THE DRIVER PERCEPTION ANALYSIS OF ROUNDABOUT INTERSECTION: A CASE OF BASECAMP INTERSECTION BATAM

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ABSTRACT

Signalized intersections and roundabouts are two types of intersections with different systems. The roundabout at Basecamp intersection, in exchange for signalized intersection in the past, is a new thing in that area. This study aims to determine the opinions of basecamp intersection users who used signalized intersections before switching to the roundabout. The effectiveness of using roundabouts compared to the signalized intersection is measured from users' experience of the basecamp intersection as a benchmark. The user-experience-based questionnaire is the primary method to obtain the user's data which is presented in the form of an average scale of performance for each parameter on the radar graph. In total, roundabout outperforms signalized intersection slightly. However, there are significant gaps in performance on driver distraction-free and traffic flow where roundabouts lead. On the other side, signalized intersections significantly dominated the performance of pedestrians' safety. Meanwhile, there are slight differences in drivers' safety and a respectable gap in drivers' ability where signalized intersections lead.

INTRODUCTION

Traffic lights are an inseparable part of the road. Traffic lights are generally located at an intersection where three or more roads meet from different directions. On the road, many users have different destinations with different vehicles too. Therefore, traffic control is done by traffic lights. Especially at intersections, intersections are controlled by traffic lights to control the vehicle movements on the road from each direction to keep the traffic movement or traffic flow. Hence, there are no traffic jams or even accidents occurring on the road (Komsiyah & Desvania, 2021). However, an intersection does not always use traffic lights, and there is also a roundabout. A roundabout is a type of circular intersection or junction in which road traffic is permitted to flow in one direction around a central island. Priority is typically given to traffic in the junction (Gadher, 2019). A roundabout is typically intended for operating speeds of around 15 mph, although a rotary or traffic circle may be designed for speeds of roughly 25 to 40 mph (Ingale & Tigga, 2022).

Traffic lights in developed countries and cities are no longer Traffic lights as usual. They already have intelligent traffic lights due to technological developments that have more functions than ordinary ones. Intelligent traffic lights are divided into particular functions to reduce traffic congestion and prioritize emergency vehicles or traffic lights that can be adjusted to the presence of pedestrians (Arifin & Zulkifli, 2021). In comparison, the use of roundabouts, which rely on construction rather than technology, such as traffic lights, is called advanced roundabouts in the
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international world. Advanced here is an advance in the construction of the roundabout itself which is more complex than the roundabout in general.

In Indonesia, traffic lights and roundabouts still need to be advanced or intelligent. Indonesia still generally uses traffic lights and roundabouts, which are not yet classified as intelligent and advanced. This is still reasonable because Indonesia is not yet included in the category of developed countries. However, Indonesia also needs help in terms of traffic. The development of traffic lights being innovative and roundabout for being advanced in Indonesia still needs to be realized since Indonesia has experienced slow growth in road network infrastructure for many years. In addition, some cities have demonstrated poor road network maintenance. These conditions produce high-density traffic and higher traffic accidents (Soehodho, 2017).

One of the industrial cities in Indonesia is Batam. Batam is a city that is undergoing development, including roads. The availability of transportation facilities and infrastructure is one of the essential elements in supporting community activities in urban areas (Rifai, Thalib, Prayogo, & Isradi, 2022). From a few years ago until now, Batam has been carrying out road construction, including road widening, adding lanes, and traffic lights at several intersections, and building roundabouts. The use of traffic lights in Batam is still relatively common. However, for the use of road roundabouts, Batam has recently experienced it. The use of roundabouts in Batam has been around for a long time, but it is only a small roundabout at a less busy or crowded intersection. A sizable roundabout was recently built and placed on a traffic-heavy road.

