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Advancing Road Safety in Urban Area: The Impact of Roundabouts on Intersection Design

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ABSTRACT Intersection represents a significant challenge around road traffic safety, posing a major problem, and particularly during peak hour of urban road traffic. The high risk of accidents at this congested intersection is a serious concern, given that they involve a variety of road users, including vehicles and pedestrians. To address these challenges and minimize the risks related to intersections, roundabout have emerged as a significant effort. To address these challenges and minimize risks related to intersections, roundabouts have emerged as a notable solution. This approach does not only contribute to improved traffic flow but also enhances overall road safety by providing a more efficient alternative compared to conventional intersection designs. This study takes a comprehensive look at the safety performance of roundabouts as an alternative intersection design, by systematically reviewing relevant literature from Scopus and Google Scholar, aiming to explain how roundabout intersections contribute to crash reduction and traffic safety improvement. The analysis reveals that roundabouts generally lead to a significant reduction in severe collisions and enhance traffic flow efficiency. This is primarily due to their design, which minimizes conflict points and promotes lower vehicle speeds, and positively impacts the visibility and safety of pedestrian crossings. However, the roundabout has challenges, such as the requirement for drivers to adapt to new traffic patterns and the public's perception of the different aspects of the roundabout design. The findings indicate that roundabouts substantially improve road safety, evidenced by significant reductions in fatal and injury crashes. The literature also emphasizes the importance of customizing roundabout design and implementation to specific conditions, highlighting that such adapting is critical to maximizing benefits and ensuring positive impacts on road safety which is important to developed in further research.

KEYWORDS Traffic Accident; Collision; Intersection; Roundabout; Safety

1 INTRODUCTION

Intersections represent a significant challenge in the field of road traffic safety, posing major problems, especially during peak hours of urban road traffic. Intersections in urban areas often become traffic accident hotspots due to severe congestion (Li et al., 2016; Wang et al., 2017; Comi et al., 2022). The high risk of accidents at these congested intersections is a serious concern, given that they involve a variety of road users, including vehicles and pedestrians. The potential for accidents at intersections should be taken into account to develop effective solutions.

A roundabout is a circular intersection where traffic circulates around a central island in a counterclockwise pattern (Adsit et al., 2021). Widely recognized as a safer alternative to other intersection types, roundabouts introduce a different approach to traffic management. When road users approach a roundabout, they instinctively reduce their speed and follow the circular path around the central island before entering the appropriate lane (Anjana and Anjaneyulu, 2015). This inherent design encourages more controlled and predictable traffic flow. Replacing four-way and signalized intersections with roundabouts provides significant operational and safety advantages. The positive impacts of roundabouts are demonstrated in improved operational efficiency and safety due to reduced speeds, optimized geometric configurations, and enhanced traffic control (Tarko et al., 2008; Day et al., 2013; Tarko et al., 2015). Compared to conventional intersections, alternative designs like roundabouts offer an attractive combination of safety and functional benefits, such as reduced collisions and fewer overall crashes (Suh et al., 2015). This shift in intersection design not only addresses safety concerns but also contributes to overall transportation infrastructure improvements by creating a safer and more efficient environment for road users.

To address these challenges and minimize risks related to intersections, roundabouts have emerged as a significant solution. Roundabouts serve as a strategic intervention aimed at reducing the likelihood of accidents and minimizing conflicts at intersections. This approach not only improves traffic flow but also enhances overall road safety by providing a more efficient alter-

native to conventional intersection designs. By implementing roundabouts, there is a concerted effort to create a safer environment for all road users, aligning with the broader goal of improving road traffic safety.

This study aims to evaluate the safety performance of roundabouts by analyzing their impact on crash reduction and overall traffic efficiency. In addition, it also seeks to identify and discuss the challenges associated with roundabout implementation worldwide.

The rest of the paper is organized as follows: Section 2 reviews literature on the introduction of roundabouts for managing road intersections. Section 3 examines roundabout design, while Section 4 discusses traffic flow efficiency, safety benefits, considerations for pedestrians and cyclists, and public perception. Finally, conclusions are drawn in Section 5.

2 THEORITICAL APPROACH

To further investigate these theoretical insights, this article employs a critical review to comprehensively examine the impact of roundabouts on urban intersection design, with a specific focus on their role in improving road safety. For data collection, two primary databases were used: Scopus and Google Scholar. The authors searched the Scopus database for relevant literature using the following search phrase: (roundabout) AND (intersection) AND (traffic) AND ("safety" OR "collision" OR "accident"). Furthermore, a Google Scholar search was conducted for articles containing the keywords "roundabout," "intersection," and "traffic," along with at least one of the following: "safety," "collision," or "accident." Articles retrieved from Google Scholar were evaluated based on their publication source, and only those published in peer-reviewed journals or official institutional reports were included.

