A Revision of Roundabouts and Exhibit Their Different Types

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Abstract

This paper overviewed to exhibit of different types of roundabouts, that they are follows: mini, single lane, multi lane, spiral, turbo, and elliptical roundabouts. Then compared them based on terms of capacity, safety, and some geometric features. At initial, reviewed for the traffic circle, and compared it with roundabouts generally. In addition, the paper describes the important factors of using roundabouts, that most of researchers conducted that roundabout is a brilliant solution to resolve the problems of traffic circles. All roundabouts have specific properties own themselves. Also, some others are evolved from old types to a new type, for example; converting multi lane roundabouts to turbo type especially in Netherlands, and employing a high developed type from elliptical roundabouts are named mega elliptical roundabouts. Finally, the paper has focused on the most common developed types of roundabouts that are widely used now; such as turbo and elliptical types.

Keywords: single lane, multi lane, turbo, and elliptical roundabouts.

1. Introduction

The implementation of the roundabouts as modern type come back to the middles of first half of the 20th century in the United States, its evolution from the old traffic circles and rotaries [Jacquemart, 1998]. Progress in roundabout design began early in Great Britain, where one-way streets and gyratory systems had existed since the mid-1920s. The term ‘roundabout’ was officially adopted in 1926 in Great Britain to replace the term ‘gyratory’ [Todd, 1991].

Today, roundabouts are good alternative to an intersection, they provide major safety benefits and efficient in comparison with conventional signalized intersections that they are widely used not only in urban areas but also on high-speed roads [Chang et al., 2013] [Abbood et al., 2018]. The most of research studies conducted that roundabouts have been introduced as a brilliant solution to resolve the problems of traffic circles, and this reason is the one behind the wide usage of roundabouts around the

world that is reported by Sone, (2010), the author also found that roundabouts have proven to be more efficient than traffic intersection and, in some cases, signalized and stops controlled intersections.

There are several types of roundabouts use all over the world, some of the alternative types of roundabouts are more recent and have been employed only in certain countries, but some of them are infrequent use in worldwide, both classes differ from the 'standard' (single or dual) lane roundabouts typically in one or more design elements, as their purposes for implementation are also specific [Brown, 1995]. A modern roundabout is slightly different from a conventional roundabout. The right of way is a main reason of difference between a modern and a conventional roundabout. A modern roundabout gives priority to a circulating flow however; a conventional roundabout gives priority to traffic that enters the roundabout [Chang et al., 2013].

Generally, in roundabouts, the drivers are not required to stop; hence, the facility is more efficient under a wide range of traffic volume as drivers need to find an acceptable gap only in the circulating traffic to merge [Montella et al., 2012].

The Objectives of the paper to overview the different types of roundabout, then particularly comparing together based on the terms of capacity, Safety, reducing delay times and reducing crash rates.

2. Literature review

2.1. Traffic circles

The concept of a one-way rotary system was first proposed by William Phelps Eno in 1903 for Columbus Circle in New York City [Todd, 1988]. Since 1905, traffic circles have been part of the transportation system in the United States, and many large circles or rotaries were built. The prevailing designs enabled high-speed merging and weaving of vehicles. Priority was given to entering vehicles, facilitating high-speed entries [Robinson et al., 2000]. (Mayne, 2007) presented in Figure (1) a sample of traffic circles in United State.

Figure 1: traditional high-speed rotary

2.2. Roundabouts

Roundabouts are an intersection with a central island around which traffic must travel counterclockwise and in which entering traffic must yield to circulating traffic [AASHTO, 2011]. In the Figure (2) shows the basic geometric features of a roundabout [AASHTO, 2011] [Rodegerdts et al., 2010]. Roundabouts generally have the following characteristics [Turner, 2011]:

i. yield control on entry, priority to circulating vehicle;
ii. slow, consistent speeds;
iii. landscaping;
iv. pedestrian access and crossing;
v. no parking; and
vi. direction of circulation (counterclockwise).

