CROSS/ROADS\
LINKING MOBILITY SOLUTIONS

IRF WORLD ROAD MEETING 2017
/ 14-17 NOVEMBER / DELHI / INDIA /

CHARACTERISING PLATOON DISPERSION MODEL ALONG URBAN ARTERIALS UNDER HETEROGENEOUS TRAFFIC

Praveen P.S. and Ashalatha R

Presented by,
Dr. Ashalatha R.
Professor and Head
Dept. of Civil Engineering
Govt. College of Engineering Kannur
ashu.cet@gmail.com

INTRODUCTION

- Traffic signals - integral part - maximize flow - maintain high degree of safety
- Arrival pattern at downstream – platoons
- Vehicles proceeding as platoons - disperse as they progress along arterial
- Modeling platoon dispersion - key element to predict arrivals at signals - enable efficient coordination

INTRODUCTION…

- Robertson's dispersion model - extensively used - homogeneous traffic
- Rely on calibration of model parameters - platoon dispersion factor (α) and travel time factor (β) - heterogeneous traffic
- **Heterogeneous traffic**
  - Several categories
  - Less cars
  - No lane discipline - occupy any lateral position

(Source: Google images)

LITERATURE REVIEW

AUTHOR(S)	WORK DONE
Robertson (1969); Michalopoulos and Pisharody (1980); Denney (1989); Virkler et al. (1991)	o Platoon dispersion modeling studies
Manar and Baass (1996)	o Dispersion for three friction conditions o Studied dispersion variation over volume
Jiang, Li and Shamo (2003)	o Investigated platoon characteristics o Developed platoon based control logic

LITERATURE REVIEW…

AUTHOR(S)	WORK DONE
Arasan and Kashani (2003)	o Heterogeneous traffic flow model to study platoon ratio o Variation in traffic composition
Yu (2000)	o Demonstrated dependency of β on α o Method for calibrating α and β from travel time
Rakha and Farzaneh (2006)	o Improved Yu's (2000) calibration procedure to account time step o Value of β is more significant than α

LITERATURE REVIEW…

AUTHOR(S)	WORK DONE
Mathew et al. (2013)	o Robertson's model - Indian conditions – calibration o Requirement of a complex platoon dispersion model
Paul, Mitra and Maitra (2016)	o Calibrated Robertson`s model in non-lane based mixed traffic o Developed empirical model to express α as a function of heterogeneity

SUMMARY OF PLATOON DISPERSION PARAMETERS

PARAMETER		CONDITION	REFERENCE
α	β		
0.20	0.80	Three-lane dual suburban arterial	Collins & Gower (1974)
0.24	0.80	Suburban arterial, two lanes per direction	Lam (1977)
0.40	0.80	Three-lane carriageway Reasonable freedom for overtaking	Seddon (1972b)
0.63	0.80	Two-way road 35 ft wide Severely restricted overtaking	Seddon (1972b)
0.60, 0.70	0.63, 0.59	Single carriageway 33 ft wide, 5 % downgrade; 1378ft & 1837ft downstream	El-Reedy & Ashworth (1978)
0.50	0.80	Single-lane to multi lane flow Heavy to no parking, Restricted to free overtaking	Robertson (1969), Hillier & Rothery (1966)
0.50	0.80	Heavy friction[1]	NCHRP 233, TRANSYT-7F Manual
0.37, 0.35	0.80	Moderate friction[2]	NCHRP 233, TRANSYT-7F Manual
0.24, 0.25	0.80	Low friction[3]	NCHRP 233, TRANSYT-7F Manual
0.15 - 0.21	0.97	Low friction	McCoy (1983)
0.13 - 0.98	0.80	Low friction, 2, 3, 4 and 5 lanes per direction, vehicles separated into lanes by separation barriers, reasonable freedom for overtaking	Bie et al. (2013)
K=α×β = 0. 022		Six lane divided carriageway, heterogeneous traffic	Mathew et al. (2013)
0.07 - 0.33	0.80	Six lane dual carriageway, heterogeneous traffic	Paul, Mitra and Maitra (2016)

NEED FOR THE STUDY

- Studies on Robertson's model parameters α and β - extensive under homogenous traffic
- Similar studies not conducted adequately under heterogeneous traffic
- Quantification of trend of variation of parameters of Robertson's model along downstream – Under heterogeneous traffic

OBJECTIVES

- To determine travel time factor (β) along downstream of signalized arterials
- To identify the trend of variation of parameters of Robertson's model under heterogeneous traffic conditions

