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The Analysis of Traffic Flow on the Three-leg Intersection – Case Study Cazin

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Abstract

This paper deals with the analysis of traffic on the three-leg intersection in the city Cazin, at the junction of the three-leg intersection. The main issue of this research refers to the left-turn of vehicles coming from the merging road of the given intersection. The extensive analysis covered the current state of traffic flow by using the software tool, SIDRA INTERSECTION program. Within the suggested measures of improvement, the construction of a unsignalised roundabout was proposed. Implementation of the construction of a unsingalised roundabout would increase the level of traffic safety, reduce time losses while taking a left turn and therefore improve the Level of Service (LOS) as a qualitative indicator of traffic flow.

Keywords: Roundabout; Level of Service; Flow.

1. Introduction

Intersections appeared by the junction of two or more roads. However, back in the day there were no rules of intersection planning, designing and conducting operational analyses. During today's fast way of life, it is important to arrive to a destination in the intended period of time. Consequently, it is crucial that roads and intersections are designed in an adequate way with the goal of fulfilling user needs.

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City Cazin is situated in northwest Bosnia and Herzegovina, occupying a territory of 365 km^2. As of 2013, it has a population of 66149 inhabitants. On the observed intersection, there are streets and intersections with a qualitative indicator of LOS A, but also, there are those with a LOS F. However, a problem of peak traffic load arises at weekends as well as during vacations because 40% of this city's population lives abroad. Traffic during that period of time, from 10 am to 10 pm, is 3 to 4 times more intense and this results in over forced conditions of traffic flow [1,2]. Further into this work, in Chapter 2, there is an overview of related works by researchers who devoted their time to micro-level traffic management in the intersection zone. In Chapter 2, a broad analysis of traffic flow conditions is given, as well as retrospective of traffic risk in the intersection zone with a possible applicable methodology and with obtained research findings. In Chapter 4, an adequate discussion on research findings was conducted. After that discussion, a conclusion was drawn in Chapter 5.

2. Related work

The most important aims of intersection design are ensuring safety and safe travel speeds. For the analysis of existing intersections, traffic count and traffic analysis is necessary. In his research, Mohammed A. explains that the computer simulation is a vital tool for street and intersection examination. In order to get as accurate and better simulation as possible, it is necessary to create an adequate mathematical model. Also, some researchers believe that intersections are one of the main causes which greatly influence time of travel, delays, LOS and traffic capacity [3,4]. Considering that traffic jams have significant social, economic and environmental costs, Prakash analysed three intersection types with series of measured loads [6]. This study concluded that unsignalised intersections work well under low traffic load, roundabouts work well under moderate traffic load and signalised intersections have shown the best results under high traffic loads. After analysing the unsignalised channelised three-leg „T“ intersection in Baghdad, after four days of measuring from 7 am to 3 pm, Mohammed A. has calculated that the Level of Service of the mentioned intersection is D. Also, he concluded that it is necessary to improve the existing state of the intersection in order to improve LOS. After analysing two unsignalised intersections, Jamil W. concludes that different parameters influence different LOS results [12]. Intersection features which influenced LOS are conflict points, flow duration, relation between cargo and passenger vehicles and the total number of vehicles. Flow duration and the number of vehicles have the biggest influence. Shaban I. claims that it is necessary to change the time distribution of working hours in order to „facilitate“ peak time [5]. If the number of vehicles during peak time reduces, traffic would function much better. Cycle time on intersections is an important element of traffic efficiency. However, it is most often based on engineering experience.

3. Method and research results

On the observed unsignalised three-leg „T“ intersection 6 conflict points occur. Traffic density causes traffic jam on the mentioned intersection.

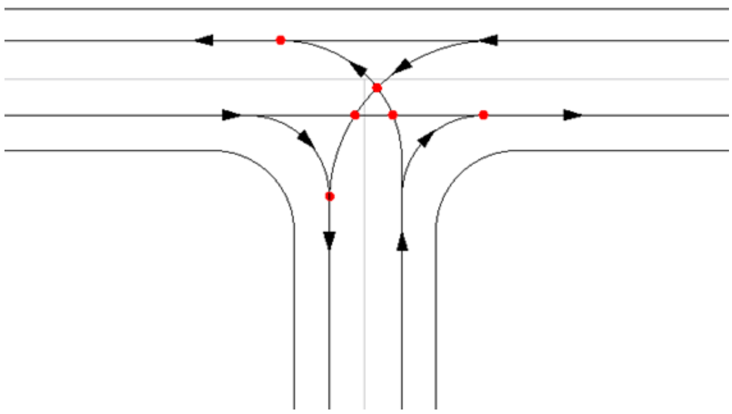

Figure 1: Conflict points of three-leg intersection crossings and convergences

The existing three-leg intersection occupies a small area because it is made at the crossing of two roads. Back in the day, it met the traveler' needs, but with the increase in motorization, the need for the increasing intersection capacity arises as well. That is, finding infrastructural solutions in order to increase traffic capacity of the given intersection with an adequate LOS. Therefore, the synthesis of the collected data was performed, as well as the analysis of the mentioned intersection.

