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AN INTERNATIONAL REVIEW ON ONE AND TWO LEVEL INNOVATIVE UNCONVENTIONAL INTERSECTION AND INTERCHANGE

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ABSTRACT

The research on road intersection and interchange has recently allowed designing innovative one and two level unconventional layouts (UIIDs) which are of undoubted interest, especially in terms of traffic functionality and safety. The main objective of the paper is to discuss the geometric layouts, the principal advantages and the disadvantages, in terms of cost, safety, performances of the most interesting UIIDs, like Two-level Signalized Intersection (TLSI), Single-point Urban Interchanges (SPUI), Center-turn Overpass (CTO), Echelon Interchange (EI), Crossover Diamond interchanges (DCD), Upstream Signalized Crossover Intersection (USC), Median U-turn Intersection (MUT), “Target”, “Flower”, “C” and “Turbo” roundabouts. Although many studies clarify the benefits of unconventional intersection and interchange designs (UIIDs) their implementation around the world is slow, mainly due to poor public support. In any cases, for some layouts the few UIIDs installations so far implemented around the world have not allowed sufficient research in order to analyze the measure of effectiveness (MOE) validated by field observations. Other layouts presented in the paper are prototypes and, for this reason, have been tested only by means of microsimulation, in prefixed traffic scenarios.

Keywords: unconventional layouts, intersection and interchange designs, MOE, construction costs.

INTRODUCTION

With the aim to improve safety and capacity of road intersections, numerous unconventional layouts of intersection and interchange designs (UIIDs) have been invented and now exist, with well-documented benefits, but their implementation has been slow.

Generally UIIDs can be distinguished in two categories:

- one level unconventional intersection (OLUIs);
- two level unconventional intersections (TLUIs).

Countries like united States have carried out many researches for the TLUIs, instead others, like European countries, have put their attention on OLUIs.

The main objective of the paper is to discuss the geometric layouts, the principal advantages and the disadvantages, in terms of cost, safety, performances of the most interesting UIIDs created around the world.

The two-level signalized intersection

The two-level signalized intersection (TLSI) was developed by Shin *et al*. (2008) [1]; it is characterized by the separation of the two crossing road into upper and lower levels both signalized [1] that completely separated east-west and north-south traffic.

The intersection layout should be founded on many factors like traffic volumes, road capacity, construction cost, safety, function into the road network, etc.

The TLSI can be used when two crossing roads have similar volumes of traffic; also TLSI allows the flexibility in the choice of signal phase and for this reason may be used to address varying traffic volume distributions.

Shin *et al*. (2008) [1], by means of micro simulation analysis, have shown that, compared with other innovative intersection types (SPUI, CTO, EI), the TLSI had the shortest delay times in most evaluation scenarios and traffic volume.

Nevertheless, the TLSI presented significant delay when traffic volumes on the major and minor roads are significantly different, so it can be used only when the two crossing roads had similar volumes of traffic.

Figure-1. Two-level signalized intersection.

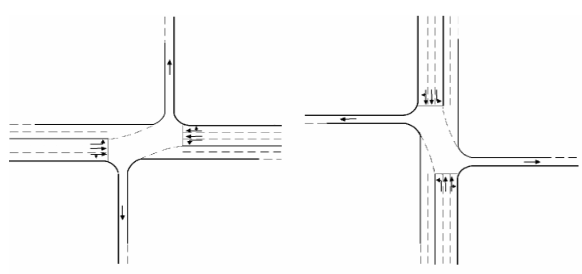

Figure-2. TLSI (upper and lower levels).

SPUIs, CTO and EI

In urban and suburban areas, for freeways and surface arterials junctions and where there is a difference

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in traffic operational conditions and in the design class between the two crossing road, tight urban diamond interchanges or single-point urban interchanges (SPUIs) are more broadly used than "free-flow" interchanges because of space, constructability, and financial constraints [2, 3, 4] (see Figure-3). The SPUI is controlled by a single signal installed usually into the upper level. This layout can be used when the traffic volume on the major road is much higher than the traffic on the minor road.

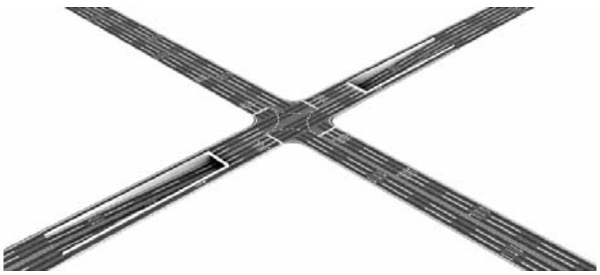

Figure-3. Single-point urban interchanges (SPUI).

