The effect of median opening on traffic characteristics on the arterial street

L E Radjawane

1Department of Civil Engineering, Hasanuddin University, Makassar, Indonesia

E-mail: eliz_louise@yahoo.com

Abstract. Pettarani street is equipped with a median opening as a facility for vehicles to reverse the direction of travel. The median opening width in the Pettarani section varies between 20 m - 37 m. The widest median opening width in Badan Pertanahan / LPMP segment, while the narrowest median opening width is The Mutiara segment. The largest traffic volume that merged in the median openings of Pettarani street for morning peak hour 1816 pc/h in HM. Asyik Mosque and Telkom segments (Pettarani S-S). For afternoon peak hour with a value of 1802 pc/h. The median opening segment HM. Asyik Mosque has the highest density value, which is 17 pc/km/ln in the morning and 16 pc/km/ln in the afternoon. The highest density value for diverging movement is 32 pc/km/ln occurs at HM Asyik Mosque median opening segment. The wider the median opening results in increased density, this is due to increased space for the vehicle to do a reverse rotation maneuver, thus increasing movement disturbances for opposite flow and flow behind the vehicles that will do reverse rotation. The greater the volume in the main section the more it affects the movement of vehicles that are in the median opening to do merging and diverging, thereby increasing density.

1. Introduction

Pettarani street with a segment length of 4.37 m, 8/2 D road type equipped with 10 median openings (three of which are reverse turns found at signaled intersections) as facilities for vehicles that will make a reverse turn. The traffic volume in the median openings is quite large if it is not accompanied by a wide median opening and a rotating radius that can not accommodate the movement of the vehicle plan will cause the movement of the surrounding vehicles to be disrupted. The activity of vehicles at the median openings (minor flow) not only causes delays and queues in the minor flow themselves but also in the major flow, especially in the edge (median) major flow for merging and diverging movements. The purpose of this study is to analyze the effect of median opening on traffic characteristics on the arterial street.

The minimum width for the median with openings is distinguished based on the function of the road. The median minimum width of the arterial road is 5 m and the collector is local or 4 m. In urban roads with distance arterial road functions, which are 2.5 m (suburbs) and 0.5 m (urban) and wide openings 4 m. Urban roads with the function of the collector path of a minimum distance between openings of 1.0 m in the suburbs and 0.3 m in the urban area and the width of openings are 4 m. As for the city roads arterial function, the median opening distance is 5 m and the opening width is 7 m. Inter urban roads with collector function the minimum distance between the median openings is 3 m and the width of the openings is 4 m. The previous study described the minimum width for the median with minimum
openings and distances between openings. The more details related to the study are shown in Tables 1, Table 2, and Figure 1 below.

**Table 1.** Minimum width for medians with openings (Elevated / Decreased Type).

| Road Function | Minimum Width (m) | Median | Road Shoulder | Edge Line |
|---------------|-------------------|--------|---------------|-----------|
| Arterial      | ≥ 5               | 0,50   | 0,25          |           |
| Collector/local | ≥ 4           | 0,50   | 0,25          |           |

The stabilizing material zeolite has a crystalline mineral of SiO2 alumina silicate between 64.57% and 81.83% [2]. Sangkaropi Zeolite Potential in North Toraja Regency, in South Sulawesi Province, has resources of approximately 168,480,000 tons over an area of 360,000 m². Zeolite is a hydrated porous crystalline alumina mineral silicate that has a three-dimensional skeletal structure formed from a tetrahedron [SiO4]4- and [AlO4]5- [3]. These tetrahedra are connected by oxygen atoms, producing an open and hollow three-dimensional structure inside which are filled with metal atoms. Usually alkaline or alkaline-earth metals and water molecules can move freely [4]. Zeolite is particularly used in the paper industry, food drying, oxygen purification, depollution (radioactive waste, household waste, SO2 gas capture, feed additives, deodorants), release ammonia nitrogen from plants, the release of metal ions into the water, fishing and ponds, agriculture and other industries [5].

Waterglass or sodium silicate is a water-soluble salt with a sodium metasilicate composition (Na2–SiO3 or NaSiO3H2O). In solid form, it looks like a crystal, dissolves in hot water and melts at a temperature of 1018°C. Waterglass with its form of liquid so that the soil pore can be filled by binding it to become stronger. Even at room temperature, the form is in the form of a gel, but with the addition of appropriate water, the movement to penetrate the pores of the soil becomes easier [6].