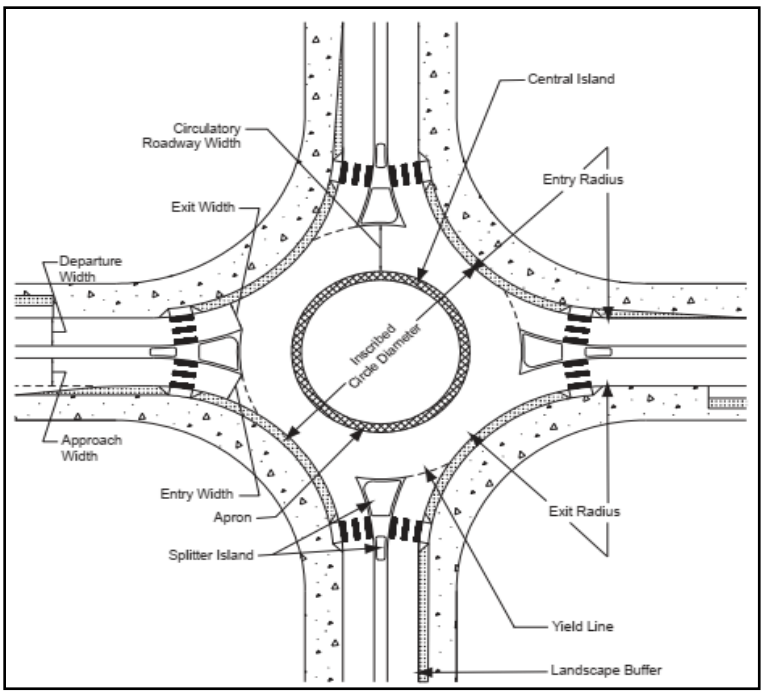

Figure 2: roundabout features

Roundabouts generally have a much smaller circumference than traffic circles or rotaries. The smaller circumferences and curved entries at roundabouts lead to much lower operating speeds than at other circular junctions. In Table (1) presented the differences between roundabouts and traffic circle [Rodegerdts et al., 2010] [Turner, 2011].

Table 1: comparison of modern roundabouts with traffic circle (rotary).

Feature	Modern Roundabout	Traffic Circle or Rotary
Control at entry	Yield at entry	Stop, signal, or give to entering vehicle.
Operational characteristics	Vehicle are sorted by destination at the approach. Weaving within the circulatory roadway is minimized.	Weaving is unavoidable and weaving sections are provided to accommodate conflicting movements.
Deflection	Large entry angle helps to create entry deflection to control speed through the roundabout.	Entry angle likely to be reduced to allow higher speed at entry.
Speed	Maintain relatively low speeds (<25 mph).	Higher speed allowed (> 25 mph)
Circle diameter	Smaller diameters improve safety.	Larger diameters allowed. Small diameter circle sometimes used for traffic calming.
Pedestrian crossing	No pedestrian activity on central island.	Some large traffic circles allow pedestrian crossing to and from the central island.
Splitter island	Required	Optional

The roundabouts are divided by as follows below:

2.2.1. Mini roundabouts

Mini roundabouts are small roundabouts with a fully traversable central island. They are most commonly used in low-speed urban environments with average operating speeds of 50 km/h or less. Figure (3) shows the features of typical mini-roundabouts [Rodegerdts et al., 2010].

2.2.2. Single lane roundabouts

Single lane Roundabouts are characterized as having a single lane entry at all legs and one circulatory lane, Figure (4) shows the features of typical single-lane roundabouts. The success of this type of roundabouts are directly related to their low number of traffic conflict points when compared to the ones of any uncontrolled or controlled intersection with the same number of branches [Rodegerdts et al., 2010] [Robinson et al., 2000].

Robinson et al., (2000) illustrated of two types of single lane: first; urban single lane roundabouts and, second; rural single lane roundabouts.

