Prediction of Delay at a Parking Garage Facility Using STARSIM Simulation Package

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Abstract

The main objective of the present paper is to predict the average delay values for delayed vehicles at the adjacent entrance and exit gates combination of a parking garage using a simulation package named STARSIM. Flow level, number of lanes at each approach of the major road, number of lanes at the entrance and exit gates, and proportion of parking vehicles from the major road are taken as the most important factors that affect the performance of the gates of the car park in term of average delay to be predicted in this paper. These traffic and geometrical conditions are used to generate a range of delay values, and the effect of these conditions on the performance of the entrance and exit gates, in term of delay, is discussed and presented figuratively.

التنبؤ بقيم أوقات التأخير لموقف مركبات باستخدام برنامج المحاكاة STARSIM

الخلاصة

يهدف هذا البحث إلى تخمين أو توقع أوقات التأخير، للمركبات التي تريد الدخول إلى أو الخروج من موقف مركبات متعدد الطوابق بحيث إن هذه الطوابق متشابهة من حيث المساحة وتوزيع أماكن الوقوف، عند مدخل ومخرج هذا الموقف باستخدام برنامج محاكاة يسمى STARSIM. ومن الجدير بالذكر بان عملية بناء ومعايرة ومطابقة برنامج المحاكاة هذا تمت في بحثين سابقين.

في هذا البحث تم فرض عدد من المتغيرات لإدخالها في البرنامج لدراسة تأثير هذه المتغيرات على قيم أوقات التأخير عند مدخل ومخرج الموقف وبالتالي على أداء هذا الموقف. هذه المتغيرات يمكن إجمالها بالتالي: عدد مركبات الشارع الرئيسي المجاور للموقف بالاتجاهين؛ عدد ممرات الشارع الرئيسي؛ عدد ممرات الدخول والخروج الخاصة بالموقف وكذلك نسبة عدد المركبات التي تريد الدخول للموقف إلى عدد مركبات الشارع الرئيسي وفي كلا الاتجاهين. إن كل هذه العوامل المرورية والهندسية استخدمت في هذا البحث للحصول على عدد واسع من قيم أوقات التأخير والتي تمت مناقشتها ودراسة تأثير هذه العوامل على أداء موقف المركبات وبدلالة أوقات التأخير هذه.

1- Introduction:

Generally, the performance inside and outside an off-street parking facility can be evaluated using selected performance measures. The performance inside the parking facility can be represented using turnover rate and/or proportion of unserved parkers during a specified period… etc. On the other hand, the performance of the parking facility outside it can be represented using different measures of effectiveness such as queue length and/or delay time (Ellson, P. B., 1984 & Young, W., 1991). In the present paper, the

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average delay values of delayed vehicles at the entrance and exit gates of a designed parking garage are predicted using the STARSIM package.

STARSIM is a simulation package which contains four main simulation models. These are AEESIM, BEESIM, SEESIM, and INPARKSIM. The first three models were developed to depict the interactions among vehicles at the entrance and exit gates of the parking facility for three different layouts, (as shown in Fig.1), while the fourth one was developed to depict the interactions among vehicles inside it (Jrew et.al. 2000a).

STARSIM was calibrated and validated using collected field observations at an appropriate selected site (Jrew et. al. 2000b).

The developed simulation package STARSIM is used, in this paper, to predict the delay values at the entrance and exit gates of a designed parking garage for three combinations of major road lanes and gates' lanes. The first layout of entrance/exit combination (i.e. the Model AEESIM) is assumed at the parking facility. The most important factors that affect the performance of the car park gates' are the flow level of the vehicles at the major road, proportion of parking vehicles from the major road, number of lanes at each major road approaches, and the number of lanes at the entrance and exit gates of the car park. These factors are taken, in the present paper, as input variables, as shown in Table (1), to predict the average delay values of the delayed vehicles at the gates of the car park.

2- Input Data:

The input data required by STARSIM are input via a free format data file.

The number of queuing lanes at the major road (i.e. approaches X and Y, in Fig. (1)) and at the entrance and exit gates of the car park can be taken from Table (1) above. Basically, availability of more service channels at a given approach to an intersection decreases the delay values on that approach.

