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# Macroscopic Pedestrian Behaviour During Room Evacuation

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**Abstract –** *The macroscopic pedestrian behaviour was studied under this research work with major focus on interaction between the pedestrians. For this purpose, evacuation experiments were conducted on groups of students, with difference in age and educational level. The speed of the pedestrians was recorded to know the difference in their behavior was made on the pedestrian behaviour changes with change in age and education along with many other factors. This paper gives comparison of the pedestrian behaviour during evacuation based on age and educational level of the pedestrians.*

**Key Words:** Macroscopic, Pedestrian Behaviour, Evacuation, Age, education

## 1.INTRODUCTION

Pedestrian walking is one of the most important parameters and it is very important to estimate the number of pedestrian and their behaviour before designing any facility such as footpath, stadium, train station, etc. [1], [2]. The pedestrian
behaviour changes under different circumstances and evacuation of pedestrian facility is a challenging task during emergency situation [3], like natural disaster and man-made disaster [4] and even in overcrowded places at different facilities, especially at transport stations, high-rise buildings, educational institutions, shopping centers where human gather on daily basis [5]. When people gather at one place in a closed space like theatre, classroom, seminar hall etc., situations may arise where emergency evacuation of close amenities is required but due to design of buildings with inadequate exits and
the panic behaviour of pedestrian, the egress get block often leads to pedestrian being crushed . The fear of pedestrian due to the out breake of the pronimemt disaster everyone in the building tries to escape the danger, that result in change in behaviour of the pedestrians, during this emergency [6]. However, the different pedestrian behaviour like self organizing [7],
group behaviour [8], [9] of pedestrian, transition in walking speed [38], have been studied by various researchers. The behaviour is affected by both physiological and psychological behaviour of the surrounding traffic [37].

Pedestrians dynamic is one of the most interesting area for researchers, especially during emergency evacuation, and is significant interm of planning or organizing the process of evacuation in emergency [10]. The number and with of egress for safe and efficient evacuation and estimation of occupancy of public amenities like subway stations, transportation terminals, shopping center, etc. is significant in designing such amenities [11], [12], [5]. Howevr, during design stage the egress may be predicted with simulation of pedestrian behaviour with different models proposed by different researchers [13].

Many simulation models have been developed and software packages for simulating pedestrian behaviour. These models can be classified based on level of detail (macroscopic / mesoscopic / microscopic). Macroscopic models take the crowd as whole such as fluid-dynamic models [14] theoretical macroscopic model approach [15]. In microscopic model, the individual characteristics are considered, such as individual interactions, direction and speed and interaction with the surrounding environment or building structure [16],[17].

In late 80s, Craig W. Reynolds studied the collective motion of flock of birds, herd of animals studied and presented simulation of his work [18].

It is very difficult and costly to perfom actual studies on crowd to know its dynamic that is why crowd modelling and simulation is used as alternative in many
fields such as safety engineering, architecture, civil engineering, computer games, [19]. Different approaches have been used for crowd modelling since the last decade some of them are :

1.1 Flow Based Approach:

In the flow-based approach the crowd is considered
as whole as a continuous flow of some fluid. The environmental impact with respect to the crowd is considered by vector field while crowd movement is considered by differential equations. However, the dissimilarity of crowd from a usual fluid is the property that a crowd has the capability of thinking of interesting new physical ideas that control their behaviour [20]

1.2 CA Model-Cellular Automata Model

The Cellular Automata model (CA Model) was first developed in 1940s by Neumann and Burks [21] to study biological reproduction [22]. The CA Model is widely used in many research areas for modelling complex processes [23], especially in traffic flow dynamics [24], [25]. However, CA model is not used much
for the pedestrian modelling [26].

The CA Model consider uniform grid of cells where individuals had the ability to move into a connecting free cell. [27], and its approach is to minimize
the contact between the agents.

1.3 SF Model-Social Force Model

The Social Force Model (SF), a part of microscopic model is popular choice of researcher to model pedestrian behaviours [28]. This model is based on Newtonian mechanics and was first proposed by Helbing [29] to study the pedestrian behaviour.

It produces realistic movements in simulations by taking the individual characteristics into account, such as pedestrian speed, destination, physical interaction with each other and can replicate pedestrian collective behaviour in nature, for example the lane formation [30],[31], the stripe formation [32], the oscillations at bottlenecks [30] the faster is slower effect , the clogging effect, the herding and ignoranceof available exits and the freezing by heating [30].

