Utilization of Variable Message Signs to Reduce the Queue Delay Values at Off-Street Parking Facilities

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Abstract

Generally, Advanced Parking Management Systems (APMS) use Variable Message Signs (VMS) to provide drivers with updated information on the number of open spaces at selected off-street parking facility to minimize or avoid parking search traffic within a full car park facility, and reduce the delay times at the entrance and exit gates of a parking facility. The simulation model STARSIM-VMS is developed, in the present study, to simulate the operation of a designed parking garage with the implementation of the VMS technology. The simulation results show that the delay values is smallest than that predicted without using the VMS technique, especially at the high proportions of vehicles waiting to park. These results reflect the importance of using the VMS in the transportation systems.

Keywords: Parking, Variable Message Sign, Delay times.

استخدام اللوحات الالكترونية القابلة لتغيير معلوماتها (VMS) لتقليل أوقات التأخير عند مواقف المركبات

الخلاصة

بصورة عامة، تقوم أنظمة إدارة مواقف المركبات (APMS) باستخدام اللوحات الالكترونية التي لها القابلية على تحديث معلوماتها (VMS) حول عدد أماكن الوقوف المتاحة ضمن موقف معين من مواقف المركبات لتقليل أو منع البحث عن مكان للوقوف ضمن موقف ملئ بالمركبات، وبالنتيجة تقليل أوقات التأخير بالنسبة للمركبات التي تروم الدخول للموقف أو تلك التي تغادره أو المركبات التي تسير ضمن الشارع المحاذي للموقف. تم في هذا البحث تطوير برنامج المحاكاة STARSIM-VMS لتمثيل حركة المركبات وتداخلها ضمن وخارج موقف للمركبات متعدد الطوابق بالاستعانة بتقنية اللوحات الالكترونية (VMS).

أشارت النتائج التي تم الحصول عليها في هذا البحث إلى أن أوقات التأخير عند موقف المركبات - عند استخدام تقنية اللوحات الالكترونية - هو أقل بكثير من أوقات التأخير عند عدم استخدام هذه التقنية وخاصة عندما تزداد نسبة المركبات التي تريد الدخول للموقف. إن هذه النتائج تعكس مدى أهمية استخدام هذه التقنية في أنظمة النقل بشكل عام وفي أنظمة إدارة مواقف المركبات بشكل خاص.

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Introduction

Generally, parking is becoming an important aspect of transportation planning. Many areas have seen explosive growth in the number of visitors as a result of urban developments. Therefore, the Intelligent Transportation Systems' technologies are designed to speed the flow of traffic on congested areas and reduce the fuel consumption and air pollution (Kanninen, 1996), as well as, to limit the interactions and accidents among vehicles (Gangisetty and Douglas, 1995; Taylor and Brian, 1997).

ITS technologies are used in Advanced Parking Management systems (APMS) to provide drivers with up to the minute information on the available parking spaces within a parking lot. Advanced Parking Management Systems (APMSs), a type of Advanced Traffic Management Systems, link information on parking availability gathered by traffic sensors at selected parking lots to a Traffic Management Center. The Traffic Management Center, then, routes the parking availability information to drivers via sign boards located in strategic locations. Each signboard is typically an electronic Variable Message Sign (VMS) that can be updated continuously to provide real-time information to drivers regarding parking availability in complex parking situations (e.g. airports, shopping districts, convention centers, etc.) (Hester et. al., 2002; Levinson and Huo, 2003).

Generally, the use of VMS avoids drivers from looking for an empty space within a full car park. Therefore, the Advanced Parking Management Systems deploys the VMS to reduce the delay time values at the entrance and exit gates of a car park. In the present paper, the simulation package STARSIM (Jrew et. al., 2000 a, b) is developed to a simulation package STARSIM-VMS to simulate the operation of a car park with the use of VMS technology, which may be lead to reduce the queue delay at the gates of a car park, especially the queue delay that results from the bank up of vehicles in the roadway beneath the off-street parking facility.

Figure (1) shows the summarized flow chart of the developed package.

Objective and Scope of the Study

The objective of the present paper is to study the ability of reducing the amount of time spent by drivers searching for an empty parking space within an off-street parking facility. This process may cause a reduction in queue delay values at the gates of parking facilities when they full.