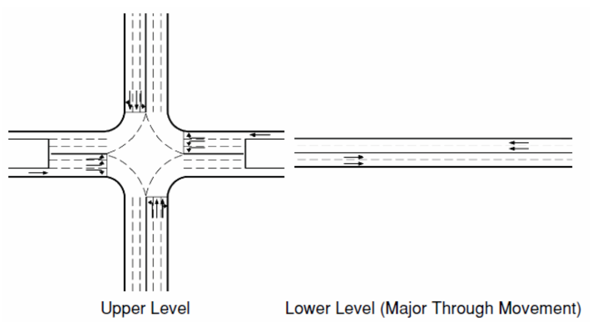

Figure-4. SPUI (upper and lower levels).

Instead, if the volumes on the minor and major roads are both very high, the upper level of the intersection could be congested due to limited capacity of the signal system (three or four phases).

In this cases can be used the center-turn overpass (CTO) and echelon interchange (EI).

The design of the first one (CTO) elevates left-turn lanes to an upper level; in the lower level there are through and the right turn manouvres [4]. The arterial and cross street through and right-turn movements continue to use the roads at normal elevation. Both the elevated and at-grade intersections are controlled by a simple two-phase signal. The left-turn traffic descends from the elevated intersection and merges into through traffic lanes.

In center-turn overpass intersection, the traffic descending from the elevated structure requires a merging/deceleration lane to merge with the through traffic of the receiving approach [5].

Specific advantages of a CTO interchange compared to a conventional at-grade intersection are as follows [6]:

- higher capacity than at-grade intersections;
- lower delay than at-grade intersections;
- direct pedestrian crossing;
- roadside access to businesses similar to conventional intersection with medians.

Some of the disadvantages are as follows:

- high structure cost;
- difficult design if streets are not perpendicular;
- blocked visibility to businesses by structure;
- costs for rights to design.

The EI eliminates left-turn and through conflicts by separating them by level [7]. This type of interchange design is not feasible for freeway facilities as there are no free-flow through movements.

Basically, an intersection is divided into two grade separated intersections that operate at two different levels. Each intersection operates independently and each intersection has fewer turning movements when compared to a typical four-legged intersection. This allows operating at lower cycle lengths reducing the delay. An obvious disadvantage of this type of design is that the concept requires the elevation of four legs of the intersection.
EI offers two significant potential advantages [7, 8]:

- it will not overpower adjacent signalized intersections to the extent free-flow movements might;
- it offers the planner/ designer significant flexibility and more discretionary planning options relative to its layout, its lack of "directionality" and its attendant land-use severance impacts.

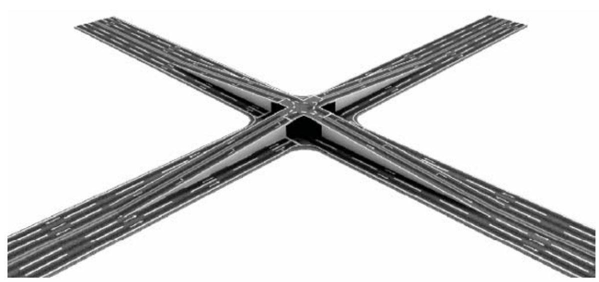

Figure-5. Center-turn overpass (CTO).

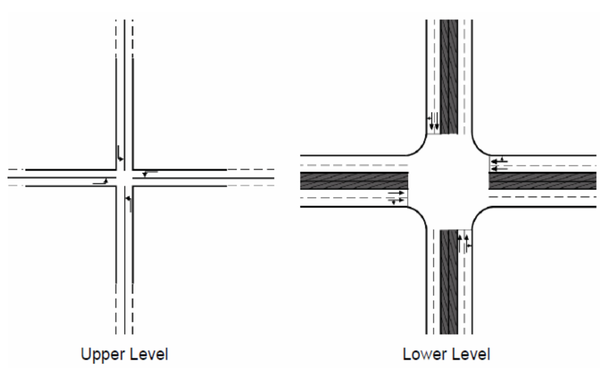

Figure-6. CTO (upper and lower levels).

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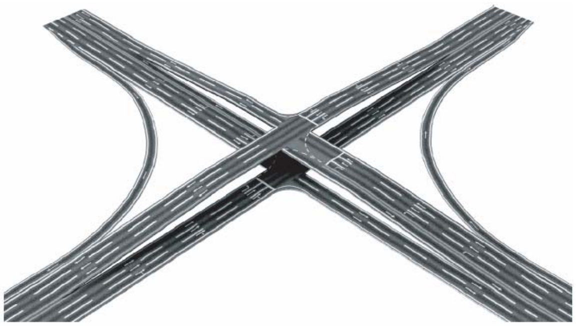

Figure-7. Echelon interchange (EI).

