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Development Of Microscopic Pedestrian Model For Urban Emergency Preparedness Using PARAMICS

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***Abstract*— In this study the use of traffic simulation as a tool for evaluating various strategies and designing various signal models and also implementing pedestrian model in response of emergency situations is considered and briefed. This paper presents a traffic simulation approach for evaluating the pedestrian behaviour by developing a model which includes pedestrians in a vehicular micro-simulation model i.e. PARAMICS. This study is based on testing of the prototypes and actual signs in order to determine if they convey the desired message in the desired time. This will let the users know the usability of their signs and make them reach the desired safe destination easily. In this report, pedestrian characteristics during emergency are also studied using suitable pedestrian model (eg: Fruins pedestrian model). Application of this car-following algorithm demonstrated by calibrating in PARAMICS will be very useful in predicting known pedestrian speed-flow relationship. The model is developed especially to enhance the complex interaction between pedestrians and vehicles. This study indicates the importance of additional factors (i.e., Pedestrian queue discharge rate, Pedestrian gap acceptance, Pedestrian speed) which is to be related with the vehicle flow. It also shows the effort to better understand pedestrian level of service under various conditions. The high variability in data sets confines the simulation resulting in a constant queue discharge rate at flows approaching saturated conditions. This work finally concludes that PARAMIC'S car-following algorithm is very much helpful in reproducing vehicle and pedestrian flow in complex as well as heterogeneous urban traffic.**

Keywords— Emergency Preparedness, Car-following, Pedestrian, Microscopic Traffic Simulation, Calibration, Validation, PARAMICS

I. Introduction

We are dealing with many natural and man-made disasters. These hurricanes, cyclones, tsunamis, floods, large storms, terrorist attacks, industrial accidents, and many similar hazards cause massive economic and social damage as well as loss of lives every year. Emergency preparedness is one of the major and often preferred protective action options available for emergency management in times of threat to the general public.

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Since last decades, research of pedestrian traffic flows has only been given limited attention till now, visualizing and analysing pedestrian flow is also very important. Transportation plays a vital role in emergency process and it solves the communication difficulties with the public which were significant. Microscopic pedestrian model will be helpful in studying the characteristics of pedestrian flow in such emergency situations. Many states are combining emergency evacuation transport facilities and resources in for its hazard preparedness planning's.

Emergency preparedness mainly involves the preparation of detailed plans that can be implemented in response to a variety of possible emergencies or disruptions to the transportation system. Microscopic pedestrian models will be very helpful to gain more information about pedestrian behaviour in emergency situations. However in the case of pedestrian there will be a lot of issue regarding the space allocation for pedestrian in pedestrian facilities. Since, there has been an increase in evacuation planning, current best practices include the need to use multi-modal transportation networks for evacuating people out of the affected area. More complex evacuation planning has to be considered for large scale evacuation within much stipulated time without causing any problem to the public.

The paper includes both pedestrian and vehicle flow by Ishaque et al [1], so it is important to analyse the real world condition of both as close as possible. In this paper the pedestrian level of service is calculated using Fruin [2] which is predominantly for city streets. These evacuation methods enhance the understanding of the scope and magnitude of the disruptions and their application to the transportation of people and goods in the transportation system.

II. Study Stretch

The area considered in this report is Mangalore city (Lalbagh junction to Hampankatta junction) a total stretch of 3.4 km with 2 signalized intersection and 2 major non-signalized intersection. The study area also consists of 18 evacuation routes connecting to the study stretch. As we know Mangalore Port is India's ninth largest port, in terms of cargo handling and consists of huge Industrial belt including petrochemical, fertilizers, and boat building industries. That's why at an average more than 20,000 heavy vehicles travel in Mangalore. (Wikipedia, Mangalore City) Major information technology and IT companies have established a presence in Mangalore due to which a huge amount official persons are been transported over area of 200 km2 (77.22 sq. mi).

III. Data Collection

The research site selected for this paper is a signalized intersection having large number of pedestrian and vehicular flow interaction, which is decided based on the pedestrian flow data from Mangalore Urban Development Authority. The signalized intersections at Ambedkar circle and Hampankatta circle and unsignalized intersection at Bunts circle of Mangalore city were considered. There are multiple lanes which can be used by all types of vehicles. The speed limit is 50km/hr.