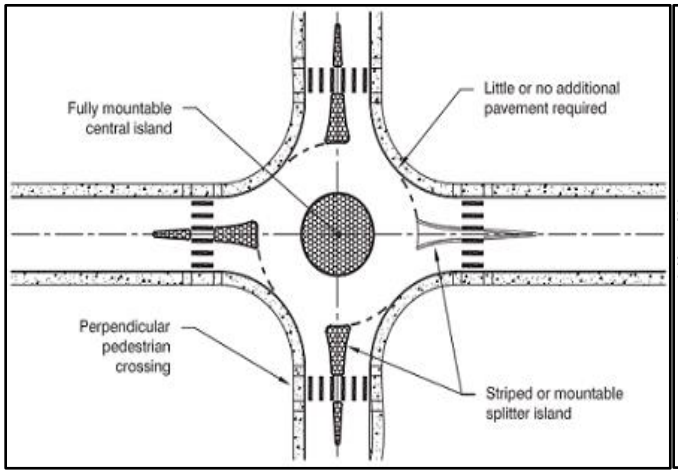

Figure 3: mini-roundabout

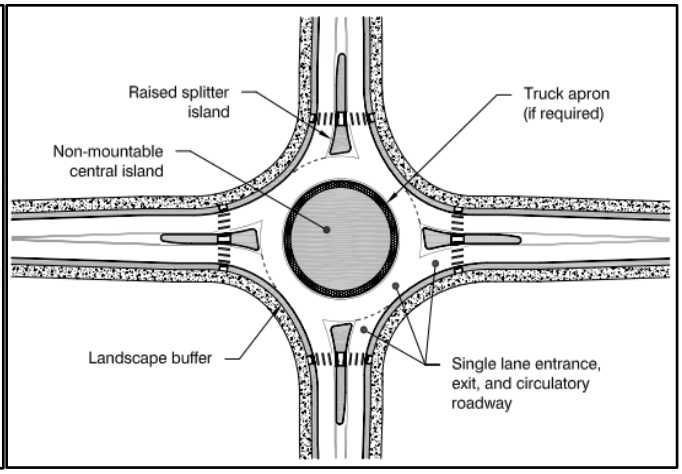

Figure 4: single lane roundabout

2.2.3. Multi lane roundabouts

Multi lane roundabouts have at least one entry with two or more lanes. The roundabouts could have a different number of lanes on one or more approaches in some cases, and their geometric design

will include; raised splitter islands, truck apron, a non-traversable central island, and appropriate entry path deflection, that were presented in Figure (5) [Rodegerdts et al., 2010] [Robinson et al., 2000].

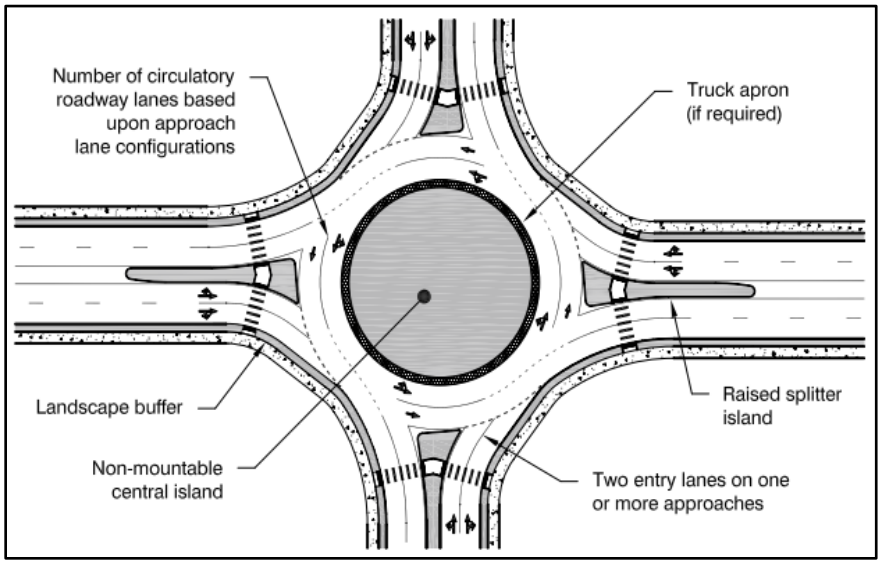

Figure 5: multi lane roundabout

Robinson et al., (2000) illustrated to types: first; urban double-lane roundabouts, include all roundabouts in urban areas that have at least one entry with two lanes. Second; rural double-lane roundabouts that have two entry lanes or entries flared from one to two lanes, on one or more approaches.

Mini roundabouts can be useful in such environments where conventional roundabout design is precluded by right-of-way constraints [Rodegerdts et al., 2010]. The comparison between the single lane and double lane roundabouts were presented, that the single types have a capacity problem, although, they have only 8 conflict points, the conflict points increase while single lane roundabout convert to multi lane roundabout, but according to growing traffic demand, roundabouts have evolved to layouts that feature more than one lane at entries, exits and circulatory roadway [Akshy, 2019] [Pratelli et al., 2018]. Multilane roundabouts grant higher capacities when compared to single-lane roundabouts. On the other hand, increase the number of conflict points by adding the number of lanes, since vehicles get the chance to change lanes in the circulatory roadway, i.e., weaving flows. Thus, increase crash rates [Pratelli et al., 2018]. In Table (2) was summarized and compared some fundamental design and operational elements for each of the three roundabout categories that were describes above [Rodegerdts et al., 2010] [Robinson et al., 2000].

