2012 International Conference on Traffic and Transportation Engineering (ICTTE 2012)
IPCSIT vol. 26 (2012) © (2012) IACSIT Press, Singapore

A Simple Traffic Flow Simulator for Two-lane Highways

Folake Akintayo [+] and Oluwole Agbede

University of Ibadan, Ibadan, Nigeria

Abstract. Traffic congestion is a common feature on highways in many cities of the world, including Ibadan, Nigeria. Previous studies have shown that several mathematical traffic flow models developed to analyse congestion cannot be easily generalised or adapted to varying situations. A simple traffic flow simulator was developed in this paper to simulate flow for different congestion scenarios by varying the minimum and maximum headways of vehicles. Comparison of simulated and field values for a heavily-trafficked highway in Ibadan metropolis produced an error of 35 % at high vehicular interaction.

Keywords: traffic flow, traffic congestion, simulator, two-lane highways, headways

1. Introduction

The highway network is an important component of the transportation system. In Nigeria, it is the principal means of transportation facilitating the socioeconomic activities of the people. Two-lane highways (single carriageway) formed the main component of this system at the local, state and federal levels. Efficient and effective flow of traffic is desirable for the highway system to operate optimally at designed capacity and for favourable level of service.

Traffic flow represents the interaction between vehicles, drivers and infrastructure. The flow can be likened to movement of particle systems [1], which can be either free or constrained [2]. In free flow conditions, drivers can choose their own speed or constrained to a car-following system. The car-following system often resulted in traffic congestion particularly on many two-lane highways in Nigeria [3]. Traffic congestion is considered one of the main urban transportation problems. It leads to increased travel time, air pollution and fuel consumption [4]. Providing additional lanes to existing highways and building new ones have been the traditional response. However, the data collection effort for this exercise is great. Consequently, the transportation engineers and researchers are increasingly developing simulation models to address traffic congestion problems [5].

Several studies have been carried out on modelling highway capacity. An improved highway capacity model that is feasible and can reflect the actual traffic flow characteristics was developed by Zang [6]. Two-regime models based on the three fundamental traffic variables: flow, speed, and density developed by Yao *et al.* also produced good estimate of highway capacity [7]. However, it has been shown that further studies should be made to develop a more reliable capacity and performance models for Turkey [8]. A quantitative method evolved from the statistical distribution of observed headways of traffic flow in Korea [9]. Simulation of queue build-up and delay times under congested traffic conditions were approximated with headway distribution models of free-flowing traffic on Ohio Freeways [10].

In this paper, a simple traffic flow simulator was developed based on minimum and maximum headway of vehicles. The simulator could be used to generate flows on two-lane highways characterised by heavy traffic and operating under non-ideal roadway, traffic and control conditions in urban centres.

[+] Corresponding author. Tel.: + 234-803-8310-210.
E-mail address: *folakintayo@yahoo.com*.

2. Traffic Flow Simulator (TRAFLOS)

2.1. Algorithm

Specify observation period, T to simulate traffic congestion scenario. For a particular scenario, specify h_1 and h_2 as the minimum and maximum headways respectively. Generate random variates h_n such that:

$$h_1 \leq h_n < h_2 \text{ and } V_R = \sum n = k_c T \qquad (1)$$

where;

V_R= number of vehicles (n) released per simulation run

k_c = congestion factor ; T = the total headway in seconds/observation period.

The flow chart for the steps above is shown in Fig. 1. The algorithm developed above was coded in JAVA programming language. It has Graphical User Interface (GUI) that provides the user with text fields for the experiment parameters and a button to initiate the experiment. An "exit" button is also provided to close the application. The progress of the experiment is shown on a white pad in the interface which shows headways as they are generated and the vehicle releases with the time each vehicle was released. Another white pad shows the summary of the experiment at the end of each run.

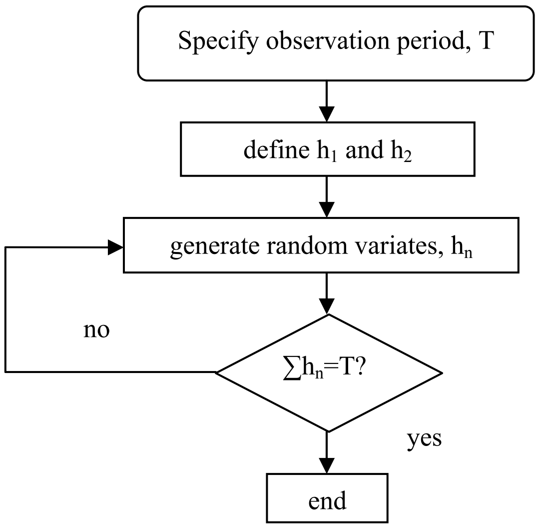

Fig. 1: Traffic Flow Simulator (TRAFLOS) Flowchart

2.2. Congestion scenarios design

Based on the preliminary traffic study on three heavily trafficked two-lane roads (Total Garden-Agodi Gate, J Allen-Oke Bola and Odo Ona-Apata) in Ibadan metropolis, different congestion scenarios were simulated with TRAFLOS by varying the minimum and maximum headways between 1 and 18 seconds. The observation period was set at 15 minutes (900 seconds) for each scenario. A total of 171 experimental runs were carried out over a period of 2,565 minutes. The maximum service flow rate (V) for each run was computed by equation 2 and the results shown in Table 1