Fig.(1) (i.e. Model AEESIM) is used, in this paper, as the combination of entrance/exit gates. Flow levels and the proportion of parking vehicles from the major road approaches are tabulated in Table (1), whereas lag and gap acceptance input data used are presented in Table (2).Crossing time from approach (Y) to the entrance gate is taken as 3.0 seconds. Move-up time, is assumed, equals 3.5 seconds. The simulation time is taken as 6 hours (21600 seconds) with 0.5 seconds of scanning and updating interval. The service time at the entrance and exit gates is assumed equal to zero. The average duration of stay value is taken equal to 15220 seconds, with a standard deviation of 2880 seconds. Normal distribution is used to generate the duration of stay values to the parking vehicles.

An area of 118.32 ft * 150 ft (35.5 m * 45.0 m) is taken as the area of the car park. This area is designed according to the dimensions used by Iranpour and Tung (1989) for the compact car for 90-degree of parking angle. Fig.(2) shows the layout of the designed area. Two storeys of stalls are assumed in this area. The average travel time between the two storeys is taken equal to 60 seconds. The two storeys are connected by an external circular ramp with an outer radius of 11.5 meters (Agop 1978 & Young, W., 1988). The average value of the required time between two adjacent stalls was produced from controlled experiments and was equal to 0.75 seconds. Other controlled experiments were performed to observe the entry and exit travel times for a number of selected stalls, parking time, and unparking time. Four stalls were randomly selected to collect the travel times. Table (3) gives the average and standard deviation values of entry and exit travel times that will be used as inputs in the simulation runs. Average values of gathered parking and unparking times during the controlled experiments were 3.59 and 6.97 seconds, respectively.

3- The Simulation Results:

The simulation package STARSIM was used to generate a range of delay values for the streams X-Entrance, Y-Entrance, and Exit using the input data (constants and variables) that mentioned in the previous section. The results of the simulation runs for the different conditions of traffic and geometry (as shown in Table 1) are tabulated in Table (4) and shown figuratively in Figs.(3,4,5,6,7,8).

It can be seen, from the results, that the effect of traffic flow on delay values begins to be more pronounced as flow levels reach a value of 400 vph for each approach of the major road for all turning proportions used. This effect decreases when two lanes are provided at the major road.

In the same way, the provision of two lanes at the exit gate of the car park decreases the delay values of unparking vehicles at high proportions of parking vehicles from approaches X and Y (0.15 and up) and when the flow levels reach the value of 400 vph as compared with all cases of one lane provision at the exit gate. In another expression, it can be seen that the delay values at the exit gate ranges from 3.7 sec./veh. to 508.2 sec./veh. for one lane provision on the streams X-Entrance, Y-Entrance, and Exit while it ranges from 3.7 sec./veh. to 105.5 sec./veh. for two lanes provision on the streams X-Entrance, Y-Entrance and one lane provision on the Exit stream. The great changes are seen clearly when two lanes provisions are used in all streams (i.e. X-Entrance, Y-Entrance, and Exit). The delay values in this case ranges from 3.7 sec./veh. to 26.7 sec./veh. with a percent decrease of 94.7 when it is compared with the first case above and a percent decrease of 79.2 when it is compared with the second case(as shown in Tables 4 & 5).

Table (5) shows percent changes in average delay of delayed vehicles for each stream (i.e. X-entrance, Y-Entrance, and Exit) for the same proportion of parking vehicles from the major road approaches X and Y and different geometrical conditions when considering the case of one lane at each stream as the basic case.

4- Conclusions:

The conclusions drawn from the present study are:

a) The effect of traffic flow on delay values begins to be more cleared when the flow levels reach a value of 400 vph for each approach of the major road.

b) The effect of traffic flow on delay values decreases when two lanes are provided at the major road.

c) The provision of two lanes at the exit gate of the car park decreases the delay values of unparking vehicles at high proportions of parking vehicles from the major road approaches X and Y (0.15 and up) and when the flow levels reach the value of 400 vph as compared with all cases of one lane provision at the exit gate.

d) This study gives an assistance to the highway engineers to expect the required number of lanes at each approach of a parking facility (i.e. major road approaches X&Y, Entrance, and Exit) for the existing flow levels and parking vehicles to control the delay with an appropriate values at the gates of the parking facility.

