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EXPLORING PEDESTRIAN BEHAVIOR ON MICROSCOPIC ANALYSIS CONTEXT: THE CASE OF YOGYAKARTA, INDONESIA

MUCHAMMAD ZAENAL MUTTAQIN,

Pursuing Doctoral degree program, Department of Civil Engineering, Universitas Gadjah Mada and Universitas Islam Riau, Indonesia.

AHMAD MUNAWAR,

Professor in Civil and Environmental Engineering, Universitas Gadjah Mada, Indonesia.

MUHAMMAD ZUDHY IRAWAN

Associate Professor, Department of Civil and Environmental Engineering, Universitas Gadjah Mada, Indonesia.

Abstract

The complexity of pedestrians lies in the activity of pedestrian movements can be predicted with the pedestrian model. A pedestrian model is used to determine pedestrian behavior in a pedestrian area. Simulation technology enables a more adaptable approach to pedestrian behavior studies. For a more extensive examination, empirical predictions of pedestrian behavior will be employed. The study's objective is to examine pedestrian behavior using quantitative models, one of which is a microscopic approach.

Index Terms— Pedestrian, Microscopic, Social Force Model, Indonesia, PTV Viswalk, Behavior, Yogyakarta

1 INTRODUCTION

Pedestrian motions are far more complicated than those of other types of transportation. The complexity of pedestrians is found in their activity, which may be anticipated using the pedestrian model. To ascertain pedestrian behavior in a pedestrian area, a pedestrian model is utilized. With a more detailed search, a pedestrian model enables the analysis of a pedestrian path's capacity[1]. By creating a simulation, the requirements for pedestrian models in the field may be met. One of the advantages of simulation is the ability to represent pedestrian situations[2]–[4]. Simulation technology enables a more adaptable approach to pedestrian behavior studies. For a more extensive examination, empirical predictions of pedestrian behavior will be employed. The study's objective is to examine pedestrian behavior using quantitative models, one of which is a microscopic approach. Pedestrian behavior is frequently examined using descriptive methods, whereas pedestrian viewpoints are investigated using qualitative methods. [5]–[7]. Pedestrians often pass through commercial locations, but they also have a higher level of complexity owing to the variety of pedestrian themes, such as shopping or simply walking along the street. [8]. Previously, the pedestrian simulation model was capable of accurately predicting pedestrian path safety using pedestrian crossing systems in a pedestrian region[9]–[11].A sidewalk lane located in the city center (Central Business District) and surrounded by mixed traffic with pedestrian dominance activity on both sides of the road area creates a fairly high dynamic for pedestrians. Pedestrian-only lanes are constructed not only as pedestrian paths down, but also to accommodate other dynamic factors such as

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pedestrians crossing from the traffic lane crossing area and movements from shopping areas on the other side. This will have an effect on the features of pedestrian movements in the primary pedestrian flow[12]. In summary, the study used the Social Force Model to pedestrian movement, aided with Viswalk assistance to simulate pedestrians in order to approach models comparable to those seen in the field. The pedestrian speed variable is used to determine the variable control to be applied. The application of speed variable control to the formulation of pedestrian behavior is restricted. Numerous density characteristics and pedestrian currents have been employed before to analyze pedestrian behavior in macroscopic and microscopic simulations ([13]–[15]. Speed parameters are utilized largely to compare the model to the theory of pedestrian simulation modelling [16]–[18]. This research is predicted to be a significant factor in the future usage of speed as a primary variable control in determining pedestrian characteristics that are consistent with the field and will be further explored in the development and assessment of pedestrian lanes.

2 SOCIAL FORCE MODEL

The Social Force model is one hypothesis of pedestrian behavior that is employed in the macroscopy of pedestrian movement. The social force model is based on a hypothesis proposed by[19]that can explain a variety of elements of human behavior[20]. The social force model is a subset of the self-driven particle model developed by[21]in which each particle is autonomous and maintains a constant speed and direction in response to other actions. Generally. The social force theory model is based on the movement of pedestrians, which is akin to Newtonian physics. This model integrates a person's social, psychological, and physical strength to provide a pedestrian physical acceleration parameter. This strength is derived from the pedestrian's desire to do something. Additionally, pedestrians are influenced by other pedestrians and other impediments in their path. The overall equation relating to the social force model is stated as the sum of many attractive and repulsive forces, i.e.