**Table 2.** The minimum distance between openings median

| Road Function | Suburb | Urban |
|---------------|--------|-------|
|               | Opening Distance (d1, m) | Opening Width (d2, m) | Opening Distance (d1, m) | Opening Width (d2, m) |
| Arterial      | 5      | 7     | 2,5   | 0,5   | 4     |
| Collector     | 3      | 4     | 1,0   | 0,3   | 4     |

**Figure 1.** The median openings distance.

1.1. Movement of the Vehicle on the Median Openings

Reversing events that affect the condition of traffic flow, namely: a rear vehicle that is blocked in front of it, then the vehicle turning must wait for the gap between the opposite direction flow. The movement of the vehicle rotates back and forth in the median openings can be seen in figure 2.
Figure 2. Vehicle moves turning direction.

The first stage, the vehicle that moves backwards will reduce the speed and will be on the far right. The slowdown in traffic flow that occurs according to the car following theory results in a queue characterized by queue length, time delay, and shock wave; The second stage, when the vehicle rotates towards the opposite lane, is influenced by the type of vehicle (maneuverability and turning radius). Vehicle maneuvering affects the median width and disturbance in both directions (in the direction and opposite direction). The width of the lane affects the reduction of road capacity for both directions. If the number of rotating vehicles is large enough, container lanes need to be provided to reduce the impact on vehicle activity behind it; the third stage, is the reverse movement of the direction, so that it needs to be considered the condition of the opposite direction of the traffic flow. Interaction occurs between the vehicle behind the direction and the vehicle moves straight in the opposite direction, and the union with the direction of the opponent to enter the same path. In this condition, the most important thing is the determination of the driver so that the movement unites with the main stream is available. This means that the driver must be able to consider the gap between two vehicles in the main direction so that the vehicle can be safely integrated with the mainstream, and the phenomenon of merging, diverging and weaving.

The gap acceptance capacity of u-turn junction at midblock opening on urban arterial based on balancing volume to Capacity Ratio is overestimated the field capacity in case of negative exponential headway distribution and underestimated in the field capacity in case of Erlang 2 headway distribution [7].

Simulation for fly over design with U-turn showed the saturation degree 0.7333, delay study 3,43905, delay vissim 3,133479, and the travel time is 526.20. The travel time would lower with an increasingly the width of median opening. Simulation showed that travel time and delay slight differences when the width of median opening large than existing U-turn.

In the process of merging on the reverse rotation in the median openings of vehicles in the mainstream must be careful of vehicles that will rotate back in the median openings because vehicles that will merge require gap acceptance to join the main stream and when diverging at the median openings where the vehicle must reduce the speed to enter the u-turn lane. The phenomenon of merging and diverging in the more clear median openings is shown in figure 3.

Figure 3. Merging and diverging phenomena on the median openings.

INAFOGA and Modified Raff’s method are used to estimate the critical gap of u-turning behaviour of vehicles at mid block median opening in six lane urban road. By INAFOGA method, values of critical gap are about 5.93% higher than traditional method and about 16.38% higher than Modified Raff’s
method. Size of vehicle and manoeuvrability characteristics influencing the values of the critical gap. The motorcycle take the smaller available critical gaps than HCV.

The level of service based on the density value that occurs when merging and diverging. Where the highest level of service with class A for density is less than or equal to 6 vehicles /km /lane. For more details the level of merging and diverging services can be seen in Table 5. The following are mathematical equations to determine the value of density when merging and diverging:

Merging

\[ D_r = 3.402 + 0.00456 \cdot V_{12} - 0.01278 \cdot L_a \]  

Diverging

\[ D_r = 2.462 + 0.0053 \cdot V_{12} - 0.0183 \cdot L_d \]

where,

- \( D_r \) = density (veh/km/lane)
- \( V_{12} \) = volume (veh/hour) determined by the equation in Table 3.
- \( L_a \) = merging length (m)
- \( L_d \) = diverging length (m)