$$V = 4^* V_R \qquad (2)$$

Table 1: Flow rates for different congestion scenarios

		Maximum Headway (seconds)																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Minimum Headway (seconds)	1	3600	2376	1800	1440	1220	1000	968	816	688	696	600	580	544	480	416	416	420	368
	2	0	1800	1432	1188	1020	888	804	708	668	620	564	568	464	452	436	392	352	364
	3	0	0	1200	1016	900	772	716	696	596	536	524	464	448	420	408	356	364	340
	4	0	0	0	900	780	704	652	588	568	504	456	440	424	392	392	356	332	340
	5	0	0	0	0	720	652	596	540	512	460	460	416	408	372	344	328	332	320
	6	0	0	0	0	0	600	552	512	480	440	428	424	364	352	324	328	324	296
	7	0	0	0	0	0	0	512	476	448	420	396	372	352	336	328	316	304	276
	8	0	0	0	0	0	0	0	448	424	396	376	360	344	320	312	296	280	272
	9	0	0	0	0	0	0	0	0	400	380	352	344	332	316	304	288	272	272
	10	0	0	0	0	0	0	0	0	0	360	340	324	312	300	284	276	264	244
	11	0	0	0	0	0	0	0	0	0	0	324	312	300	284	272	264	260	244
	12	0	0	0	0	0	0	0	0	0	0	0	300	284	272	268	252	248	244
	13	0	0	0	0	0	0	0	0	0	0	0	0	276	264	264	248	236	228
	14	0	0	0	0	0	0	0	0	0	0	0	0	0	256	244	236	232	224
	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	240	228	220	216
	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	224	216	212
	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	208	204
	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200

The congestion factor increased linearly with increased flow rate and the corresponding equivalent level of service is shown in Table 2.

Table 2: Congestion factors and equivalent level of service

Congestion Factor, k_c	Level of Service
0.1	A
0.2	B
0.3	C
0.4	D
0.5	D
0.6	D
0.7	E
0.8	E
0.9	F
1.0	F

2.3. Comparison of simulated and field capacities

The simulated and field capacities at different congestion factors for J Allen-Oke Bola road are shown in Table 3. The errors are computed with equation 3 below as proposed by Brockfield *et al.* [11]

$$e = \frac{\sum \left| C^{(Sim)} - C^{(field)} \right|}{\sum C^{(field)}} \qquad (3)$$

where C^{sim} and C^{field} are simulated and field capacities respectively. The maximum error of 35.0 % was computed at the highest congestion factor of 1. This is a situation of high vehicular interactions on the highway.

Table 3: Capacity Analysis of dualised J Allen-Oke Bola Road

Congestion Factor	Simulated	Field	Error (%)
0.1	2726	2240	21.7
0.2	2732	2249	21.5
0.3	2739	2207	24.1
0.4	2746	2186	25.6
0.5	2753	2164	27.2
0.6	2759	2162	27.6
0.7	2766	2144	29.0
0.8	2773	2099	32.1
0.9	2780	2078	33.8
1	2786	2064	35.0

2.4. Conclusion

The traffic flow simulator (TRAFLOS) successfully simulated the traffic situations on the selected roads for flows ranging between 700 to 1200 vphpl. In addition, information derived from the simulator are useful in predicting arrival patterns of vehicles at strategic points on the roadways, testing the randomness of traffic flow, and for the overall efficient and effective management of traffic on the roads.

3. References

[1] D. Helbing. Traffic and related self-driven many particle systems. *Rev. Model Physics.* 2001, 73: 1067-1141.

[2] T. Nagatani. The physics of traffic jams. *Reports on Progress in Physics.* 2002, 65: 1331-1386.

[3] J. R. Aworemi, I. A. Abdul-Azeez, A. J. Oyedokun, and J. O. Adewoye,. A study of the causes, effects and ameliorative measures of road traffic congestion in Lagos Metropolis. *European Journal of Social Science.* 2009, **11**(1): 119-128.

[4] W. Hook. *Urban congestion: the motorisation crisis in the world transport.* Sterling publishers, 1995.

[5] W. P. Lee, M. A. Osman, A. Z. Talib and A. I. Md.Ismail. Dynamic traffic simulation for traffic congestion problem using an enhanced algorithm. *World Academy of Science, Engineering and Technology.* 2008, 45: 271-278.

[6] X. Zang. Modelling and simulation for theoretic capacity model of highway. *Computer Modelling and Simulation.* 2010, 1: 261-263.

[7] J. Yao, H. Rakha, H. Teng, V. Kwigizile, and M. Kaseko. Estimating highway capacity considering two-regime models. *Journal of Transportation Engineering.* 2009, **135** (9): 670-676.

[8] S. Tanyel, T. Baran, and M. Ozuysal. Determining the capacity of single-lane roundabouts in Izmir, Turkey. *Journal of Transportation Engineering.* 2005, **131** (12): 953-956.

[9] M. Chang and Y. Kim. Development of capacity estimation method from statistical distribution of observed traffic flow. *Transportation Research Board.* 2000: 299-309.

[10] H. T. Zwahlen, E. Oner and K. R. Suravaram. . Approximated headway distributions of free-flowing traffic on Ohio freeways for work-zone traffic simulations. *Transportation Research Record.* 2007, 1999: 131-140.

[11] E. Brockfield, R. D. Kuhne and P. Wagner. Calibration and validation of microscopic flow models. *Transportation Research Record.* 2004, 1876: 62-70.