Flow level, number of lanes at each approach of the major road, number of lanes at the entrance and exit gates, and proportion of vehicles waiting to park from the major road are taken as the most important factors which have the great effect on the delay values that reflect one of the performance measures of the parking facility.

The Simulation Results

The developed simulation package STARSIM-VMS is used to generate a range of queue delay values of the delayed vehicles at the gates of a designed parking garage shown in Figure (2). The results represent a 270 runs of the STARSIM-VMS simulation package. These delay values is compared with the delay values for the scenario without providing updated information, about the off-street parking facility, as a base line, using the simulation package STARSIM (Ismail and Al-Ubaidy, 2007) to predict the benefits of giving real-time information about the availability of parking spaces via the VMS. The difference between the two delay measures is the estimated delay benefit of VMS deployment. The package allows for the prediction of queue delays for one hour, as well as, multiple hours of deployment. In this paper, six hours is taken as the simulation time (or deployment time) with 0.5 seconds of scanning and updating intervals of the car park facility.

It is important to note that when the simulated parking facility reaches its capacity, any entering of vehicles to the facility is prohibited by the "**Parking Facility is Full**" message sign.

Table (1) shows the average delay values of delayed vehicles at the entrance and exit gates of the designed off-street parking facility without using the VMS technique using the simulation package STARSIM, while Table (2) represents the average delay values with the deployment of VMS technique using the simulation package STARSIM-VMS. The predicted delay benefit values are shown in Table (3). These values can be used to generate number of curves to help the traffic engineer understand and assess the trend of how delay benefits change with the change of proportion of vehicles waiting to park if the VMS technique is used. It can be seen from Figure (3), as an example, that the delay benefits are, always, positive and increase with the increase of proportion of vehicles waiting to park, except some values. These benefit values appear, especially, at the high proportions.

Conclusions

a) The technologies developed through Intelligent Transportation Systems (ITS) by using Variable Message Signs (VMS) provide extensive benefits of operation of the off-street parking facilities.
b) The simulation technique can provide an illustration to the operation of parking facilities.
c) The use of VMS at the gates of the off-street parking facilities reduces the queue delay values of delayed vehicles at these gates with good benefits, due to the elimination of queues entering parking facilities and fuel consumed while searching for available parking space in a full parking facility.
d) It can be seen, from the simulation results, that the predicted delay benefit values ranges from 0.0 to approximately 500 sec./vehicle according to the boundary conditions used in the present paper.

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Table (1) The simulation results of average delay of delayed vehicles using the simulation package STARSIM (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

Source: (Ismail and Al-Ubaidy, 2007)