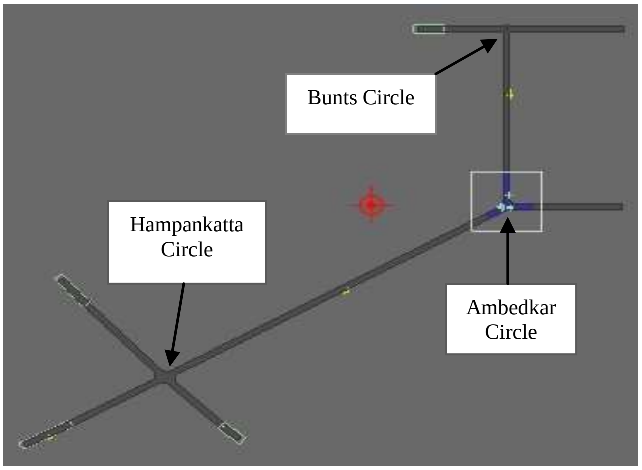

Figure 1. Road network as coded in PARAMICS

The area considered forms an important interchange for public transport, commercial complexes, hospitals, hotels and Cineplex. Two major bus stops are present within the study area i.e. one near Ambedkar circle and the other near Hampankatta circle. Figure 1 shows the study area considered in this paper.

A. *Flows & Vehicle Travel Times*

Apart from vehicular and pedestrian interaction, vehicular traffic may also be in conflict with pedestrian crossing at the intersection. Data collection from the site for both vehicle and pedestrian traffic is very important in order to represent traffic flow in micro simulation. Data on vehicle travel time, pedestrian flow, vehicle flow were simultaneously collected at three locations 1300 m and two signalized intersections for two days in Jan, 2014. One of the two days is weekday and the other is Sunday. Data were collected in those locations using two video cameras each in every location.

As in India it is a mixed traffic condition, since heterogeneous or mixed traffic systems operate very differently, compared to homogeneous traffic systems. The traffic in mixed flow is comprised of fast moving and slow moving vehicles or motorized and non-motorized vehicles. The vehicles also vary in size, maneuverability, control and dynamic characteristics. Traffic is not segregated by vehicle type and therefore, all vehicles travel in the same right of way. Smaller size vehicles often squeeze through any available gap between large size vehicles and move in a haphazard manner; therefore cameras were focused on each and every vehicle number plates. The vehicle flow on Bunts Circle and Hampankatta Circle for both weekday and Sunday is shown in Table 1.

TABLE 1. VEHICLE FLOWS PER HOUR FOR THROUGH TRAFFIC

Date	Bunts Circle Intersection	Hampankatta Circle Intersection
Sun, Feb 09 2014	1864	2047
Mon, Feb 10 2014	1971	2139

Pedestrians moving in opposing directions on the pedestrian crossing separately. The pedestrian flow data is enlisted in Table 2.

TABLE 2. HOURLY PEDESTRIAN FLOWS AT AMBEDKAR AND HAMPANKATTA CIRCLE INTERSECTIONS FOR TWO DAYS

Date	Ambedkar Circle Intersection			Hampankatta Circle Intersection		
	South bound	*North bound*	*Total*	*South bound*	*North bound*	*Total*
Sun, Feb 09,2014	297	231	528	279	361	640
Mon, Feb 10,2014	317	269	586	457	612	1109

The traffic composition was observed from the video recordings and is listed in Table 3.

TABLE 3. HOURLY VEHICLE COMPOSITION OF THROUGH TRAFFIC AT BUNTS CIRCLE INTERSECTION

Date	2-Wheeler	3- Wheeler	4-Wheeler	Bus
Sun, Feb 09,2014	899	255	544	166
Mon, Feb 10,2014	951	269	575	176

Vehicle composition were matched form each camera and the travel time is calculated. The effective travel time taken by the vehicle is shown Table 4.

