Roundabout performance analysis in the city of Medan

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Abstract. Medan city as one of the largest cities in Indonesia, currently has problems in the field of transport is quite worrying. Like the other cities in Indonesia, the growth of traffic volume can not be followed by improvement of existing infrastructure. It is characterized by frequent traffic jams, long queues and delays contained in the segment or intersection. One type of arrangement is a roundabout intersection. Roundabout intersection canalization is composed of a central circle surrounded by a one-way street. Roundabout can act as a controller, divider and guidance for the traffic system which rotates in the direction. This study aims to determine the performance of the roundabout on the road Ir. Haji Juanda, Medan. Analyses were performed to obtain the performance of these intersections. Analyses were performed by using a calculation method MKJI 1997 and the Australian Road Research Board (ARRB) manually. The performance measures analyzed in the form of the degree of saturation, delay and queue opportunities using the method MKJI 1997. whereas the ARRB method, the calculated performance of the roundabout is the degree of saturation and delay. Good infrastructure handling can create a reduction of delay, and congestion, so that it can reduce pollution and support a more green environment.

1. Introduction
Intersection as part of a road network is a critical area in serving the flow of traffic. Therefore improvement of the intersection will reduce the barriers and will increase capacity and is expected to be able to reduce the occurrence of accidents. One type of intersection setting is with roundabout.

Intersection with roundabouts have a very important role in ensuring the smooth flow of traffic. In addition to being a meeting point between different roads, the roundabout part can act as a controller, a divider and a driver for a one-way rotating traffic system. Capacity and measure of performance in the degree of saturation, delay and queue opportunities for the roundabout part of the roundabout can be calculated which represents a geometric condition, environment and traffic flow. The traffic flow data required for calculation is the traffic flow data for each movement. The required traffic movement data is the volume and direction of the traffic movement during peak hours. The obstacle in this calculation is the fundamental difference between the MKJI 1997 method and the ARRB in terms of the roundabout performance assessment. In the ARRB not counted motorcycles in its performance assessment while in Indonesia traffic conversion in motorcycle dominance.

The purpose of writing this paper is to compare the performance measures of both methods and provide solutions to improve roundabout performance.
1.1. Basic theory
Roundabout is one type of intersection control commonly used in urban and out-of-town areas as a meeting point between several road segments with medium traffic levels because it has a relatively lower level of traffic accidents than the type of signaled intersection or non-signaled intersections. The roundabout can be considered a special case of canalization that the island in its center can act as a controller, divider and guide for a one-way rotating traffic system. Continuous movement and a large turn on the entire leg of the road meeting will reduce the source of the accident and provide more comfort to the driver's condition (Hobbs, 1995).

For larger intersections, closure of the braided area is easy and the safety of the roundabout decreases. Although the impact of the roundabout traffic in the form of delay is always better than other types of intersections such as a signal intersection, signal installation is still preferred to ensure a certain capacity can be maintained even in peak hour currents. The roundabout is preferred because it can reduce the delay and allow many vehicles to cut the intersection without having to stop completely (MKJI, 1997).

1.2. Roundabout Concept
The roundabout is a canalization junction consisting of a central circle surrounded by a one-way street. The roundabout is a special form of canalization intersection where the incoming vehicle rotates clockwise around the central traffic island. The intersection entrance is governed by the Give Way marker and priority is given to the vehicle circulating at the roundabout.

Channelization is the process of separating or regulating conflicting vehicle flows into clear road routes by placing paved concrete or pavement rails to create a safe and orderly movement for vehicles and pedestrians. Proper canalization can increase capacity, improve security, provide full comfort, and also boost driver confidence. Channelization is often used in conjunction with stop signs or speed control signs or at traffic light intersections.

The principle of the roundabout is to create a continuous stream of traffic without stopping and the purpose of the roundabout plan is to ensure the safety of traffic between intersecting traffic and minimum delay. The efficient operation of the roundabout depends on the gap acceptable to the driver in the circulating traffic flow. Because traffic flows together and separates at small angles at relatively low speeds, traffic accidents in roundabouts rarely have fatal consequences.

2. Methodology
2.1. Research location
The research location is in Medan city where the roundabout to be studied is Ir. H Juanda roundabout which is a road intersection between Jl. Ir. H Juanda direction to Polonia, Jl. Samanhudi, and Jl. Ir. H Juanda direction to Taman Makam Pahlawan. Locations can be seen on the map below:

![Research Location Map](image_url)

Figure 1. Research Location
2.2. Research Analysis
There are two analysis that carry out on this research, to obtain the performance of roundabout; MKJI 1977 and ARRB. The performance measures analyzed in the form of the degree of saturation, delay and queue opportunities using the method MKJI 1997. whereas the ARRB method, the calculated performance of the roundabout is the degree of saturation and delay.

3. Data Acquisition Analysis and Discussion

3.1. MKJI 1997 data
The data obtained from the field is the volume during peak hour morning, afternoon and evening for each approach of the intersection. The volume data can be seen in Table 1 below.