METHODOLOGY

Platoon Dispersion Modelling

- Simulate dispersion of traffic stream at downstream by estimating arrivals at downstream based on upstream departure
- Robertson model, 1969 - extensively used
- Robertson’s platoon dispersion model - characterising parameters - α and β
- Method relies on the proper calibration of its model parameters

METHODOLOGY…

Robertson's Platoon Dispersion Model

$q^d_t = F_n \times q^d_{t-T} + (1-F_n) \times q^d_{t-n}$

$$F_n = \frac{1}{1+\alpha\beta T_a} \qquad T = \beta T_a$$

q^d_t - arrival flow rate at the downstream signal at time t

q^d_{t-T} - departure flow rate at the upstream signal at time t-T

T - lag time (time gap between initiation of green at upstream stop-line and arrival of first vehicle at downstream stop-line)

T_a - average link travel time measured in units of time steps

n - modelling time step duration

F_n - smoothing factor

METHODOLOGY…

- Robertson's model estimates the downstream flow at a given time interval
- Model to be applied recursively to predict the flow - Seddon (1972) rewrote the Eq

$$q^d_t = \sum_{i=T}^{\infty} F_n(1 - F_n)^{i-T} \times q_{t-i+T}$$

- Predicted downstream arrivals follow shifted geometric series
- Rakha and Farzaneh, 2006 – calibrated α and β directly from travel time of vehicles
- Simplest of the calibration methods and provides adequate accuracy

METHODOLOGY…

$$\beta_n = \frac{1}{1+\alpha_n} \qquad \alpha_n = \frac{1-\beta_n}{\beta_n}$$

$$F_n = n\frac{\sqrt{n^2 + 4\sigma'^2} - n}{2\sigma'^2}$$

$$\beta_n = \frac{2T_a' + n - \sqrt{n^2 + 4\sigma'^2}}{2T_a'}$$

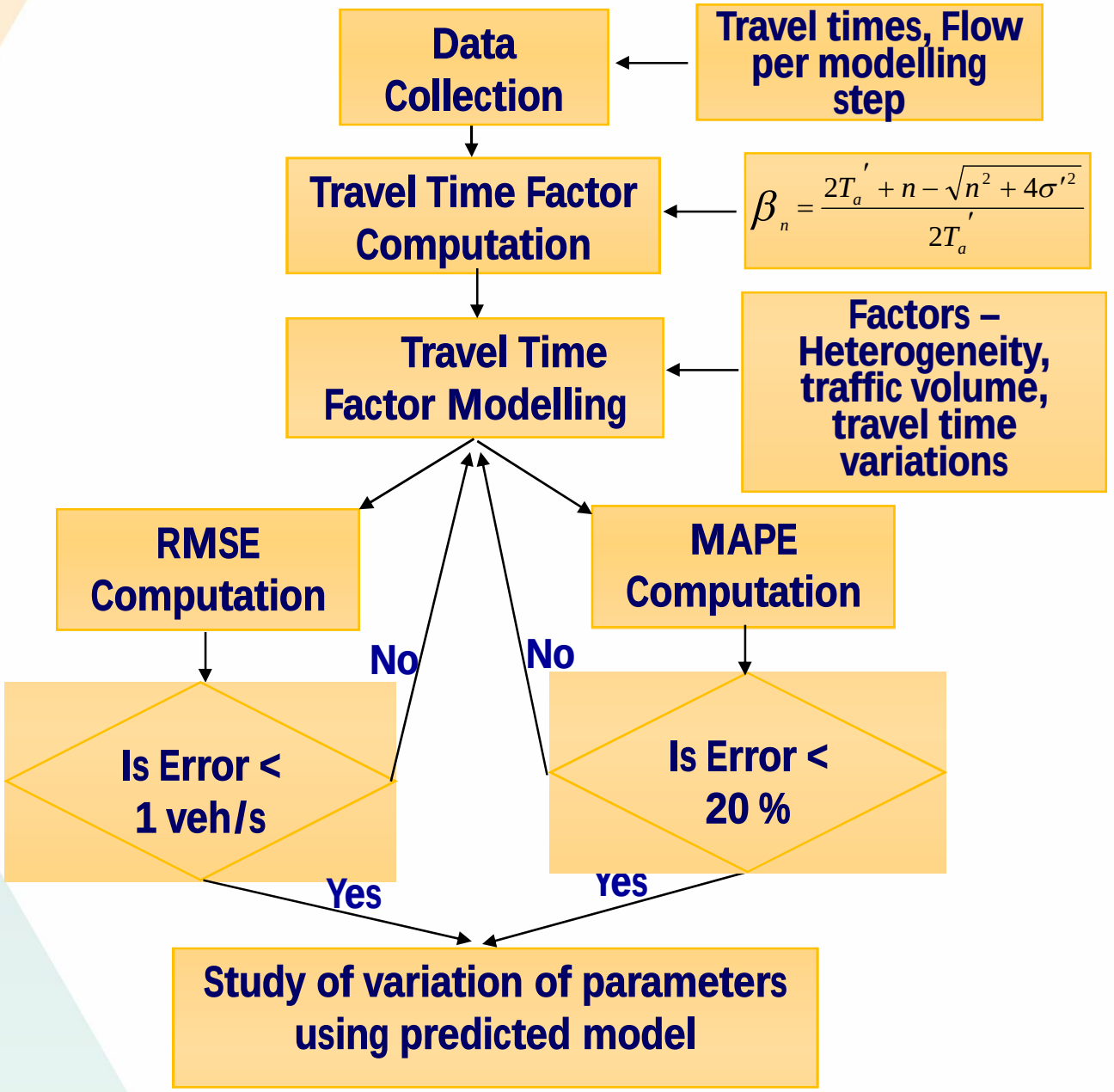
where β_n, F_n, and α_n are model parameters for step size of n (s)