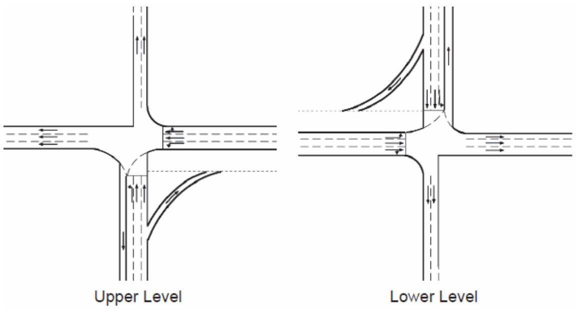

Figure-8. EI (upper and lower levels).

Crossover diamond interchanges (DCD)

Hughes *et al*. (2010) [5] examined two unconventional interchange designs, called Crossover Diamond (DCD) and DLT interchanges. The DCD interchange, also called Diverging Diamond interchange (DDI), is a “recent” interchange design that is being considered as a viable interchange form to improve traffic flow and reduce congestion.

The first DCD intersection was built in France in the 1970s. Only in 2009 the first DCD was constructed in the U.S. in Springfield, MO and in the following years, several additional DCDs opened to traffic [9].

The main characteristic of this interchange design is to accommodate left-turning movements onto arterials and limited-access highways while eliminating the need for a left-turn bay and signal phase at the signalized ramp terminals. The highway is connected to the arterial cross street by two on-ramps and two off-ramps.

The major potential advantage of the DCD is its ability to combine the ramp-turning movement phases with the through movement phases without penalizing other phases.

A DCD interchange should be used when high left-turn and through volumes contribute to high delays. In this intersection the signal-controlled crossovers operate with two-phase signal control compared to a conventional diamond interchange which normally has three-phase signal control. The advantages of the DCD intersection respect to conventional diamond intersection are [10]:

- two-phase signal control;
- fewer conflict points;
- narrower bridge structure.

Some of the disadvantages are as follows:

- driver confusion that may result from the unintuitive direction of travel between the ramp terminals of the interchange;
- due to two-phase signal control, pedestrians cross the junction in two different stages.

A research developed in U.S. shown a very good evaluation of DCD intersection by users, in terms of safety, delay decreases and understanding that how to navigate through a DCD interchange [11].

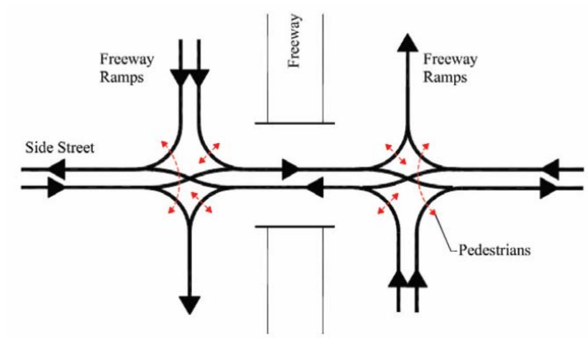

Figure-9. DCD interchange configuration.

Figure-10. DCD interchange in Springfield, MO.

Upstream signalized crossover intersection (USC)

The USC is used for eliminating the left-turn opposing conflict. In this unconventional layout (see Figure-11) through and left turn traffic cross the median to the left side of the road at a location upstream of the main intersection, while right turn traffic is maintained on the right side. Through traffic is also displaced to the other side of the road resulting in a complete switch of traffic at the main through traffic is also displaced to the other side of the road resulting in a complete switch of traffic at the main intersection. Left turns are made at the main intersection from the left side of the road and through traffic remains on the left side intersection. The same

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movements are made for traffic in the opposite direction, creating a symmetrical crisscrossing movement of traffic.

In the case of unbalance traffic the micro simulation analysis shows improvements for the USC for higher left-turn volumes compared to the conventional intersections [12].

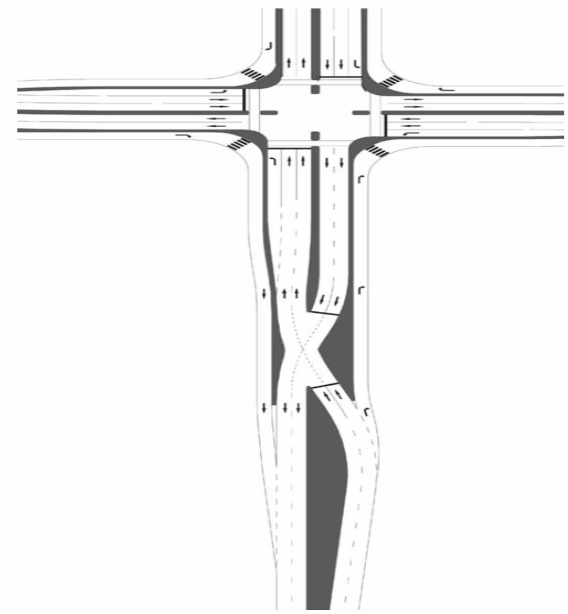

Figure-11. Upstream signalized crossover intersection (USC).