### Table 3. Determination of \( V_{12} \) for merging and diverging.

| \( V_{12} \) = \( Vf \cdot PFM \) (On Ramps) | \( V_{12} = V_R + (V_F - V_R) \cdot PF_D \) (Off Ramps) |
|---------------------------------------------|-----------------------------------------------|
| 4 /2 \( PFM = 0.5775 + 0.000092L_a \) | \( PFD = 1 \) |
| 6 /2 \( PFM = 0.7289 - 0.0000135(V_F + V_R) - 0.002048S_{FR} + 0.0002L_{up} \) | \( PFD = 0.717 - 0.00039V_F + 0.18V_U/L_{up} \) |
| \( PFM = 0.5487 + 0.0801V_D/L_{down} \) | \( PFD = 0.616 - 0.00021V_F + 0.038V_D/L_{down} \) |
| 8 /2 \( PFM = 0.2178 - 0.000125V_R + 0.05887L_a/S_{FR} \) | \( PFD = 0.436 \) |

### Table 4. Level of service (Merging and Diverging)

| Level of Service | Density (veh/km/lane) |
|------------------|------------------------|
| A                | \( \leq 6 \)          |
| B                | > 6-12                 |
| C                | > 12 - 17              |
| D                | > 17 - 22              |
| E                | > 22                   |
| F                | Volume exceeds capacity |
2. Methodology
This study was carried out in the median openings in the Pettarani street, Makassar. The location of the study can be seen in figure 4. The following:

![Research study location](image)

Figure 4. Research study location.

The survey of traffic volume in the median openings is determined during the morning and evening busy times as follows:

- 06:30 - 08:30 am
- 4.00 – 6.00 pm

Based on observations at the study location, in some median openings facilities, not only was there a series of vehicles experiencing interference in the u-turn maneuver, but also seen a series of vehicles in the main stream which was disrupted due to vehicle activity in the median openings.

3. Results and discussion

3.1. Median Openings
The double type median openings in the Pettarani section have a width that varies from 20 m to 37 m. The median openings with a width of 20 m are in the The Mutiara segment and the LPMP segment has a median opening with a width of 37 m. The median openings in the PWI, Ramayana, and Telkom Building segments have a median opening width of 26 m, while the median openings of the HM. Asyik Mosque segment has a width of 31.95 m. The full width of the median openings in the Pettarani street can be seen in Table 5.

| Segment                        | Median opening width (m) |
|--------------------------------|--------------------------|
| The Mutiara                    | 20                       |
| Gedung PWI                     | 26                       |
| Ramayana                       | 26                       |
| Masjid HM. Asyik               | 31.95                    |
| Badan Pertanahan/LPMP          | 37                       |
| Telkom                         | 26                       |

3.2. Merging Performance
Reversing vehicles must wait for the gap between the reverse flows (mainstream), where the conditions of merging, vehicles that will join the main stream are generally only given the opportunity to use the edge lane (median) during peak hour conditions, so that at the flow on the contrary, the activities of vehicles in other lanes are not so affected by the vehicles that will join.
The density value at merging due to the influence of the median openings of The Mutiara segment for the direction of Pettarani (South) - Pettarani (South) morning peak hour conditions are 12 vehicles / km / lane and 11 vehicles / km / lane for the direction of Pettarani (North) - Pettarani (North). The afternoon peak hour, the density value in the median openings of The Mutiara segment for Pettarani (S) - Pettarani (S) is 12 kend / km / lane and 13 kend / km / lane for the direction of Pettarani (N) - Pettarani (N). The effect of the median opening of the PWI Building segment is 26 m wide on the segment performance, during peak hour morning and evening for the direction of Pettarani (S) - Pettarani (S) and Pettarani (N) - Pettarani (N), the density of each is 13 kend / km / lane, 14 vehicles / km / lane, 13 vehicles / km / lane, and 14 vehicles / km / lane with service levels for both directions are category C. The largest volume in the median openings of the Ramayana segment is for the Pettarani direction (N) - Pettarani (N) in the morning peak hour which is 1298 kend / hour, service level category C, density value 14 kend / km / lane. The level of merging services due to the median openings of the HM.Asyik Mosque segment has category C with a density value for Pettarani (S) - Pettarani (S) and Pettarani (N) - Pettarani (N) peak hour conditions in the morning and evening, each of 16 pc / km / lane, 14 pc / km / lane, 14 pc / km / lane, and 14 pc / km / lane. The median openings for the LPMP segment have the largest volume in the median openings and the main flow volume in the direction of Pettarani (N) - Pettarani (N), each morning peak hour is 765 pc / hour, 456 pc / hour, 7979 pc / hour and 8376 pc / hour. Whereas for the reverse direction the volume in the median openings and volume in the section, each 243 pc / hour, 321 pc / hour, 6808 pc / hour, and 5721 pc / hour. The level of service in this segment is C for both directions both during morning and evening peak hours. The performance of merging that occurs due to the median opening of the Telkom segment for morning and evening peak hours in the direction of Pettarani (S) - Pettarani (S) and Pettarani (N) - Pettarani (N) has a density of 14 pc/km /lane service level C, 13 pc / km/lane service level C, 13 pc / km/lane service level C, and 11 pc/ km/lane service level B. For more details, the merging performance due to the median openings of the Pettarani section is shown in Table 6. and Figure 5.