σ'^2 - standard deviation of link travel times(s)

T_a' - mean roadway travel time (s)

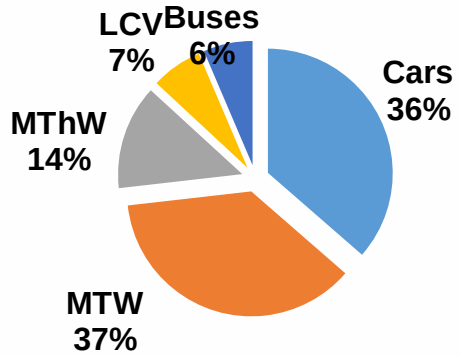
(Rakha and Farzaneh, 2006)

- β values - basis for modelling β as function of parameters describing heterogeneity


Data Collection
Travel times, Flow per modelling step
Travel Time Factor Computation
$\beta_n = \frac{2T_a' + n - \sqrt{n^2 + 4\sigma'^2}}{2T_a'}$
Travel Time Factor Modelling
Factors – Heterogeneity, traffic volume, travel time variations
RMSE Computation
MAPE Computation
No
No
Is Error < 1 veh/s
Is Error < 20 %
Yes
Yes
Study of variation of parameters using predicted model

DATA COLLECTION

- Study stretch - isolated signal on 4 lane divided urban road Thiruvananthapuram city
- Peak and off peak hours - video survey
- Traffic signal cycle timings noted
- Road sections up to 420m - marked manually - at every 30m intervals
- Vehicles - grouped into five categories
- Arrival times - every 30m intervals downstream of intersection up to 420m
- 50 cycles



Study stretch at Vettu Road Junction, Trivandrum, Kerala

DEVELOPMENT OF MODEL FOR ESTIMATING TRAVEL TIME FACTOR

- Factors explaining the variation of β
  - **Heterogeneity -** traffic composition effect
    - Vehicular categories - large and small

      LV - LCV and Buses

      SV – Motorised Two wheelers and Motorised Three wheelers
  - **Effect of traffic volume -** V/C ratio
  - **Variations in travel time of vehicles**
    - Link travel time of cars and its standard deviation

MODEL FOR ESTIMATING TRAVEL TIME FACTOR…

$$\beta_n = \frac{0.93 \times e^{(\frac{V}{C} \times (LV+SV))}}{n^{0.003}(1+\log(\frac{30\sigma_c}{T_C}))}$$