1.4 Emergency Building Evacuation

Emergency is an event, actually happened or imminent to happen, which endangers or threatens to endanger life, property, or the environment and which require significant and coordinated response [33]. It is very important to have well established evacuation plan and consider this during design phase of building. When an emergency such as a fire, earthquake, terrorist attack, flood, breaks out the occupants try to evacuate the building and at this time most of the evacuee loss their temper, that why their behaviour changes.

To handle the situation and to respond to the situation there is a person called incident commander, who is familiar with the plan and prepared to handle the situation and is responsible for efficient coordination and allocation of resources [34]. Moreover, the occupants must be familiar with the plan and the egress so that they escape quickly and as safely as possible.

4. Evacuation Rehearsal

With the increasing number of population huge number of people of gather at one place like educational institution, shopping places, religious building. Most often the emergency situation arises during such gathering of people at one place, where emergency evacuation is required. During emergency evacuation due to fear of the danger of natural or man-made hazard, the evacuees are rushing toward egress [35]. Therefore, the pedestrians push each other to escape the danger. However, if they have the the knowledge and is in use to the evacuation plan of

building then the evacuation process is smooth and fast [36].

### 3. Analysis

Cadence (steps/s) and velocity (m/s) recorded for different group of pedestrians during the experiments under normal and emergency condition have been analyzed.

Regression analysis is used for estimation of dependence of one variable (dependent variable) with the other variable (independent variable), this relationship may be linear, non-linear, or multiple regression for complex problem. Regression analysis gives the relationship of an independent variable on a dependent variable and give how is percentage of total variation in the dependent variable that is accounted for by the independent variable, whether it is straight line or quadratic. Moreover, it tells that how the regression line fits the data ('goodness of fit') $R^2$, the coefficient of determination, and its value varies between 0-1 that from 0 to 100 percent. Further statistical analysis can be achieved with multiple regression analysis.

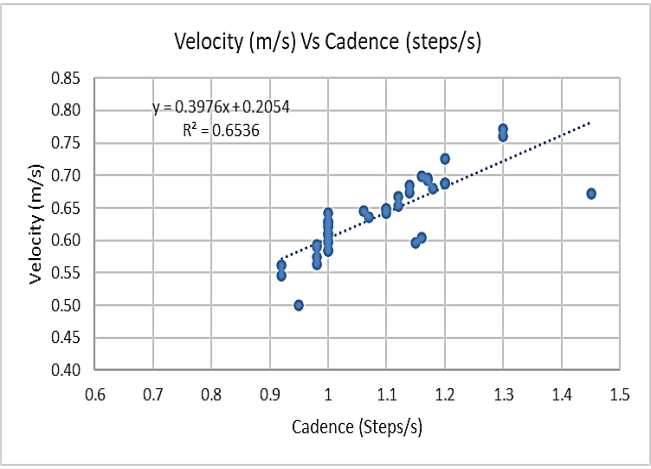



Figure 1: Velocity and cadence analysis, regression coefficient $R^2$ = 0.6536 for linear regression y = 0.3976x +0.2054.

From Figure 1, which shows velocity Vs Cadence plot for a group of pedestrians under normal evacuation. The dots show actual observations taken during experiments, the value of the R2 shows that how is fitting of the data into the regression line, which in this case is moderate. For the linear regression line R-square value is $R^2$ = 0.6536. However, for changing trend line from linear to quadratic the R-square value changes $R^2$ 0.7426 as given in Figure 2, that is the value of R-square increases this means that it is quadratic variations. Similarly, the equation of y changes from linear to quadratic equation.

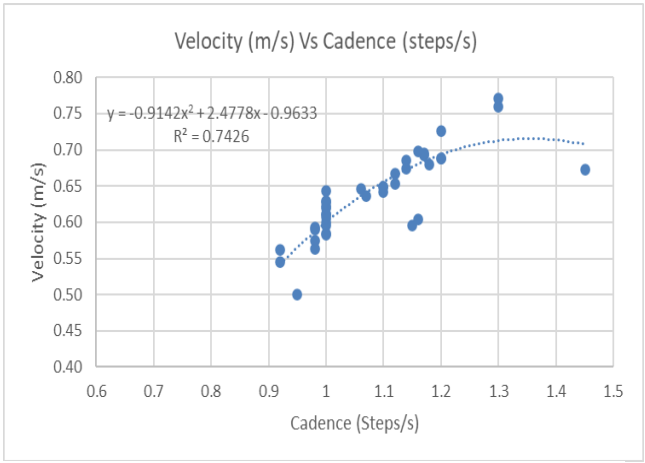



Figure 2: Velocity and cadence analysis, regression coefficient $R^2$ = 0.7426 for quadratic regression $y = 0.9142x^2 + 2.4778 x + 0.9633$.