Table 2. roundabout category comparison [Rodegerdts et al., 2010] [Robinson et al., 2000].

Design Element	Mini-Roundabout	Single-Lane Roundabout	Multi-Lane Roundabout
Desirable maximum entry design speed	25 to 30 km/h	30 to 40 km/h	40 to 50 km/h
Maximum number of entering lanes per approach	1	1	2+
Typical inscribed circle diameter	13 to 27 m	27 to 55 m	46 to 91 m
Central island treatment	Fully traversable	Raised (may have traversable apron)	Raised (may have traversable apron)
Typical daily service volumes on 4-leg roundabout below which may be expected to operate without requiring a detailed capacity analysis (vehicle/day) *	Up to approximately 15,000	Up to approximately 25,000	Up to approximately 45,000 for two-lane roundabout

*Operational analysis needed to verify upper limit for specific applications or for roundabouts with more than two lanes or four legs.

2.2.4. Spiral roundabouts

Spiral roundabouts are multilane roundabouts with spiral lane markings, which are still made of segments of concentric circles, but adjacent circular segments are connected by spiral transitions. The inner spiral transitions originate from the central island that is shown in Figure (6). The purpose of spiral lane markings is to provide drivers distinct guidance on how they can reach the desired exit without changing lanes [Amanamba, 2016].

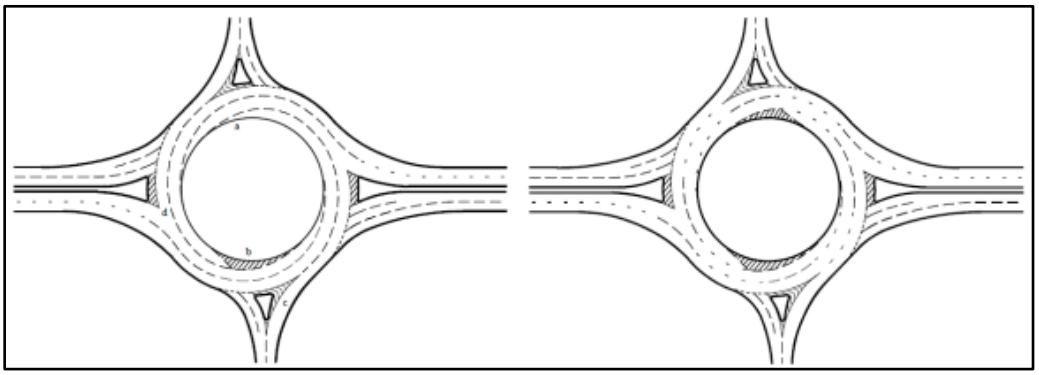

Figure 6: spiral roundabout layout

This kind is useful in reducing conflict between vehicles at the exits where more than one exit lane is provided. In order to enter the spiral lane that leads to the desired exit, vehicles need to select the correct entry lane; therefore, entry lane arrangement must be clear and visible in advance [Homola et al., 2014].

2.2.5. Turbo roundabouts

In recent years researches have been focused on a new type of multi lane roundabout as an alternative that are turbo roundabouts that provide sufficient level of traffic safety and capacity. Turbo roundabout include the following design features that were summarized below [Homola et al., 2014] [CROW, 2008]:

i. entries are usually perpendicular to the circulatory roadway (radial design);
ii. mountable raised lane dividers control the traffic path and speed by keeping vehicles in their lane with a smaller roundabout Inscribed Circle Diameter (ICD);
iii. at least one entry has a second lane inserted on the central island side;
iv. radial entry lane design;
v. traffic must choose the appropriate lane for the desired turning movement prior to entering the roundabout; and
vi. spiral road markings guide traffic from inside to outside, avoiding weaving and reducing conflicts in the roundabout.

Turbo roundabouts are variation of the conventional multi-lane roundabout, where drivers are forced to follow a specific path according to their intended destination [Silva et al., 2013]. The entries of all turbo roundabouts are perpendicular to the circulatory roadway in the Netherlands that is showed in Figure (7) [Engelsman et al., 2007]. The concept of this type emerged in the Netherlands in 1996 by researcher (Lambertus Fortuijn) [Silva et al., 2013]. Their specific geometry of spiral leading circulatory lanes and raised lane dividers exclude sideswipe collisions and waving, decrease number of conflict points and driving speeds in comparison with conventional multi lane roundabouts [Silva et al., 2013] [Petru et al., 2016]. Silva et al., (2013) compared the performance of conventional roundabouts with turbo roundabouts. They conducted that turbo roundabouts provided more capacity. Mauro et al. (2010)

found that, under specific situations, turbo roundabouts performed better than roundabouts in terms of capacity and delay.