$$\vec{f_i}(t) = m_i \frac{d\vec{v_i}}{dt} = m_i \frac{v_i^0(t)\vec{e_i^0} - \vec{v_i}(t)}{\tau_i} + \sum_{j(\neq i)} \vec{f_{ij}} + \sum_w \vec{f_{iw}}$$

By f indicated a vector style that depicts the resultant effect of pedestrian attraction and re-research. This force is affected by the mass of the pedestrian (m) and the change in the pedestrian's speed (dv) at any given time (dt). Additionally, the formula above illustrates the function of tau value(), which allows for an easy evaluation of pedestrian movement today with the use of technology and a simulation theory. The pedestrian movement simulation technique is classified into two stages: macro simulation and micro simulation. The macro-simulation of pedestrian movement treats pedestrians as fluid currents, whereas micro-simulations focus on the interactions between pedestrians while walking. [22]The Social Force model is a frequently used pedestrian simulation theory. The social force theory model presupposes that walkers will be impacted by the social circumstances of the environment in which they are traveling. Tools that accelerate the simulation process are extensively used to facilitate pedestrian simulations. Additionally, the tool is capable of producing visual conditions for pedestrian movement, which enables comparisons between the findings of pedestrian movement analysis and field-based

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data, such as PTV Viswalk assistance.

3 RESEARCH METHODS

This research takes place in the business district of Malioboro in Yogyakarta, Indonesia. PTV Viswalk tools are used to simulate data. The simulation is conducted by specifying the geometric design of pedestrian routes, as well as data on pedestrian volume input and relative speed, as well as pedestrian type and direction of travel. The characteristics of pedestrian traffic in commercial districts in Yogyakarta, more especially in the Central Business District Malioboro sidewalk area, were measured in this study using the results of a field survey in the form of manually computed video footage. This neighborhood is centrally placed in Yogyakarta and is a popular shopping destination for travelers. By positioning the camera in a location that does not obstruct pedestrians in their movement activities, data in the form of uninterrupted traffic movements may be collected.

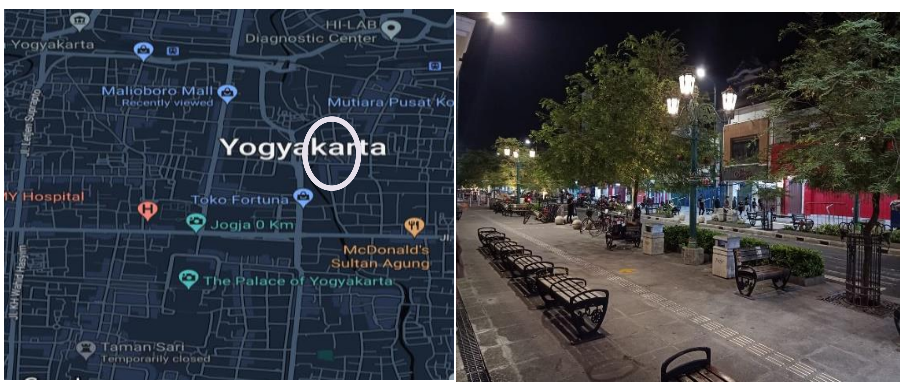

Fig 1. Malioboro Research Location, Yogyakarta

According to field observations, the total volume included in the pedestrian simulation is up to 2183 people divided into three conditions, namely the morning peak hours (at 10:00 PM) with up to 430 people, the daylight peak hours (at 14.30 WIB) with up to 925 people, and the afternoon peak hours (at 17.30 WIB) with up to 825 people. Male pedestrians (49 percent) outnumber female pedestrians (51 percent). Additionally, pedestrian data revealed that pedestrians transported more things by fusing them to their bodies or carrying them (49 percent) than by fortifying or pushing them (20 percent).

Additionally, the pedestrian characteristics data takes the acquired speed into account. The table below illustrates the size of each pedestrian's speed number. Speed data is required to generate the appropriate speed distribution distribution, which is used as an input parameter in the PTV Viswalk simulation model[23]. In comparison to other categories of pedestrians, men and women carrying goods had an average peak speed of 3.62 km / h with a standard deviation of 1.2. This might occur as a result of people' conduct when walking in the pedestrian way area.