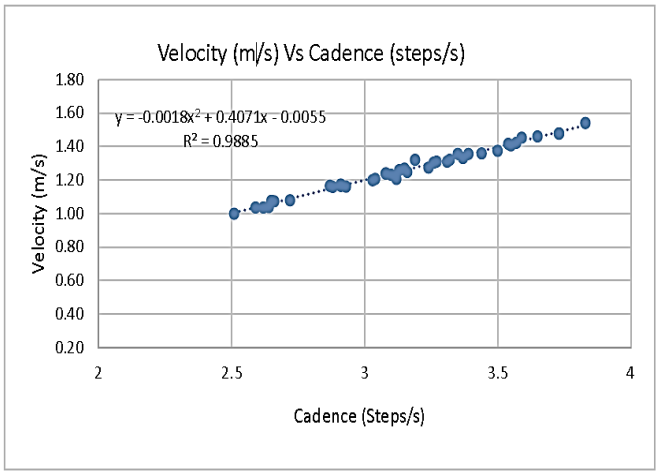



Figure 3 : Velocity and cadence analysis, with regression coefficient R2 = 0.9885, and equation of line y = -0.0018x2 + 0.4071x - 0.0055 for experiment II.

From Figure 3, which shows velocity Vs Cadence plot. The dots show actual observations, the value of the R-Square show that how is fitting of the data into the trend line for experiment II, that is for emergency evacuation, which in this case R-square value is strong that is it is very close to 1,that is with $R^2$ = 0.9885, and equation of line y = -0.0018x2 + 0.4071x - 0.0055.

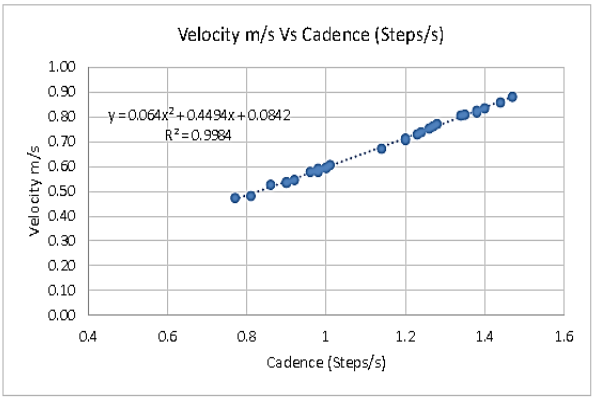
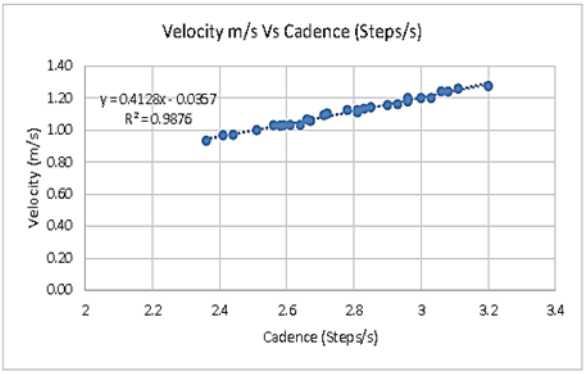



Figure 4: Velocity and cadence analysis, regression coefficient $R^2$ = 0.9984, and equation




y = 0.064x2 + 0.4494x + 0.0842 experiment IV.
Figure 5: Velocity and cadence analysis, regression coefficient $R^2$ = 0.9876, and equation
y = 0.4128x - 0.0357 experiment IV.

From Figure 4 & Figure 5, which shows velocity Vs Cadence plot. The dots show actual observations, the value of the R-Square with $R^2$ = 0.9984, and equation y = 0.064x2 + 0.4494x + 0.0842 for experiment-III and $R^2$ = 0.9876, and equation y = 0.4128x - 0.0357 for experiment-IV and show that how is fitting of the data into the trend line which in this case is strong , as it is very close to 1.

## 4. CONCLUSIONS

In this study it was found that the behaviour of pedestrian changes with the change in the surrounding conditions, especially during emergency evacuation. Different scientists have developed different mathematical models for different scenarios, that is used to simulate the behaviour of pedestrians. Therefore, it is essential to analyze the behavior of pedestrians during planning and designing pedestrians faciality, by using the models to simulate the pedestrian behaviour to accommodate for emergency conditions. For educational institutions evacuation rehearsals make the students familiar and use to the egress plan.