3.1 Analysis of traffic safety

Based on data from Una Sana Canton Ministry of the Interior [11], data on the number of traffic accidents on the observed intersection were analysed. There were no traffic accidents with fatalities on the observed intersection. Number of persons with minor and serious injuries will be shown on figures 2, 3. And 4, as well as the number of traffic accidents. Number of vehicles involved in traffic accidents is lower than 0.01% of the total number of vehicles which pass through the intersection. From 2016 to 2019, number of traffic accidents on the observed intersection reduces. During the year of 2016 and 2019, there were no injured persons in traffic accidents, while in 2017 and 2018, there were total of 7 injured persons which can be viewed on the next table and diagram [11].

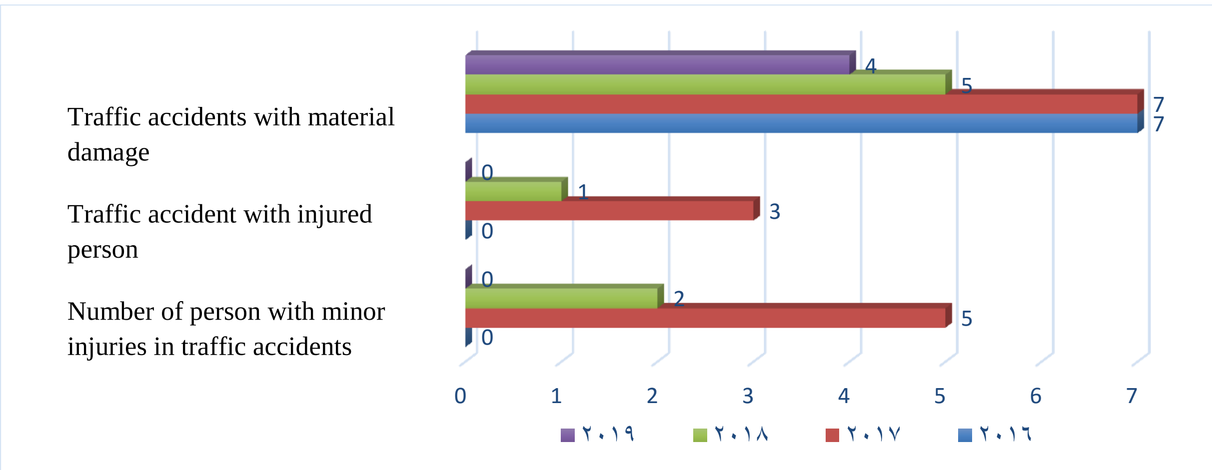

Figure 2: Types of traffic accidents [11]

All of the traffic safety indicators within this work are classified into the following groups:

- Indicators related to the behaviour of traffic users
- Indicators related to roads
- Indicators related to vehicles
- Indicators related to the care of the injured in accidents [10]

Behaviour of traffic participants, especially following the traffic regulations, has the greatest influence on the traffic safety. Especially risky behaviours in traffic are: significant speed infringements, disregard of traffic signals (going through the red light), overtaking on prohibitory lines and in dangerous situations, disregard of priority pass, not keeping a safe distance between vehicles, not using the protective equipment and crossing the pavement outside the pedestrian crossing.