The following were the inclusion criteria for this systematic process: 1) the study focused on roundabouts and safety; 2) the research was published between 2000 and 2023 (final search conducted in July 2024); 3) the article was written in English; and 4) it was in the final stage of publication. The exclusion criteria were: 1) topics that did not discuss roundabouts and safety; and 2) articles that were not in the final stage of publication.

Through this process, a total of 119 articles were initially selected—49 from Scopus and 70 from Google Scholar. After reviewing the titles, abstracts, and full texts, 53 articles were included in the final analysis (29 from Scopus and 24 from Google Scholar). The systematic selection process is illustrated in Figure 1.

A critical review was then conducted to evaluate the findings in depth, highlighting gaps in existing research—such as the trade-offs between safety and operational efficiency across different roundabout designs. The synthesis of these findings provided a comprehensive understanding of the topic, emphasizing key challenges including public perception and the integration of roundabouts in high-traffic environments.

2.1 The emerging of roundabout

The concept of roundabouts dates back to the early 20th century, with the first roundabouts constructed during that period. However, even before formal roundabouts were introduced, traffic islands in the middle of roads were already in use (Hrapović, 2022). The evolution of roundabouts has continued since 1902, leading to the development of various types now used globally (Tollazzi, 2015). The construction of modern roundabouts gained momentum in the UK during the 1960s as a strategic solution to the challenges posed by older traffic circles (Park et al., 2015; Tollazzi, 2015).

Since their introduction in the early 1960s, modern roundabouts have progressively replaced traditional traffic circles and channelized intersections, demonstrating significant improvements in vehicle flow and reductions in emissions (Deshmukh, 2017). This evolution reflects a proactive approach to addressing transportation challenges, with innovative roundabout designs offering effective solutions for improving traffic management and environmental sustainability. The continued development and adoption of roundabouts globally underscores their significance in contemporary urban planning and transportation systems.

One of the defining characteristics of a modern roundabout is its distinctive design, which includes traffic deflection at entry points and a circulating speed typically between 25 to 40 km h^{-1} (Tollazzi, 2015). This deliberate speed reduction aims to enhance safety and streamline traffic flow within the circular intersection (Helliwell, 2019). A thorough review of the literature reveals the widespread adoption of modern roundabouts—not only throughout Europe, but also in over 60 countries worldwide, including the United States, Canada, and Australia. This global implementation reflects the universal recognition of roundabouts as effective tools in managing traffic dynamics.

Table 1 presents a summary of empirical studies on roundabouts. The reviewed studies are categorized by year, country, assessment attributes, and key findings. Evidence shows that converting traditional intersections into roundabouts can reduce fatal crashes by up to 65% and injury crashes by 40% (Gross et al., 2013; Elvik, 2017). Geometric features such as wider entry lanes, optimized entry angles, and splitter islands are critical in reducing crash risk and improving traffic flow (Anjana and Anjaneyulu, 2015; Hatami and Aghayan, 2017). For high-traffic volumes, turbo

roundabouts—an advancement of conventional multi-lane roundabouts—are particularly effective, as they minimize conflict points and increase capacity (Giuffrè et al., 2017; Pilko et al., 2018). Roundabouts also enhance traffic efficiency by reducing delays and fuel consumption, especially under moderate traffic conditions (Yang and Magalotti, 2016).

Public perception plays an important role in the successful implementation of roundabouts. Single-lane roundabouts are widely favored for their simplicity and perceived safety benefits (Distefano et al., 2018). A further discussion of these benefits is provided in the following subsections.