Table (2) The simulation results of average delay of delayed vehicles using the developed simulation package STARSIM-VMS (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	3.4	3.2	3.4	3.3	3.2	3.4	3.3	3.2	3.4
200	3.6	3.6	4.5	3.3	3.6	4.5	3.3	3.6	4.2
300	3.6	4.2	4.9	3.3	3.9	4.9	3.3	3.9	4.7
400	3.6	4.3	7.8	3.3	3.9	7.0	3.3	3.9	7.0
500	3.9	4.7	9.8	3.3	3.9	9.8	3.3	3.9	9.3
Proportion of parking vehicles from approaches X & Y = 0.10									
100	3.3	3.7	3.3	3.3	3.6	3.3	3.3	3.6	3.3
200	3.5	3.7	3.9	3.3	3.6	3.9	3.3	3.6	3.8
300	3.5	3.9	5.6	3.3	3.9	5.6	3.3	3.9	5.1
400	3.8	4.6	7.8	3.3	4.0	7.6	3.3	3.9	7.2
500	4.3	4.9	13.2	3.3	4.0	13.5	3.3	3.9	11.2
Proportion of parking vehicles from approaches X & Y = 0.15									
100	3.6	3.6	3.2	3.3	3.6	3.2	3.3	3.6	3.2
200	3.8	3.6	3.9	3.3	3.6	3.9	3.3	3.6	3.9
300	3.7	4.1	5.3	3.3	4.1	4.9	3.3	4.1	4.4
400	4.0	6.8	8.1	3.4	4.2	6.9	3.3	4.2	6.5
500	4.6	6.9	8.4	3.4	4.2	7.5	3.4	4.2	7.5
Proportion of parking vehicles from approaches X & Y = 0.20									
100	3.4	3.4	3.6	3.3	3.4	3.6	3.3	3.4	3.5
200	3.7	4.1	4.5	3.3	3.9	4.1	3.3	3.9	4.1
300	3.8	4.6	6.1	3.3	4.6	5.5	3.3	4.6	5.3
400	3.8	5.7	7.5	3.4	5.0	6.4	3.3	5.0	6.2
500	4.6	7.8	12.3	3.5	6.1	11.1	3.3	5.6	9.7
Proportion of parking vehicles from approaches X & Y = 0.25									
100	3.6	3.3	3.6	3.3	3.3	3.6	3.3	3.3	3.6
200	3.6	4.0	4.8	3.4	3.7	4.8	3.3	3.7	4.3
300	3.8	4.5	5.4	3.4	4.5	5.1	3.3	3.7	5.0
400	4.0	6.2	6.9	3.5	4.5	5.8	3.3	4.4	5.7
500	4.2	8.0	8.8	3.5	4.7	8.8	3.3	4.7	8.7
Proportion of parking vehicles from approaches X & Y = 0.30									
100	3.4	4.0	3.6	3.3	4.0	3.6	3.3	4.0	3.6
200	3.7	4.3	5.0	3.5	4.3	4.8	3.3	4.0	4.3
300	3.8	4.6	6.1	3.5	4.3	4.9	3.3	4.0	4.6
400	4.1	4.8	6.6	3.5	4.3	5.9	3.4	4.1	5.8
500	4.4	9.8	11.9	3.5	5.8	10.9	3.4	5.6	7.9

Table (3) The predicted delay benefit values (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	0.2	0.5	0.3	0.0	0.5	0.3	0.0	0.5	0.3
200	0.0	0.9	0.1	0.0	0.3	0.1	0.0	0.3	0.1
300	0.0	1.4	1.5	0.0	0.4	1.3	0.0	0.4	1.4
400	0.0	2.0	0.0	0.0	1.5	0.5	0.0	1.5	0.5
500	0.0	7.6	6.3	0.0	3.4	6.0	0.0	2.6	0.1
Proportion of parking vehicles from approaches X & Y = 0.10									
100	0.0	0.1	0.3	0.0	0.1	0.3	0.0	0.1	0.3
200	0.1	0.4	0.9	0.0	0.4	0.3	0.0	0.4	0.2
300	0.3	1.5	0.5	0.0	0.6	0.0	0.0	0.6	0.1
400	0.0	2.0	4.4	0.0	1.9	2.3	0.0	1.9	1.7
500	0.0	4.1	6.5	0.1	2.0	1.0	0.0	2.5	0.6
Proportion of parking vehicles from approaches X & Y = 0.15									
100	0.0	0.7	0.7	0.0	0.2	0.7	0.0	0.2	0.7
200	0.0	1.1	0.8	0.0	0.8	0.7	0.0	0.8	0.5
300	0.2	1.4	0.6	0.0	0.4	1.0	0.0	0.5	1.5
400	0.2	0.9	2.5	-0.1	2.1	2.3	0.0	2.2	0.6
500	-0.2	2.3	14.6	-0.1	3.4	10.2	-0.1	3.6	5.6
Proportion of parking vehicles from approaches X & Y = 0.20									
100	0.1	0.3	0.0	0.1	0.2	0.0	0.0	0.2	0.1
200	-0.1	0.7	0.3	0.1	0.3	0.7	0.0	0.4	0.4
300	-0.1	1.0	0.7	0.1	0.6	1.2	0.0	0.3	0.6
400	0.3	1.8	5.5	0.1	1.3	5.4	0.0	1.2	3.0
500	-0.3	2.3	37.6	0.1	2.1	19.4	0.0	2.4	5.9
Proportion of parking vehicles from approaches X & Y = 0.25									
100	-0.2	0.6	0.3	0.0	0.4	0.2	0.0	0.4	0.2
200	0.1	0.4	0.1	0.0	0.4	0.1	0.0	0.5	0.4
300	0.0	1.0	2.6	0.1	0.4	1.9	0.0	1.5	1.5
400	0.2	1.3	9.1	0.1	2.1	9.7	0.1	1.8	3.5
500	0.5	5.8	125.9	0.2	3.6	43.0	0.1	4.5	10.4
Proportion of parking vehicles from approaches X & Y = 0.30									
100	0.2	0.0	0.2	0.2	-0.2	0.2	0.0	-0.3	0.1
200	0.0	0.2	0.2	0.0	0.0	0.3	0.0	0.3	0.3
300	0.0	1.6	2.4	0.0	0.7	3.3	0.0	1.1	1.2
400	0.1	3.3	27.1	0.2	1.9	13.8	0.0	2.7	6.6
500	0.4	2.6	496.3	0.4	3.5	94.6	0.0	3.6	18.8