Table 1. Volume at all approach, on Ir. H. Juanda roundabout

| Time         | Jln Samanhudi | Jln Ir H Juanda | Jln Ir H Juanda | Total Volume (pcu/hour) |
|--------------|---------------|-----------------|-----------------|-------------------------|
| 07.00 - 08.00| 878           | 2955            | 1838            | 5671                    |
| 07.15 - 08.15| 951           | 2955            | 1777            | 5683                    |
| 07.30 - 08.30| 997           | 2869            | 1609            | 5474                    |
| 07.45 - 08.45| 926           | 2653            | 1462            | 5041                    |
| 08.00 - 09.00| 823           | 2427            | 2450            | 5699                    |
| 11.30 - 12.30| 1329          | 1736            | 1844            | 4909                    |
| 11.45 - 12.45| 1438          | 1672            | 1885            | 4995                    |
| 12.00 - 13.00| 1494          | 1778            | 1908            | 5181                    |
| 12.15 - 13.15| 1438          | 1926            | 1894            | 5257                    |
| 12.30 - 13.30| 1302          | 1975            | 1670            | 4947                    |
| 16.30 - 17.30| 1168          | 1975            | 1985            | 5127                    |
| 16.45 - 17.45| 1197          | 2079            | 2033            | 5309                    |
| 17.00 - 18.00| 1200          | 2189            | 2108            | 5497                    |
| 17.15 - 18.15| 1139          | 2182            | 2299            | 5620                    |
| 17.30 - 18.30| 1024          | 2196            | 2512            | 5732                    |

Note: Peak Hour on 17.30 to 18.30

3.2. ARRB data
In contrast to the way MKJI is calculated, ARRB takes into account the cycles of each of the existing cross-linking arms. The volume of each approach for each cycle calculated can be seen in Table 2 and Figure 2 below.
Table 2. Ir Hanida's traffic jam traffic volume at 1 hour interval for each approach

| Time        | Jln Samanahudi (A) | Jln Ir H Juanda (B) | Jln Ir H Juanda (C) | Total volume each cycle (veh/hour) |
|-------------|--------------------|---------------------|---------------------|-----------------------------------|
| 07.00 – 08.00 | 194                | 1090                | 968                 | 2252                              |
| 07.15 – 08.15 | 220                | 1092                | 969                 | 2281                              |
| 07.30 – 08.30 | 258                | 1100                | 924                 | 2282                              |
| 07.45 – 08.45 | 244                | 1049                | 877                 | 2170                              |
| 08.00 – 09.00 | 220                | 947                 | 828                 | 1995                              |
| 11.30 – 12.30 | 406                | 936                 | 1107                | 2449                              |
| 11.45 – 12.45 | 444                | 896                 | 1123                | 2463                              |
| 12.00 – 13.00 | 484                | 952                 | 1140                | 2576                              |
| 12.15 – 13.15 | 491                | 989                 | 1143                | 2623                              |
| 12.30 – 13.30 | 446                | 1019                | 1007                | 2472                              |
| 16.30 – 17.30 | 308                | 1048                | 1155                | 2511                              |
| 16.45 – 17.45 | 333                | 1075                | 1147                | 2555                              |
| 17.00 – 18.00 | 355                | 1104                | 1153                | 2612                              |
| 17.15 – 18.15 | 333                | 1081                | 1205                | 2619                              |
| 17.30 – 18.30 | 292                | 1029                | 1277                | 2598                              |

Note: peak hour on 12.15 – 13-15 cycle

In addition to volume, the ARRB also requires other parameters calculated, Intra Bunch Headway, Headway Follow Up and Mean Critical Gap, as shown in Figure 2.3 and 4 below.

Figure 2. intra bunch headway value fluctuation
4. Analysis and Discussion

4.1. Analysis by MKJI method 1997

For analysis with the MKJI 1997 method, the RWEAV-II form is used, to obtain roundabout capacity and traffic characteristics such as degree of saturation, traffic delays and queuing opportunities, as shown in Table 3.

Figure 3. follow – up headway value fluctuation

Figure 4. mean critical gap value fluctuation
Table 3. RWEAV – II for MKJI 1997 analysis

| RWEAV-II Form Roundabout analysis | Date : 25 November 2016 | City Size (mil) : 2.1 |
|-----------------------------------|------------------------|----------------------|
| City : Medan                      | Road enviroment : Komersial |
| Road A : Jln Samanhudi            | Side Friction : Rendah |
| Road B : Jln Ir H Juanda          | Period : 17.30 – 18.30 |
| Road C : Jln Ir H Juanda          |                        |

1. Geometric Parameters, weaving area

| Weaving | Entry Width | Avrg Entry Width | Weaving Width | Length of Weaving | W_W/L_W |
|---------|-------------|------------------|---------------|------------------|---------|
|         | Aprr.       | Aprr.            | W_E           | W_W              | L_W     |
|---------|-------------|------------------|---------------|------------------|---------|
| 1       | 8           | 2 (m)            | 10.5          | 12               | 0.875   | 30      | 0.40   |
| 2       | 10          | 10               | 10            | 12               | 0.833   | 30      | 0.40   |
| 3       | 13          | 10               | 11.5          | 16               | 0.719   | 22      | 0.73   |