β_n - travel time factor for step size of n sec

σ_c - standard deviation of link travel times of cars in sec

T_c - mean travel time of cars in sec

V/C - volume to capacity ratio

SV - composition of small vehicles

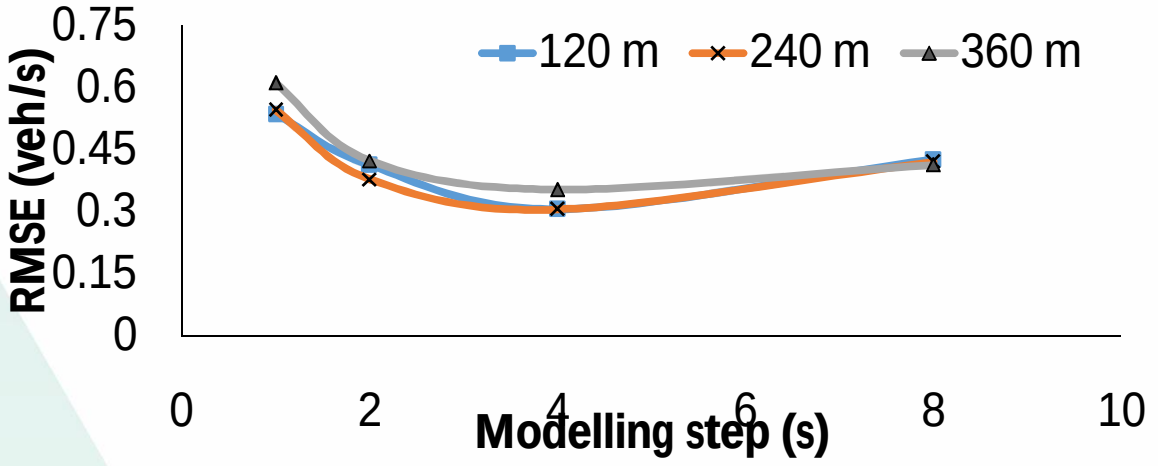
LV - composition of large vehicles

MODEL FOR ESTIMATING TRAVEL TIME FACTOR…

- Modelling step size - significant parameter for calibration
- Four sizes - 1, 2, 4, 8 sec – investigated
- Root Mean Square Error (RMSE) - standard deviation of prediction errors

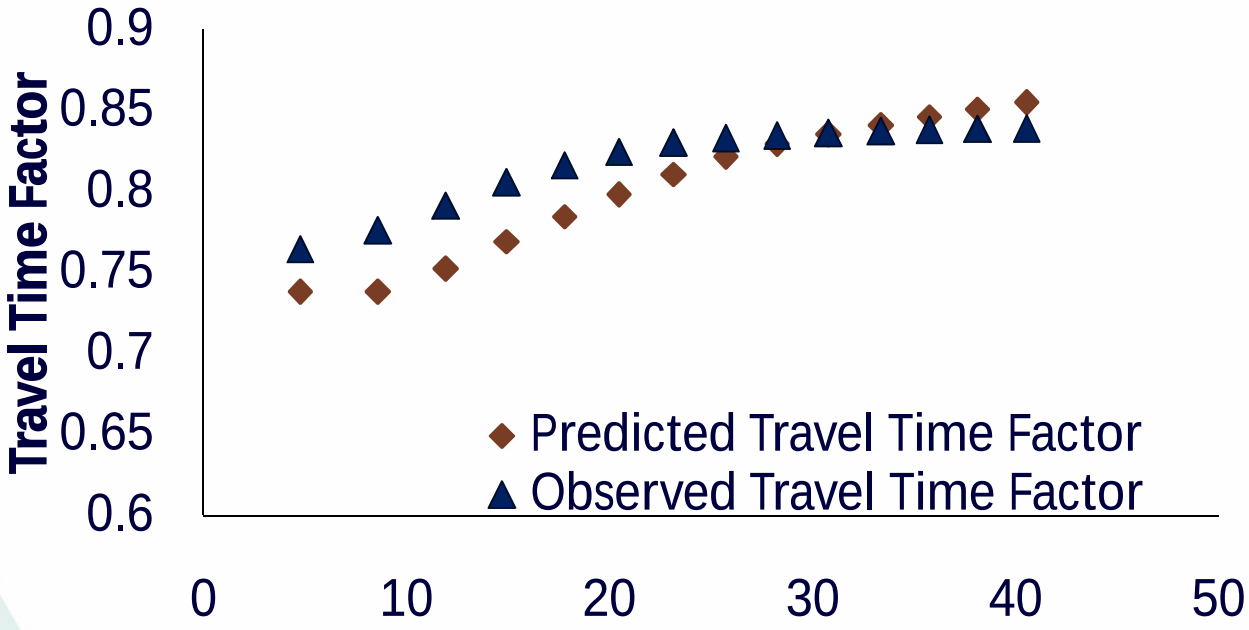
$$RMSE = \sqrt{\frac{1}{n}\left(\sum_{i=1}^{n}(p-o)^2\right)}$$