One of the newly built roundabouts is located at an intersection known as the Basecamp intersection. The Basecamp intersection is the meeting point of the main road from the marina, Sekupang, Batu Aji, and Tanjung Uncang. Therefore, the basecamp intersection is an intersection that is dense with vehicles ranging from small vehicles to large vehicles because it is traversed by four main roads originating from densely populated areas and industrial areas, namely Tanjung Uncang. The use of the roundabout at the new intersection will last for one year, starting in 2021. Before that, the Basecamp intersection was using traffic lights. The use of the roundabout goes in tandem with the ongoing construction. Roundabouts have many positive environmental and socio-economic benefits which can be monetized to express the financial value of the positive effect they have on their environment (Krivda & Petru, 2019).

This study presents the effectiveness of using roundabouts compared to traffic lights at the basecamp intersection. The roundabout as a medium for connecting the intersections in Batam is a new thing that has never been used in the area. From the use of traffic lights to the roundabout at the Basecamp intersection, it has a purpose. Are roundabouts much more effective than traffic lights? From how it works, the roundabout looks more effective than the traffic lights because there is no pause in changing roads at intersections. However, if so, roundabouts should have been used long ago. This study aims to determine the opinions of users of the basecamp intersection who have also used traffic lights before switching to the roundabout. The effectiveness of using roundabouts compared to traffic lights is measured from users' experience of the Basecamp intersection as a benchmark.
LITERATURE REVIEW

Roundabout

A roundabout is a basic form of the absence of signalized sign type of intersection. A roundabout eliminates the conflict point at the traditional intersection that's why roundabout is a common intersection in the urban area (Wu, et al., 2022). However, the various patterns of movement will intersect each other, causing conflict points at an intersection (Isradi, Mufhidin, Dermawan, Rifai, & Prasetijo, 2022). There are two established alternative types of roundabouts (turbo and flower roundabout) and two alternative types of roundabouts in the development phase (reduced-turbo and semi-turbo roundabouts) (Tollazzi, Zgrablić, & Bergoč, 2020). The Turbo roundabout is the most advanced to the semi-turbo roundabout, is the least advanced dan the most common.

Basecamp intersection roundabout is a semi-turbo roundabout. As previously explained, using a semi-turbo roundabout at the Basecamp intersection is the slightest advance in the line of roundabout types. Unlike the other roundabout, with more complicated but advanced structures, such as Turbo-roundabout, becomes fundamental to offer a better level of service to users, allowing them to travel in the shortest time possible on the route of the road they have chosen (Severino, Pappalardo, Curto, Trubia, & Olayode, 2021). However, in terms of traffic safety, among all types of roundabouts, users are best perceived as single-lane roundabouts (semi-turbo roundabouts), and spiral roundabouts are the worst (Macioszek & Lach, 2018).

(Yusuf, Abur, Ako, & Bilewu, 2018) Presented a research paper on "A Qualitative Performance Analysis of Rotary Intersections in An Urban Metropolis, Nigeria". The qualitative performance of the Fate roundabout located in the Ilorin metropolis concerning factors such as delays, queues, level of services, accidents, operation cost, and environmental issues is discussed in this paper. They manually collected the traffic data at each of the four arms of the roundabout. As a result, they discovered the heavy vehicle proportion on the roundabout traffic is < 5%. This low percentage of heavy vehicle contribution on the roundabout did not affect the capacity of the roundabout analysis period and had no significant effect on roundabout performance.

(Alshannaq & Imam, 2020) Presented a research paper on "Evaluating The Safety Performance of Roundabouts". They evaluated 12 roundabouts using data collections, geometric and operations analysis, accident mapping, and an accident prediction model. The main target is to evaluate the most influential factor of the accidents and their locations within the road of the roundabouts. They have found that among the causes of accidents, the highest contribution was a violation of traffic rules at 42%. The most likely account for this significant percentage of violation rules may be that the driver needs more ability and skill to pass through the roundabout. Another characteristic of accidents is the area within the roundabout. The most area where accidents happened the most is the center-traffic circulating area of the roundabouts.