Median U-turn intersection

Median U-turn Intersection (MUT) is an innovative intersection characterized by elimination of direct left turns at signal-controlled intersections from major and/or minor street approaches. The MUT intersection layout require the elimination of direct left turns from major and/ or minor approaches (generally both).

Drivers desiring to turn left from the major road onto an intersecting cross street must first travel through the signal-controlled intersection and then execute a Uturn at the median opening downstream of the intersection [6, 8].

The main advantages of the Median U-turn Intersections include:

- reduced delay and better progression for through traffic on the major street;
- increased capacity at the main intersection;
- fewer conflict points;
- Two-phase signal control on the approaches without a left turn phase allows shorter cycle lengths;
- Reduced risk to crossing pedestrians.

The main disadvantages of MUT intersection include:

- Possible driver confusion and violation of left-turn prohibition at the main intersection.
- increased delay, travel distances, and stops for left-turning traffic;
- larger rights-of-way required for the main street;
- higher operation and maintenance costs attributable to additional traffic signal control equipment.
- longer minimum green times for cross-street phases or two-cycle pedestrian crossing.

The layout of the main intersection of the MUT is similar to the design of a conventional intersection; except that the main intersection is designed for larger volumes of right-turn movements than a conventional intersection serving the same total volumes because the left-turning vehicles become right turning vehicles [8, 9]. For this reasons, the intersection must be designed with right-turn bypass of sufficient width and length to accommodate the volume of turning vehicles [13, 14, 15].

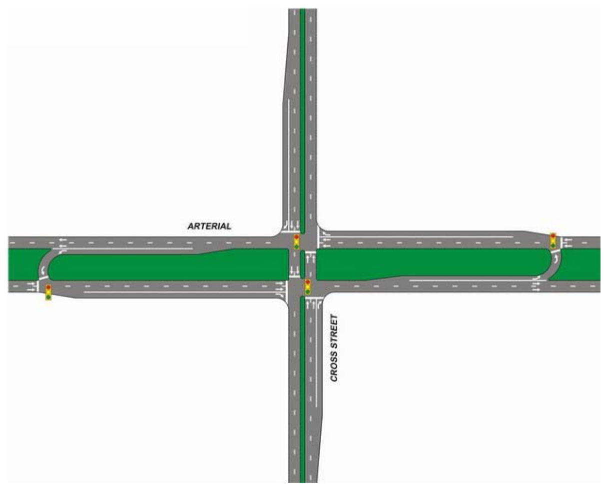

Figure-12. MUT intersection.

Continuous flow intersections

The Continuous Flow Intersections (CFI) has a particular layout that allows the elimination of the conflict between left-turn and opposing through traffic by relocating the left-turn bay a significant distance upstream of the primary intersection so that the through and left-turn flows can move concurrently [15, 16]. The installation of CFIs has become more prevalent in the United States where there are 18 CFIs [16]; 13 were installed since 2010, and of those, nine were installed in Utah.

In the CFIs, the traffic signal is timed so that the left-turning vehicles at the upstream location can cross over to the left side of the opposing through lanes (displaced to the left to become a DLT) while the opposing through movement is stopped at the main intersection and cross-street traffic is served. In CFIs is very important for the performance of the intersections the length of the displaced left-turn lane (DLTL). Current literature provides only general guidance for determining the DLTL length and recommends an offset length range of 300 to 500 ft.

Numerous researches have generally concluded the superior performance of CFIs over conventional intersections [15].

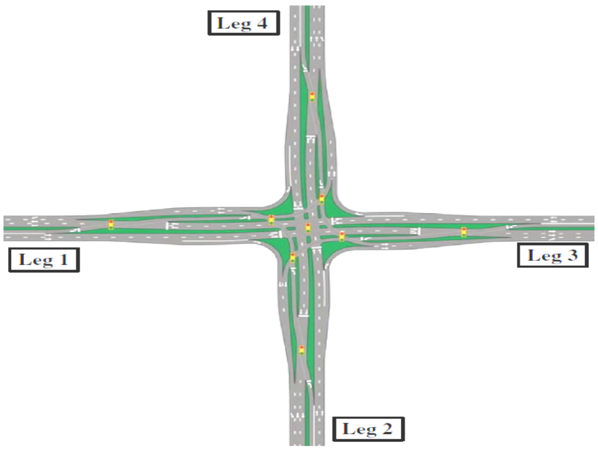

Figure-13. Continuous-flow intersection (CFI).