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Individual characteristics such as emotional state, bodily state, or the pedestrian's perception of the surroundings around the table bleow all impact pedestrian behavior.[24]

Table 1. Types of Pedestrians

Types of Pedestrians	Average Exposure (km/h)	Standard Deviation
Men don't carry things.	3.51	1.43
Men carrying things	3.62	1.51
Men carrying things.	3.49	0.98
Women don't carry things.	3.61	1.16
Women carrying things	3.62	1.73
Women carrying things.	3.54	1.17

Apart from the speed of each type of pedestrian, the next set of input data pertains to pedestrian pathways. Field observations revealed three distinct types of foot traffic movements: down, lane crossing, and swerving. The walk is defined as the continuous movement of pedestrians from the beginning to the finish of the observation site. Additionally, there is movement associated with the type of crossing along the same path. Pedestrians cross the route, as do movements in the vicinity of traffic crossings. Additionally, same swerving action happens when people travel north or south and then east or west. This occurs when a person wishes to turn towards a store that is adjacent to the pedestrian way.

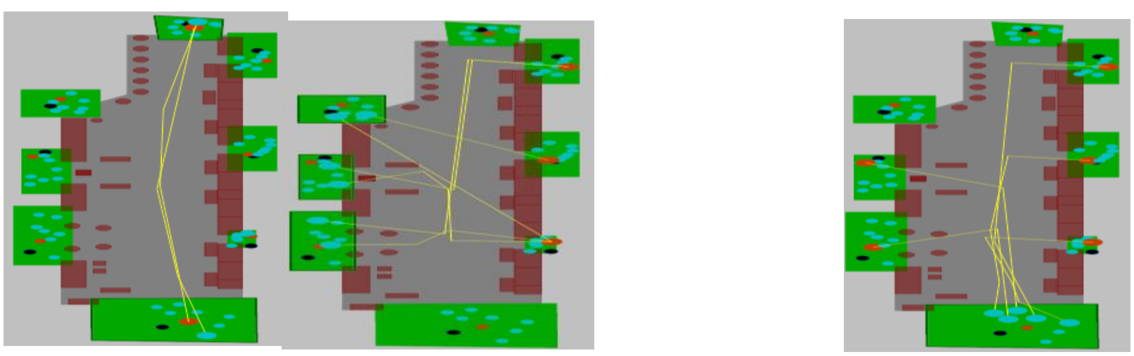

Fig 2. Pedestrians walk down (left), cross (middle), and swerve (right)

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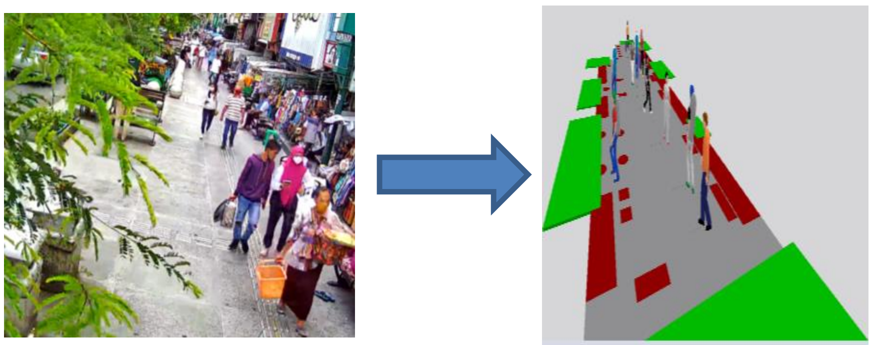
The simulation model is run through various pedestrian compositions based on the direction and type of pedestrian. Pedestrians are restricted to movement only on routes and areas that have been planned. Routes and areas are also described manually according to conditions on the ground. A snapshot of the simulation model and field conditions is shown in the image below,

Fig 3. Field movement vs simulation model



4 RESULT AND DISCUSSION

Research is aimed at predicting the behavioral characteristics of walking based on a pedestrian microscopic approach. The value of pedestrian behavior in the Social Force Model theory is determined by the coefficient of behavior parameters. The pedestrian simulation model was compared to the actual results to equalize the pedestrian model. The model is simulated for all hours of observation, both in morning conditions, afternoon conditions, and afternoon conditions. In general, the results showed that changes in pedestrian behavior parameters had a significant effect on pedestrian speed. The pedestrian influence model approach in general is a linear approach on the parameters tau, Asociso, Lamdha, VD and grid size. The linear influence model of behavior parameters in general is in a negative direction which means that the larger the number of behavior parameters, the smallerthe speed of pedestrians. In addition, there is a logarithmic model approach to the influence of behavior parameters on pedestrian speed, such as React to n, and Noise. The logarithmic approach is also no different from the linear model approach where it has a negative slope. Aside from both approach models, there is a quadratic model on asocmean parameters and a constant linear model (zero gradient value) obtained on the influence of obstacle distance.