Controlled Intersection

Controlled or Signalized intersections are one of the intersection types in which the lights provide the sequence and duration of the flow at the intersection. Generally, signalized intersections are used on roads with high traffic volume (Demir & Demir, 2020). These lights control the road users to get traffic conditions to run correctly. These traffic lights are usually tuned to turn on and off signals at regular intervals.

However, because each road at the intersection has a different volume, using signals with the same timeframe will cause congestion. One solution to the traffic congestion problem is using an automated traffic control system (ATCS). Adaptive traffic light control adjustable to traffic
intensity is an attractive solution (Andronov & Leverents, 2018). As an essential part of the infrastructure in smart city transportation, a traffic signal controller is a primary coordinator for the urban traffic flows (Lee & Chiu, 2020).

Discussing the effectiveness of controlled or signalized intersections, especially in Indonesia, there are still many traffic violations and vehicle accidents. By observing data on road accidents and their factors in the last two decades, it can be hypothesized that young motorcyclists are consistently the most actors with risky behaviors (Joewono, Legi, & Tarigan, 2019). This is a convincing case because the percentage of motorcycles contributed to urban roads reaches 60% to 70% of all motorized vehicles. That said, motorcycles will dominate the road space, potentially triggering traffic chaos, reducing the road capacity, and saturation flows at the area of signalized intersections (Purba, Kustiani, & Pramita, 2019).

A large capacity of road space used by motorcycles at a signalized intersection, an ESS (existence of exclusive stopping space) or red box was built for motorcycles. This red box collects the motorcycle in an exclusive space and discharges it early when the signal is displayed to turn green. There has been a previous paper discussing the effectiveness of this red box (Purba, Kustiani, & Pramita, 2019) presented “A Study on the Influences of Exclusive Stopping Space on Saturation Flow” in Bandar Lampung and (Mulyadi, 2019) presented "Red box motorcycle evaluation at signalized intersection in Denpasar Bali". These findings indicate that Red Box or ESS can decrease traffic conflict and flow.

**User Experience (UX)**

Research on the effectiveness of switching the use of a signalized controlled intersection to the roundabout at the Basecamp intersection uses User Experience (UX) as a comparison reference. Although UX is beneficial for collecting recommendations or suggestions for system improvement, it is essential to evaluate uses satisfaction using the questionnaire method (Gunawan & Indrawan, 2021). Therefore, they can be distributed to larger groups of users, especially if they are designed as online questionnaires. In addition, analyzing the numerical data from such questionnaires is highly standardized and thus efficient as well (Schrepp, Hinderks, & Thomaschewski, 2017).

UX-based research is very suitable for comparing the effectiveness of switching the use of a signalized intersection to the roundabout at the Basecamp intersection. Respondents will be cautious that the statements will be collected, archived, and saved for future research (Eckerdal & Hagström, 2017). This transition is a permanent change in the basecamp intersection's crossing system, which can only be experienced based on the past and present. Therefore, user experience is very suitable because the respondent has just recently experienced a transition to the intersection system change at the basecamp intersection.

The basecamp intersection is an intersection of four roads originating from densely populated and industrial areas. Therefore, the user experience is very suitable because there are many users. In obtaining user experience data, questionnaires are the most commonly used method. Standardized questionnaires are reliable and valid for measuring the user experience. They are also economical for researchers and self-applied so that the respondents can use them efficiently (Díaz-Oreiro, López, Quesada, & Guerrero, 2019).

Not only are questionnaires easy to use, but they are also easy to make since they do not require long preparation and require specialized skills or scientific instruments (Grassini & Laumann, 2020). Moreover, they are more likely to be conducted online because so many options can be applied, such as e-mail, social media, URL, and website advertised. They are relatively fast and inexpensive to collect the indicators and road users' experience if they are conducted online.
In summary, multiple versions of a questionnaire can easily be customized to customer criteria such as demographics, language, purchase experience, etc. (Latkovikj & Popovska, 2019).