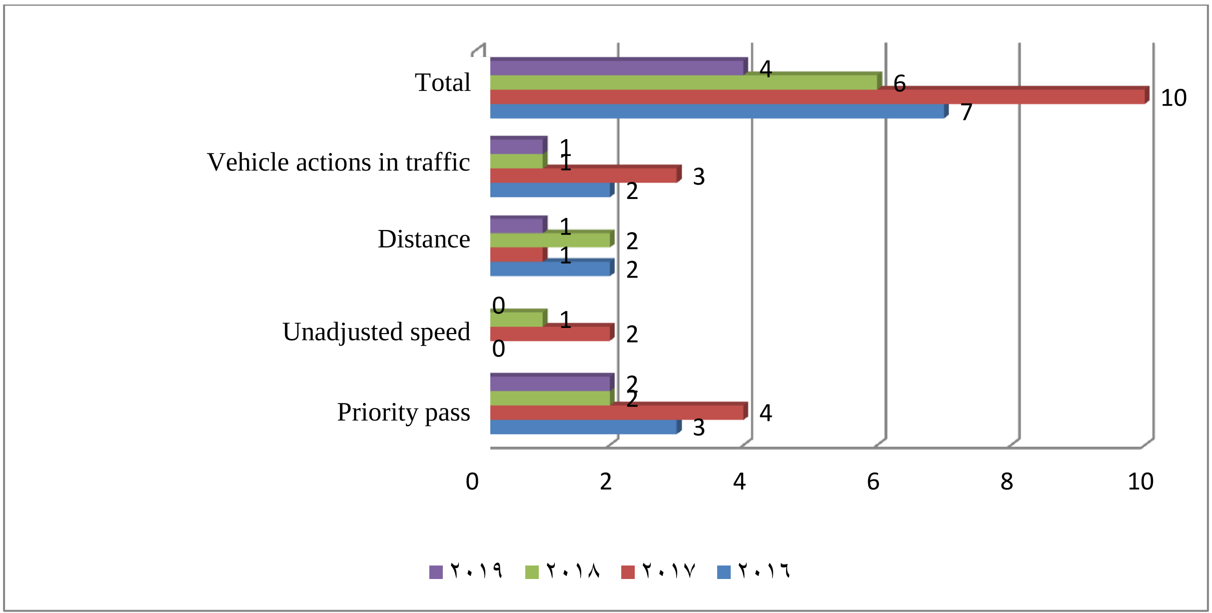

Figure 3: Indicators of traffic safety which relate to the behaviour of traffic users [10]

After analysing the causes of recorded traffic accidents for 2016, it is clear that the most frequent cause is the disregard of the priority pass with a percentage of 42,86%. According to the percentage, the next most frequent causes of traffic accidents are violation of safe distance and vehicle actions in traffic with a percentage of 28,57% each. For 2017, it is evident that the most frequent cause is the violation of the priority pass, as well as for 2016. Percentage is 40% which is 2,86% less than in the previous year. Next cause is vehicle actions in traffic with 30%, followed by unadjusted speed with 20% and violation of safe distance with 10%. For 2018, the most frequent causes of traffic accidents are violations of priority pass and safe distance with 33% each. In 2019, there was the lowest percentage of traffic accidents compared to the observed period. The most frequent cause is the priority pass with 50% of occurence. Statistically, 13 types of traffic accidents are known. Considering the time period and the location on which the analysis was performed, 4 types of traffic accidents were noticed, results of which can be found in the table below.

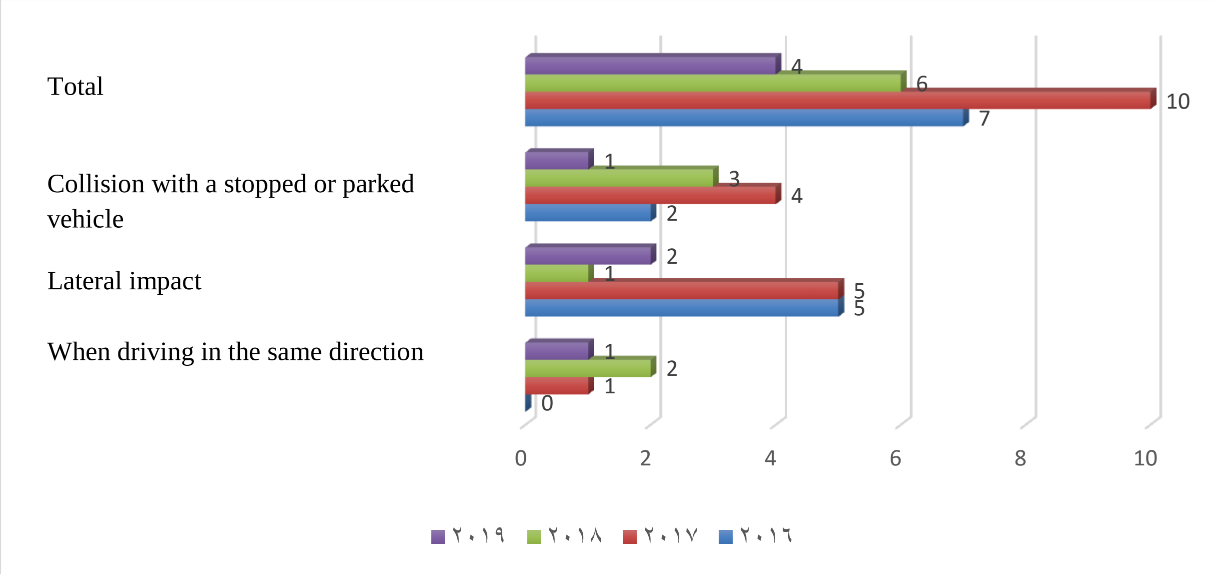

Figure 4: Types of traffic accidents [11]