4.1. Tau Parameters

Tau characteristics denote behavior that encourages people to engage in walking activities on the path. The results indicated that adjustments in the Tau parameters had a significant effect on pedestrian speed. These findings corroborate prior studies indicating that changes in tau parameters have a significant effect on pedestrian speed.[25], [26]. The default tau value of

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0.5 does not make desired speed the highest that can be achieved. Pedestrians in a psychologically eager crowd to be moved to reach the goal [27] Therefore,the smaller value of tau, it can be predicted that pedestrians will do the maximum speed to walk in the area can be approached by the conclusion that Pedestrian behavior in a crowd will become more rushed and tend to approach the speed of free flow. This can be a major consideration in optimizing the pedestrian model that suits the field conditions.

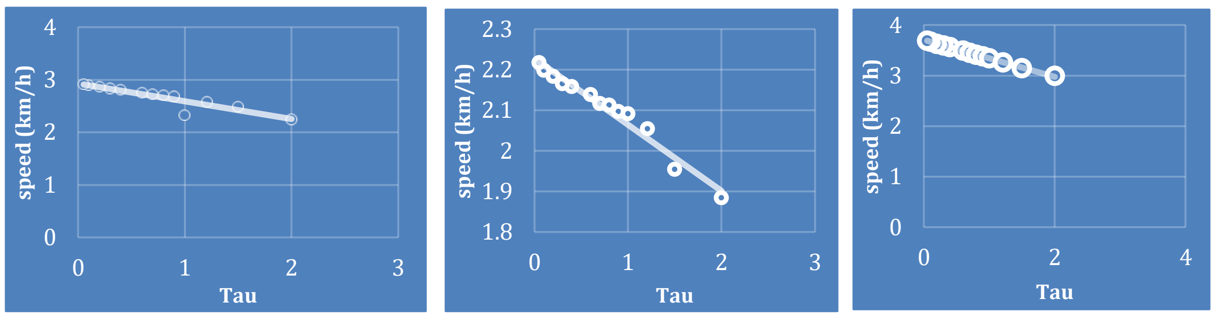

Fig 4. Desired speed for each value tau morning conditions (left), noon (middle), and afternoon (right)

Based on the movement of the observation point visually, predictable appropriate equations are linear equations. The linear equation for each condition can be seen in the table below. The model match number for an entire equation approaching number one indicates that the desired speed relationship to the increase in tau values is linear. A large chart tilt number shows a large desired speed range. The results showed that in the afternoon conditions, desired speed has the largest range linearly compared to morning or afternoon conditions. This indicates that pedestrians are getting in the afternoon tend to be more rushed than in the morning conditions. This is supported by Vásquez et al, (2020) that tau parameters show pedestrian behavior in terms of internal motivation that results in pedestrians going to walk. relax or rush in a designated area of walking trails.

4.2. React to N parameters

The *react to n* parameter is used to set the maximum number of other nearby pedestrians balanced in *social force* (Fsocial) calculations. This parameter meansthat a pedestrian will be affected by the number of people who are around the pedestrian. The image below explains that each pedestrian will have at least 9 boxes which is assumed the stuffing of each box will affect the movement of pedestrians. Theoretically, if the number of people in the box is small or low, then pedestrians will feel panicked and move from one position to another continuously to avoid the person. This was influenced by the formation of 9 new boxes as a new mobile comfort area for free moving pedestrians. In addition, jika 8 boxes filled, then pedestrians will tend to run stable because of the presence of *social force* that balances each other. In other words, pedestrians will have no gap in making movements due to the presence of others in the pedestrian privacy area. This area is also called grid size.