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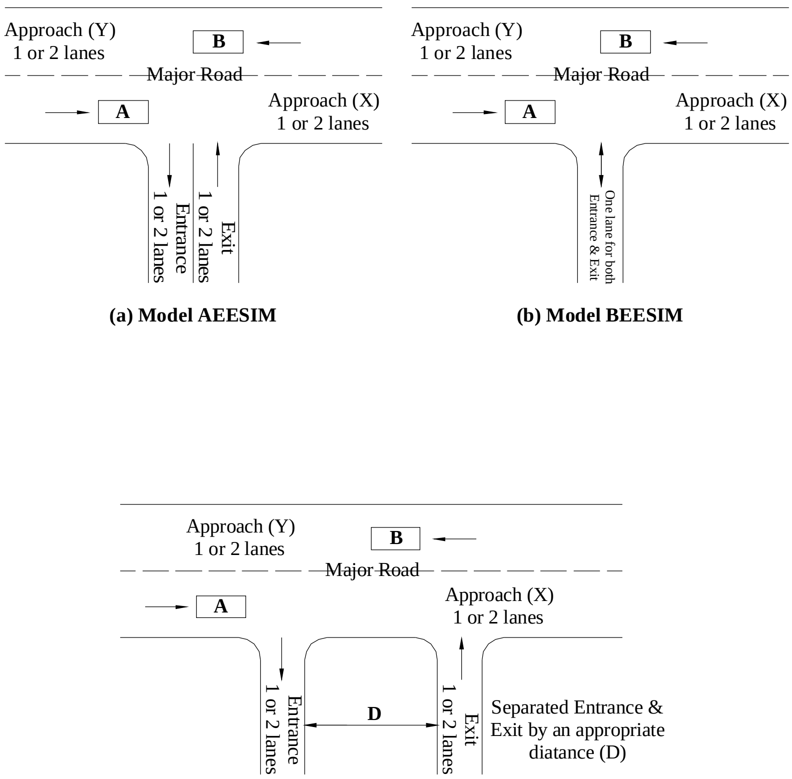


(c) Model SEESIM

Figure (1) Layout considered in the models AEESIM, BEESIM & SEESIM.

Table (1) Values of variables used as a part of input data.

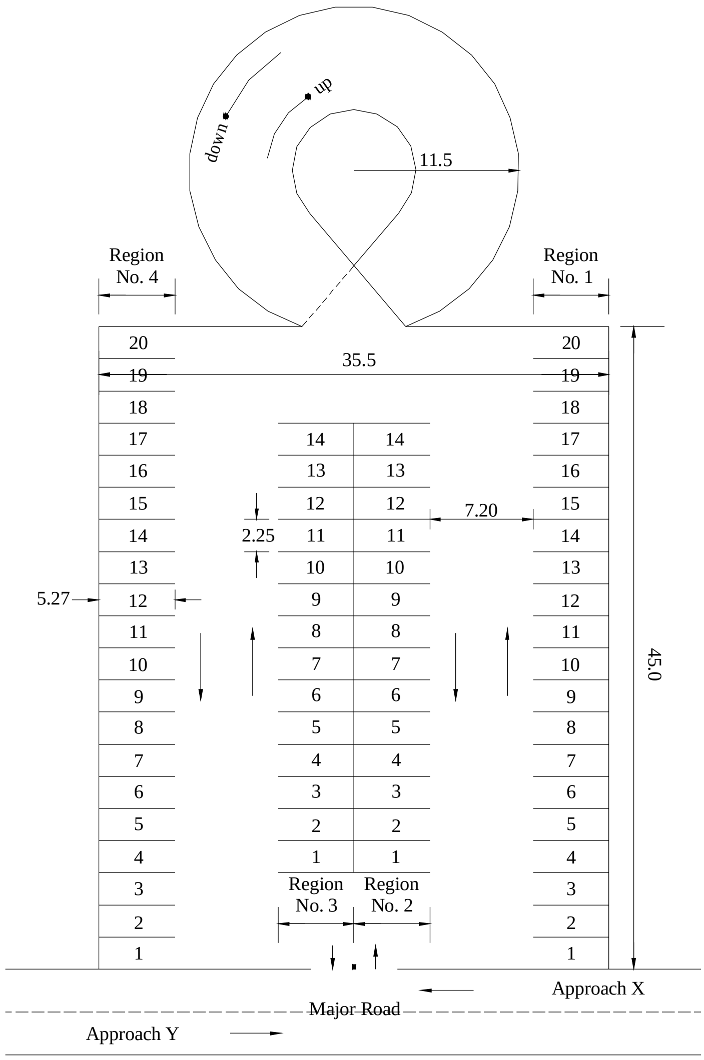
Flow level (vph)	No. of major road lane(s) of each approach	No. of lanes at entrance and exit gates	Proportion of parking vehicles from approaches X and Y
100-500	One-lane	One-lane	0.05-0.30
100-500	Two-lane	One-lane	0.05-0.30
100-500	Two-lane	Two-lane	0.05-0.30