p -predicted value o - observed value



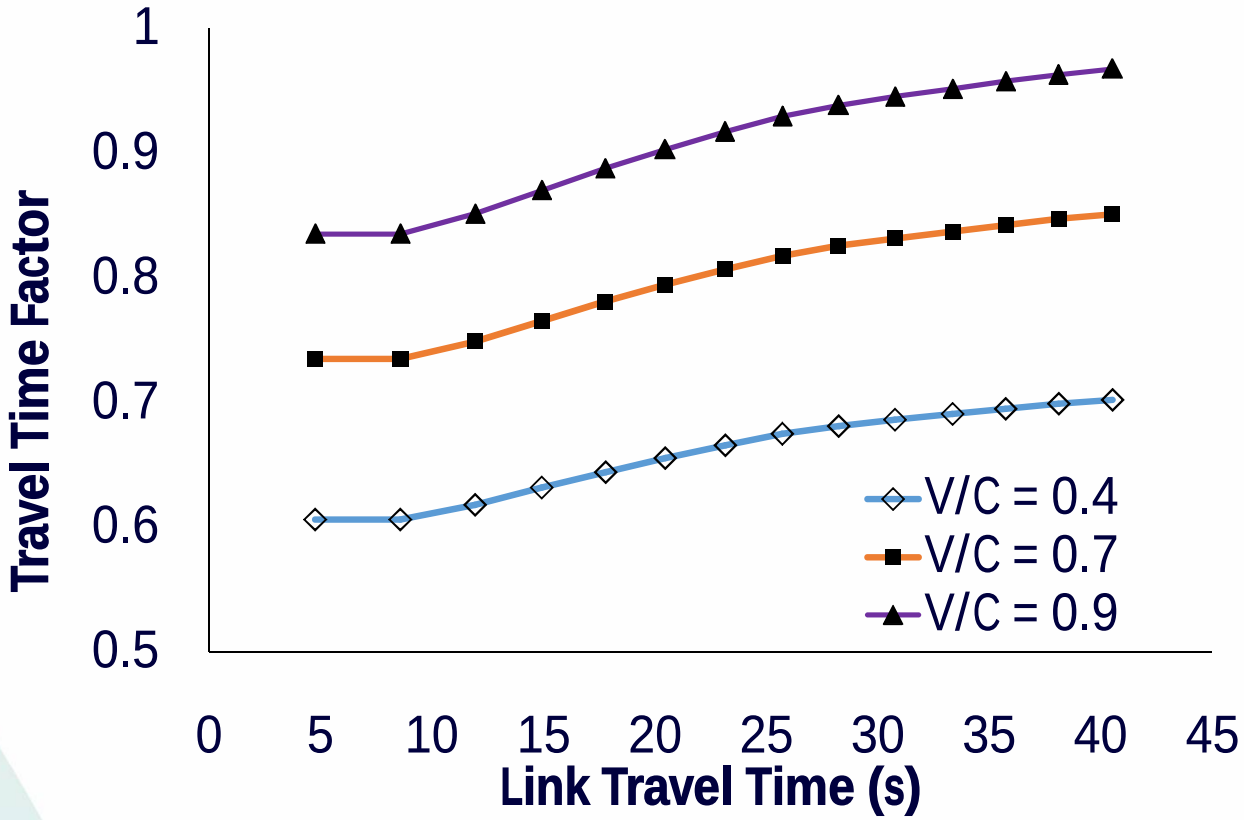
MODEL FOR ESTIMATING TRAVEL TIME FACTOR…

