Study of Pedestrians Proportion to Roadside Friction Index

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Abstract. Activities of land use on the roadside have an impact on traffic. The more roadside activities increasingly affect the performance of the road section. This research was conducted on 2/2 UD type of road and the purpose of the study was to determine the effect of the proportion of roadside friction (pedestrians) to traffic characteristics and roadside friction index on access roads of Makassar Municipality and Gowa Regency. Greenshields model is used to determine the relationship between speed - flow - density. The results showed pedestrians are very influential in the average speed of space and free-flow speed. The greater the proportion of pedestrians as roadside friction, the value of the roadside friction index increases, but the value of the average speed of space and free flow speed decreases. Motorized vehicles will run slower to avoid or adjust to the pedestrian speed, especially light vehicles and heavy vehicles, yet the addition of the pedestrian does not significantly affect the movement of motorcycles.

1. Introduction
The development of a city cannot be separated from the development of its land use. Activities of land use on the roadside have an impact on road traffic. Disturbances arising from activities on the roadside to traffic are side friction. The more occurrences of roadside friction activity increasingly affect the performance of the road section. Pedestrians, on-street parking, slow-moving vehicles, in this case including non-motorized vehicles. This study aims to determine the effect of the proportion of pedestrians to traffic characteristics and roadside friction index of the access road of Makassar Municipality and Gowa Regency.

Some previous studies regarding pedestrian and roadside friction are On-street parking, bus stops, and bus bays reduce stream speed, respectively 45-67% and 49-57%. The longer time of dwelling time of bus stop duration the more effect on road capacity [1]. Sidewalk width, pedestrian density, side friction, the presence of a walking partner, age, and gender contribute to the determination of the speed of pedestrian walking. Based on flow rates, Farmgate has LOW C and Shukrabad and Shahbag both have LOW B. The average free-flow velocity of the three locations is around 1.18 m/s [2]. The results of physical and cognitive test simulations for older people as pedestrians showed several participants who when divided attention would make risky decisions to make crossings that were not safe either [3]. In developing countries, such as India, on-street parking activities, pedestrian movements, lack of driving discipline, heterogeneous traffic, the presence of street hawkers reduce capacity [4]. The decrease in the actual capacity value of the influence of side barriers on Jalan Sam Ratulangi is 36% and the side friction index is 0.64. Meanwhile, according to the 1997 Indonesian Road Capacity Manual, the decrease in road capacity due to side friction is 19% with a side friction index value of 0.81 [5]. High pedestrian and vehicle currents can cause congestion problems that cause extended network delays. One way to reduce delays is to design a Skywalk [6]. Theoretically, for four-wheeled vehicles, the capacity will decrease with the increase of crossing pedestrians, but conversely, for motorcycle vehicles, the capacity becomes increased. Fuel consumption and travel
time are affected by a significant reduction in vehicle speed [7]. The travel of urban transportation users is influenced by travel time and departure time, but not on trip length and cost [8]. When Non-motorized vehicle percentages are 5% and 25%, midblock capacity on urban arterial roads will decrease by 3.60% -35.82% [9]. Capacity depends on traffic conditions, road width, geometry designs, and so on and varies with time and position. The reduced width of the road causes reduced capacity. The existence of side obstacles will cause a reduction in capacity and cause congestion [10]. Side barriers affect road congestion but not for road surface conditions [11]. Signalized intersection and midblock must consider the amount of pedestrian, pedestrian speed, crossing length, crossing width and losing pedestrian time [12]. The higher roadside friction, the higher of degree of saturation value [13].

2. Methodology
The study location was conducted on Daeng Tata street, Makassar City, 2/2 UD of road type without pedestrian facilities/sidewalks, 5 m of width and is a residential area that is used as a connecting access road between Makassar Municipality and Gowa Regency. The speed and traffic counting surveys were collected on weekdays for 10 hours of observation at 5 minutes intervals for both lanes on February 2020. The analysis was performed using the Greenshields model, then compared the capacity of the traffic flow with roadside friction to traffic flow without roadside friction. Study location can be seen in Figure 1.