Table (2) Lag and gap acceptance input data.

Approach	Item	Statistical distribution	Average (sec.)	Standard deviation (sec.)
Y	Lag	Normal	4.50	1.20
	Gap	Normal	5.50	1.40
Exit	Lag			
	Left	Normal	4.30	1.30
	Right	Normal	3.98	1.83
	Gap			
	Left	Normal	5.40	1.35
	Right	Normal	5.31	1.96

Table (3) Entry and exit travel times of selected stalls.

Region no.	Stall no.	Entry travel time (sec.)		Exit travel time (sec.)	
		Average	S.D.	Average	S.D.
1	6	10.08	0.90	10.76	2.59
2	12	17.52	2.45	18.36	0.99
3	5	13.50	0.82	12.26	0.82
4	8	14.26	2.24	15.00	1.70

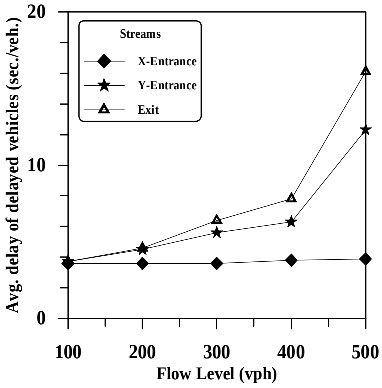


Note: All dimensions are in meters.

Figure (2) Designed layout of the parking garage.

Table (4) The simulation results of average delay of delayed vehicles (sec./veh.).

Flow level (vph)	Geometrical conditions								
	No. of lanes at: App-X=1, App-Y=1 Entrance=1, Exit=1			No. of lanes at: App-X=2, App-Y=2 Entrance=1, Exit=1			No. of lanes at: App-X=2, App-Y=2 Entrance=2, Exit=2		
	Stream			Stream			Stream		
	X-Ent.	Y-Ent.	Exit	X-Ent.	Y-Ent.	Exit	X-Ent.	Y-Ent.	Exit
Proportion of parking vehicles from approaches X & Y = 0.05									
100	3.6	3.7	3.7	3.3	3.7	3.7	3.3	3.7	3.7
200	3.6	4.5	4.6	3.3	3.9	4.6	3.3	3.9	4.3
300	3.6	5.6	6.4	3.3	4.3	6.2	3.3	4.3	6.1
400	3.6	6.3	7.8	3.3	5.4	7.5	3.3	5.4	7.5
500	3.9	12.3	16.1	3.3	7.3	15.8	3.3	6.5	9.4
Proportion of parking vehicles from approaches X & Y = 0.10									
100	3.3	3.8	3.6	3.3	3.7	3.6	3.3	3.7	3.6
200	3.6	4.1	4.8	3.3	4.0	4.2	3.3	4.0	4.0
300	3.8	5.4	6.1	3.3	4.5	5.6	3.3	4.5	5.2
400	3.8	6.6	12.2	3.3	5.9	9.9	3.3	5.8	8.9
500	4.3	9.0	19.7	3.4	6.0	14.5	3.3	6.4	11.8
Proportion of parking vehicles from approaches X & Y = 0.15									
100	3.6	4.3	3.9	3.3	3.8	3.9	3.3	3.8	3.9
200	3.8	4.7	4.7	3.3	4.4	4.6	3.3	4.4	4.4
300	3.9	5.5	5.9	3.3	4.5	5.9	3.3	4.6	5.9
400	4.2	7.7	10.6	3.3	6.3	9.2	3.3	6.4	7.1
500	4.4	9.2	23.0	3.3	7.6	17.7	3.3	7.8	13.1
Proportion of parking vehicles from approaches X & Y = 0.20									
100	3.5	3.7	3.6	3.4	3.6	3.6	3.3	3.6	3.6
200	3.6	4.8	4.8	3.4	4.2	4.8	3.3	4.3	4.5
300	3.7	5.6	6.8	3.4	5.2	6.7	3.3	4.9	5.9
400	4.1	7.5	13.0	3.5	6.3	11.8	3.3	6.2	9.2
500	4.3	10.1	49.9	3.6	8.2	30.5	3.3	8.0	15.6
Proportion of parking vehicles from approaches X & Y = 0.25									
100	3.4	3.9	3.9	3.3	3.7	3.8	3.3	3.7	3.8
200	3.7	4.4	4.9	3.4	4.1	4.9	3.3	4.2	4.7
300	3.8	5.5	8.0	3.5	4.9	7.0	3.3	5.2	6.5
400	4.2	7.5	16.0	3.6	6.6	15.5	3.4	6.2	9.2
500	4.7	13.8	134.7	3.7	8.3	51.8	3.4	9.2	19.1
Proportion of parking vehicles from approaches X & Y = 0.30									
100	3.6	4.0	3.8	3.5	3.8	3.8	3.3	3.7	3.7
200	3.7	4.5	5.2	3.5	4.3	5.1	3.3	4.3	4.6
300	3.8	6.2	8.5	3.5	5.0	8.2	3.3	5.1	5.8
400	4.2	8.1	33.7	3.7	6.2	19.7	3.4	6.8	12.4
500	4.8	12.4	508.2	3.9	9.3	105.5	3.4	9.2	26.7