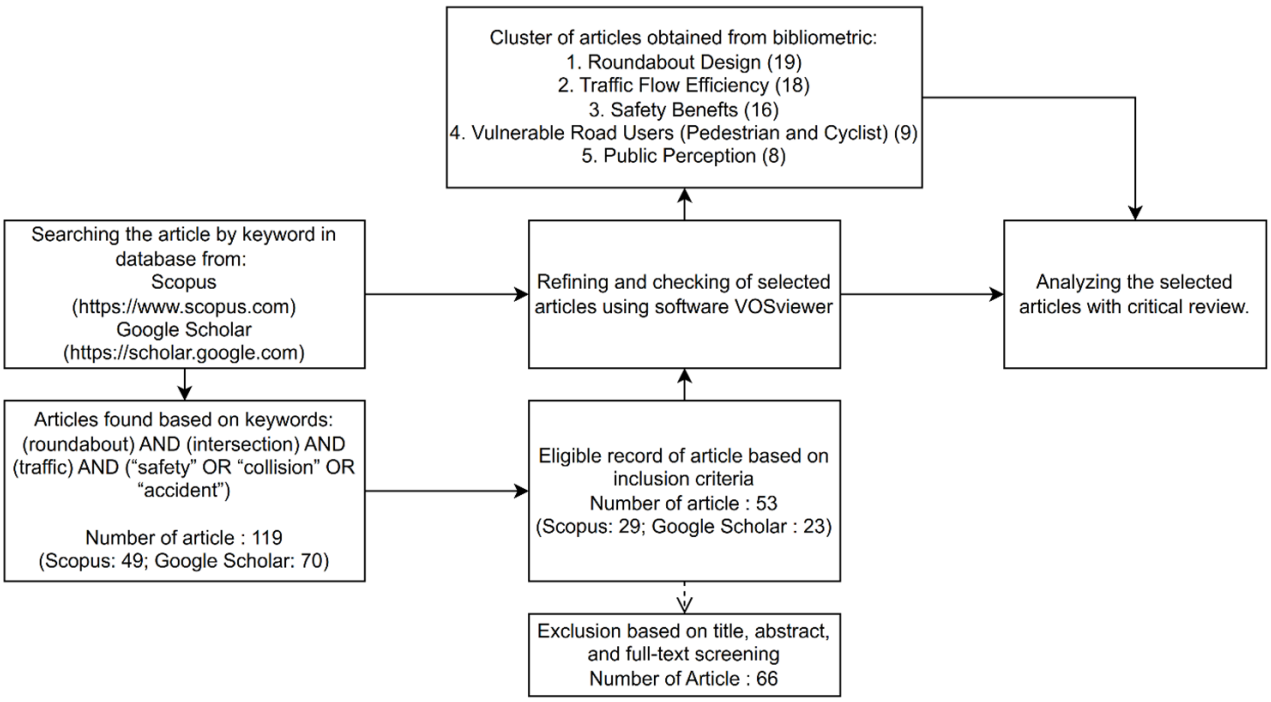


Figure 1 Systematic process of literature review

Table 1. Empirical studies concerning the advantage of roundabout

Year	Author(s)	Country	Attributes	Finding
2013	Gross et al.	United States	Safety	Roundabouts substantially reduce accidents and severity at intersections with traffic signals.
2015	Anjana & Anjaneyulu	India	Safety, Design Features	Improved geometric designs (wider roads, optimized angles) significantly lower crash rates.
2016	Michalaka et al.	United States	Safety, Traffic Management	Roundabouts enhance safety for pedestrians and cyclists by addressing traffic flow conflicts.
2016	Vujanić et al.	Serbia	Safety, Traffic Management	Converting intersections to roundabouts reduces collisions by 76% and injury crashes by 80%.
2016	Yang & Magalotti	United States	Safety, Traffic Management	Roundabouts improve safety, traffic flow, air quality, and fuel efficiency in moderate traffic.
2017	Elvik	—	Safety, Meta-analysis	Roundabouts reduce fatal crashes by 65% and injury crashes by 40%.
2017	Giuffrè et al.	Italy	Safety, Traffic Management, Design Features	Turbo roundabouts improve safety and capacity under high traffic volumes.
2017	Hatami & Aghayan	Iran	Traffic Management, Design Features	Roundabouts outperform signalized intersections by reducing delays under low traffic volumes.
2018	Distefano et al.	Italy	Public Perception	Single-lane roundabouts receive high public approval for their safety and simplicity.
2018	Pilko et al.	Croatia	Safety, Traffic Management, Design Features	Turbo roundabouts reduce conflict points, and increase capacity, especially for right turns.
2018	Zhao et al.	Canada	Safety	Replacing signalized intersections with roundabouts reduces injury and fatal crashes by 20%.

2.2 Benefit of roundabout in managing road safety

As shown in the studies summarized in Table 1, converting intersections into roundabouts has proven to be a highly effective approach in substantially reducing the frequency of injury crashes, particularly those resulting in fatal or severe injuries (Polders et al., 2015). Studies have highlighted that this reduction in crashes is closely linked to specific design features of roundabouts.

Firstly, the curved geometric layout and central island encourage speed reduction, naturally slowing vehicles to speeds of 25–40 km h^{-1}, which significantly decreases the impact forces during collisions (Tollazzi, 2015). Secondly, the reduced number of conflict points—thanks to the circular traffic flow—eliminates the perpendicular and head-on collision risks typically found in conventional intersections.

Research by Vujanic et al. (2016) estimated that converting intersections into roundabouts led to a 76% reduction in all crash types and an 80% reduction in injury crashes. Similarly, Gross et al. (2013) highlighted that roundabouts substantially decrease both the frequency and severity of traffic accidents compared to signalized intersections.