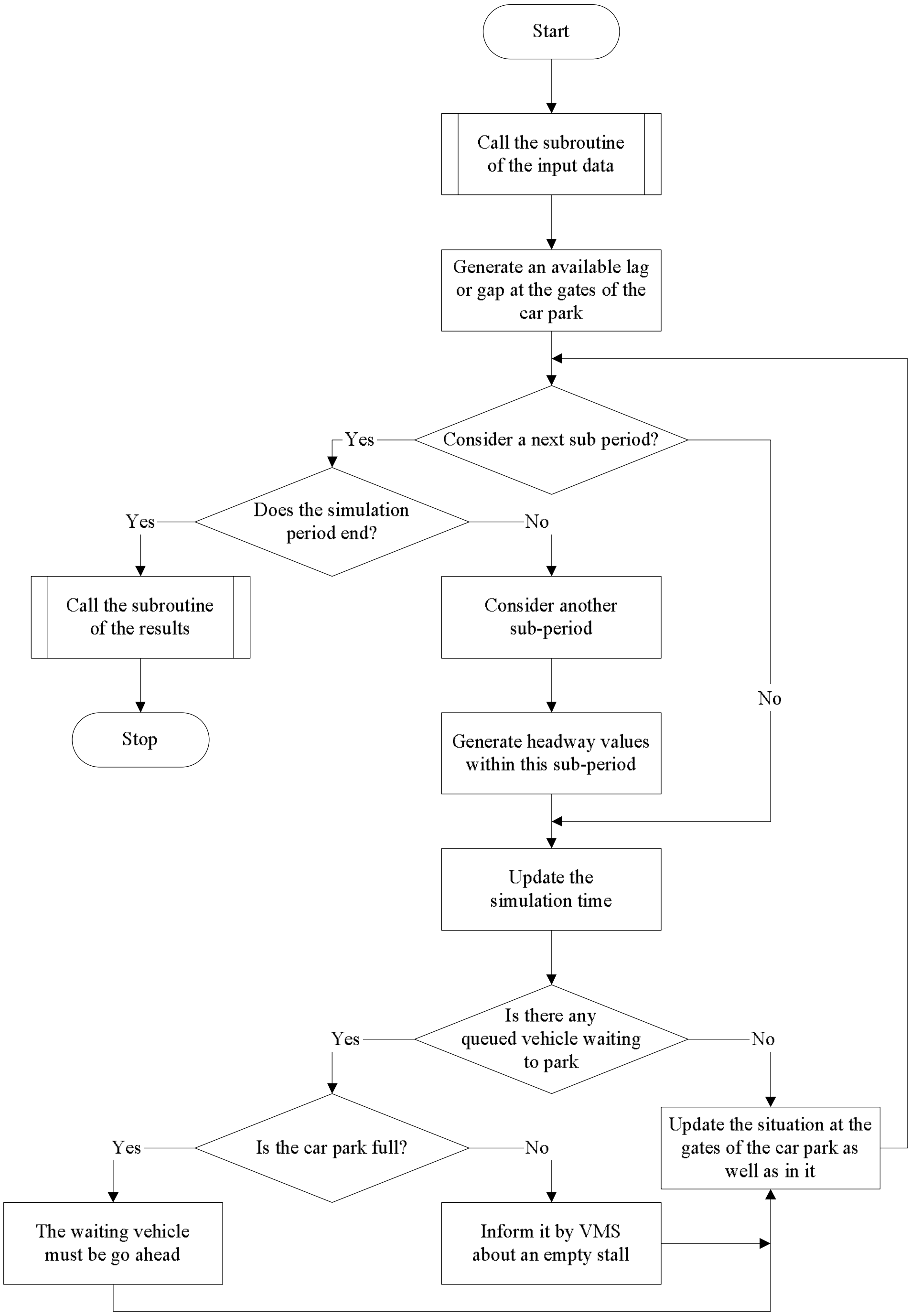