Through-about intersection

The through-about intersection (also called "hamburger" intersection) is a variant of the signalized roundabout. The primary difference is that the mainline through movements are allowed in the central island.

The through and left-turn movements from the minor street are executed by following the circulatory movement around the semicircular islands at the main intersection.

This layout allows the use of two-phase signal. The "hamburger" intersection can be used, for example, when light rail through an intersection (see Figure-14).

Figure-14. Through-about intersection.

Raindrop interchange

The raindrop interchange, called also roundabout interchange, uses the concept of roundabouts at the grade-separated interchange. In effect, the minor streets through movements navigate through roundabouts. There can be two types of raindrop interchanges-double and single. The double roundabout version uses two roundabouts at the ramp terminals (see Figure-15).

The single roundabout type has a single large roundabout designed over the arterial and serves as the overpass for the turning movements.

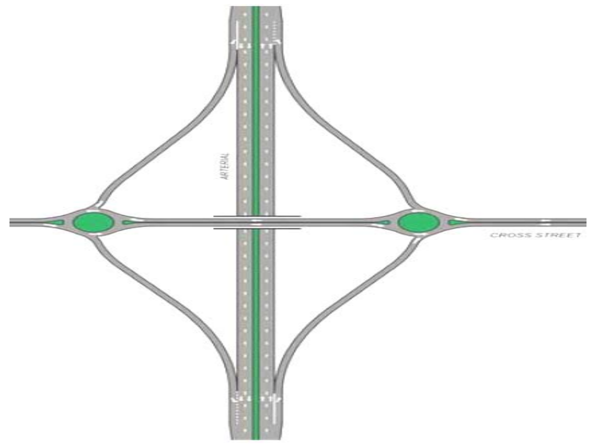

Figure-15. Layout of double roundabout interchange.

Roundabout with circular foot bridge (RCFB) and intersections with cyclist bridge (ICCB)

To increase the safety of pedestrians and cyclists and the level of service (LoS) of the intersections a bridge around the intersections can be build. For example we can examine two new innovative layouts in China and in Europa:

- in Lujiazui, China was built a new roundabout in which there is a foot 'bridge' that helps thousands of pedestrians navigate safely above the traffic (see Figure-16). The bridge connects different entry ways to buildings, offices, shops and other attractions demonstrating China's plans for better pedestrianization;
- in Netherlands a Floating Suspension Bridge was constructed in 2012 for the cyclist safety (cf. Figure-17). The deck itself is suspended from cables that span from a 210-foot-tall steel pylon, in the center.

Figure-16. Roundabout with circular foot bridge.

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Figure-17. Intersections with Cyclist Bridge.

Turbo roundabout

A turbo roundabout was invented by Fortuijn (2009) [17, 18]. In Europe, there is same country in which was built many turbo roundabouts. For example nowadays, in Slovenia there are 11 turbo roundabouts in exercises and for 3 new turbo roundabouts the project documentation is in the stage of confirmation.

This layout is a particular type of roundabout where all lanes are bounded by traffic signs and by non-mountable curbs installed at entering and circulating lanes. Turbo roundabouts also have a very particular shape to accomplish the splitting of traffic streams and to prevent cars weaving through. As a result of the lane dividers, turbo roundabouts force circulating traffic flows to spiral trajectories; each entering lane is therefore specialized in a single turning maneuver and drivers have to choose their direction before they enter the intersection and the appropriate lane on the circulatory roadway.

In particular, turbo-roundabouts are characterized by the following features:

- entry lanes are specialized for turning manoeuvres, physically bounded by curbs;
- users who are going to get onto the intersection have to select the lane along the entry arm in order to make their manoeuvre (through and left movements, right turnings);
- after choosing their own lane, their path is partially constrained by the presence of curbs installed along the circulatory roadway up to the exit;
- all the vehicles coming from the entries, even if they follow different behavioural patterns, have to give priority to circulating vehicles;
- through movements and left-turn manoeuvres come into conflict with circulating vehicles which are along one or two lanes and need to be passed through, so that entering vehicles can get onto the appropriate circulating lane (i.e., the inner lane at the circulatory roadway). In this case, unless the conflicting vehicles are forced to stop, entering vehicles have to wait for the joint probability to find gaps wide enough (i.e., above the critical gap) between vehicles distributed along the circulatory roadway in parallel lines;
- unlike the above, the right-turn manoeuvres occur in the same way as at traditional roundabouts.