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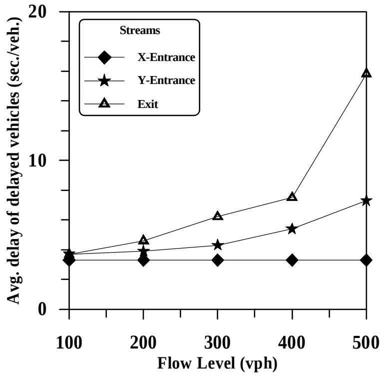

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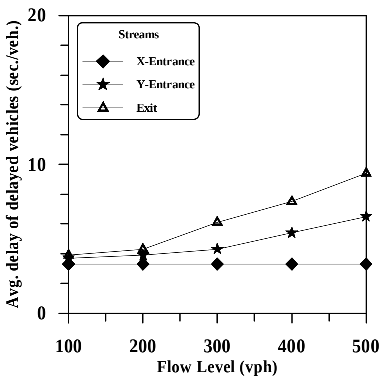
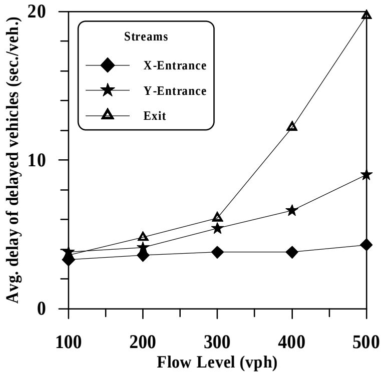


(c) (App.-X=2, App.-Y=2, Ent.=2, Ext.=2)*

(*)
App.-X = No. of lanes at approach X
App.- = No. of lanes at approach Y
Ent. = No. of lanes at the entrance gate
Ext. = No. of lanes at the exit gate

Figure (3) Average delay of delayed vehicles at the entrance and exit gates of the designed parking garage for a different number of lanes at the major road as well as at the entrance and exit gates and for different flow levels, (proportion of parking vehicles from approaches X & Y=0.05)



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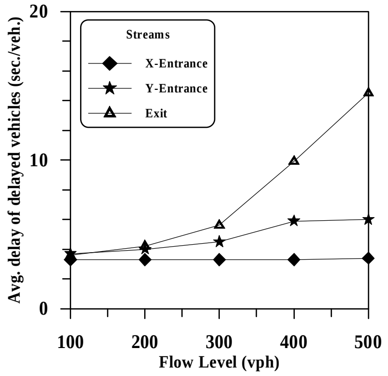