- Mean Absolute Percentage Errors
  - MAPE values of predicted β < 20%



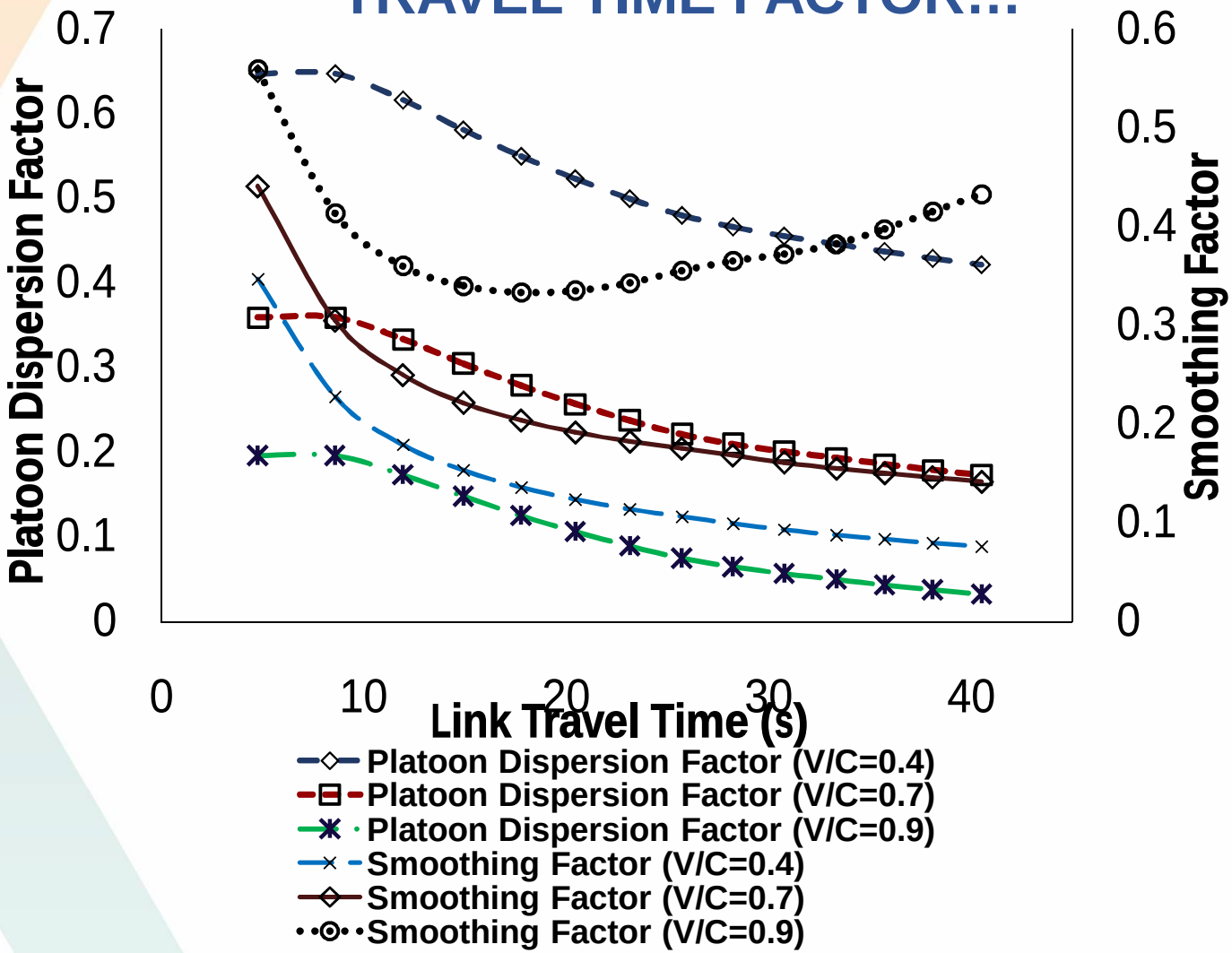
Variation of predicted and observed travel time factor at modelling step of 4 s

MODEL FOR ESTIMATING TRAVEL TIME FACTOR…



Variation of travel time factor at different volume levels at modelling step of 4 s

MODEL FOR ESTIMATING TRAVEL TIME FACTOR…



Variation of platoon dispersion factor and smoothing factor with volume at modelling step of 4 s

CONCLUSIONS

- Developed an empirical model to determine β of Robertson's model - factors - Indian traffic heterogeneity
- Predicted values of β ranges from 0.71 to 0.96 for observed traffic conditions
- Variation of parameters of Robertson's model along downstream – investigated
- Analyses of Robertson model parameters - insight into the trend of platoon dispersion under heterogeneous traffic