Number of vehicles involved in traffic accident is lower than 0,001% of the total number of vehicles which pass through the intersection. Considering the daily traffic on the intersection, it can be said that the number of traffic accidents is not concerning. However, it is certainly desirable that that number is as close to zero as possible. After analysing the existing state and objectively showing the traffic flow conditions on the given intersection, hypothetical premise can be derived. This premise shows that with the change of regime of traffic control and traffic regulation on the three-leg intersection, it would be possible to ensure a higher quality level of traffic flow. This premise especially refers to the possible change of geometric features of the given intersection.

3.2 Analysis of traffic count

Figure 5: The existing state of the observed intersection

The first step into this analysis was collecting data on the number of vehicles and mode of movement on this intersection. The research included a sample of 3183 vehicles over a 180-minute period (2122 vehicles/h). Instead of the classic on-site traffic count, it was decided to record at the mentioned intersection in order to obtain as precise data for traffic analysis as possible. The recording was done on Thursday, the 6th of February, 2020 from 7 am to 8 am, 12 am to 1 pm, and 4 pm to 5 pm, which represents forenoon peak time, noon and afternoon peak time. At this intersection, it is possible to move in six different directions. Purpose of traffic lanes is mixed (forward and left, left and right, forward and right). Lane 1 and 2 have a priority pass which is the reason of delays on the lane 3 which is marked as the lane with a potential congestion.

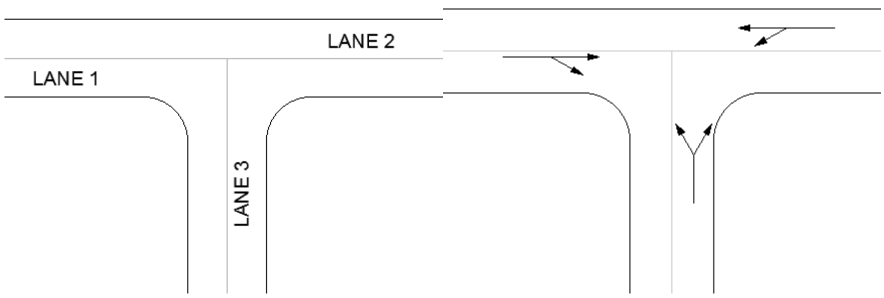

Figure 6: Left – schematic view of traffic distribution, Right – possible vehicle movements from certain lanes

Table 1: Vehicle number distribution depending on the movement over 180-minute period according to structure or composition of traffic flow.

Total - 3183	Right	Left	Forward
Lane 1	567 + 7TV	-	726 + 7TV
Lane 2	-	250 + 7TV	795 + 8TV
Lane 3	214 + 3TV	599	-

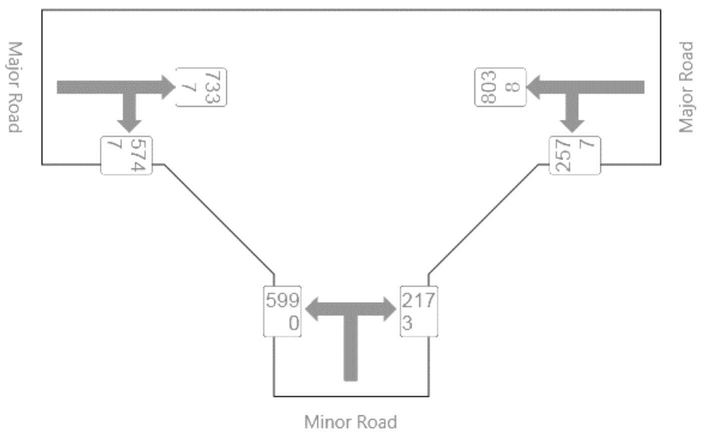

Figure 7: Data on vehicle number and mode of movement entered into SIDRA program over 180-minute period (the number above indicates the total number of vehicles while the lower number indicates only the number of cargo vehicles)