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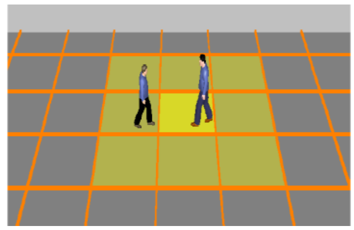

Fig 5. Pedestrian grid size

The graph below illustrates the study's findings about the effect of reacting to n values. In the morning and evening, pedestrians will walk steadily when at least four persons are present in a pedestrian-free region. Pedestrian patterns can be assumed in the morning, with the lowest peak peak hour pedestrian volume of 430 people per hour, and in the evening, with the greatest desirable speed of 825 people per hour. This occurs when there is just one person in a pedestrian-free zone. The impulse to avoid other pedestrians becomes overwhelming and is influenced by the surrounding factors that allow people to evade. It can be seen that there are constraints on pedestrian mobility that cause people to be hesitant to avoid other pedestrians and instead tend to follow their motions. Who is in the unoccupied area. This supposedly follows the leader-follower rule, which claims that pedestrians in a throng will follow the leaders. to stimulate pedestrian activity. This notion is heavily influenced by the kind of group walker[29],[30]. While the react to n value of 1 results in the greatest desired speed during peak hours, particularly in daylight circumstances with a volume of 925 persons / jam, when the react to n value is 2 or 3, the pedestrian's speed decreases dramatically and stabilizes at react to n by 5. This is attainable with a high density, such that walkers' ability to maneuver to avoid and follow other pedestrians is balanced toward a more steady movement.

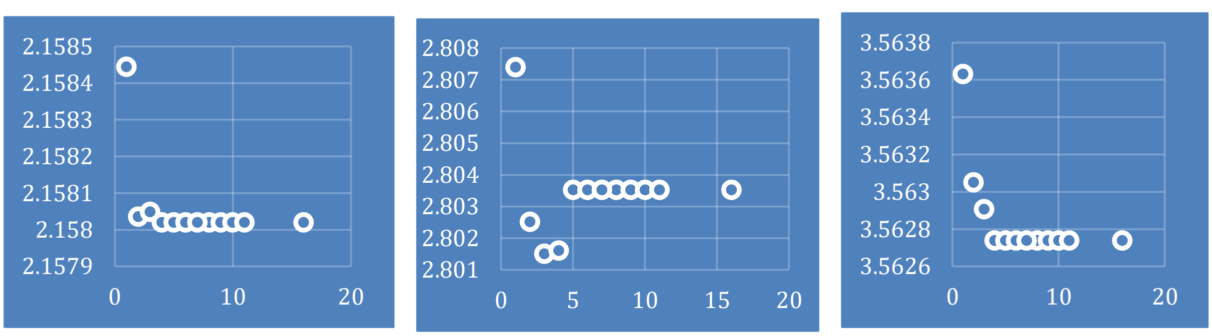

Fig 6. Desired speed for react to N values morning conditions (left), noon(center), and afternoon (right)

4.3. Parameters of Asociso

Asociso's parameters would theoretically determine the identic basic strength of a direction of movement that depends on the distance of one pedestrian to another. Mathematically, the

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Asociso parameter is the coefficient that will determine the force strength in meters per square second. While the parameter *Bsociso* is the magnitude of the range of the social force *model.*which represents the radius of the pedestrian in meters. Increasing social A*isotropic values* will increase the *headway* and make the current lower and the possibility of *deadlock* will be greater. The results showed that the parameters of Asociso simultaneously greatly affect the speed of walking (figure below). The default value on the Parameters Asociso of 2.72 m / square second does not result in the highest desired speed or lowest. Theoretically, these results support previous research that the larger these two parameters, the greater the pedestrians who exert social force influences will be more and more and encourage pedestrians to slow down in order to collide with each other [31].