Table 6. Basic properties and mechanical properties of laterite soil.

| Segment          | From - to         | Median opening volume (veh/h) | Slow and fast Lane volume (veh/h) | Median opening width (m) | Density (veh/km/ln) | Level of Service |
|------------------|-------------------|------------------------------|----------------------------------|--------------------------|---------------------|-----------------|
| The Mutiara      | Pettarani (S – S) | 104                          | 187                              | 6371                     | 12                  | 12 C            |
|                  | Pettarani (N – N) | 123                          | 213                              | 4973                     | 13                  | 13 B            |
| Gedung PWI       | Pettarani (S – S) | 632                          | 980                              | 6292                     | 13                  | 13 C            |
|                  | Pettarani (N – N) | 566                          | 1216                             | 7147                     | 14                  | 14 C            |
| Ramayana         | Pettarani (S – S) | 833                          | 1110                             | 7932                     | 14                  | 14 C            |
|                  | Pettarani (N – N) | 1298                         | 1100                             | 7755                     | 15                  | 15 C            |
| Masjid HM.Asyik  | Pettarani (S – S) | 744                          | 1343                             | 9343                     | 16                  | 16 C            |
|                  | Pettarani (N – N) | 1816                         | 1611                             | 7580                     | 14                  | 14 C            |
| Badan Pertanaha/ | Pettarani (S – S) | 243                          | 321                              | 6808                     | 17                  | 17 C            |
| LPMP             | Pettarani (N – N) | 765                          | 456                              | 7979                     | 15                  | 15 C            |
| Telkom           | Pettarani (S – S) | 1653                         | 1802                             | 8635                     | 14                  | 14 C            |
|                  | Pettarani (N – N) | 765                          | 456                              | 5928                     | 13                  | 13 B            |
3.3. Diverging performance
Conflicts that occur during peak hour conditions in diverging movements where some vehicles that will conduct flow separation do not use the edge lane (median), but use all available lanes on the lane, and vehicles in the main stream which are initially in the lane (median) move lanes to avoid delays or slow down due to vehicles in front of them that will reverse play. So that conditions like this disrupt the smooth flow of the other lanes. The level of diverging services that occur as a result of the median openings of the section Pettarani morning peak hours vary from C to F. Service level category C with a density of 15 pc/km/lane occurs due to the median openings of The Mutiara segment for Pettarani (S) - Pettarani (S) with volume in the median openings of 109 pc/hour and volume in sections 6371 pc/hour. As for the reverse direction in the The Mutiara segment, the density is 19 pc/km/lane, the service level is category D, the volume in the segment is 4973 vehicles/hour and 101 kend/hour for volume in the median openings. The PWI Building segment during the morning and evening peak hours for the Pettarani (S) - Pettarani (N) directions has a density of 23 pc/km/lane, 20 pc/km/lane, 28 pc/km/lane, and 22 pc/km/lane. The vehicle volume in the section and median openings for this segment is larger in the afternoon than in the morning peak hour. The largest density value in the Ramayana segment for morning and evening is 27 pc/km/lane of service level category E, occurring in the reverse rotation direction Pettarani (N) - Pettarani (N). The largest volume in this segment occurred during the afternoon peak hour, namely 8176 pc/hour (S-S survey) and 7988 pc/hour (Pettarani N-N). The level of service segment due to the influence of median openings in HM. Asyik Mosque segment has categories E and F with density values for the direction of Pettarani (S-S) and Pettarani (UU) morning and evening peak hours, 24 pc/km/lane, 32 pc/km/lane, 27 pc/km/lane, and 32 pc/km lane. The median openings of the LPMP segment have the largest volume and segment for the direction of Pettarani (N) - Pettarani (N), each 765 pc/hour and 7979 pc/hour in the morning and 456 pc/hour and 8376 pc/hour in the afternoon. The density value in the segment as the effect of the median openings of the Telkom segment during peak hour morning and evening for the direction of
Pettarani (SS) and Pettarani (N-N), each of 23 pc / km / lane, 27 pc / km / lane, 21 pc / km / lane, and 16 pc/ km / lane. The service level of the morning peak hour condition for this segment is category E, while for the afternoon peak hour category D (S-S Survey) and C (Pettarani, N-N).