In addition to safety benefits, roundabouts also enhance traffic flow by reducing delays and vehicle queues. Signalized intersections often result in increased overall travel time, longer queues, higher vehicle operating costs, and a lower level of service (Mahmudah et al., 2021). In contrast, the design of roundabouts contributes to smoother traffic movement and improved performance metrics. Research by Demir and Demir (2020) supports this, showing that modern roundabouts can increase capacity by 67.8% while reducing average delays by 72.8%.

As evidenced by Table 2, converting conventional intersections to roundabouts has led to significant reductions in traffic accidents in countries across Europe, America, and Australia. However, this positive outcome has not yet been consistently demonstrated in Asian countries, where existing studies have primarily focused on optimizing intersection level of service, with less emphasis on safety performance.

The analysis of these findings clearly shows that converting conventional intersections into roundabouts offers significant advantages in multiple areas. This transformation not only reduces crashes but also decreases delays, improves fuel efficiency, and lowers air pollutant emissions (Yang and Magalotti, 2016). Furthermore, roundabouts enhance pedestrian crossing visibility and safety (Zhao et al., 2018; Vignali et al., 2020).

Table 2. Crash reduction by converting intersections to roundabouts (Vujanic et al., 2016)

Year	Author	Country	Reduction related to	Overall reduction
1993	Schoon and Van Minnen	Netherlands	n.a.	-47%
1999	ITE	USA	n.a.	-15%
2000	Hyden and Varhelyi	Sweden	all crashes	-46%
2001	Persaud et. al.	USA	all crashes	-39%
			injury crashes	-76%
2003	Elvik	-	injury crashes	from -30% to -50%
2007	Debrabander and Vereeck	-	injury crashes	-39%
2010	Rodegerts et. al.	Australia	all crashes	from -41% to -61%
			injury crashes	from -45% to -87%
		France	injury crashes	from -57% to -78%
		Germany	all crashes	-36%
		Netherlands	all crashes	-47%
		UK	injury crashes	from -25% to -39%
		USA	all crashes	-35%
			injury crashes	-76%
2013	Gross et. al.	USA	all crashes	-21%
			injury crashes	-66%

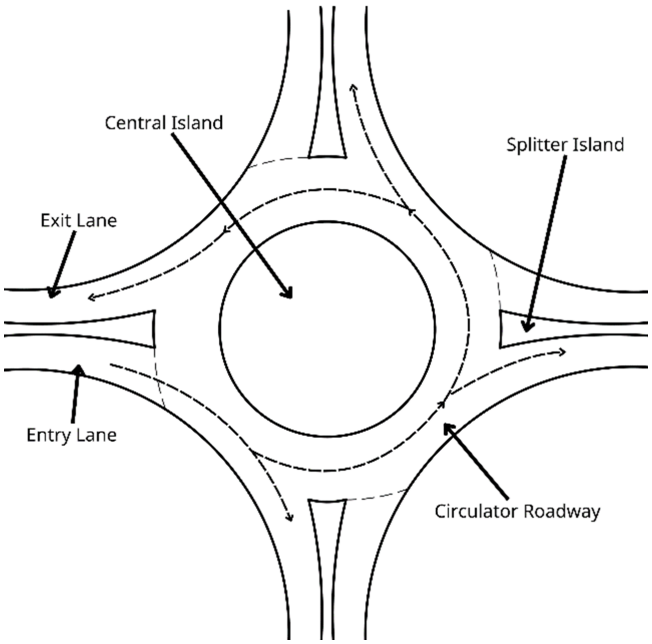
Table 3. Criteria design of roundabout (Board et al., 2010)

Design Element	Mini Roundabout	Single-lane Roundabout	Multi-lane Roundabout
Max entry design speed (km h^{-1})	25-30	30-40	40-50
Max number of entering lanes	1	1	2+
Inscribe Circle Diameter (m)	13-27	27-55	46-91
Central Island Treatment	Fully mountable	Raised (may have mountable apron)	Raised (may have mountable apron)
Typical daily service volume on 4-leg roundabout (vehicles/day)	15000	25000	45000

3 IMPROVE ROAD SAFETY BY CONSIDERING FEATURES IN ROUNDABOUT DESIGN

There are several roundabout designs that have been used and developed including mini roundabouts, single-lane roundabouts, and multi-lane roundabouts. Some existing roundabout types differ in their design elements. Based on U.S. roundabout designs listed in Table 3, the basic roundabout types consist of mini roundabouts, single-lane roundabouts, and multi-lane roundabouts.

Figure 2 shows a typical roundabout that consists of several key features including: 1) the central island which controls vehicle movement and reduces speed; 2) the splitter islands, which separate traffic flows and provide refuge for pedestrians; 3) the circulatory roadway where vehicles navigate the roundabout; and 4) entry and exit lanes, which facilitate the smooth en-



(a) Key features of roundabout

(b) Central island and circulator roadway (source: google earth)

(c) Splitter island, entry and exit lane (source: google earth)

Figure 2 Standard features in roundabout

try and exit of vehicles into and out of the roundabout. These components work together to ensure safety and efficiency.