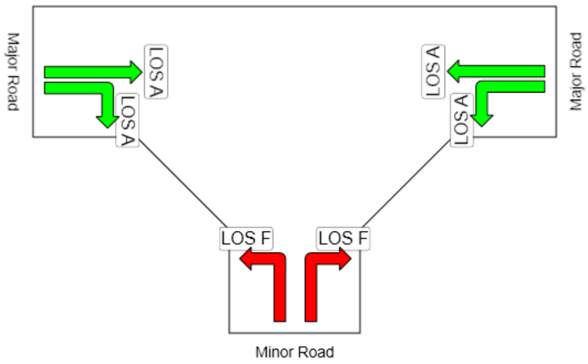

Figure 8: LOS of the observed three-leg intersection over the 180-minute period (A- the best LOS, F – the worst LOS)

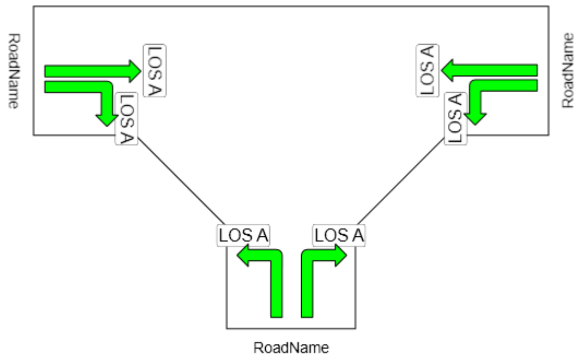

Figure 9: Level of service of the roundabout with the same number of vehicles and mode of movement as on the observed three-leg intersection (A – the best LOS, F – the worst LOS)

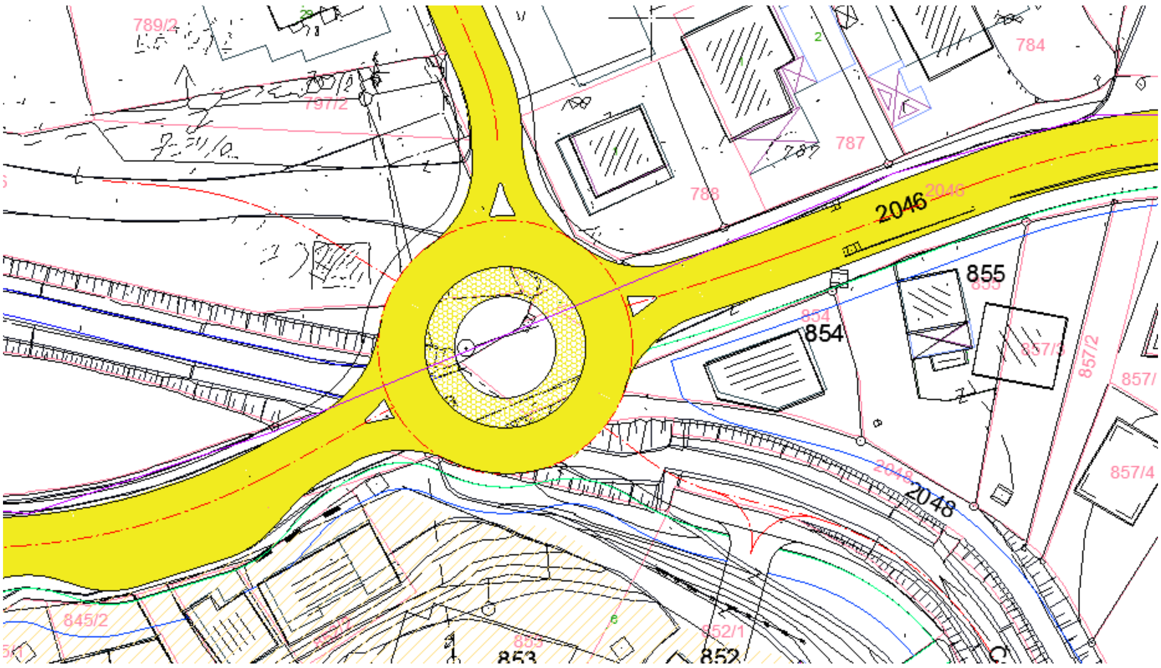

Figure 10: Conceptual design of the solution for the intersection using a roundabout

In this case, several market segments of passenger cars are distinguished according to class:

- A-segment vehicles (They are characterised by lengths up to 3.5 m. These are small city cars (minicompact) like Toyota Aygo, Citroen C1 and his colleagues)
- B-segment vehicles (They are characterised by lengths up to 4.0 m. These are again, small city cars (subcompact) like VW Polo, Opel Corsa, Mercedes A class and his colleagues)
- C-segment vehicles (They are characterised by lengths up 4.5 m. These are smaller family cars like BMW series 3, Mercedes C class, Dacia Logan and his colleagues)
- D-segment vehicles (They are characterised by lengths over 4.5 m. These are bigger family cars and cars which can be used for business purposes like VW Passat, Opel Vectra, Toyota Avensis, Audi A6 and his colleagues)
- SUV (Sport Utility Vehicles (These combine characteristics of C or D segments with features of off-road vehicles. Typical representatives of this segment are Hyundai SantaFe, Toyota Rav 4, Honda CR-V and his colleagues)
- Off-road vehicles (These are characterised by the capability of going through impassable terrains as well as four-wheel drive, a body-on-frame construction or high ground clearance.
- S-segment vehicles (They are characterised by lengths over 5 m. These are exclusively high-class cars which only the world's best car manufacturers have in their manufacturing program. Representatives of this segment are Audi A8, Mercedes S-class, BMW series 7 and his colleagues) [7]

Figure 11 shows the number of certain passenger car segment and the vehicle ratio of certain segments over the observed time period. Percentage wise, occurence of C-segment cars in traffic is 34,45%, followed by B-segment cars with 31,07%, D-segment with 14,47% and finally A-segment with 9,6% on the given three-leg intersection.

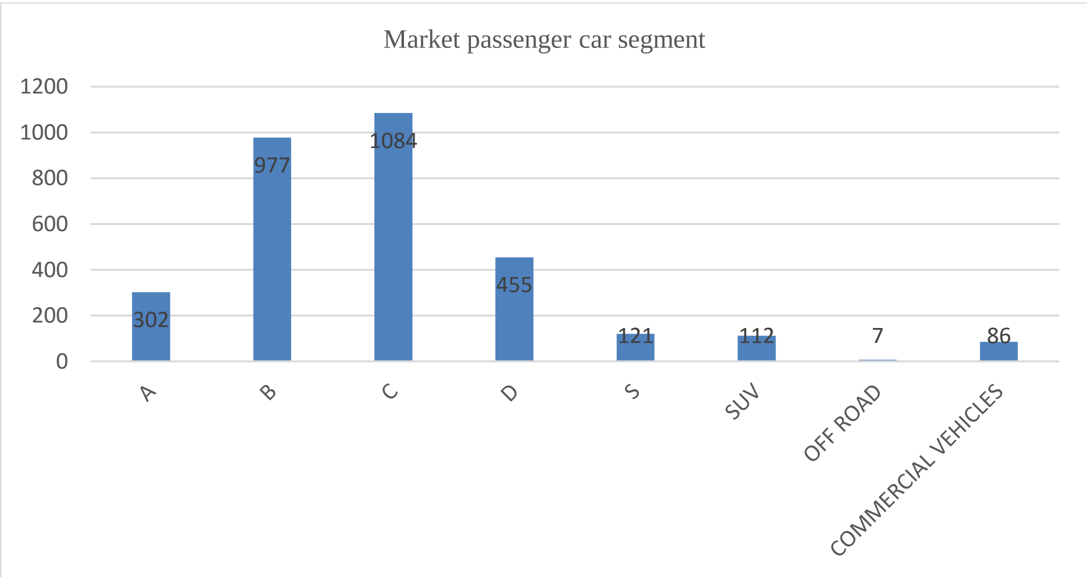

Figure 11: Diagram of the car ratio with different market segments of passenger cars on the observed intersection over the 180-minute period

Variants of car body constructions can be divided into several types:

- Sedan (four-door vehicle)
- Hatchback (three-door or five-door vehicle)
- Caravan (an extended five-door vehicle)
- Convertible (a vehicle with a fixed, retractable or removable roof)
- Van (a multifunctional vehicle for passenger and cargo transportation with a distinctive appearance of a smaller van) [7]

Next diagram shows the number of vehicles categorised on the basis of car body construction. Percentage wise, the biggest number of vehicles which appeared on the intersection are hatchback with 52,4%, followed by Sedan with 22,45%, caravan with 16,62%, Van with 8,43% and finally the convertible with just 0,1%.