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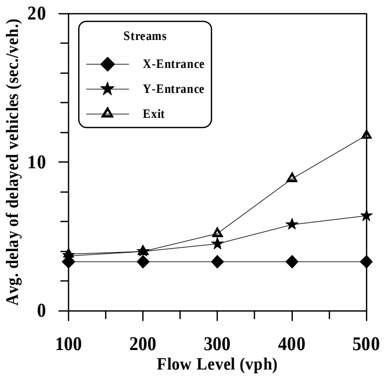
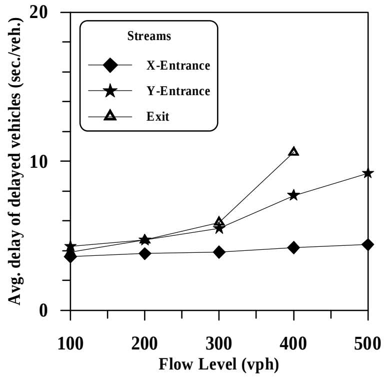


(c) (App.-X=2, App.-Y=2, Ent.=2, Ext.=2)*

(*)
App.-X = No. of lanes at approach X
App.-Y = No. of lanes at approach Y
Ent. = No. of lanes at the entrance gate
Ext. = No. of lanes at the exit gate

Figure (4) Average delay of delayed vehicles at the entrance and exit gates of the designed parking garage for a different number of lanes at the major road as well as at the entrance and exit gates and for different flow levels, (proportion of parking vehicles from approaches X & Y=0.10)



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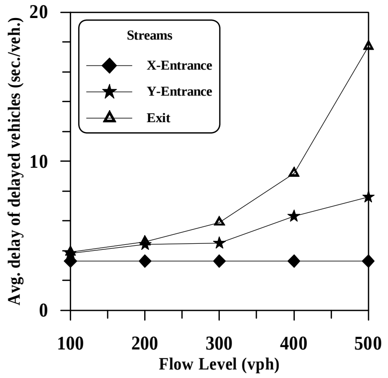

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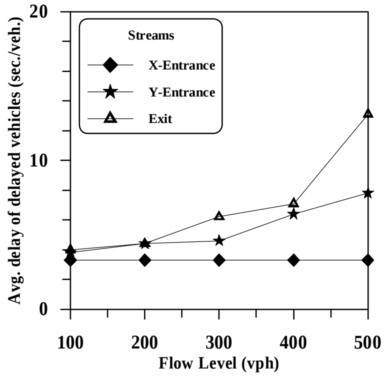
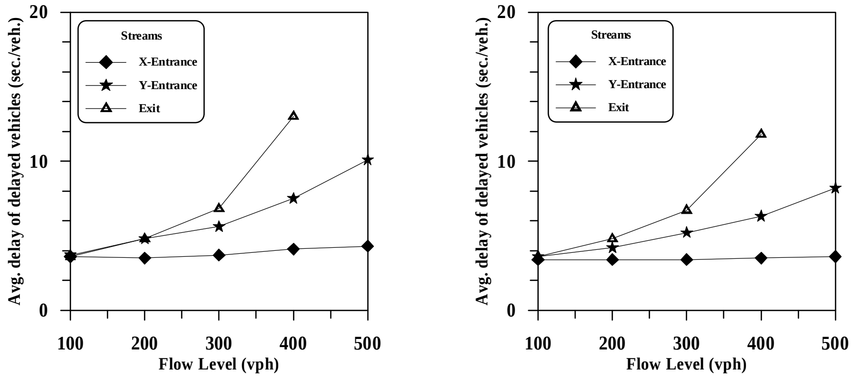


(c) (App.-X=2, App.-Y=2, Ent.=2, Ext.=2)*

(*)
App.-X = No. of lanes at approach X
App.-Y = No. of lanes at approach Y
Ent. = No. of lanes at the entrance gate
Ext. = No. of lanes at the exit gate

Figure (5) Average delay of delayed vehicles at the entrance and exit gates of the designed parking garage for a different number of lanes at the major road as well as at the entrance and exit gates and for different flow levels, (proportion of parking vehicles from approaches X & Y=0.15)