If compared with conventional roundabouts, the main benefits of a turbo roundabout are [17, 18, 19, 20]:

- lower number of potential conflict points between vehicles; for example, a four-arm turbo roundabout is characterized by ten conflict points, whereas a two-lane roundabout has twenty-two;
- slower speed along the ring;
- lower risk of side-by-side accidents.

In light of these considerations, turbo roundabouts could be an alternative to two-lane roundabouts, especially to guarantee a high safety level, for example in case of quite heavy cyclist/pedestrian traffic.

Geometric Design parameters of Turbo-roundabouts are explained in [21, 22], instead the environmental benefits are discussed in [23, 24, 25].

The capacity at each entry of a turboroundabout has been shown to be conditioned by the capacity at single lanes, by conflicting vehicles and pedestrian flow, by the combination of circulating flows along lanes at circulatory carriageway (in case of North and South entries), by user behaviours (through parameters T_g, T_f, T_{min}) as well as by the balance of traffic demand at the entry. Contrary to models for conventional roundabouts, at entries of turbo-roundabouts there is no biunique relation between circulating flow and entry capacity but only a continuous set of capacity values related to degrees of utilization.

Table-1 shows the indicative values of capacity at conventional and turbo roundabout. The Definition of types of roundabouts by their inscribed circle diameter and their maximum capacity in terms of average daily traffic (ADT) are explained by Brilon [26].

Table-1. Indicative values of capacity at conventional and turbo roundabout.

Type of two-lane roundabout	**Maximum daily traffic burdening** [veh/day]
Conventional Two-lane with one-lane exits and entries	20000 - 25000
Conventional Two-lane with two-lane exits and entries	22000 - 30000
Roundabouts with spiral course of the circulatory carriageway with two two-lanes entries	Approx. 37000
Spiral Turbo roundabout	Approx. 42000
Turbine Turbo roundabout	Approx. 50000

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Figure-18. Flower roundabout.

Flower roundabout

Flower roundabouts (see Figure-19) were designed by Tollazzi [13] with the ambitious objective of gathering the positive aspects of the different types of roundabout intersections and, at the same time, eliminating the negative ones, in other words getting the safety level better than conventional and turbo roundabouts without reducing capacity. As a matter of fact, a flower roundabout is a roundabout with two lanes at entries, two lanes at exits and a ring lane which makes right-turning vehicles get onto a free-flowing bypass lane, and not into the ring. From this viewpoint, flower roundabouts are not a novelty at all in the panorama of road intersections but they are rather simply a specific type of conventional roundabout with a ring lane, a lane at entries and an additional lane to turn on the right [14, 27].

As far as safety matters are concerned, it is worth pointing out that there is no weaving in circulatory roadway but only eight conflict points (more exactly, 4 diverging points and 4 merging points) which characterize a conventional roundabout with a ring lane. As to bypass lanes, it is also required to calculate the diversion points concerning the right turn routing manoeuvre and the entry points in the flow from the roundabout.

The results of the capacity analyses carried out in [14, 28] have shown that flower roundabouts lead to a significant reduction in delays in all the flow conditions compared to conventional roundabouts with one entry lane (configuration (1+2) or (1+1)). With regard to multilane roundabouts (2 lanes at the ring + 2 lanes at entries) flower roundabouts cause higher delays up to 70% of the total right-turn flows. Once such a threshold is exceeded, flower roundabouts prove to be more convenient than the other schemes, in that, traffic conditions being equal, average vehicle delays decrease more and more markedly.

Figure-19. Flower roundabout.

C-Roundabout

The C-roundabout (cyclist roundabout) is a new multi-lane roundabout designed to improve the safety of cyclists at and make multi-lane roundabouts more cyclist-friendly. The main features of the C-roundabouts are the following [29, 30, 31]:

- two-lane configuration;
- geometric scheme such that unimpeded vehicle through speed is around 30km/h (maximum path radius of 30-40 m is required);
- narrow entry width - approximately 5.4 m, kerb-to-kerb (i.e., 2.7 m lane widths);
- narrow circulating carriageway width, with a minimum of 0.5 m clearance between cars and kerbs.

Also, a single lane roundabout can easily be transformed to a C-Roundabout at minimal cost using approximately the same road reserve and results in a significant increase in capacity.

The potential applications of the C-roundabouts are the following:

- at an existing multi-lane roundabout where there are many cyclist crashes;
- at site where an existing single lane roundabout is going to be converted to a multi-lane roundabout for improved capacity;
- at site where a signalized intersection has a crash problem and a roundabout is being considered.