2. Roundabout Capacity

| Weaving area | Factor | Factor | Factor | Base Capacity | Faktor penyesuaian | Capacity |
|--------------|--------|--------|--------|---------------|---------------------|----------|
|              | W_W   | W_E/W_W| P_W   | W_W/L_W       | City               | Road     | C       |
|              | (Co)   | (FCS)  | (FRSU) | (pcu/hour)    | Size (pcu/hour)    |
| 1            | 3414.046 | 2.567 | 0.848 | 0.546 | 4074 | 1 | 0.95 | 3854 |
| 2            | 3414.046 | 2.482 | 0.816 | 0.546 | 3776 | 1 | 0.95 | 3587 |
| 3            | 4563.020 | 2.253 | 0.835 | 0.374 | 3493 | 1 | 0.95 | 3318 |

3. Traffic Behaviour

| Weaving area | Flow on Weaving | Degree of Saturation | Traffic Delay | Total Delay | Q PRob. |
|--------------|-----------------|----------------------|---------------|-------------|---------|
|              | Q (pcu/hour)    | DS (sec/pcu)         | DT (sec/hour) | DT tot = QxDT | QP%     |
| 1            | A-B             | 3341                 | 0.867         | 7.20        | 24      | 53      |
| 2            | B-C             | 2705                 | 0.754         | 4.80        | 12984   | 15      | 36      |
| 3            | C-A             | 3310                 | 0.994         | 14.90       | 49319   | 38      | 78      |

Avg. Traffic Delay DTr (sec/pcu) 14.543

| Average Roundabout Delay Dtr (DTr+4) (sec/pcu) | 18.543 |
| Prob. Roundabout Delay QP% | 38 | 78 |
From the table above it can be concluded that the degree of saturation for each current of the intersection of the arm has approached the saturation point. The most critical link is the C-A braid, where the value of degree of saturation has reached 99.4%, as well as the queue probability reaching 78%, which means during peak hours, there will almost certainly be queues at the roundabout.

4.2. Analysis by ARRB method

**Figure 5.** Calculation of Traffic Volume on the movement of vehicle inflows at the roundabout for the three approaches includes U rotation for qc and qe (peak hour at 12.15-13.15).

**Table 4.** Capacity Analysis

| Pendekat          | qc (kend/jam) | qe (kend/dtk) | β (dtk) | α (dtk) | Δc (dtk) | φ (kend/dtk) | λ (kend/jam) | Qe (kend/jam) |
|-------------------|---------------|---------------|---------|---------|----------|--------------|--------------|---------------|
| Jln Samanhudi (A) | 1045          | 0.29028       | 1.83    | 4.96    | 1.98     | 0.3196       | 0.2177       | 531           |
| Jln Ir H Juanda (B) | 116           | 0.03167       | 1.88    | 4.75    | 1.88     | 0.7053       | 0.0232       | 1731          |
| Jln Ir H Juanda (C) | 437           | 0.12139       | 1.98    | 8.18    | 1.85     | 0.5802       | 0.0908       | 867           |

**Table 5.** Degree of Saturation Analysis

| Pendekat          | qc (kend/jam) | Qe (kend/jam) | qe (kend/jam) | Derajat kejenuhan (x) |
|-------------------|---------------|---------------|---------------|-----------------------|
| Jln Samanhudi (A) | 1045          | 531           | 491           | 0.9249                |
| Jln Ir H Juanda (B) | 116           | 1731          | 989           | 0.5713                |
| Jln Ir H Juanda (C) | 437           | 867           | 1143          | 1.3183                |
Table 6. Delay Analysis

| App.                     | qe (kend/jam) | Qe (kend/jam) | x   | Z   | T (jam) | dm (dtk) | k (kend/dtk) | d (dtk) |
|--------------------------|---------------|---------------|-----|-----|---------|----------|--------------|---------|
| Jln Samanhudi (A)        | 491           | 531           | 0.9249 | -0.0751 | 0.25 | 6.8 | 1.003 | 45.7    |
| Jln Ir H Juanda (B)      | 989           | 1731          | 0.5714 | -0.4286 | 0.25 | 48.1 | 23.1 | 99      |
| Jln Ir H Juanda (C)      | 1143          | 867           | 1.3183 | 0.4159 | 0.25 | 11.38 | 2.73 | 191.9   |

From Table 6 above it can be seen that the largest volume comes from the C approach, but the capacity C has is the smallest capacity of the three approaches. As a result of the degree of congestion, the delay value of the C approach is the greatest value of the three approaches. The delay value of the C approach is 2 times the value of B approach and more than 4 times from A.

5. Resume

In the calculation using the ARRB method, the characteristics and performance values of each approach can be known, whereas with the method of MKJI the characteristic and performance of the roundabout becomes the final result of its evaluation. An improvement is needed at the intersection so that there is an increase in capacity, crossing, reducing the degree of saturation and the amount of delay and the probability of queuing. The most important improvement is the C approach, because in addition to having a small braid length, it also has the largest volume of the three arms.

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