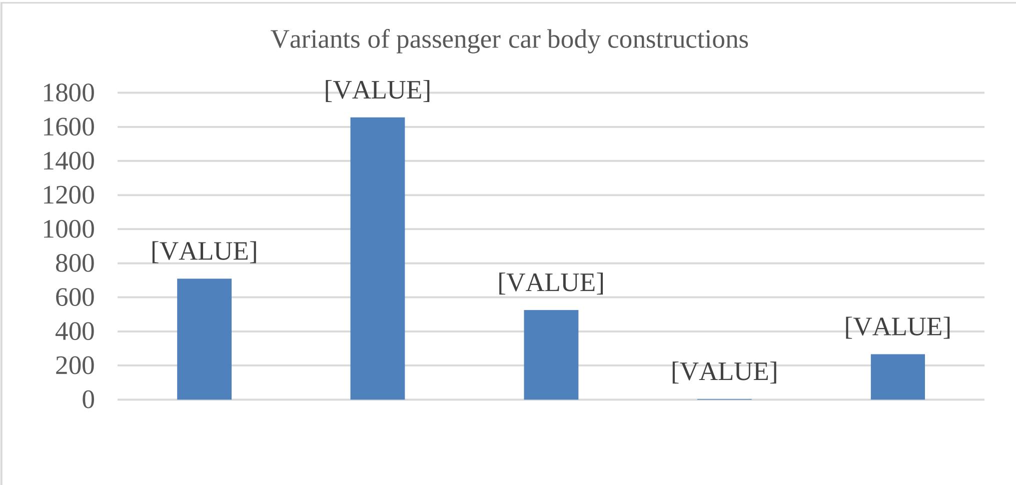

Figure 12: Diagram of the vehicle ratio with different car body constructions on the observed intersection over the 180-minute period

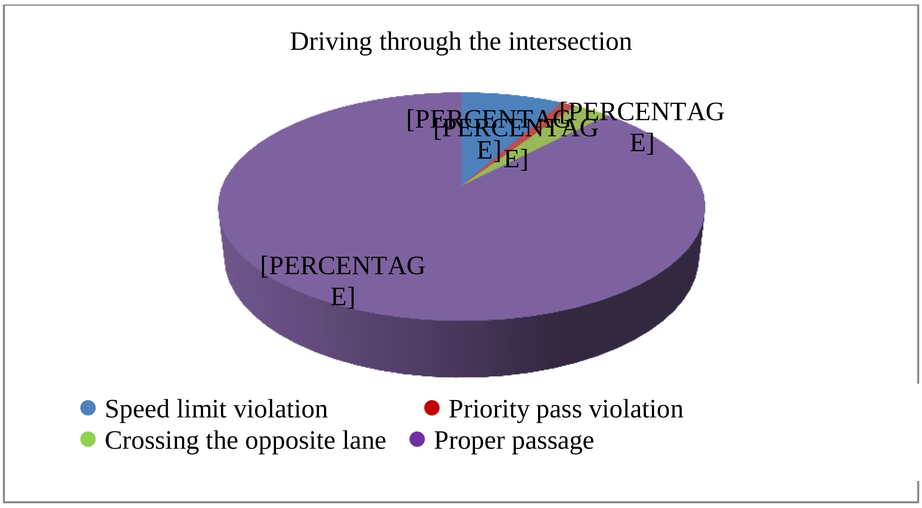

Figure 13: Ratio of the manner of vehicle passage through the intersection

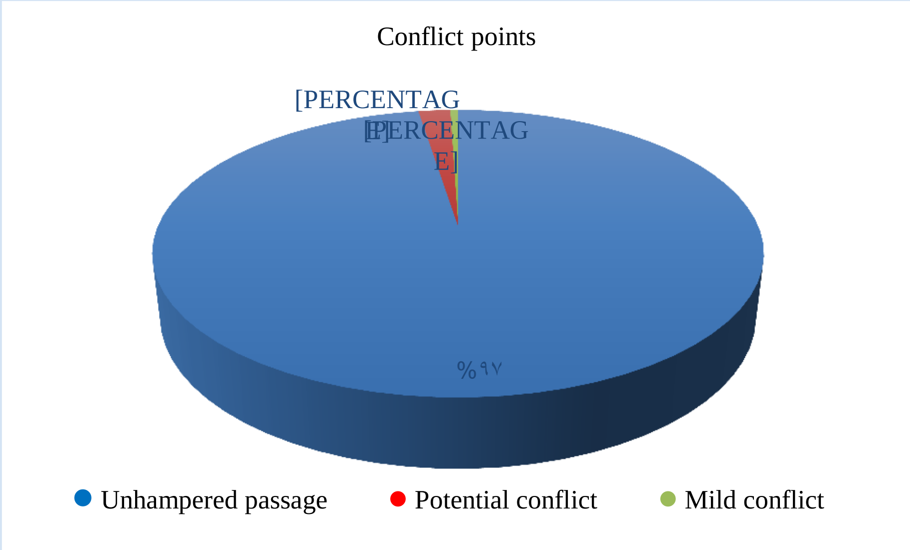

Figure 14: Ratio of conflict point types of the observed intersection

Within the obtained results of the research in this work, the possibility of proposing the conceptual design for the roundabout construction on the existing three-leg intersection arises.