A before-after research between existing single lane roundabout converted into a new C-roundabout (see Figure-20) has shown a speed and injury crashes reduction [29] (in this case the original central island and splitter islands were modified to increase the deflection and hence reduce the vehicle through speeds for all approaches). Also, the research explain that the car drivers users' impressions were negative about the C-roundabout because they found it tight and slow, and would prefer a wider conventional roundabout.

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Figure-20. C-Roundabouts.

Double lane roundabouts with spiral marking system

With the aim to resolve the conflict between vehicles entering and exiting a double lane roundabout, in New Zealand was introduced the spiral-marking system [32] also called Alberta marking scheme (AMS). The continuous spiral-type markings (see Figure-21) is used to demonstrate the rules that traffic exiting a roundabout has priority over traffic in the outer circulating lane, and circulating traffic has priority over any approaching traffic [33]. For example, with the traditional concentric marking scheme (CMS) of a conventional double lane roundabout, in Figure-22, vehicle C must give way to circulating traffic in the outer lanes, while with the spiral-type lane markings, vehicle C has priority over any conflicting traffic.

Wong, *et al*. (2012) shown that drivers preferred the spiral-marking system to the conventional system and perceived the spiral-marking roundabouts to be safer and less difficult to use but the performance of the spiral-marking system on intersections with moderate to heavy traffic is yet to be established and merits future investigation. Comparing the two typologies of markings, the CMS discourages users from using the circular inner lane while the AMS induces a lane use pattern that is better balanced.

Bie, *et al*., [34] developed a research on roundabouts with lower traffic values in which AMS and CMS were compared by means a before-and-after field study. The research conclusions are the following:

- spiral-marking system give better traffic flows balance between the two circulatory lanes;
- AMS ensure shorter delay and higher capacity and safety level than CMS.

Figure-21. Spiral-marking roundabout.

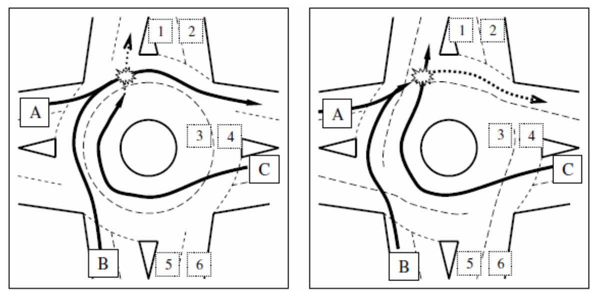

Figure-22. Priorities of different traffic streams on a conventional roundabout and a spiral-marking roundabout (left-hand driving rule in effect).

Dual one-lane roundabouts on two levels with right-hand turning bypasses - "Target roundabout"

The target roundabout (invented at the Centre for Road Infrastructure at the Faculty of Civil Engineering, University of Maribor [35]) is designed by two one lane roundabouts, situated in two levels (Figure-23), and all right turners in both roundabouts have their own, separate right - turn bypass lanes. Two one lane roundabouts in two levels allow driving from all directions to all directions.

This roundabout type "forgive errors": if driver mistakenly stays on left lane at the entrance it is still allowed to turn right on next exit (different to turbo roundabout).

In the target roundabout there are 8 merging and 8 diverging conflict points (like in two one lane roundabouts), and weaving conflict points transfer from the circulatory carriageway to the road section before the roundabout, which is a better solution from traffic safety point of view. However, in accordance with the results of micro simulation, Tollazzi, *et al*., [35] shown that target roundabout (with diametre D = 75 m) could serve the interchange with 50.000 AADT with a good Level of service and up to 60.000 AADT with a Level of service F, in accordance to HCM 2010 criteria.

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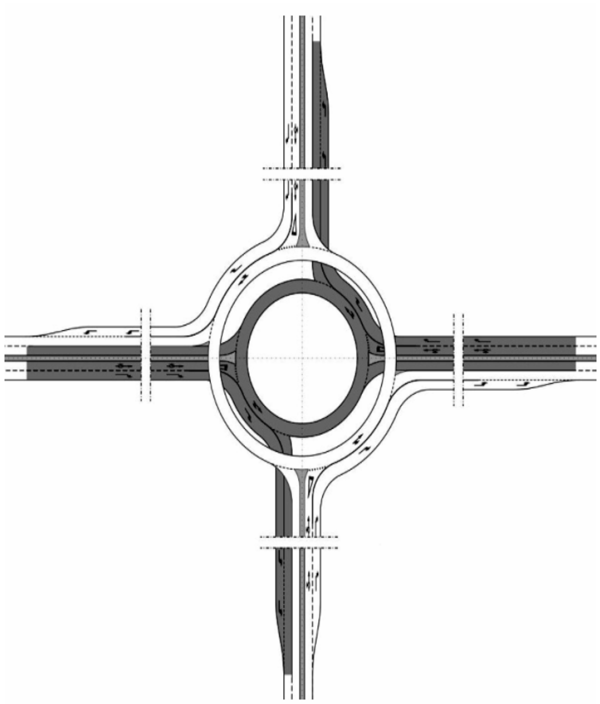

Figure-23. Target roundabout.