The capacity of a turbo roundabout is about 25 to 35 percentage higher than the capacity of a conventional two-lane roundabout, depending on the balance of the traffic volumes on the approaches. The main reason for the higher capacity of the turbo roundabout is the reduction of conflict points for traffic entering and exiting the roundabout [Engelsman et al., 2007].

Figure 7: (Fortuijn turbo roundabout, Netherland)

Fortuijn, (2013) and DeBaan et al., (2017) demonstrated that there are 10 conflict points for vehicles on a typical turbo roundabout are observed, while on a two-lane roundabout there are 16, thus represents 60% more conflict points, including four weaving conflicts and two exiting conflicts, which amount to a higher accident risk for a two-lane roundabout were presented in Figure (8). A turbo roundabout is therefore a significantly safer option. A quantitative safety data comparison of the conversions of several 2-lane roundabouts to turbo roundabouts in the Netherlands was completed in 2015 using 3 years 'before' to 3 years 'after' data. The conversion from 2-lane roundabouts to turbo roundabouts resulted in a 53% reduction of injury accidents [DeBaan et al., 2017].

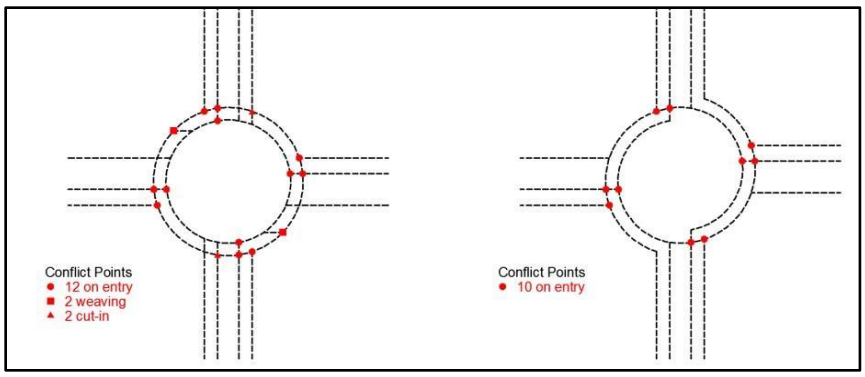

Figure 8: conflict points comparison: two-lane roundabout vs. turbo roundabout (Fortuijn).

CROW, (2008) illustrated the different types of turbo roundabouts (four and three legs), that can be constructed by consideration of the planned traffic volume and capacity distribution on roundabout approaches, that are showed in Figure (9) and (10) respectively.