![Image](image.png)

Figure 1. Study location

3. Results and Discussion
Roadside frictions that were seen during the observation were pedestrians and non-motorized vehicles, there were no on-street parking vehicle and slowing vehicles, or activities on the roadside that disrupted the traffic. Pedestrians contributed the largest proportion, which was 77% compared to non-motorized vehicles 23%. The proportion of roadside friction can be seen in Figure 2.
Figure 2. Roadside friction proportion

The relationship between each parameter (flow - speed - density) for conditions without roadside friction and based on the proportion of pedestrians was analyzed by Greenshields models. Without roadside friction, the relationship between the flow-speed model Greenshields $70V - 0.51V^2$, the relationship between flow-density $36k - 1.94k^2$, and the relationship between speed – density $36 - 1.94k$. The relationship between speed-density, flow density, and speed-flow for 0-25% pedestrian proportion are $35.5 - 1.69k; 35.5k - 1.69k^2$, and $60V - 0.59V^2$. The relationship between speed-density, flow density, and speed-flow for 25.1-50% pedestrian proportions are $35.1 - 1.94k; 35k - 1.94k^2$, and $68V - 0.51V^2$. The relationship between speed-density, flow density, and speed-flow for 50.1-75% pedestrian proportion are $34.2 - 2.5k; 34k - 2.5k^2$, and $85V - 0.4V^2$. The relationship between speed-density, flow density, and speed-flow for 75.1-100% pedestrian proportion are $30 - 5k; 30k - 5k^2$, and $150V - 0.2V^2$. Flow - speed-density relationship based on the pedestrian proportion can be seen in Table 1.

Table 1. Flow-speed-density relationships

| Pedestrian (%) | Speed - Density | Flow - Density | Speed - Flow |
|----------------|----------------|---------------|--------------|
| 0 - 25         | 35.5 - 1.69k   | 35.5k - 1.69k^2 | 60V - 0.59V^2 |
| 25.1 - 50      | 35-1.944k      | 35k - 1.94k^3  | 68V - 0.514V^2 |
| 50.1 - 75      | 34-2.5k        | 35k - 1.94k^3  | 85V - 0.4V^2  |
| 75.1 - 100     | 30-5k          | 30k - 5k^2     | 150V - 0.2V^2 |

The most event of roadside friction occurred at 11.34-11.40 am, which consisted of a non-motorized vehicle and 15 pedestrians. At this time most pedestrians were students. The maximum number of non-motorized vehicles at observation time were 4 vehicles and 15 people for the maximum number of pedestrians. Roadside friction fluctuation is presented in Figure 3. The peak hour occurred at 07.30 - 07.35 am, 867.6 pcu/h, consisting of 9% of light vehicles, 90% of motorcycles, 1% of heavy vehicles, while roadside friction consisted of 100% pedestrian (2 people) and there was no non-motorized vehicle. For day time, peak hour occurs at 643.2 pcu/h at 2.40 - 2.45 pm with 12% light vehicle composition, 87% motorcycle, 1% heavy vehicle, while no roadside friction is present. In the afternoon the peak hour occurred at 3.50 - 3.55 pm where motorcycles dominated by 83%, light vehicles 14%, heavy vehicles 2%, and there were 80% roadside friction pedestrian and 20% non-motorized vehicles. The number of roadside friction to traffic flow can be seen in Figure 4.
3.1. Effect of Pedestrian Proportion to Traffic Characteristics
Roadside friction affects the amount of traffic speed, drivers will avoid interactions with roadside friction by reducing speed, sharing the space between motor vehicles with roadside friction will reduce the average speed of space. The lowest speed of 24 km/h occurs when the highest number of side friction, with 16 events. Without roadside friction, free-flow speed of 36 km/h, the capacity of 160 vehicles/5 minutes, and side fraction index are 1. Roadside friction consisted of pedestrians and non-motorized vehicles. For this study, the proportion of pedestrians and non-motorized vehicles as roadside friction was divided into 4 groups, namely 0-25%, 25.1 - 50%, 50.1 - 75%, and 75.1 - 100%.
Free flow velocity for pedestrian proportion groups is 0-25%, 25.1 - 50%, 50.1 - 75%, and 75.1 - 100%, respectively 35.5 km/h, 35 km/h, 34 km/hr, and 30 km/hr. The influence of the proportion of pedestrians on average speed can be seen in Figure 5.