METHOD

Data is one of the main strengths in compiling research and scientific modeling (Rifai A. I., Hadiwardoyo, Correia, & Cortez, 2015). The systematic scientific research process must begin with identifying the right problem (Rifai A. I., Hadiwardoyo, Correia, & Pereira, 2016). The Data for this comparative analysis will be based on the User Experience method. In other words, the data will be collected from users of the basecamp intersection who has been experienced both the signalized intersection and roundabout at the Basecamp intersection.

These users' experiences will be collected by using an online questionnaire from Google Forms. The data will be taken from respondents who have only been through the Basecamp intersection when it was a signalized intersection and as a roundabout in the current time. This
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questionnaire which contains parameters as a comparison material is being distributed online and recorded during November 2022 with a target of 100 informants.

Parameters

The research data based on user experience were collected using a questionnaire through a google form. This questionnaire uses parameters to compare the performance of the basecamp intersection, which was a signalized intersection and a roundabout at the moment. These parameters are as follows:

1. Driver distraction-free (Khashayarfar & Nassiri, 2021). Signalized intersection is where a driver would have to stop for a moment for another turn to cross the intersection. Within that duration of stopping, a driver could have done something to wait for during that duration. That moment of signalized intersection could distract the driver from losing focus on driving. This could be using a smartphone or a busker approaching the driver. Meanwhile, in the roundabout, there is no stop to cross the intersection. Therefore, this parameter is to prove that roundabouts make an impact on making a driver distraction-free better than a signalized intersection.

2. Pedestrians’ safety (Marisamynathan & Vedagiri, 2020). Since the roundabout is a non-stop crossing intersection, this could be trouble for pedestrians to cross near the intersection, in this case, pedestrians' safety. Therefore, this parameter is to prove that roundabouts and signalized intersections have a difference in pedestrian safety experienced by users.

3. Drivers’ safety (Elzaher & de Albuquerque, 2021). The roundabout is a non-stop intersection, meaning a driver should cross paths with other drivers with different intersection branch destinations. This parameter has the purpose of proving whether there is any difference in drivers' safety on both signalized intersections and roundabouts since they both have different crossing systems.

4. Drivers’ ability (Han, 2022). Due to the non-stop and cross-lane system with other riders who have different intersection branch destinations on the roundabout, the driver should have a different way of crossing between the signalized intersection and roundabout. Drivers' ability discussed which type of intersection has the better impact on the driver's ability to cross the road of that intersection.

5. Traffic flow (Estévez-Mauriz & Forssén, 2018). Since the different systems of signalized intersections and roundabouts have from the previous explanation, especially the stopping and non-stopping systems, this has a different traffic flow outcome. Therefore, the traffic flow parameter discussed the difference in effectiveness in traffic flow on both intersections.

RESULT AND DISCUSSION

This research aims to analyze the effectiveness comparison of the roundabout and signalized intersection on the Basecamp intersection. This comparison analysis used the data taken from the user of the intersection itself, signalized intersections in the past, and roundabouts in the current time. The total number of users that contributed to the Data is 100 respondents.
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Characteristics of Research Respondents

The male respondents have more significant participation than the female respondents. However, the difference is insignificant with six different in quantity. From the data, it can be concluded that the basecamp intersection users are not highly dominated by one gender. Therefore, the data collected is balanced regarding the gender impact of opinion.

Meanwhile, the variant of the respondents in terms of age, as shown in Figure 3 above, varies between 18 – 50 years old. With the 18 – 20 and 21 – 30 classes of age being the massive participant of the data, the productive respondents play a massive role in the collected data. Therefore, it can be stated that the productive age of people is the primary user of the basecamp intersection. However, the Data also collected users' experiences from another older class of age, with the 31 – 40 class collecting four respondents and six respondents for the 41 – 50 class of age. From these statements, it can be stated that the researchers collected the Data not only from one main range of age, which is productive age, but also another more comprehensive range of age (elder age).