THANK YOU

REFERENCES

- **Mathew J., Thomas H., Sharma A., Devi L. and L. Rilett. Studying Platoon Dispersion Characteristics under Heterogeneous Traffic in India. *Proceedings of the 2nd Conference of Transportation Research Group of India, Procedia Social and Behavioral Sciences,* Vol. 104, 2013, pp. 422-429.**
- **Little, J. D. C. The Synchronization of Traffic Signals by Mixed-Integer Linear Programming. *Operations Research,* Vol. 14, No. 4, 1966, pp. 568-594.**
- **Baras, J.S., Dorsey, A.J., and W.S. Levine. Estimation of Traffic Platoon Structure from Headway Statistics. *IEEE Transactions on Automatic Control*, Vol. 2, No. 4, 1979, pp. 553-559.**
- **Michapoulos, P.G. and V. Pisharody. Platoon Dynamics on Signal Controlled Arterials. *Transportation Science*, Vol. 14, No. 4, 1980, pp. 365-396.**
- **Denney, R. W. Traffic platoon dispersion modeling. *Journal of Transportation Engineering,* Vol. 115, No. 2, 1989, pp. 193-207.**
- **Virkler, M., Madsen, W., and J. Sutton. Measuring Signal Platoon Flow. *Journal of Transportation Engineering*, Vol. 117, No. 5, 1991, pp. 513–523.**
- **Manar, A. and K. G. Baass. Traffic Platoon Dispersion Modeling on Arterial Streets. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 1566, 1996, pp. 49-53.**
- **Yu, L. Calibration of Platoon Dispersion Parameters on the Basis of Link Travel Time Statistics. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1727, 2000, pp. 89-94.**
- **Arasan, V. T., and S. H. Kashani. Modeling Platoon Dispersal Pattern of Heterogeneous Road Traffic. *Transportation Research Record: Journal of the Transportation Research Board,* Vol. 1852, 2003, pp. 175-182.**

REFERENCES…

- **Jiang, Y., Li, S., and D. Shamo. *Development of Vehicle Platoon Distribution Models and Simulation of Platoon Movements on Indian Rural Corridors*. Publication FHWA/IN/JTRP-2002/23, Indiana Department of Transportation, Purdue University, 2003.**
- **Skabardonis, A. and N. Geroliminis. Prediction of Arrival Profiles and Queue Lengths along Signalized Arterials by using a Markov Decision Process, *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 1934, 2005a, pp. 116–124.**
- **Skabardonis, A. and N. Geroliminis. Real-Time Estimation of Travel Times on Signalized Arterials, *Proceedings of the 16th International Symposium on Transportation and Traffic Theory*, University of Maryland, College Park, Maryland, 19-21 July 2005.**
- **Rakha, H.A. and M. Farzaneh. Issues and Solutions to Macroscopic Traffic Dispersion Modeling. *Journal of Transportation Engineering*, Vol. 132, No. 7, 2006, pp. 555-564.**
- **Puan, C. O. and N. Mashros. *Sustainable Transportation Systems and Seaport Operations*, Penerbit Universiti Teknologi Malaysia, First Edition, Malaysia, 2008.**
- **Mauro, R., Branco, F. and M. Guerrieri. Contribution to the platoon distribution analysis in steady-state traffic conditions, *Periodica Polytechnica Civil Engineering*, Vol. 58, No. 3, 2014, pp. 217-227.**
- **Paul, B., Mitra, S. and B. Maitra. Calibration of Robertson's Platoon Dispersion Model in Non-lane Based Mixed Traffic Operation. *Transportation in Developing Economies*, Vol. 2, No. 2, 2016. http://x.doi.org/10.1007/s40890-016-0016-7.**

REFERENCES…

- **Robertson, D. I. *Road Research Laboratory Report LR 253: TRANSYT- A Traffic Network Study Tool*, Road Research Laboratory, Crowthorne, 1969.**
- **Seddon P.A. The prediction of platoon dispersion in the combination methods of linking traffic signal. *Transportation Research*, Vol. 6(2), 1972, pp.125–130.**
- **Praveen, P. S. and V. T. Arasan. Influence of traffic mix on PCU value of vehicles under heterogeneous traffic conditions, *International Journal for Traffic and Transport Engineering*, Vol. 3(3), 2013, pp. 302–330.**
- **Paul, B., Maitra, B. and S. S. Mitra. Simulation of Vehicle Progression i.e. A Macroscopic Traffic Behaviour using a Microscopic Model, *Proceedings of the 12th Transportation Planning and Implementation Methodologies for Developing Countries*, 2016, Mumbai.**
- **Mathew, T.V. and P. Radhakrishnan. Calibration of Microsimulation Models for Nonlane-Based Heterogeneous Traffic at Signalized Intersections. *Journal of Urban Planning and Development*, Vol. 136(1), 2010, pp. 59-66. http://dx.doi.org/10.1061/(ASCE)0733-9488(2010)136:1(59).**
- **Siddharth, S. M. P. and G. Ramadurai. Calibration of VISSIM for Indian Heterogeneous Traffic Conditions, *Proceedings of the 2nd Conference of the Transportation Research Group of India, Procedia - Social and Behavioral Sciences*, Vol. 104, 2013, pp. 380-389.**
- **Kenneth, D.L. and K.K. Ronald. *Advances in Business and Management Forecasting*, Emerald Books, Bingley, U.K, 1982.**
- **Bie Y, Liu Z, Ma D, Wang D (2013) Calibration of platoon dispersion parameters considering the impact of number of lanes. J Transp Eng 139:200–207**