## REFERENCES

[1] I. von Sivers and G. Köster, "Dynamic stride length adaptation according to utility and personal space," *Transp. Res. Part B Methodol.*, vol. 74, pp. 104–117, 2015.

[2] Y. Zhang, Y. Li, C. Peng, D. Mou, M. Li, and W. Wang, "The height-adaptive parameterized step length measurement method and experiment based on motion parameters," *Sensors (Switzerland)*, vol. 18, no. 4, 2018.

[3] N. Shiwakoti, M. Sarvi, G. Rose, and M. Burd, "Animal dynamics based approach for modeling pedestrian crowd egress under panic conditions," *Transp. Res. Part B Methodol.*, vol. 45 `, no. 9, pp. 1433–1449, 2011.

[4] A. J. Pel, M. C. J. Bliemer, and S. P. Hoogendoorn, "A review on travel behaviour modelling in dynamic traffic simulation models for evacuations," pp. 97–123, 2012.

[5] S. A. H. Al-gadhi, "REVIEW ARTICLE A Review Study of Crowd Behavior and Movement," *J. King Saud Univ. Eng. Sci.*, vol. 8, no. 1, pp. 77–107, 1996.

[6] A. Journal, "The Nature and Conditions of Panic Author ( s ): E . L . Quarantelli Published by : The University of Chicago Press Stable URL : http://www.jstor.org/stable/2772684 . Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use," vol. 60, no. 3, pp. 267–275, 2015.

[7] D. Helbing, P. Molnár, I. J. Farkas, and K. Bolay, "Self-organizing pedestrian movement," *Environ. Plan. B Plan. Des.*, vol. 28, no. 3, pp. 361–383, 2001.

[8] L. Cheng, R. Yarlagadda, C. B. Fookes, and P. K. Yarlagadda, "A review of pedestrian group dynamics and methodologies in modelling pedestrian group behaviours," *World J. Mech. Eng.*, vol. 1, no. 1, pp. 2–13, 2014.

[9] M. Moussaïd, N. Perozo, S. Garnier, D. Helbing, and G. Theraulaz, "The walking behaviour of pedestrian social groups and its impact on crowd dynamics," *PLoS One*, vol. 5, no. 4, pp. 1–15, 2010.

[10] L. Lian *et al.*, "Pedestrian merging behavior analysis : An experimental study," *Fire Saf. J.*, no. February, pp. 1–8, 2017.

[11] S. C. Moore, M. Flajšlik, P. L. Rosin, and D. Marshall, "A particle model of crowd behavior: Exploring the relationship between alcohol, crowd dynamics and violence," *Aggress. Violent Behav.*, vol. 13, no. 6, pp. 413–422, 2008.

[12] R. Tomastik, S. Narayanan, A. Banaszuk, and S. Meyn, "Pedestrian and Evacuation Dynamics 2008," *Pedestr. Evacuation Dyn. 2008*, 2010.

[13] X. Pan, C. S. Han, K. Dauber, and K. H. Law, "Human and social behavior in computational modeling and analysis of egress," *Autom. Constr.*, vol. 15, no. 4, pp. 448–461, 2006.

[14] L. F. Henderson, "The statistics of crowd fluids," *Nature*, vol. 229, no. 5284, pp. 381–383, 1971.

[15] M. Hilliges and W. Weidlich, "A phenomenological model for dynamic traffic flow in networks," *Transp. Res. Part B*, vol. 29, no. 6, pp. 407–431, 1995.

[16] D. Yanagisawa, A. Tomoeda, and K. Nishinari, "Improvement of pedestrian flow by slow rhythm," *Phys. Rev. E - Stat. Nonlinear, Soft Matter Phys.*, vol. 85, no. 1, pp. 1–5, 2012.

[17] A. . Fallis, "Modelling Pedestrian Behaviour in Downtown Shopping Areas," *J. Chem. Inf. Model.*, vol. 53, no. 9, pp. 1689–1699, 2013.

[18] C. W. Reynolds, "Flocks, herds, and schools: A distributed behavioral model," Proc. 14th Annu. Conf. Comput. Graph. Interact. Tech. SIGGRAPH 1987, vol. 21, no.July, pp. 25–34, 1987. doi:10.1145/37402.37406

[19] S. Zhou et al., "Crowd modeling and simulation technologies," ACM Trans. Model.Comput. Simul., vol. 20, no. 4, 2010. oi:10.1145/1842722.1842725.