As shown in Figure 3, mini roundabouts are small roundabouts with a fully mountable central island. A fully mountable central island is provided to accommodate large vehicles. This is one of the distinguishing

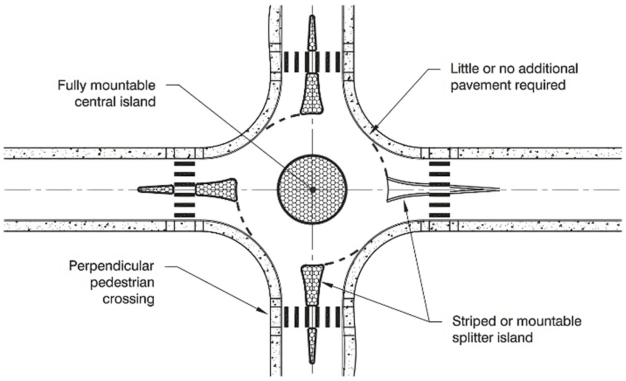


Figure 3 Mini roundabout layout design (Board et al., 2010)

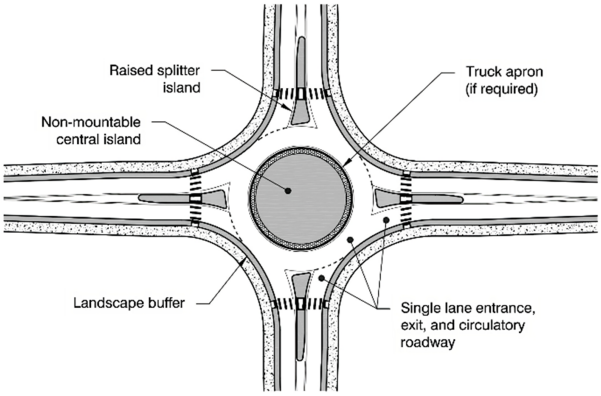


Figure 4 Single-lane roundabout layout design (Board et al., 2010)

features of a mini roundabout (Surdonja et al., 2012; Montella et al., 2013; Board et al., 2010). The features in this roundabout can be useful in low-speed urban environments, particularly in cases where the design of a conventional roundabout is not possible due to right-of-way constraints. Mini roundabouts are much less expensive, requiring only paint or a different pavement material to distinguish the central island, and can usually be installed with relatively minor changes to the intersection geometry (Lochrane et al., 2014; Mak et al., 2021).

Single-lane roundabouts are widely implemented in modern traffic systems because they significantly reduce collision rates compared to conventional intersections. This reduction is attributed to the streamlined geometric design, which minimizes conflict points and promotes safer traffic movements (Gross et al., 2013; Vujanic et al., 2016). Furthermore, safety is enhanced as the lane curvature generally results in lower speeds, reducing collision angles and eliminating intersection conflict points (Pratelli et al., 2018). As shown in Figure 4, the geometric design typically includes raised splitter islands, a non-mountable central island, pedestrian crossings, and a truck apron (Montella et al., 2013). Features that contribute to safety in this roundabout include raised splitter islands that protect vulnerable

road users while crossing, non-mountable central islands with a larger diameter than those in mini roundabouts to alert drivers and reduce speed, and patterns that are easily understood by drivers.

To cope with increased traffic growth, the use of multi-lane roundabouts is preferable, as they provide greater capacity with more than one lane. However, multi-lane roundabouts also raise safety concerns, mainly related to improper driver behavior in the entry zone, circulating maneuvers within the roundabout, and the exit zone—resulting in conflicts and an increased probability of accidents (Giuffrè et al., 2017; Pratelli et al., 2018).

Spiral roundabouts and turbo roundabouts are developments of the multi-lane roundabout layout design. As shown in Figure 5 spiral roundabouts are designed with spiral-shaped road markings on the lanes. The objective is to offer clear instructions and guidance toward the exit area without requiring lane changes, thereby effectively minimizing conflicts among motorists at exits with multiple exit lanes (Amanamba, 2016; Kwakwa and Adams, 2016).

Figure 6 illustrates a turbo roundabout, featuring a shifted center and a spiral geometric configuration. This design facilitates easier lane selection for drivers moving from the entry zone to the exit zone (Gallelli et al., 2016; Pratelli et al., 2018). Research shows that turbo roundabouts can reduce accident frequency by about 70%, similar to single-lane roundabouts, and decrease conflict points from 24 to 14 compared to conventional multi-lane roundabouts (Gallelli et al., 2016; Pilko et al., 2018). This significant reduction is attributed to the guided lane markings and spiral geometric design, which minimize lane-changing conflicts and streamline vehicle movement.

