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Modeling Jordan University of Science and Technology Parking Using Arena Program

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***Abstract*—**Over the last decade, the over population that has happened in urban areas has been reflecting on the services that various local institutions provide to car users in the form of car parks, which is becoming a daily necessity in our lives. This study focuses on car parks at Jordan University of Science and Technology, in Irbid, Jordan, to understand the university parking needs. Data regarding arrival and departure times of cars and the parking utilization were collected, to find various options that the university can implement to solve and develop an efficient car parking system. Arena software was used to simulate a parking model. This model allows measuring the different solutions that solve the parking problem at Jordan University of Science and Technology.

***Keywords*—** Car park, modeling, service time, simulation.

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I. Introduction

WITH the development of transportation during the last decade, the percentage of people using methods of transportation, such as cars, has greatly increased. This leads to the fact that facilities, such as parking, have an increasing need. In this study, the parking lots at Jordan University of Science and Technology were analyzed to define the needs of the parking lots to obtain the best utilization of the available parking lots. By achieving the best utilization, the operating costs are minimized.

Several researchers aiming to improve the efficiency and user-friendliness of car parks had studied smart car parking systems utilizing wireless sensor networks [1], [2]. A study conducted by Shital et al. aim to finding empty space in car parks utilizing a navigation system to guide unmanned vehicle in an environmental intelligent system [3].

Padiachy et al. [4] have performed a study to analyze different parking systems. Several surveys on existing parking technology were used to describe and analyze the available parking technology [5], [6]. In another study by Faheem et al., integration between intelligent parking services as a part of intelligent transportation systems was conducted to improve the management of parking systems from economic point of view [7]. Wang et al. performed a study on the causes of accidents during reversing inside the parking lots [8].

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In Jordan, modes of public transportations are used by a high percentage of students; however, good number use their personal cars.

There are four major parking lots at the university in this investigation namely, the engineering parking lot, the medical parking lot, the employee parking lot and the new medical parking lot.

This study focuses on the medical parking lot as a model and analyzes the behavior of vehicle movement; this specific parking lot has one port used as the entrance and exit points, which made the simplified the monitoring of car movements. The parking lot was monitored by video cameras between 7:00 a.m. and 6:00 p.m. for a week in July 2018 for counting number of cars entered and exited the parking area per the unit of time. The collected data were used for determining the arrival and departure distributions for the cars, which will help in simulating the data. It was observed that most vehicles used the parking lot between 9 a.m. and 3 p.m. Observations concluded that within the designated timeframe of the study, the number of vehicles entering the parking lot exceeded that of exiting vehicles.

The collected data were used to make a simulation model for the medical college parking lot using Arena software. The simulation model was then used to create different scenarios to solve the parking problems, which will be explained later. It can be also extended in future to solve other problems regarding the same parking lot or other lots in the university.

II. Data Collection and Analysis

This study focuses on a medical college parking lot at Jordan University of Science and Technology as a case study, the finding and methodology used in this study extends to all car parks at the university and other institutions in Jordan.

A. Time Pattern of Arrival Cars in the Car Park

Data were collected for a full working week (Sunday to Thursday in July 2018), for 11 hours, each day in one parking lot (the medical colleges parking lot in the university). The Jordan University of Science and Technology is open from Sunday until Thursday. The lecturing system (class schedule) is divided between Sunday, Tuesday and Thursday classes where each lecture is scheduled for an hour and Monday and Wednesday classes, where each lecture is scheduled for 1.5 hours. The operating hours for both schedules are the same; between 7:00 a.m. and 6:00 p.m. Data collection was based on intervals of 10 minutes each. Fig. 1 shows the data collected on Sunday. The figure shows that at 08:00 a.m. the number of

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vehicles in the parking lot was 20, and that the maximum limit was reached at 11:30 a.m.

Based on Fig. 1, the number of parked cars starts to decrease after 11:30 a.m., this means that the rush hours started approximately at 10:30 a.m. and finished by 2:00 p.m.