4. Discussions of research analysis

This work shows the flow of individual passes through the intersection in the morning (7am-8am), noon (12am-1pm) and afternoon (4pm-5pm). Data analysis in "SIDRA INTERSECTION 5" programme shows that lane 3 has the lowest LOS because of the priority pass of the remaining two lanes. In order to improve the LOS of lane 3, construction of a intersection with a roundabout was suggested. In the programme, an analysis of a roundabout with the traffic count of the existing three-leg intersection was conducted. LOS of all three lanes of the roundabout is A. Based on the results obtained from the analysis of video recordings over the 180-minute period, it is determined that 303 passenger cars were passing improperly through the intersection, which means that 2790 vehicles passed properly through the intersection. In percentage terms, 8% of cars violated the speed limit, 2.9% crossed on the opposite lane and 1.16% of vehicles violated the priority pass. In total, 12,06% passenger cars were passing passing improperly through the intersection. Situations in traffic (events) can be shown as levels on a pyramid: on the bottom of the pyramid are harmless traffic situations (normal driving), while traffic accidents are on the top of the pyramid [8]. Height determines the event's danger while width determines its frequency.

Five levels can be defined on the pyramid:

- Undisturbed passes – safe traffic situations
- Potential conflicts – participants' paths intersect, but there is an early detection and a slight reaction
- Mild conflicts – The participants head towards a collision, but take an evasive action. They react timely and there is no forced braking, nor other sudden reactions.
- Serious conflicts – Participants head towards a collision and react late, so the accident was barely

avoided. We also call these situations near accidents.

- Accident – avoidance was too late and an accident with consequences occurs [8].

The largest number of conflicts are potential conflicts with a total of 64 conflicts over the observed period while the number of mild conflict for the same observed period is 16. No serious conflicts nor accidents happened during the observed period.

5. Conclusion

The existing unsignalised three-leg intersection did not satisfy the needs of current users and a broad analysis of traffic count was performed. Based on the results obtained from the analysis of video recording over the 180-minute period, it is determined that even 386 vehicles were moving inadequately on the intersection. This means that 88% of passengers moved properly on the intersection. Lane 3 has the lowest LOS over the total observed period, which is LOS F. For this exact reason, a proposal of the potential intersection's geometry advancement with a suggestion of an inclusion of a roundabout whereby the intersection leg 3 was rated with LOS A. This confirms the hypothetical premise that by the change of traffic control and traffic regulation regime on the three-leg intersection, it is possible to ensure a higher quality level of traffic flow. Roundabout falls into the category of intersections at the level in which all the access roads flow in and all the exit roads flow out from mostly one-way circular traffic flow which spans around the central island of the intersection. Modern roundabout regulates the conflicts of flows with a redistribution of priorities in a manner in which vehicles that move on the roundabout have a priority in conflict zones over those flows which intend to enter the roundabout from access roads. Lower risk levels on a roundabout are contributed by lower vehicle speeds on access roads conditioned by traffic which makes these unprioritized and also by intersection geometry (deflection of vehicle paths) which imposes deceleration of vehicles even in cases when it has no conflicts with vehicles coming from the priority flow. Consequently, roundabout's LOS on that area was analysed. LOS of all lanes is A at a roundabout. Therefore, the number of accidents on the observed intersection would reduce. Higher number of accidents was caused by mistakes made by traffic participants coming from lane 3. The main goal of a roundabout introduction is a more efficient and safe functioning of traffic.

6. Recommendations

In the direction of further researches, the proposal of measures with the aim of increasing traffic safety for all traffic participants is particularly important. This relates to education. In order to achieve better traffic safety on future roundabouts, it is necessary to pay special attention, during the training of driver candidates, to traffic behaviour regulations as well as proper movements on the roundabout. Education of all drivers in traffic, especially older drivers, on behaviour rules on a roundabout is very important. Also, in the direction of further researches, it is especially important to note that a constant enforcement of traffic and plan analyses is highly necessary. This has an aim to create an idea of roundabout's capacity and its qualitative traffic flow conditions.

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