Turbo roundabouts are a significant advancement in multi-lane design, characterized by spiral road markings and distinct circulation lanes. According to Demir and Demir (2020), they offer substantial benefits in both capacity and safety without requiring extra space. Their geometric design minimizes deflection and aligns with vehicle speeds, effectively reducing conflict points and enhancing traffic flow. Overall, turbo roundabouts present a promising solution to improve safety and efficiency at complex road intersections.

The design of the planned roundabout must conform to the geometric conditions on the ground (Pilko et al., 2018). Research by Anjana and Anjaneyulu (2015) in India has shown that the geometric design of roundabouts has a significant impact on the speed at which drivers accept and maneuver around them. It is therefore crucial to establish safety performance standards for urban roundabouts. Table 4 shows a summary of single-lane roundabout design characteristics from the United States, United Kingdom, Australia, Germany, and France. Each country applies different parameter limits, although the guidelines from the United States and the United Kingdom are the most widely adopted.

Figure 5 Spiral roundabout layout design (Source: google earth)

Figure 6 Turbo roundabout layout design (Source: google earth)

Table 4. Single-lane roundabout design characteristic

Parameter	US	UK	Australia	Germany	France
Inscribe Circle Diameter (m)	27-55	28-36	26-54	26-40	30-50
Circulation Rotation width (m)	4.8-6.1	1.0-1.5 × entry width max	4.8 minimum (vehicle tracking)	6.5-9.0	6.0-9.0
Entry width (m)	4.2-5.5	3-4.5	5 minimum (vehicle tracking)	3.5-4	3.75-4
Splitter Island Length (m)	15-30	15-20	8-10 minimum	-	15-25
Max Entry Design Speed (km h^{-1})	30-40	30-40	30-40	30-40	30-40

4 DISCUSSIONS

This discussion section explores existing research gaps related to traffic flow efficiency, safety benefits, pedestrian and cyclist considerations, and public perception and acceptance of roundabouts. Each of these subsections provides a comparative analysis of different types of roundabouts—mini roundabouts, single-lane roundabouts, and multi-lane roundabouts—to highlight the distinct advantages and challenges associated with each design.

4.1 Traffic flow efficiency

In recent decades, roundabouts have gained global recognition as a viable alternative to conventional intersections, with the primary goal of improving operational efficiency and overall safety (Fernandes et al., 2020). One of the main advantages of using roundabouts is their ability to reduce vehicle speeds, thereby improving overall mobility and traffic flow (Yang and Magalotti, 2016; Distefano and Leonardi, 2019; Helliwell, 2019; Ahac et al., 2021). However, according to Board et al. (2010), the capacity of mini-roundabouts and single-lane roundabouts is relatively low (less than 40,000 vehicles per day) compared to multi-lane roundabouts. This limitation stems from geometric differences, including the number of lanes in the circulatory roadway, entry and exit lanes, and the roundabout's radius. Consequently, mini-roundabouts and single-lane roundabouts may be less effective in high-traffic scenarios, potentially leading to increased delays.

Beyond controlling speed, roundabouts significantly enhance driver awareness and attentiveness. According to Rodrigues et al. (2018), roundabouts function as regulators at intersections, requiring drivers to be more alert and to adjust their behavior based on surrounding traffic conditions. As they navigate laterally around the central island, drivers experience controlled deceleration, fostering heightened attentiveness. This increased driver awareness is directly linked to the unique design characteristics of roundabouts (Fernandes et al., 2016).

Furthermore, roundabouts have proven effective in reducing delays compared to conventional intersections (Kwakwa and Adams, 2016). Guerrieri and Sartori (2020) highlight that roundabouts not only decrease travel speeds but also eliminate many complexities and hazards present in signalized intersections. However, to maximize these benefits, roundabout designs must be carefully tailored to enhance driver attentiveness and ensure effective speed control. Such strategic design considerations are crucial for sustaining the advantages of roundabouts in improving both road safety and traffic efficiency (Surdonja et al., 2012).