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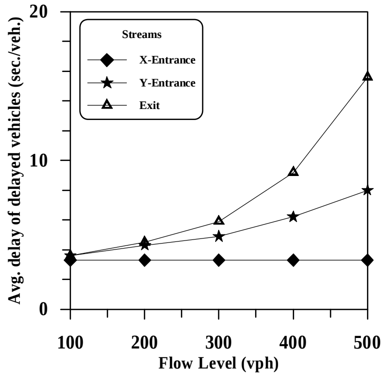
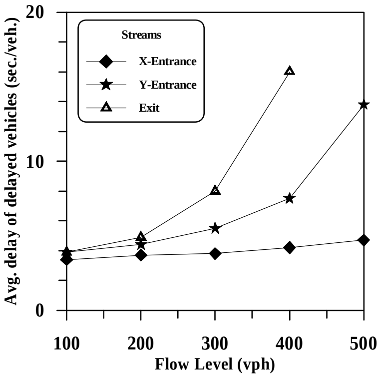


(*)
App.-X = No. of lanes at approach X
App.-Y = No. of lanes at approach Y
Ent. = No. of lanes at the entrance gate
Ext. = No. of lanes at the exit gate

(c) (App.-X=2, App.-Y=2, Ent.=2, Ext.=2)*

Figure (6) Average delay of delayed vehicles at the entrance and exit gates of the designed parking garage for a different number of lanes at the major road as well as at the entrance and exit gates and for different flow levels, (proportion of parking vehicles from approaches X & Y=0.20)



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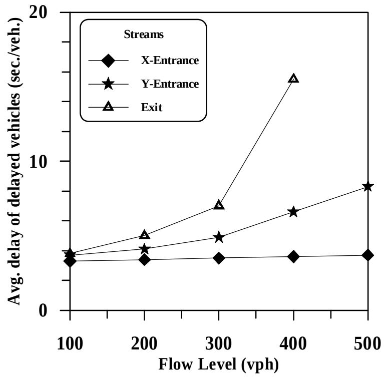

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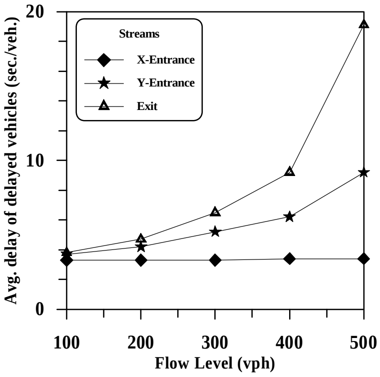
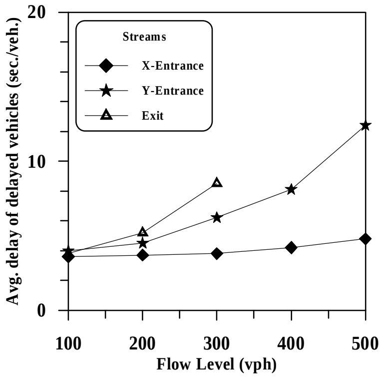


(c) (App.-X=2, App.-Y=2, Ent.=2, Ext.=2)*

(*)
App.-X = No. of lanes at approach X
App.-Y = No. of lanes at approach Y
Ent. = No. of lanes at the entrance gate
Ext. = No. of lanes at the exit gate

Figure (7) Average delay of delayed vehicles at the entrance and exit gates of the designed parking garage for a different number of lanes at the major road as well as at the entrance and exit gates and for different flow levels, (proportion of parking vehicles from approaches X & Y=0.25)



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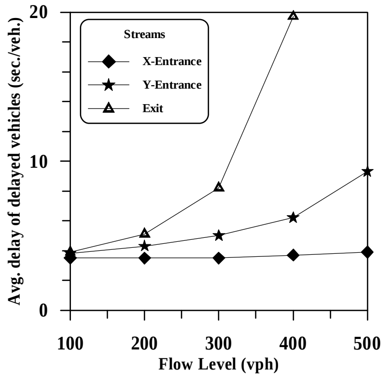

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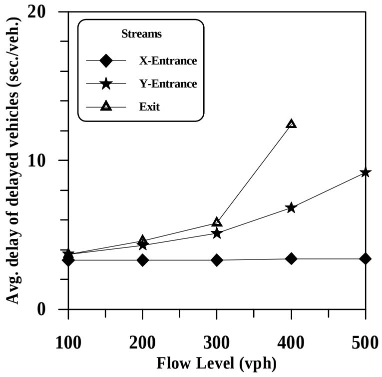

(c) (App.-X=2, App.-Y=2, Ent.=2, Ext.=2)*

(*)
App.-X = No. of lanes at approach X
App.-Y = No. of lanes at approach Y
Ent. = No. of lanes at the entrance gate
Ext. = No. of lanes at the exit gate

Figure (8) Average delay of delayed vehicles at the entrance and exit gates of the designed parking garage for a different number of lanes at the major road as well as at the entrance and exit gates and for different flow levels, (proportion of parking vehicles from approaches X & Y=0.30)

Table (5) Percent decreases in average delay of delayed vehicles (%).