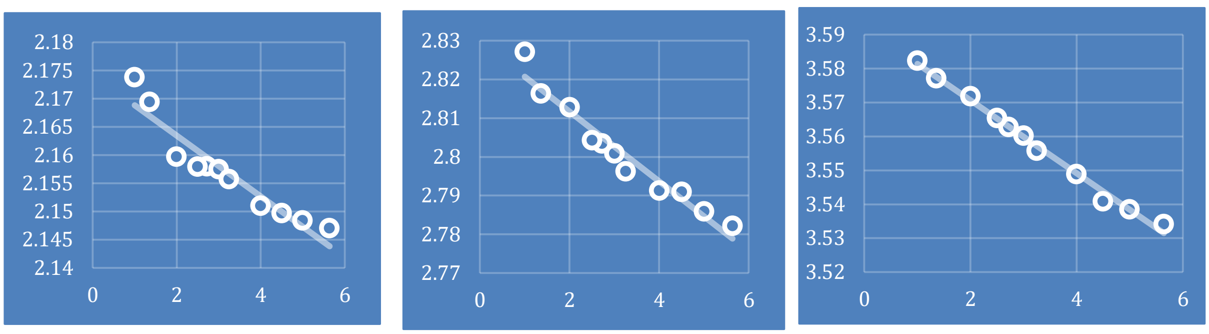

Fig 7. Desired speed for Asociso value morning conditions (left), noon(center), and afternoon (right)

The relevant equation may be anticipated visually based on the movement of the observation point. The table below contains the linear equations for each condition. The model match number approaching one implies that the expected speed connection with increasing Asociso and BsocIso values is linear with a negative slope. A significant chart tilt value indicates a wide intended speed range. The results indicated that afternoon conditions had the highest linear range of desired speed when compared to morning or afternoon conditions on asociso parameters. This suggests that in the afternoon, the pedestrian headway is more variable, according to the intended speed range. This is consistent with[31]which claims that the connection between intended speed and Asociso parameters is linear, and that as Bsociso increases, desired speed decreases, indicating that the current becomes denser.

4.4. Lamdha Parameters

Lambda parameters are used to control the number of various social factors that act on incidents involving pedestrians. The magnitude of the lamdha parameters indicates the variation in

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perception between pedestrians in close proximity. These criteria will produce results for speed depending on alertness against the environment. The graphic below illustrates the impact of lamdha values. The range of lamdha values that have an effect on the social force model is zero to one, where zero indicates that pedestrians are only impacted by pedestrians directly front of them, and one indicates that pedestrians are influenced by movement in a 360-degree region surrounding pedestrians..

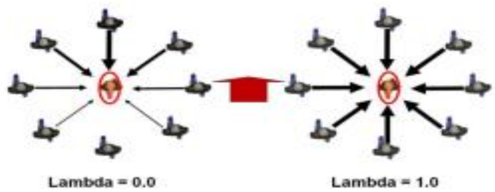

Fig 8. Illustration of the influence of lambdha values

The results indicated a strong correlation between lamdha and speed levels. In the morning peak hours, speed decreases as lamdha grows; in other peak hours, speed increases as lamdha increases. The default value of 0.176 is regarded to have minimal effect on the movement of pedestrians behind him except for the pedestrian in front of him. It can be anticipated that pedestrians will be alert in the morning when the pedestrian way is vacant. That example, the hazard posed by pedestrians will be greater if they are strolling on deserted sidewalks. While pedestrians are safer in the afternoon and evening owing to the throng, the greater the value of lamdha, the safer pedestrians are. Quick. Additionally, with lamdha levels of zero to 0.5, the anticipated speed change is not significant throughout the day. This demonstrates that pedestrians share a similar impression of pedestrians behind them. When lamdha exceeds 0.5, the required speed begins to decrease. This is because pedestrians adhere to the leader-follower idea, in which they opt to follow the actions of individuals who are seen to provide them with a sense of security and protection. pedestrians. While in the afternoon, the tighter the current, particularly the opposing current, the more people will attempt to avoid passing or walking. Faster. This is consistent with[20]which asserts that the greater the value of lamdha in two directions, the greater the effect on the road's speed. It is becoming quicker, to the point that, despite the density caused by high traffic, walkers are nevertheless able to alleviate congestion that develops swiftly.

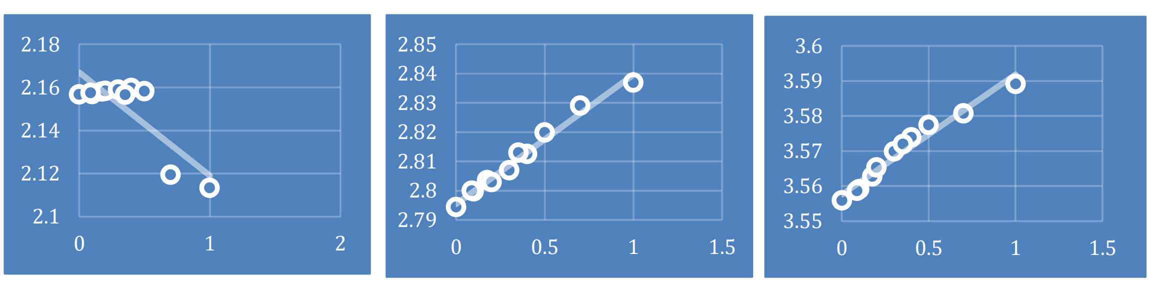

Fig 9. Desired speed for lamdha value of morning conditions (left), noon(center), and afternoon