For more details, u-turning facilities diverging performance on Pettarani street is presented in figure 6 and table 7.

![Figure 6. Median Openings Diverging Performance.](image)

### Table 7. Basic properties and mechanical properties of laterite soil.

| Segment          | From - To     | Median opening volume (pc/h) | Slow and fast Lane volume (pc/h) | Median opening width (m) | Density (pc/km/ln) | Level of Service |
|------------------|---------------|------------------------------|----------------------------------|--------------------------|---------------------|------------------|
| The Mutiara      | Pettarani (S - S) | 109                         | 6371                             | 20                       | 15                  | C                |
|                  | Pettarani (N - N) | 101                         | 4973                             | 19                       | 19                  | D                |
| Gedung PWI       | Pettarani (S - S) | 632                         | 6292                             | 26                       | 23                  | E                |
|                  | Pettarani (N - N) | 566                         | 7147                             | 20                       | 22                  | D                |
| Ramayana         | Pettarani (S - S) | 833                         | 7932                             | 26                       | 25                  | E                |
|                  | Pettarani (N - N) | 1298                        | 7755                             | 27                       | 27                  | E                |
| Masjid HM.Asyik  | Pettarani (S - S) | 744                         | 9343                             | 31,95                    | 24                  | E                |
|                  | Pettarani (N - N) | 1816                        | 7580                             | 32                       | 32                  | F                |
| Badan Pertanaha n/ LPMP Telkom | Pettarani (S - S) | 243                         | 6808                             | 37                       | 23                  | E                |
|                  | Pettarani (N - N) | 765                          | 7979                             | 27                       | 18                  | E                |
|                  | Pettarani (S - S) | 1653                        | 8635                             | 26                       | 23                  | E                |
|                  | Pettarani (N - N) | 765                          | 5928                             | 27                       | 16                  | C                |
3.4. Relationship between median openings width and density

In Figure 7, it can be seen that the width of the median openings and density on the road has a relationship proportional to the coefficient of determination $R^2 = 0.0552$, indicating that 5.52% of the density value is influenced by the width of the median openings, the rest there are other factors that affect such traffic volume in the median openings and traffic volume in the main stream. The wider the median opening results in increased density, this is due to increased space for the vehicle to do a reverse rotation maneuver, thus increasing movement disturbances for the opposite flow as well as the flow behind the vehicles that will reverse.

![Figure 7. Relationship between Median Openings Width and Density.](image)

3.5. Relationship between traffic volume in the mainstream and density

Relationship between Traffic Volume in The Mainstream and density can be seen in Figure 8. Traffic volume in the mainstream dan density on the road has a relationship proportional to the coefficient of determination $R^2 = 0.4823$, indicating that the greater the volume in the main section the more it affects the movement of vehicles that are in the median opening to do merging and diverging, thereby increasing density.

![Figure 8. Relationship between traffic volume in the main stream and density.](image)

4. Conclusions

The width of the median openings of the double type in Pettarani street varies between 20 m - 37 m, with the widest median opening width found in Badan Pertanahan / LPMP segment, while the
narrowest median openings are found in The Mutiara segment. The largest traffic volume is merging in the median openings of the Pettarani section for directions Pettarani (N) - Pettarani (N) morning peak hours 1816 pc/h in the median opening of HM. Asyik Mosque and Telkom segment (Pettarani S-S) for afternoon peak hours with a value of 1802 pc/ hour. In the median openings segment of the HM. Asyik Mosque has the highest density value, which is equal to 17 pc / km/lane conditions in the morning peak hour and 16 pc /km/lane in the afternoon peak hour conditions. The largest density value for diverging movements is 32 pc /km/ lane occurring in the median openings of the HM. Asyik Mosque segment. The wider the median opening results in increased density, this is due to increased space for the vehicle to do a reverse rotation maneuver, thus increasing movement disturbances for opposite flow and flow behind the vehicles that will do reverse rotation. The greater the volume in the main section the more it affects the movement of vehicles that are in the median opening to do merging and diverging, thereby increasing density.

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