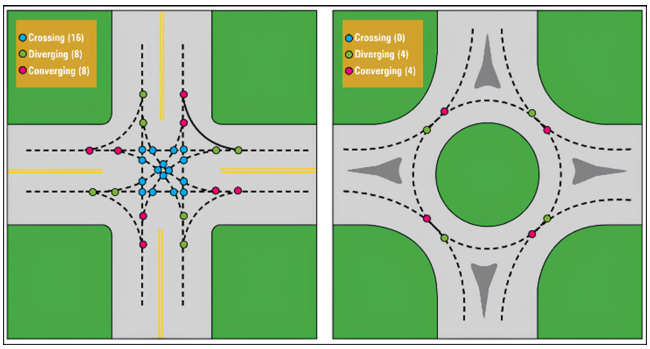


Figure 7 Illustration of conflict points for conventional intersections and roundabouts (Gross et al., 2013)

4.2 Safety Benefit

Numerous studies have consistently demonstrated the effectiveness of roundabouts in reducing the severity of traffic crashes. As highlighted by Issa (2018), roundabouts can decrease both the number and severity of crashes that occur at intersections. Nevertheless, crash frequency may still be influenced by other factors, such as the exact location of the roundabout, time of day, vehicle types involved, and driver behavior.

Roundabouts have shown greater efficacy in reducing injury-related crashes when compared to signalized intersections (Sadeq and Sayed, 2016). For instance, research by Gross et al. (2013) found a stark difference in conflict points between traditional signalized intersections and one-lane roundabouts. A conventional intersection exhibited 32 vehicle conflict points, whereas a single-lane roundabout had only 8, as illustrated in Figure 7. This significant reduction in conflict points underscores the potential of roundabouts to improve road safety.

Additionally, the impact of roundabouts on crash outcomes is substantial. According to Guerrieri and Sartori (2020), the implementation of roundabouts led to an 80% reduction in injury crashes and a 40% reduction in fatal crashes. Elvik (2017) similarly reported that replacing conventional intersections with roundabouts can result in a 65% decrease in fatal crashes and a 40% decrease in injury crashes. These findings are further supported by the data in Table 2, which emphasize the vital role of roundabouts in improving road safety and reducing crash severity.

However, multi-lane roundabouts introduce different safety challenges compared to single-lane roundabouts (Demir and Demir, 2020). One major issue is the difficulty drivers face when merging into multi-lane roundabouts due to higher circulating speeds. A related concern is that drivers often struggle to enter the correct lane, leading to lane changes within the circulatory roadway (Ahmed, 2018). These challenges—particularly overlapping lanes at entry and exit points—com-

bined with higher speeds, reduce the safety benefits typically seen in smaller roundabout types like mini or single-lane roundabouts (Pilko, 2017).

In some cases, roundabouts may not be suitable for locations with very high traffic volumes. Safety performance appears to decline as traffic volumes increase, particularly in terms of crash frequency (Gross et al., 2013; Eva and Andrea, 2017). The safety concerns associated with multi-lane roundabouts illustrate the trade-off between safety and operational performance (Demir and Demir, 2020). While multi-lane roundabouts can improve traffic flow and intersection capacity, the compromises in safety highlight the importance of careful planning and strategic design in their implementation.

4.3 Pedestrian and cyclist considerations

Roundabouts offer advantages to pedestrians and cyclists passing through the intersection. As drivers approach a roundabout, they are required to reduce their speed in anticipation of yielding, which fosters greater awareness of their surroundings. This reduction in speed harmonizes with the typical speed of cyclists, creating a safer environment. Driving at speeds comparable to cyclists not only makes it easier to stop quickly when needed, but also reduces the likelihood of collisions (Apardian and Alam, 2015).

In contrast to signalized intersections, pedestrians at roundabouts face a simpler crossing process. Pedestrians only need to focus on vehicles from one direction when crossing to the splitter island, without needing to consider both sides of the road simultaneously. These strategically placed splitter islands serve multiple purposes—diverting traffic, reducing vehicle speeds, and providing a safer waiting area for pedestrians (Demir and Demir, 2020; Vignali et al., 2020). The incorporation of splitter islands has proven highly effective, contributing to a 64% reduction in pedestrian crashes (Mako, 2015). This highlights the significant role of roundabouts in improving pedestrian safety and creating a more pedestrian-friendly traffic environment.

Roundabouts can be designed to significantly enhance safety for pedestrians and cyclists. Key design features include splitter islands, which allow pedestrians to cross one lane at a time, and raised crosswalks, which increase visibility and compel vehicles to slow down. In addition, roundabouts can include dedicated cycle lanes that are physically separated from motorized traffic. This reduces conflict points and prioritizes cyclist safety. However, to ensure effectiveness, such design features should be supported by clear signage, contrasting road markings, and traffic-calming measures around pedestrian crossings. These enhancements contribute to a safer environment for all road users.

Some studies suggest that the pedestrian-friendly benefits of roundabouts may not apply as effectively to multi-lane roundabouts. Pedestrians and cyclists often face greater challenges when attempting to cross roundabouts with multiple lanes, increasing the complexity and risk involved (Demir and Demir, 2020). Research by Akgün et al. (2018) indicates that the severity of cyclist crashes at roundabouts is primarily influenced by the number of lanes on the approach and the entry path radius. These findings emphasize the importance of careful design and implementation to ensure the safety of all users—especially in the context of multi-lane roundabouts.