![Figure 5. Effect of pedestrian proportion to free-flow speed](image)

The average speed of space due to the number of pedestrians 0-25% is 31.36 km/h, the proportion of pedestrians 25.1-50% is 30.33 km/h, the proportion of pedestrians 50.1 - 75% is 29.43 km/h, and 28.55 km/h for the proportion of pedestrians 75.1 - 100%. Whereas without roadside friction, the average speed of the space is 31.44 km/h. The higher the proportion of pedestrians the lower the free-flow speed, because the vehicle will reduce speed to avoid interaction with pedestrians. Compared to the presence of non-motorized vehicles in traffic flow, motorized vehicles will run slower to avoid or adjust pedestrian speed, whereas for non-motorized vehicles have speeds greater than pedestrians. The influence of the proportion of pedestrians on space mean speed can be seen in Figure 6.

![Figure 6. Effect of pedestrian proportion to space mean speed](image)

The capacity for the proportion of pedestrians 0 - 25% is 532.5 pcu/h, 25.1 - 50% is 595 pcu/h, 50.1 - 75% is 722.5 pcu/h, and 75.1 - 100% is 1125 pcu/h. Whereas without roadside friction, capacity is 630 pcu/h. The addition of pedestrians reduced light vehicles but increased motorbikes. With smaller
dimensions, a motorcycle has wider maneuvers than other motorized vehicles, thus the addition of pedestrians does not significantly affect the movement of motorcycles. The influence of the proportion of pedestrians on capacity is presented respectively in Figure 7.

![Effect of Pedestrian Proportion to Capacity](image)

**Figure 7.** Effect of pedestrian proportion to capacity

### 3.2. Effect of Pedestrian Proportion to Roadside Friction Index

Roadside friction index greater accompanied by a high proportion of pedestrians. In the proportion of pedestrians from 0-25%, side friction index 0.845 and in the proportion of pedestrians 75.1 - 100% is 1.786, while for the proportion of pedestrians 25.1 - 50% and 50.1 - 100%, respectively 0.944 and 1.147. The effect of pedestrian proportion to side friction index can be seen in Figure 8.

![Effect of Pedestrian Proportion to Side Friction Index](image)

**Figure 8.** Effect of pedestrian proportion to side friction index

Traffic characteristics without the influence of side friction with a range of percentage of light vehicles are 0-57%, motorcycle 77-100%, and heavy vehicles 0-3%, have an average mean speed space of 31.39 km/h, free-flow speed of 36 km/h, the capacity of 630 pcu/h, and roadside friction index 1. Overall, motorcycles dominate in traffic flow for all percentage of side friction, especially in the pedestrian proportion of 75.1-100%, where proportions of motorcycles vary from 3 to 100%. The effect of pedestrian proportion to traffic characteristics and roadside friction index can be seen in Table 2.
Table 2. The effect of pedestrian proportion to traffic characteristics and roadside friction index

| Side Friction (%) | Non-Motorized Vehicle | Light Vehicle | Motorcycle | Heavy Vehicle | Average Speed (kmh⁻¹) | Free-flow speed (kmh⁻¹) | Capacity (pcu⁻¹) | Roadside Friction Index |
|-------------------|----------------------|---------------|------------|---------------|----------------------|------------------------|------------------|------------------------|
| 0                 | 0                    | 0 - 57        | 77-100     | 0 - 3         | 31.3957              | 36                     | 630              | 1                      |
| 0 - 25            | 75 - 100             | 0 - 17        | 71 - 95    | 0 - 7         | 31.3615              | 35.5                   | 532.5            | 0.845                  |
| 25.1 - 50         | 50 - 75              | 0 - 21        | 33 - 96    | 0 - 33        | 30.3294              | 35                     | 595              | 0.944                  |
| 50.1 - 75         | 25 - 50              | 2 - 31        | 66 - 97    | 0 - 3         | 29.4349              | 34                     | 722.5            | 1.147                  |
| 75.1 - 100        | 0 - 25               | 0 - 16        | 3 - 100    | 0 - 7         | 28.5544              | 30                     | 1125             | 1.786                  |

4. Conclusion

Pedestrians are very influential in the average speed of space and free-flow speed. The greater the proportion of pedestrians as side friction, the value of the side friction index increases, but the value of the average speed of space and free flow speed decreases. Motorized vehicles will run slower to avoid or adjust to pedestrian’s speed, especially light vehicles and heavy vehicles, yet the addition of pedestrians does not significantly affect the movement of motorcycles.

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