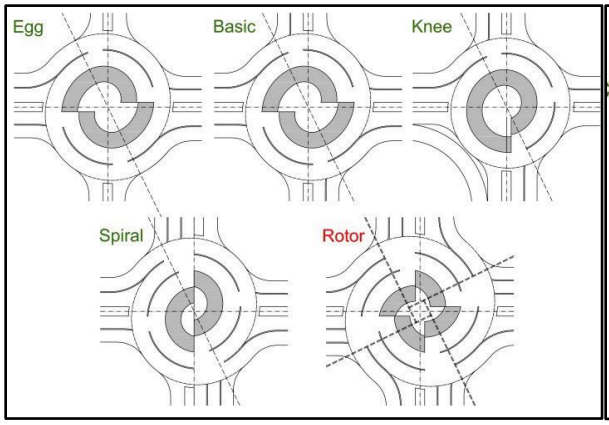

Figure 9: four leg turbo roundabouts

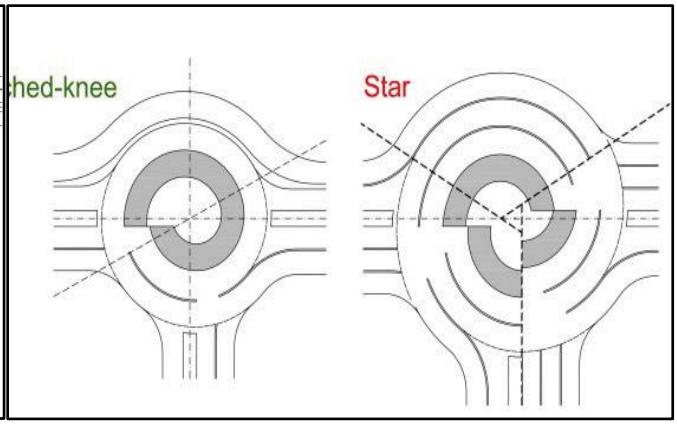

Figure 10: three leg turbo roundabouts

Knee, Spiral, Stretched-knee roundabouts, Egg, and Basic turbo roundabouts are recommended when one of the traffic flows is predominant, and Rotor or Star roundabout shapes are recommended in case of equal traffic volumes on all approaches, Other modified types can further be designed by varying the number of entry lanes [Fortuijn, 2009].

Tollazzi et al., (2013) conducted a new type of roundabout that shown in Figure (11), that is a dual one-lane roundabouts but, on two different levels with right-hand turning, it was named a 'target roundabout' that it has higher design, traffic safety and capacity characteristics than the standard two-lane roundabouts. The target roundabout is designed as two (one-lane roundabouts), located on two levels.

It has just eight merging, and eight diverging conflict points, with the weaving conflict points

transferred from the circulatory carriageway to the road section before the roundabout, which is a better solution from the traffic safety point of view [Tollazzi et al., 2013].

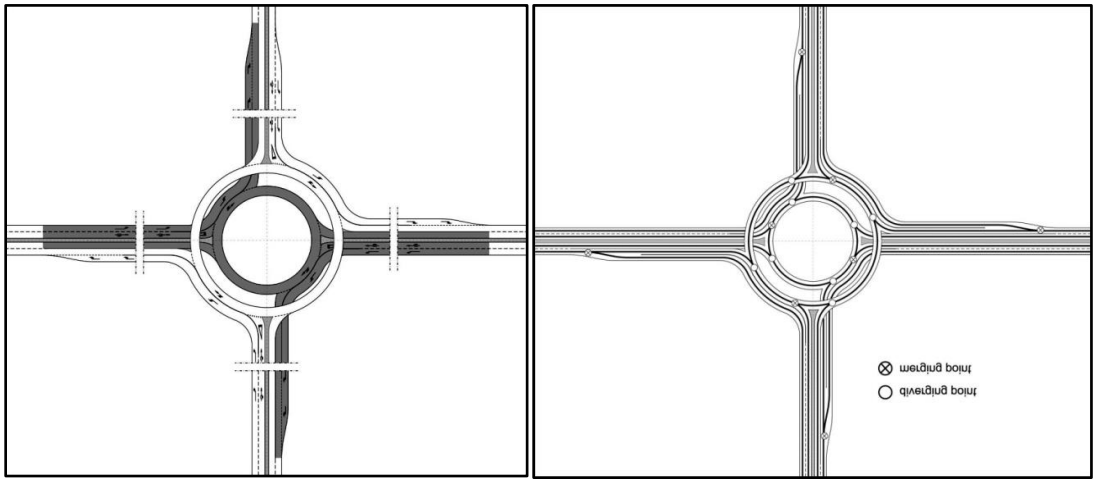

Figure 11: typical layout of a target roundabout with conflict points

2.2.6. Elliptical roundabouts

The elliptical roundabouts are form of classical double lane roundabouts with the emphasis that they are not a proper circular shape, but their geometry corresponds to a closed curve ellipse. These forms of double-lane roundabouts are characterized by two semi-axes (R and 2R). Usually the higher semi-axis (2R) is located in the main traffic direction while the lower semi-axis is located in the secondary traffic direction [Giuffrè et al., 2017].

Hatami et al., (2017) conducted that by increasing the central radius of island of elliptical roundabouts had positive and negative effects on capacity and delay. However, a positive effect on these variables was detected, when increasing the speed limit. Also, in saturated flow conditions, the elliptical roundabout has the best performance in terms of delay. Also, elliptical roundabouts have the highest capacities in unsignalized and signalized controls [Hatami et al., 2017].