Flow level (vph)	Geometrical conditions								
	No. of lanes at: App-X=1, App-Y=1 Entrance=1, Exit=1			No. of lanes at: App-X=2, App-Y=2 Entrance=1, Exit=1			No. of lanes at: App-X=2, App-Y=2 Entrance=2, Exit=2		
	Stream			Stream			Stream		
	X-Ent.	Y-Ent.	Exit	X-Ent.	Y-Ent.	Exit	X-Ent.	Y-Ent.	Exit
Proportion of parking vehicles from approaches X & Y = 0.05									
100	0.0	0.0	0.0	8.3	0.0	0.0	8.3	0.0	0.0
200	0.0	0.0	0.0	8.3	13.3	0.0	8.3	13.3	6.5
300	0.0	0.0	0.0	8.3	23.2	3.1	8.3	23.2	4.7
400	0.0	0.0	0.0	8.3	14.3	3.8	8.3	14.3	3.8
500	0.0	0.0	0.0	15.4	40.7	1.9	15.4	47.2	41.6
Proportion of parking vehicles from approaches X & Y = 0.10									
100	0.0	0.0	0.0	0.0	2.6	0.0	0.0	2.6	0.0
200	0.0	0.0	0.0	8.3	2.4	12.5	8.3	2.4	16.7
300	0.0	0.0	0.0	13.2	16.7	8.2	13.2	16.7	14.8
400	0.0	0.0	0.0	13.2	10.6	18.9	13.2	12.1	27.0
500	0.0	0.0	0.0	20.9	33.3	26.4	23.3	28.9	40.1
Proportion of parking vehicles from approaches X & Y = 0.15									
100	0.0	0.0	0.0	8.3	11.6	0.0	8.3	11.6	0.0
200	0.0	0.0	0.0	13.2	6.4	2.1	13.2	6.4	6.4
300	0.0	0.0	0.0	15.4	18.2	0.0	15.4	16.4	0.0
400	0.0	0.0	0.0	21.4	18.2	13.2	21.4	16.9	33.0
500	0.0	0.0	0.0	25.0	17.4	23.0	25.0	15.2	43.0
Proportion of parking vehicles from approaches X & Y = 0.20									
100	0.0	0.0	0.0	2.9	2.7	0.0	5.7	2.7	0.0
200	0.0	0.0	0.0	5.6	12.5	0.0	8.3	10.4	6.3
300	0.0	0.0	0.0	8.1	7.1	1.5	10.8	12.5	13.2
400	0.0	0.0	0.0	14.6	16.0	9.2	19.5	17.3	29.2
500	0.0	0.0	0.0	16.3	18.8	38.9	23.3	20.8	68.7
Proportion of parking vehicles from approaches X & Y = 0.25									
100	0.0	0.0	0.0	2.9	5.1	2.6	2.9	5.1	2.6
200	0.0	0.0	0.0	8.1	6.8	0.0	10.8	4.5	4.1
300	0.0	0.0	0.0	7.9	10.9	12.5	13.2	5.5	18.8
400	0.0	0.0	0.0	14.3	12.0	3.1	19.0	17.3	42.5
500	0.0	0.0	0.0	21.3	39.9	61.5	27.7	33.3	85.8
Proportion of parking vehicles from approaches X & Y = 0.30									
100	0.0	0.0	0.0	2.8	5.0	0.0	8.3	7.5	2.6
200	0.0	0.0	0.0	5.4	4.4	1.9	10.8	4.4	11.5
300	0.0	0.0	0.0	7.9	19.4	3.5	13.2	17.7	31.8
400	0.0	0.0	0.0	11.9	23.5	41.5	19.0	16.0	63.2
500	0.0	0.0	0.0	18.8	25.0	79.2	29.2	25.8	94.7