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(right)

The relevant equation may be anticipated visually based on the movement of the observation point. The table below contains the linear equations for each condition. The model match number for the entire equation approaching one shows that the required speed increases linearly with the lamdha value. The results indicated that the afternoon circumstances had the least linear range of required speed when compared to other situations. While the morning has the steepest gradient.

4.5. VD parameters

The VD parameters will influence how long it takes pedestrians to avoid being approached by other pedestrians. Walking in perspective requires a certain amount of time to move away from the pedestrian in front of him, particularly in adverse weather. Given that the ethical value of VD is more than zero empirically, the relative speed of pedestrians crossing must be considered when determining the desirable speed [20]. Empirically, this calculation is found by generalizing the distance d and substituting the following formula,

$$d_{a,01} = \left|\left(\vec{x}_0 + \vec{v}_0 VD\right) - \left(\vec{x}_1 + \vec{v}_1 VD\right)\right| = \left|\overrightarrow{d_{01}} + \vec{v}_{rel,01} VD\right|$$

Where, d_{01} is the existing distance between 2 pedestrians 0 and 1, $d_{a.01}$ is the distance ekspektasi between 2 pedestrians in a VD base in seconds, if both are at a constant speed. Modifications to the VD settings have a significant influence on pedestrian speed. When the VD parameters are set too high, people will move too rapidly to avoid colliding with pedestrians ahead of them with a predefined distance equal to the grid size. If it is too narrow, the pedestrian will be unaware of other pedestrians approaching him, creating the chance of collision. This tendency is connected to pedestrian speed; when pedestrians move fast to avoid, their speed will also be linear, allowing them to swiftly avoid people who are crossing. This is seen in the graph below, where the greater the VD value, the higher the desired speed. This, however, contradicts prior study by [31]who concluded that the change in VD values had no effect on desired speed. This might be because the study was conducted in Indonesia, a poor nation, whereas Lagervall and Samuelsson were conducted in 2014. He performed his investigation in Sweden's foothills, a prosperous nation. Additional study is required to determine the variances in pedestrian behavior throughout the country.

As previously stated, the connection between VD parameters and required speed with slope (gradient) is positive. In terms of traffic behavior, this pedestrian conduct corresponds to a hindrance time comparable to the crossing waiting time. Pedestrians will alter the features of their movement by veering in the direction of approaching pedestrians. Visually, the change in VD values to achieve the required speed is as follows:At a minimum value of one, the same desired speed value is at the lowest speed for all conditions.

1. Significant desirable value changes occur in the range of 1 to 2.5 seconds in the morning, 1 to 2 seconds during the day, and 1 to 3 seconds in the circumstances Afternoon.

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2. The change in desired speed value rises, but only in landau circumstances between 3 and 7 a.m., a value of 2 to 2.5 in daylight conditions, and a value of 3.5 to 7 in afternoon conditions.
3. Especially for daytime situations with a higher volume than morning and nighttime conditions, the value of there is a substantial change in desirable speed values between 3.5 and 4 seconds, before reverting to 4.5 to 7 seconds.