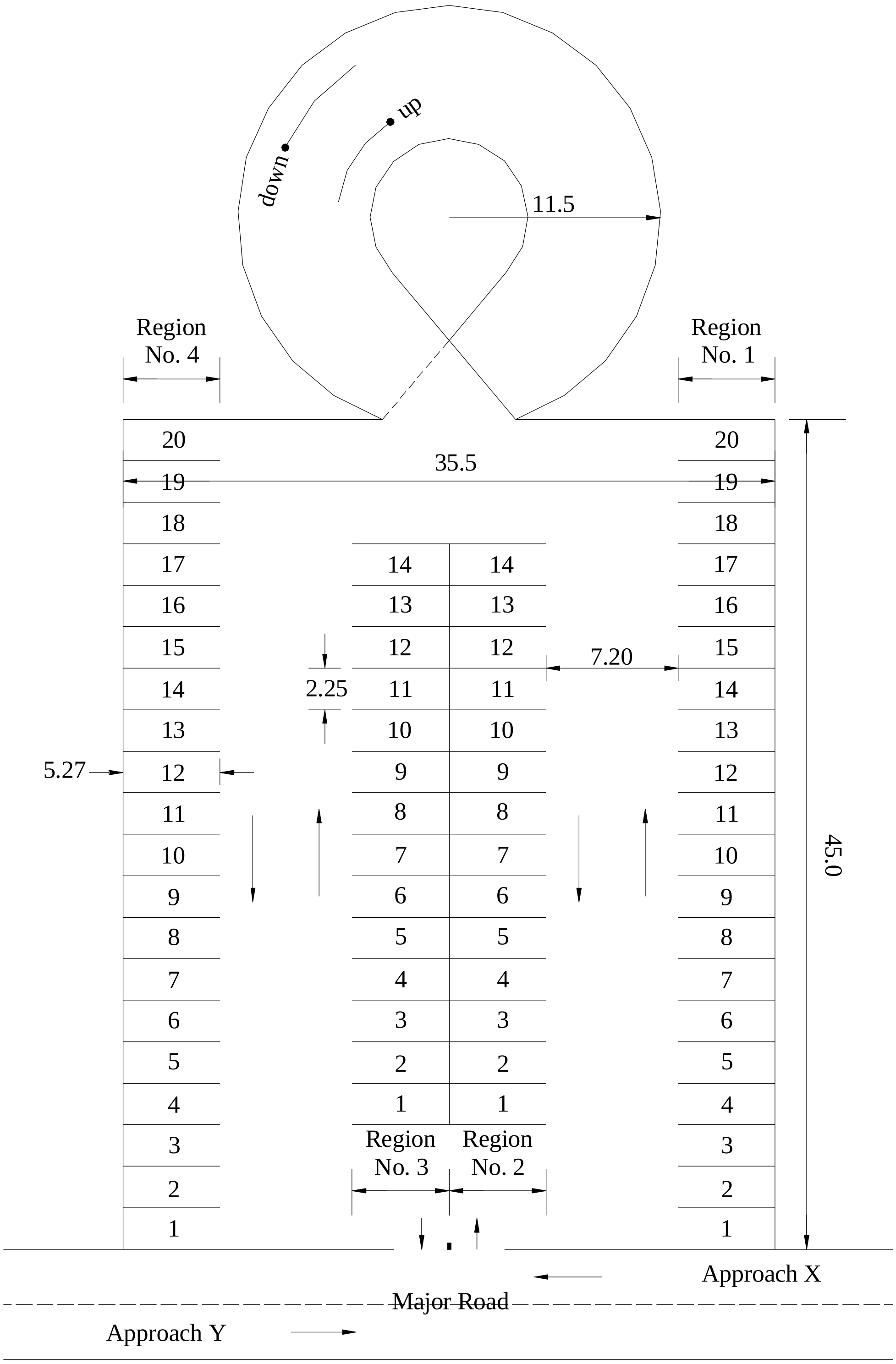


