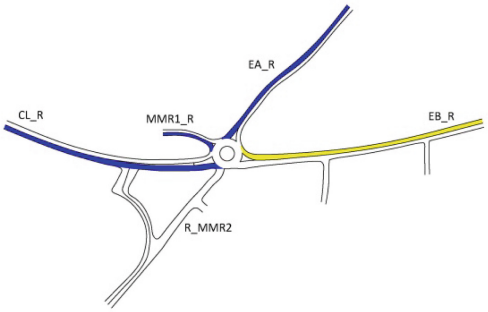
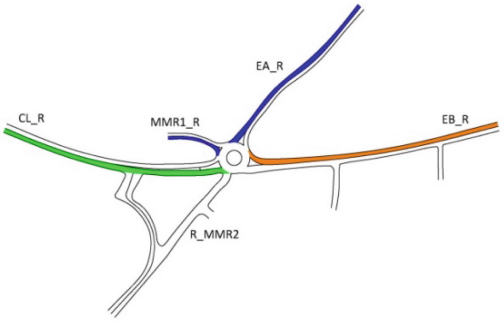


Fig. 8. Compariosn considering Travel time (seconds) for different scenarios

This criterion represents - for each vehicle that leaves the sub network - the time elapsed since it first crossed the entry point. Considering the travel time, on the other hand, direction CL_EB and EB_CL are those with the highest values, especially with the increase in the construction site area as shown in Fig. 8.

Finally, a synthetic judgment of LOS was expressed by evaluating the overall delay of the intersection in the neighboring roundabout as shown in the table below, which shows that the infrastructure under recorded flow conditions and considering the geometry implemented has an optimal level of service while this reduces drastically from level A to level C positioning a construction site of about 100 m along the lane with EB_R direction. The North-South direction is affected by the increase in the size of the construction site by reducing the level of service beyond the intersection in the roundabout as shown in the layout of the TTMS2 scenario, as there is a substantial increase in the length of the queues and the number of stops they produce basically congestion in this direction (Table 2).

Table 2. Level of Service LOS layout and RD values (roundabout delay seconds)

Level of Service (LOS)	Layout with LOS for each arms
A B C D E F	
scenario R RD 4,32 LOS A	
scenario TTMS1 RD 12,44 LOS B	
scenario TTMS2 RD 27,16 LOS C	

5 Conclusion

Sustainable urban infrastructure development must consider the variability of the scenarios that characterize the road infrastructures.

Different scenarios are generally considered like standard or maintenance or evacuation phenomena. This study highlights how micro-simulation analysis can analyze and mitigate the problems connected to the presence of a road construction located in a high-traffic road which can generate a problem of accessibility to nearby areas.

The scenarios were selected after a period of monitoring (about 1 year) through inspections and photographic reports and having ascertained the most applied construction site layouts.

The comparison between the different functional parameters of the infrastructure and the synthetic judgment expressed through the LOS show that the analyzed area has undergone a general reduction of the points of conflict through the construction of an inclined roundabout. Considering the peak of the traffic flow, the recent infrastructure undergoes a change in the level of the LOS service from A to C caused by the presence of a TTMS that does not allow the use of a lane for a space of 50 and 100 meters respectively. The layouts allow an alternating sense of the use of the unoccupied lane but with particular reference to the TTMS2 layout, there is a reduction in manoeuvres and an increase in critical issues with a greater tendency to road congestion.

The location of local bus stops and private access closed to the residential and commercial areas were also considered. This study lays the foundations for other comparisons relating to the other arms of the roundabout and allows the person responsible for the road to evaluate how the presence of the construction site can generate possible conflicts between vehicular currents and therefore reduce the general safety of the infrastructure. The limitation of this work consists in a partial analysis of possible construction site layout, not considering the possibility to have 2 or 3 maintenance sites in the same time. This study also did not consider different traffic flow composition. These assessments will be the subject of future research. The obtained results can be hypothesized in terms of the possible impact mitigation scenarios and at the same time lay the foundations for a more in-depth assessment of the case studies.

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Conflicts of Interest. The authors declare no conflict of interest.

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