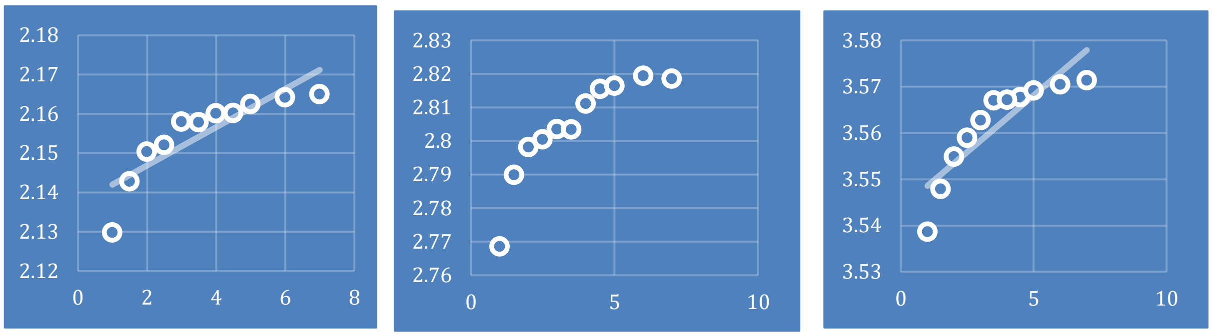

Fig 10. Desired speed for VD values morning conditions (left), noon(center), and afternoon (right)

4.6. Gridsize Parameters

By adjusting the size of each cell, grid size parameters specify the maximum distance between a pedestrian and another passerby who has an effect on him. Essentially, grid size parameters are not displayed as pedestrian behavior characteristics, but rather as factors that govern the efficiency of calculating algorithms. However, upon closer examination, this value is a pseudo-value over the footnotes included inside the eight squares around the main box, which will confer social power on someone[20], [32].

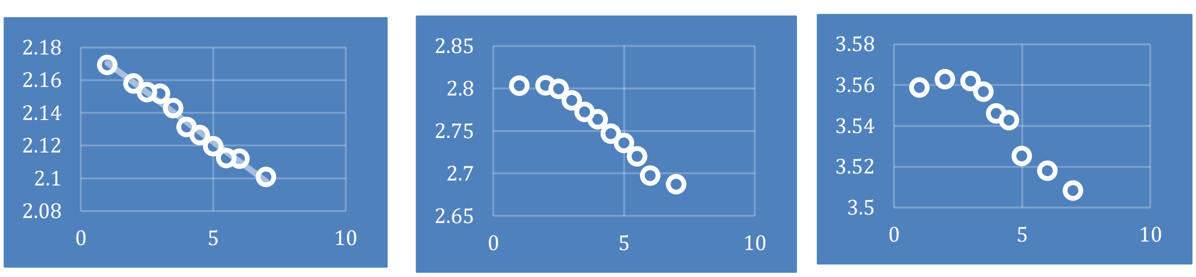

Fig 11. Desired speed for grid size values morning conditions (left), noon(center), and afternoon (right)

This is demonstrated in study by the fact that as the grid size increases, the required speed value decreases. This is due to a combination of pedestrian awareness and the accumulation of social force models that occurs in big grid sizes. On the other hand, if the grid size settings are set too tiny, people will respond more slowly to other pedestrians or nearby objects, increasing the speed attained. On the other hand, if the grid size is large, pedestrians' speed will be reduced owing to the number of accumulated social force models that arise.

The relevant equation may be anticipated visually based on the movement of the observation point. The table below contains the linear equations for each condition. The model match number for the full equation approaching one shows that the anticipated speed connection with the grid size increase is linear with a negative slope. A significant chart tilt value indicates a wide intended speed range. The results indicated that in the afternoon, desired speed has a smaller linear range than in the morning or afternoon. This implies that, even when the number of social force models increases, pedestrians respond more to following the current crowd in the afternoon. This is represented by a slight gradient according to the intended speed of travel. This is in contrast to daylight situations, where pedestrians are extremely sensitive to pedestrians when the amount of pedestrians is great (during the busiest peak hour conditions). the throng and sought to respond more variably, as evidenced by the biggest chart tilt. High volume throughout the day is also one of them, owing to the variety of activities that take place surrounding pedestrians, such as shopping centers or other side barriers. This is reinforced by the statement[33]which argues that sidewalk vendor activity (street vendors) has an effect on how pedestrians respond in a city.

5 CONCLUSION

Microscopic simulation models based on Social Forces have been frequently utilized to study pedestrian behavior on pedestrian routes. The simulation model will be beneficial for evaluating alternate planning techniques for pedestrian paths. Each pedestrian behavior characteristic has an effect on pedestrian speed in its own way. Certain factors, such as tau, Asociso, Lamdha, and grid size parameters, have a linear effect. For future study, this tiny model may be utilized to plan the design until the pedestrian path's upkeep can be evaluated in greater depth. This is because the path's design and maintenance will be tailored to the characteristics of pedestrians who are more in tune with field circumstances.

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