Figure (1) Flowchart of the developed simulation package STARSIM-VMS.



Note: All dimensions are in meters.
Figure (2) Designed layout of the parking garage.
Source: (Ismail and Al-Ubaidy, 2007)

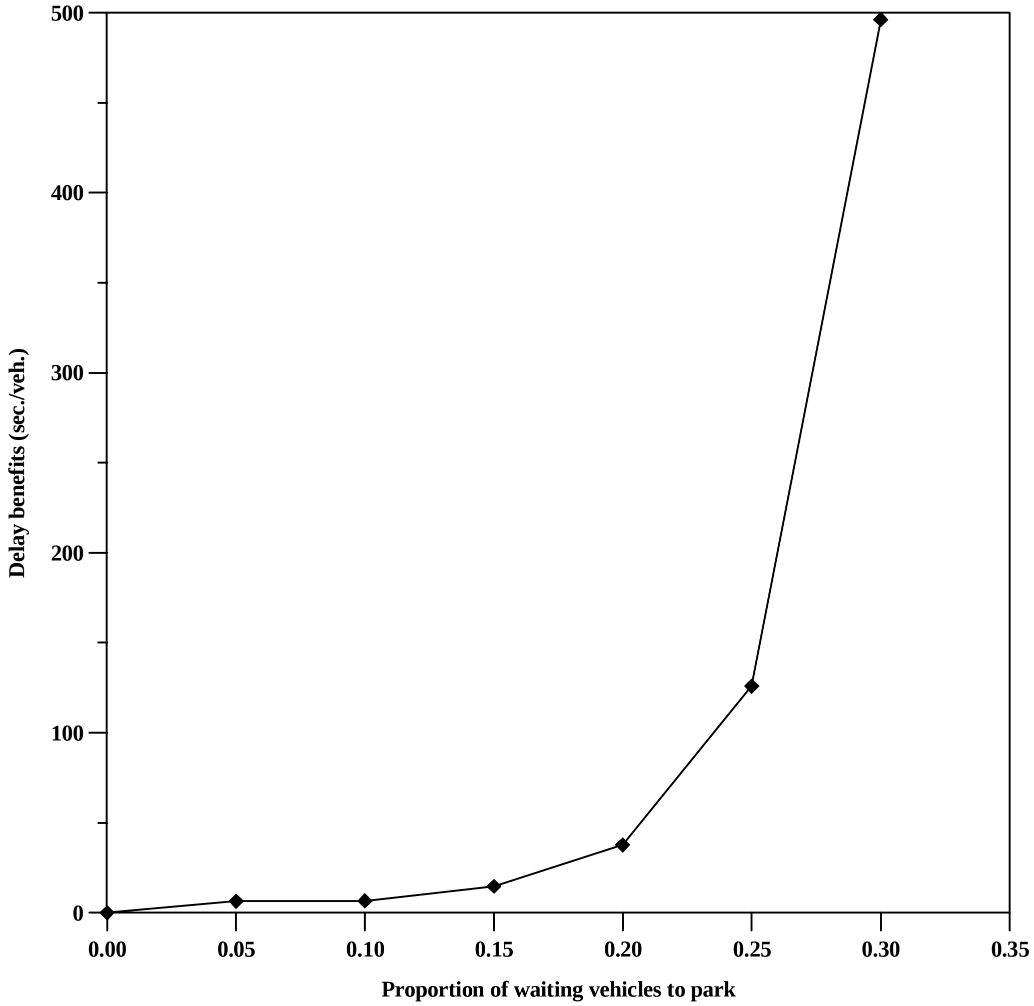


Figure (3) Example of delay benefit curves as a function of the proportion of waiting vehicles to park.