4.4 Public perception and acceptance

The adoption of roundabouts as an alternative to conventional intersections often faces mixed public perceptions and varying levels of acceptance. A major challenge is resistance to change, largely stemming from unfamiliarity and discomfort with roundabout traffic patterns. Many drivers—especially those inexperienced with roundabouts—may find them intimidating and raise concerns about safety and efficiency (Debada and Gillet, 2019). Non-signalized roundabouts require drivers to be more situationally aware and adaptive (Rodrigues et al., 2018).

Research on public perception conducted by Adsit et al. (2021) highlights a clear difference in acceptance between single-lane and multi-lane roundabouts. While single-lane roundabouts are more favorably received, multi-lane configurations face greater resistance. In a study conducted in Indiana, 76% of respondents expressed confidence in navigating single-lane roundabouts, whereas confidence dropped to just 60% for multi-lane roundabouts. The findings also indicate that driver experience plays a pivotal role in influencing public approval. For instance, experienced drivers are more comfortable with single-lane roundabouts, while confusion and apprehension persist with multi-lane roundabouts—even one year after implementation. Further research by Hu et al. (2014) shows that older drivers tend to deliberately avoid multi-lane roundabouts due to perceived complexity. This behavioral trend aligns with the findings of Distefano et al. (2018), which confirm a general preference for simpler, single-lane configurations.

Based on the reviewed literature, single-lane roundabouts are the most publicly favored option, as their traffic patterns are easier to understand compared to multi-lane designs. Increasing the number of lanes can complicate the circular traffic pattern and require drivers to change lanes within the roundabout, which may cause confusion and elevate the risk of conflicts.

Using different methods to explore public perceptions,

such as discrete choice models Setiawan et al. (2024); Arifianto et al. (2025), can provide quantitative insights into the factors that shape user preferences. These models can reveal trade-offs that drivers make between safety, efficiency, and complexity, helping planners tailor roundabout designs that align with public expectations.

4.5 Future research challenges

A review of the literature reveals that roundabouts have demonstrated positive safety outcomes in Europe, America, and Australia. However, the effectiveness of roundabouts in improving traffic safety in Asia remains underexplored, largely due to a lack of region-specific studies. Most existing research in Asia focuses on intersection performance metrics rather than safety outcomes. Furthermore, many Asian countries—particularly developing nations—continue to rely on traffic signals over roundabouts. This presents a long-term challenge in shifting public preference and promoting wider acceptance of roundabouts as a safer traffic solutioncontrol measure.

Based on the existing literature, single-lane roundabouts are shown to offer the highest safety levels. Their design naturally reduces speed and limits conflict points at intersections. They are also widely preferred by the public due to their simplicity, which makes it easier for drivers to maneuver through the circulating area. However, where spatial constraints exist, mini roundabouts are a viable alternative, offering compact designs with small inscribed circle diameters and greater accommodation for vulnerable road users such as pedestrians and cyclists.

From a capacity perspective, multi-lane roundabouts are more effective; however, they fall short in terms of safety and public acceptance. Their higher design speeds, additional entry and circulating lanes, and the need for complex lane changes can confuse drivers and elevate accident risks. To address these limitations, specialists have introduced variations of multi-lane roundabouts—most notably the turbo roundabout—which offer improved safety through guided lane markings and simplified vehicle paths.

5 CONCLUSION

Various studies have consistently underscored the safety benefits associated with roundabout implementation. Features such as reduced conflict points, lower vehicle speeds, and decreased crash severity contribute to substantial improvements in overall road safety. The evidence suggests that roundabouts can significantly reduce the likelihood of severe crashes, particularly those resulting in fatalities or serious injuries. Beyond safety, roundabouts have proven to be an efficient alternative to conventional intersections, particularly in optimizing traffic flow. The continuous movement facilitated by roundabouts, combined with reduced idle times, leads to increased intersection capacity, lower congestion levels, and the development of a more sustainable transportation system.

Recognizing the importance of public perception is critical to the successful implementation of roundabouts. Numerous studies highlight both the challenges and opportunities related to public acceptance, emphasizing the need for effective communication strategies and community involvement during the planning and design stages. Over time, as road users become more familiar with the new traffic patterns, acceptance tends to increase, reflecting a broader recognition of the advantages roundabouts offer over conventional intersections. Thus, while public perception and acceptance—particularly in developing countries—present significant challenges, they also offer substantial opportunities to enhance road safety and traffic efficiency through targeted education and engagement initiatives. The findings of this study may serve as a foundation for future research focused on roundabout modeling and its contribution to the ongoing improvement of road traffic safety.

DISCLAIMER

The authors declare no conflict of interest.

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