![Figure 3. Characteristics of Respondents](image)

This research also collected data on the vehicle being used by respondents at the Basecamp intersection. This is to prove that the Data is not only responded to by respondents who only use one type of vehicle. Figure 4 above shows the data filled in by respondents using bicycles, motorcycles, and cars. Also, many individual respondents have experience crossing the Basecamp intersection with multi-vehicles.

Research Results of Questionnaire-based User Experience by Respondents

One hundred respondents' data has been collected from the google form questionnaire of the performance analysis of the effectiveness of using signalized intersection and roundabout at basecamp intersection with five parameters. The following results from the collected data are presented in the form of the number of data distributions for each intersection, Signalized Intersection, and roundabout. A scale of 1 – 5 represents the quality performance from low to high, with one as very Bad to 5 as very good. This data distribution can be seen in the following table below.

![Table 1. Result of The Questionnaire Survey](image)
Data collected and distributed in the table above have gaps between performance on both intersection types. These gaps stated the difference between each parameter and the total parameters. In the comparison result, the visual comparison result of signalized intersection and roundabout performance differences are presented using the spider web method. The Data is presented in the radar chart below.

![Radar Chart of Respondent Statements](image)

**Figure 4. Radar Chart of Respondent Statements**

From Table 1, the total gaps of both signalized intersection and roundabout are relatively insignificant. With the value of total gaps 0.81, it can be stated in the final judgment from 5 parameters that there is a slight difference in the effectiveness of both intersection types, with roundabout outperforming signalized intersection. However, there are significant and insignificant value differences in each parameter comparison. Roundabouts outperform signalized intersections significantly on driver distraction-free and traffic flow. Meanwhile, signalized only outperform roundabout significantly in pedestrians' safety parameter. Signalized intersection has better performance slightly on drivers' safety and respectably better on drivers' ability.
Pedestrians' safety is the first parameter that can be visualized with the most significant gaps. With a value of 2.82 gaps, the signalized intersection has better performance of the safeness of pedestrians in the area of the intersection. This is because the stopping system that signalized intersections has given pedestrians more safety and confidence when crossing the road in the area of the intersection. Also, with the help of traffic lights can be seen, so pedestrians know when and when it is not to cross the road.

The second parameter that has a significant performance difference value is traffic. It is well known that the non-stopping systems give the benefit of a roundabout in terms of traffic flow. With gaps of 2.7 and a performance value of 4.35, roundabouts perform traffic flow way better than a signalized intersection. For example, the basecamp intersection is a busy intersection where four main roads from 4 populous areas; with the presence of a roundabout, the Basecamp intersection now performs traffic flow significantly better to users.

Roundabout also performs better in driver distraction-free environments for users. With 2.2 ahead of the roundabout's value, many users experience a distraction-free trip while crossing its road. There is no stopping phase on the roundabout giving the users or drivers no time to distract. Since the basecamp intersection is a sizeable roundabout, users need to maintain focus since, in the roundabout area, drivers meet other drivers with both the same and different destinations of the branch of the intersection.

With slight gaps in drivers' safety and quite significant on drivers' ability, 0.36 and 0.91, signalized intersection leads the performance for both types of intersections on these parameters. The presence of more traffic lights on signalized intersections to guide the driver one by one per branch to enter the intersection gives the users more safety on the trip and less ability skill to cross.

CONCLUSION
The conclusion based on the research is that in a total distribution of all five parameters, there are no significant gaps in performance, with roundabout performing better at 0.81 value. Regarding each parameter, roundabout outperforms signalized intersection on driver distraction-free and traffic flow. However, the cost of better traffic flow with non-stop trip from each branch of the roundabout has made the pedestrians' safety, drivers' safety, and drivers' ability performance fall. Signalized intersection has a better system for pedestrians' safety, drivers' safety, and drivers' ability. This can be concluded that, at the current time, basecamp intersection gives the users benefit of traffic flow and a driver distraction-free environment. However, intersection users must increase their alertness and driving skills to cross the roundabout.

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