TABLE 4. VEHICLE COUNTS FOR WHICH TRAVEL TIMES WERE MEASURED

Date	Number of Vehicles Captured	Capture Duration (min)	Volume Capture (%)
Sun, Feb 09, 2014	278	60	13
Mon, Feb 10,2014	331	60	15

B. *Vehicle Queue Discharge Rate*

Determining the saturation flow rate can be a somewhat complicated matter. The saturation flow rate depends on roadway and traffic conditions. The saturation flow rate is a fundamental parameter to measure the intersection capacity and time the signalized intersections. It is also important that the vehicle is not affected by any blocks in the downstream from the position they are starting. The saturation flow rate is normally given in terms of straight-through passenger cars per hour of green. Vehicle headways were then measured between the fifth and tenth vehicle leaving the stop line. Vehicle headway obtained from the observations is 2.17 sec. Based on this vehicle headway value; saturation flow rate calculated using the procedure given by Turner *et al* [3] is 1659 PCU per lane per hour.

C. *Pedestrian Speeds*

The most relevant parameter that can have a direct impact on the speed results of pedestrians is the desired speed distribution as studied by Willis *et al* [4]. From the video obtained from site pedestrian free flow speed has taken into considerations. Pedestrian travel time is measured, at the instant pedestrian stepping off at the first curb to stepping onto the opposite curb. The length of the pedestrian crossing was 14m onsite. The sample collected is not mentioned in separate age groups. The disaggregated result of pedestrian flow is shown in Table 5.

TABLE 5. PEDESTRIAN SPEED STATISTICS

Gender	Sample Size	Mean Speed (km/hr)	Standard Deviation
Male	182	4.58	0.4097
Female	151	4.25	0.3387

IV. Network Coding

The road network was coded in PARAMICS considering all the road features and keeping map obtained from Google map on the background as layout. These features included such as location and width of pedestrian crossings, width and length of central medians at staggered crossings, vehicle stop lines, and location of bus stops. All major and minor streets crossing or joining the network is also coded in PARAMICS.

Pedestrian origins and destinations were coded so that pedestrians either walked only along or across Ambedkar circle. As our main aim is to study the interaction between pedestrians and vehicles and validate this in PARAMICS, we are not concerned with actual destinations.

Dimensions for buses, cars, 2-wheeler, and 3-wheeler were obtained from the data obtained from Mangalore Urban Development Authority as well as through field observations. Vehicle desired speed were also considered while network coding and their speed distribution are shown in Table 6.

TABLE 6. PERCENTAGE DISTRIBUTION OF VEHICLE SPEEDS

Speed Range (kmph)	2 - Wheeler	3 - Wheeler	4 - Wheeler	Bus
< 30	51	63	47	69
30 - 45	37	29	38	27
45 – 60	12	08	10	04
>60	00	00	05	00

V. Calibration of Vehicle flow

The data collected on weekday is calibrated using PARAMICS. The driving behaviour in PARAMICS is defined by a number of parameters that control the car-following behaviour, lateral position, lane-changing behaviour, and driver reaction to traffic lights. Most microscopic traffic simulation models have the property to represent random variations in the behaviour of the simulated traffic.

In microscopic models this randomness, is used in many of the simulated processes. Since the simulation has these random processes as components, several runs are required to generate valid predictions. Therefore, for this project we have run every simulation scenario 20 times. Our simulations have duration of 1 real hour for each run. From the weekday data travel time graph is plotted considering both observed and simulated travel time for each category of vehicle. This graph is shown in Figure 2.

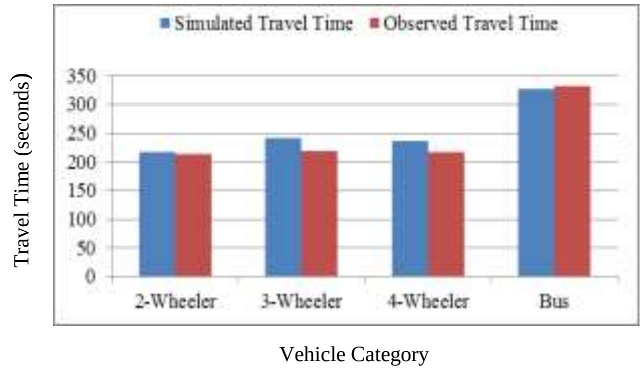

Figure 2. Travel time plots from multiple PARAMICS runs and weekday data

The result for statistical correlation obtained using Pearson's Correlation Coefficient shows a very strong relation between the PARAMICS runs and weekday field data. The statistical correlation results are shown in Table 7.