[20] R. L. Hughes, " The Flow of Human Crowds ," Annu. Rev. Fluid Mech., vol. 35, no.1, pp. 169–182, 2003. doi:10.1146/annurev.fluid.35.101101.161136

[21] [78] A. W. and others Von Neumann, John and Burks, "Theory of self-reproducingautomata," IEEE Trans. Neural Networks, vol. 5, no. 1, pp. 3–14, 1966.doi:10.1126/science.157.3785.180 doi:10.1006/jtbi.1993.1007

[22] G. B. Ermentrout and L. Edelstein-Keshet, "Cellular automata approaches to biological modeling," J. Theor. Biol., vol. 160, no. 1, pp. 97–133, 1993. doi:10.1006/jtbi.1993.1007

[23] B. Chopard, "Cellular automata and lattice boltzmann modeling of physical systems," Handb. Nat. Comput., vol. 1–4, pp. 288–331, 2012. doi:10.1007/978-3540-92910-9_9

[24] M. Fukui, and Y. lshibashi, "Traffic Flow in lD Cellular Automaton Model Including Cars Moving with High Speed," J. Phys. Soc. Japan, vol. 65, no. 6, pp. 1868–1870, 1996. doi:10.1143/jpsj.65.1868

[25] K. Nagel and M. Schreckenberg, "A cellular automaton model for freeway traffic,"Journal de Physique I, vol. 2, no. 12, pp. 2221–2229, Dec. 1992. doi:10.1051/jp1:1992277

[26] M. Muramatsu, T. Irie, and T. Nagatani, "Jamming transition in pedestrian counter flow," *Phys. A Stat. Mech. its Appl.*, vol. 267, no. 3, pp. 487–498, 1999.

[27] C. M. MacAl and M. J. North, "Tutorial on agent-based modelling and simulation,"J. Simul., vol. 4, no. 3, pp. 151–162, 2010. doi:10.1057/jos.2010.3

[28] L. Wang, J. H. Zheng, X. S. Zhang, J. L. Zhang, Q. Z. Wang, and Q. Zhang,"Pedestrians' behavior in emergency evacuation: Modeling and simulation,"Chinese Phys. B, vol. 25, no. 11, pp. 1–17, 2016. doi.org/10.1088/16741056/25/11/118901

[29] D. Helbing and P. Molnár, "Social force model for pedestrian dynamics," Phys. Rev.E, vol. 51, no. 5, pp. 4282–4286, 1995.doi:10.1103/physreve.51.4282

[30] A. F. Aveni, "The Not-So-Lonely Crowd: Friendship Groups in Collective Behavior," Sociometry, vol. 40, no. 1, p. 96-99, 1977. doi: 10.2307/3033551

[31] Helbing, Dirk & Johansson, Anders & Al-Abideen, Habib.. Dynamics of crowd disasters: An empirical study. Physical review. E, Statistical, nonlinear, and soft matter physics. vol. 75, pp. 046-109 ,2007. doi: 10.1103/PhysRevE.75.046109

[32] N. Candappa, N. Fotheringham, M. Lenné, B. Corben, C. Johansson, and P. Smith,"Evaluation of an Alternative Pedestrian Treatment at a Roundabout,"

pp.110,2005.url:https://www.researchgate.net/publication/263047484_Evaluation_of_an_alternative_pedestrian_treatment_at_a_roundabout

[33] A. N. Khan, Introduction to hazards and disasters. Al-Azhar Environmental Planning and ManagementCenter(AEPMaC), Peshawar Pakistan, 2016.

[34] N. Dimakis, A. Filippoupolitis, and E. Gelenbe, "Distributed building evacuation simulator for smart emergency management," Comput. J., vol. 53, no. 9, pp. 1384–1400, 2010. doi:10.1093/comjnl/bxq012

[35] D. Helbing, I. Farkas, and T. Vicsek "Simulating dynamical features of escape panic", Nature, vol. 407, pp. 487–490, 2000. doi.org/10.1038/35035023.

[36] K. J. Zhu and Q. Shi, "Experimental Study on Choice Behavior of Pedestrians during Building Evacuation," Procedia Eng., vol. 135, pp. 206–215, 2016.doi:10.1016/j.proeng.2016.01.110

[37] Z. H. Khan, T. A. Gulliver, and k. Azim. K. S. Khattak, "Macroscopic Model on Driver Physiological and Psychological Behavior At Changes In Traffic." J. Engg. and Appl. Sci. Vol.38 No,2 July-December 2019.

[38] Khan, Zawar H., and T. Aaron Gulliver. "A Macroscopic Traffic Model Based on Transition Velocities." Journal of Computational Science 43 (May 2020): 101131.