TRAFFIC DATA EXTRACTION SHEET

Vehicle types : Cars, Motorised Two wheelers (M.T.W.), Motorised Three wheelers (M.Th.W.), Light Commercial Vehicles (L.C.V.), Buses, Trucks, Tricycles

Road type: 4 lane divided | Road width: 7.5m | Accuracy(in sec): 0.04sec

Place: Vettu Road | Date: 25-2-15 | Time: Eve | Green Time: 40sec | Red Time: 50sec | Yellow Time: 3sec

Cycle length: 93sec

Sl. No:	Vehicle type	Distance of stopped vehicle from stopline(m) Least count-5m	Vehicle position (I row/II row/III row etc.)	Vehicular starting time from rest	Vehicular arrival time ahead of stopline at (for through vehicles)		Entry time of vehicle at															Remarks (include effects of left turning vehicles affecting platoons, parking between 0-420m affecting platoons, identify through vehicle unhindered, identify through vehicle catching up with platoon)
					60m	30m	0m	30m	60m	90m	120m	150m	180m	210m	240m	270m	300m	330m	360m	390m	420m	
CYCLE NO: 1																						
1	3W	0	IROW	55.28			55.28	1.1.12	4.88	8.4	11.08	13.96	16.64	19.4	22.12	25.08	27.92	30.96	33.88	36.84	39.92	PASSENGER 3W
2	BUS	0	I ROW	55.8			55.8	1.2.16	6.08	9.4	12.28	14.92	17.32	20	22	24.2	26.24	28.28	30.2	32.08	33.96	
3	2W	0	I ROW	56.12			55.52	1.1.88	6.16	9.68	12.88	15.88	18.8	21.64	24.6	27.44	30.2	33.24	36.28	39.24	42.2	
4	2W	0	I ROW	56.76			56.12	1.1.80	4.96	7.44	9.68	12	14.12	16.32	18.44	20.6	22.72	24.88	26.96	29.04	31.08	
5	2W	10	II ROW	57.84			58.08	1.2.48	6.44	9.16	11.8	14.12	16.44	18.72	21.08	23.48	25.8	28.56	30.56	32.92	35.32	
6	2W	15	III ROW	57.84			58.88	1.3.04	7.08	10.84	13.88	16.88	19.96	23.12	26.2	29.2	32.08	35.08	37.96	40.88	43.8	
7	2W				47.68	51.96	58.52	3.68	7.56	11.24	14.36	17.48	20.72	23.92	26.6	29.04	31.52	34.08	36.88	39.6	42.2	THRU VEH CATCHING UP
8	2W				48.6	53.64	59.6	1.4.28	7.92	10.92	14.12	16.92	19.52	22.04	24.44	26.8	29.44	32.36	35.2	38	41.12	THRU VEH CATCHING UP
9	2W				53.8	58.2	1.2.52	6.52	9.84	12.96	15.76	18.72	21.36	24.08	26.68	29.24	31.8	34.52	37.2	40.04	42.88	THRU VEH CATCHING UP
10	LCV	15	II ROW	55.84			1.0.04	4.68	8.56	12.16	15.12	17.88	20.48	23.08	25.4	27.72	29.8	31.88	33.84	35.76	37.64	GOODS VEH TEMPO
11	CAR	20	III ROW	57			2.36	7.68	11.6	14.84	17.8	20.48	23.24	25.8	28.44	31	33.28	35.64	37.72	39.72	41.84	SMALL CAR
12	CAR	15	III ROW	55.88			1.1.04	6.96	11.36	14.68	17.4	20.12	22.76	25.32	27.8	30.16	32.32	34.44	36.44	38.36	40.32	SMALL CAR

Study stretch at Vettu Road Junction


0m
30m
60m
90m
120m
150m
180m
210m
240m
300m
330m
360m
390m
420m
TCG 00:01:32:16
00:01:32:64