TABLE 7. CORRELATION BETWEEN MEAN OF FIELD TRAVEL TIME DATA OF WEEKDAY AND 10 PARAMICS RUN MODEL USING PEARSON'S CORRELATION COEFFICIENT

	PARAMICS Run	Field Data
Correlation Coefficient	1.00	0.91
Significance (2-tailed)		0.00
N	19	19

VI. Validation of Vehicle Flow

The travel time data obtained from Sunday is used for validation of vehicle flows. The major difference observed between Sunday data and weekday data was traffic composition. Data collected on Sunday was having low proportion of 2-wheeler, 3-wheeler, 4-wheeler and buses as compared to the weekday data. The travel time graph shown in Figure 3 indicates both observed and simulated travel time obtained from Sunday data.

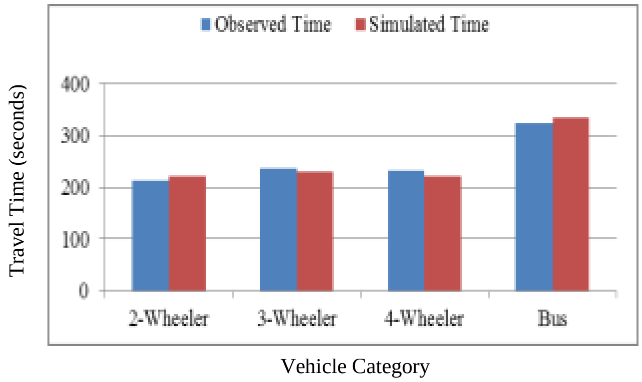

Figure 3. Vehicle travel time plots from multiple PARAMICS runs and Sunday data

These differences were not a cause of concern due to the expected day-to-day variation in the time ranges. Sacks *et al* [5] shows statistical tests were performed for validation same as performed for calibration of vehicle flows, to check correlations and significance of the difference in means. A strong correlation coefficient between the mean of 10 PARAMICS run and the Sunday data was found and shown in Table 8.

TABLE 8. CORRELATION BETWEEN MEAN OF FIELD TRAVEL TIME DATA OF SUNDAY AND 10 PARAMICS RUN MODEL USING PEARSON'S CORRELATION COEFFICIENT

	PARAMICS Run	**Field Data**
Correlation Coefficient	1.00	0.93
Significance (2-tailed)		0.00
N	10	10

VII. Calibration of pedestrian flow

According to the existing literatures, pedestrian simulation models mainly include two categories: discrete models and continuous models. Continuous models are based on pedestrian flow dynamics, which describe pedestrian moving behaviour by establishing continuous function according to pedestrian behaviour characteristics.

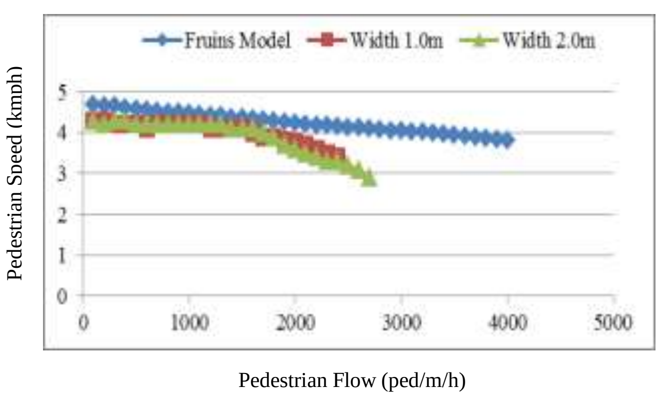

Figure 4. Pedestrian speed-flow relationship with the results of calibrated PARAMICS model plotted against Fruins models

In this study, pedestrian flow speed is the average value of 25% samples among all pedestrians. Therefore, the parameter Calibration in this study only aims at social force model developed by Helbing *et al* [6]. Calibration of pedestrian flows in PARAMICS was performed on a 100 m long simple network consisting of one path. Pedestrian walkway of two widths of 1m and 2m were analyzed for the 100 m long pedestrian path. Pedestrian size and parameters in the vehicle-following model of PARAMICS were altered to result in a close match to Fruin's speed-flow model for bidirectional pedestrian movements. The pedestrian speed flow curve for different widths against Fruins bidirectional model is shown in Figure 4. Fritzsche car following model is used for selecting parameters for pedestrian modelling in PARAMICS.