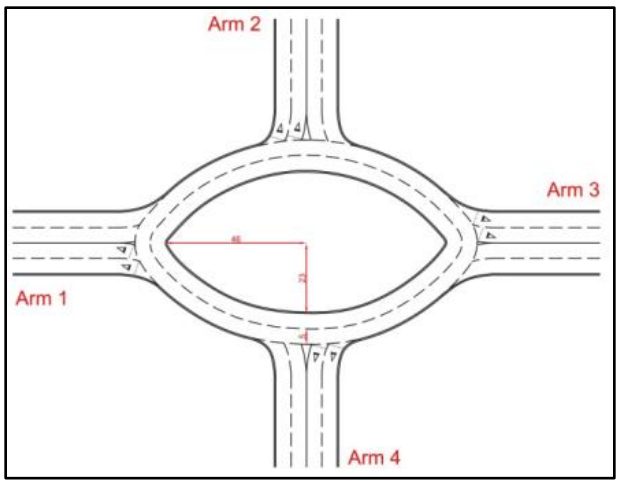

Figure 12: elliptical roundabout

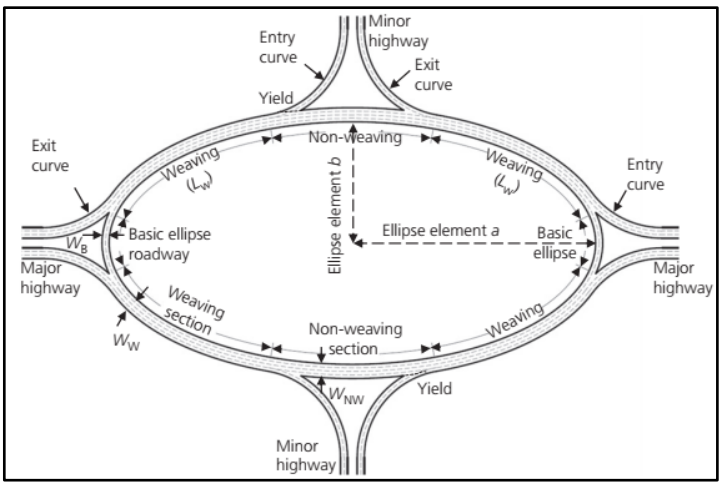

Figure 13: mega elliptical roundabout

A new type of elliptical roundabout was proposed by [Mohamed et al., 2019,2020], that is called the mega elliptical roundabout. It is a new idea for intersections on rural multilane highways in the form of an elongated ellipse. Central island and the ellipse roadway are two main features of a mega elliptical roundabout, which shown in Figure (13). The central island is characterized as elongated on the major highway to provide sufficient length for the weaving sections. Also, this island is in the form of an ellipse which has an ellipse element b to provide the appropriate radius for the basic ellipse roadway to be suitable for heavy vehicles to make a U-turn on it [Mohamed et al., 2019,2020].

When, the mega elliptical roundabout intersection is compared to a conventional intersection, that reducing the total conflict points from 32 to 8. Crossing conflict points are reduced by 100% (from 16 to zero). Thus, the mega roundabout decreases the potential for right-angle crashes, resulting in improved intersection operations and safety. Moreover, it eliminates the negative impacts of traffic signals because the mega roundabout is an uncontrolled intersection [Mohamed et al., 2019,2020].

3. Conclusion

The roundabouts have higher capacity than traffic circle or rotary. Both types differ in the features of control at entry, operational characteristics, deflection, speed, circle diameter, pedestrian crossing, and splitter island.

Generally, many types of roundabouts reviewed in this paper, that are: mini, single lane, multi lane, spiral, turbo, and elliptical roundabouts, the study concluded the following:

I. Single lane roundabouts have a capacity problem. But the multilane roundabouts have higher capacities when compared to single-lane roundabouts, especially in the terms of reducing crash rate. If increased

II. Spiral roundabouts have a problem of diverging, when the drivers want to departure from circle lanes, they conduct a problem of complexity in decision, due to discontinuity in the rotary lanes, and finished into the side of circle island.

III. Turbo roundabouts provide more sufficient level of traffic safety and capacity. They have many geometric forms as four and three legs, and can be constructed by consideration of the planned traffic volume and capacity distribution. Therefore, they have widely used in the worldwide.

IV. The target roundabouts are new important types of turbo roundabouts, that illustrated in the paper. They can be used dual one-lane roundabouts on two different levels, but they only have an economic problem.

V. The elliptical roundabouts have the highest capacity and most efficiency to reduce the crashes and delay time. while increasing the number of lanes. Especially, mega elliptical type is a new one that is most useful type in the term of capacity, safety, reducing delay time and reducing crash rates.

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