UIIDs PERFORMANCE ANALYSIS

The capacity determination, the queue lengths and delays (measures of effectiveness, MOE) in UIIDs generally are carried out through traffic micro simulation.

The majority of researches on UIIDs examined in this paper used the Vissim software; only for innovative roundabouts are available closed-form models for capacity estimation [13, 14, 15, 19, 21, 36].

CONSTRUCTION COSTS

An estimation of construction costs for innovative two level intersections (without factoring in right-of-way costs) was carried out by Shin *et al*. (2008) [1], considering two possible construction models for the TLSI, SPUI, and EI, as follows:

- **Option-1:** where the lower level is built at-grade;
- **Option-2:** where the lower level is depressed.

Estimated construction costs are the following:

- **TLSI:** $11.8 million for Option-1, $11.5 million for Option-2;
- **SPUI:** $12.0 million for Option-1, $12.3 million for Option-2;
- **EI:** $11.3 million for Option-1;
- **CTO:** $11.4 million for Option-1.

Mauro and Cattani [37] presented a procedure to compare different on level layouts, taking into account the costs of construction, management/maintenance and delays at the approaches. The overall costs of a road intersection consist of the following elementary elements:

- fixed construction costs;
- land;
- pavement;
- traffic signal;
- variable costs;
- management and maintenance;
- time (delays).

In the research six layouts were chosen to represent both traditional intersections and roundabouts:

a) Four-leg signalized intersection

- single lane approaches;
- double lane approaches on the major road, single lane on the minor;
- double lane approaches;

b) Four-leg roundabout

- compact single lane roundabout: external diameter 30m, single lane approaches and single lane circulatory roadway;
- large double lane roundabout: external diameter 80m, single lane approaches and double lane circulatory roadway;
- large double lane roundabout: external diameter 80m, double lane approaches and double lane circulatory roadway.

With references only to the constructions costs (without the variable costs, management and maintenance costs and time costs, but with road barriers costs [38, 39]) Table-2 shows the values for the one level conventional intersection and for spiral-marking, "turbo" and "flower" roundabouts.

Table-2. Construction costs.

Layout	**Land** (€)	**Pavement** (€)	**Signal** (€)	**Construction costs** (€)
Roundabout diam. 16m (1 lane)	520.000	150.000	0	670.000
Roundabout diam. 60m (1 lane)	953.300	194.250	0	1.147.550
Roundabout diam. 60m (2 lane)	1.121.700	243.750	0	1.365.450
spiral-marking roundabout diam. 20 m (2 lane)	710.000	160.000	0	870.000
Intersection 4x1	510.000	153.000	40.000	703.000
Intersection 2x2 2x1	568.000	170.400	40.000	778.400
Intersection 4x2	630.000	189.000	40.000	859.000
Turbo roundabouts diam. 60m (2 lane)	1.300.000	260.000	0	1.560.000
Flower roundabouts diam. 60m (2 lane)	1.200.000	280.000	0	1.480.000

Obstacles to implementation of unconventional intersections

Although many studies explain the benefits of unconventional intersection and interchange designs (UIIDs) their implementation around the world is slow [40]. The biggest categories of barrier to the use of UIID identified by Shumaker [40, 41] are:

- public support;
- potential for driver confusion;
- lack of proof that the designs function well;
- safety and cost considerations.

In the United States the relatively recent success with roundabouts proves it is possible to overcome obstacles affecting unconventional designs.

Nevertheless in some countries (like Italy [42]), the rigid design guidelines for road intersection restrict the implementation of new and unconventional road intersection.

CONCLUSIONS

The paper presents numerous one and two level typologies of unconventional layouts of intersection and interchange designs (UIIDs). For the choice of a road intersection layout is required a cost benefit analyses because, usually, the layouts which provide higher capacities are the most expensive ones. In the light of this consideration, for some of the most interesting UIIDs, the study provides the geometric layouts, the principal advantages and the disadvantages, in terms of cost, safety and performances. Due to weak public support, the use of new unconventional intersection around the world is yet slow comparatively to other traditional layout, even though many studies explain the benefits of UIIDs in terms of MOE and construction costs.

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