VIII. Validation of pedestrian flow

The pedestrian speed flow data collected from Ambedkar Circle is further introduced into PARAMICS and calibrated for Fruins model which resulted the correlation coefficient of 0.84. As the correlation coefficient value was feasible for accommodating higher number of pedestrian flow, recalibration was not needed. The parameters used for calibrating the pedestrian model using Fruins model were left unchanged for pedestrian flow on the sidewalk as high pedestrian densities were present at crossing compared to the sidewalks. Pedestrian travel time obtained from Sunday field data and PARAMICS run is shown in Figure 5.

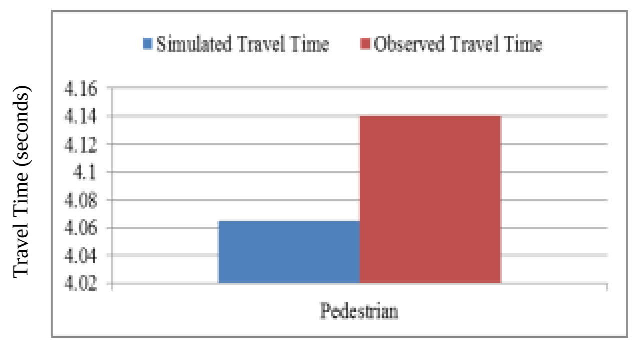

Figure 5. Pedestrian travel time plot from multiple PARAMICS runs and Sunday data

IX. Conclusions

The calibration and validation of the vehicle-pedestrian traffic model concludes that PARAMIC'S car-following algorithm is very much helpful in reproducing vehicle and pedestrian flow in mixed or heterogeneous urban traffic condition. Many works have been done based on pedestrian flow, as studied by Naveen *et al* [7], but using car-following theory for pedestrian modelling is very different. Fritzsche car-following model is used in this paper for pedestrian modelling. Application of this car-following algorithm demonstrated by calibrating in PARAMICS will be very useful in predicting known pedestrian speed-flow relationship.

The graph between observed and simulated vehicle travel time obtained from validation of vehicle flow shows that there is no significant difference. For the calibration of pedestrian flows, speed flow relationship is plotted for different widths using multiple PARAMICS runs against Fruins model.

In this paper Pearson's correlation coefficient is used to correlate the field data and simulated data for both weekday and Sunday. The correlation coefficient value obtained during validation of pedestrian flow is more than 0.8 shows the feasibility for large number of pedestrian flow and also satisfies the main objective of the study. There are a number of issues that could be studied further in this field.

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References

[1] Calibration in multimodal traffic simulation." *J. Transp. Eng.*, ASCE, 135:338-348.

[2] Fruin, J. J. (1971). "Designing for pedestrians: A level of service concept." *Highway Res. Rec.*, 355, 1–15.

[3] Turner, J., and Harahap, G. (1993). "Simplified saturation flow data collection methods." Transport Research Laboratory, *Rep. PA1292/93*, Crowthorne, U.K.

[4] Willis, A., Gjersoe, N., Havard, C., Kerridge, J., and Kukla, R. (2004). "Human movement behaviour in urban spaces: Implications for the design, and modelling of effective pedestrian environments." *Environ. Plan. B: Plan. Des.*, 31, 805–828.

[5] Sacks, J., Rouphail, N., Park, B., and Thakuriah, P. (2002). "Statistically based validation of computer simulation models in traffic operations, and management." *J. Transp. Stat.*, 5(1). 1–24

[6] Helbing, D., and Molnar, P. (1995). "Social force model of pedestrian dynamics." *Phys. Rev. E*, 51, 4282–4286.

[7] Navin, F. P. D., and Wheeler, R. J. (1969). "Pedestrian flow characteristics." Traffic Eng., 39(4), 30–36.

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