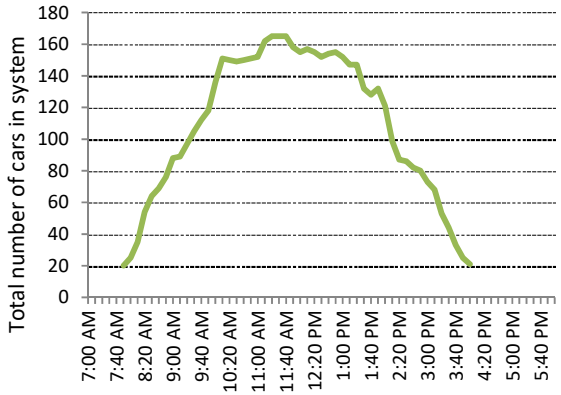


Fig. 1 Parking data in Sunday over time intervals

Data collected on Tuesday and Thursday showed the same behavior as that for Sunday with approximately the same arrival and departure patterns. On the other hand, Monday and Wednesday have the same arrival and departure patterns, which is different from that recorded for Sunday, Tuesday and Thursday. During Monday and Wednesday, the number of vehicles entering the parking lot increased during the day but never reached the maximum capacity of the car park; the maximum number of vehicles recorded in Monday was 162 vehicles at 1:30 p.m. For Wednesday, the highest number of vehicles entered was at 1 p.m. with 154 vehicles, as shown in Fig. 2. This variation between maximum number of vehicles and daily patterns attributed to the university classes schedule.

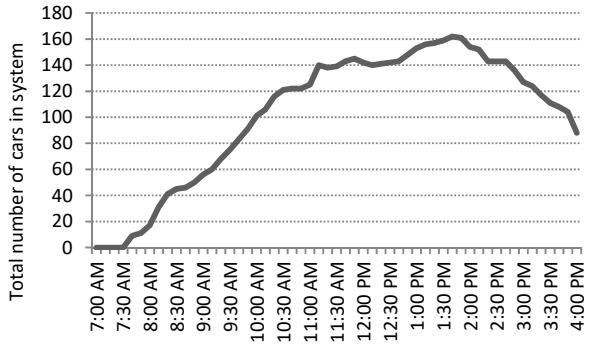


Fig. 2 Parking data in Monday over time intervals

B. Service Times

The service time is the parking time in which the vehicle uses the parking lot, the following is based on survey returned from medical colleges students (car park users), and was prepared and distributed using Google forms. The survey categories are shown in Fig. 3.

1) The number of days the student attends the university. Especially if the student attends classes during the Sunday, Tuesday and Thursday schedule, or the Monday and Wednesday schedule, or both schedules. As the lecture schedules are different as mentioned earlier.
2) The student's method of transportation.
3) If a personal vehicle is used, where do they park it?
4) The time at which they arrive at the university.
5) The time at which they depart from the university.

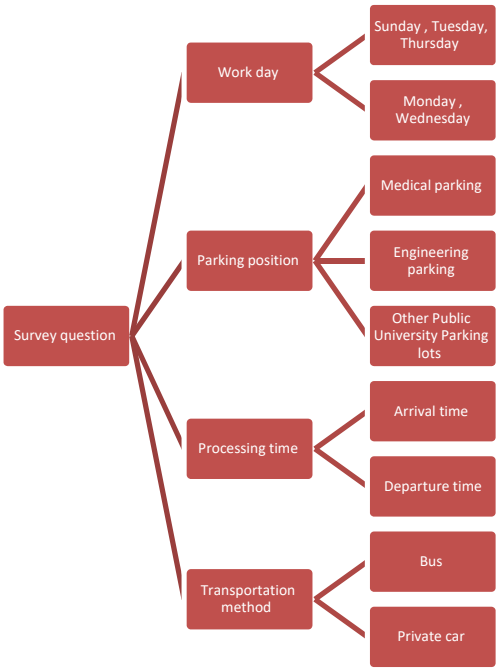


Fig. 3 Categories (questions) investigated in the survey

Data collected through the survey were analyzed. The survey shows that 77.6% of the sample size use public transportation, while the remaining 22.4% use a personal vehicle (Fig. 4). Note that this car park is designated for students use.

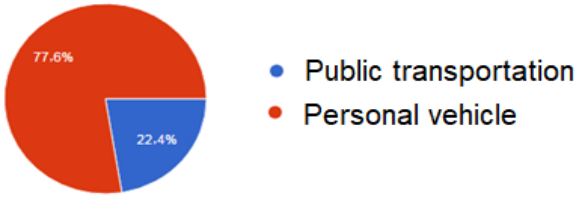


Fig. 4 Usage percentages of transportation modes

For Sunday, Tuesday and Thursday: Results show that about 24.85% of parking lot users park their cars for 6-hours, about 18% park for 7-8 hours, 16.76% for 5-hours, 13.29% for 4-hours, and 6.06% for about 3-hours, while 1.4% park for 2-hours and 0.289% for about an hour (Fig. 5).

Fig. 6 shows the results of the occupation of parking time for Monday and Wednesday users: About 19.54% of parking lot users are parked for 6-hours at a time, about 18% for 5-hours, 15.7% for 8- hours, 9.2% for 7-hours, 14.17% for about 4-hours, 12.64% for 3- hours, 8.81% for 2-hours and 1.149% for about an hour.

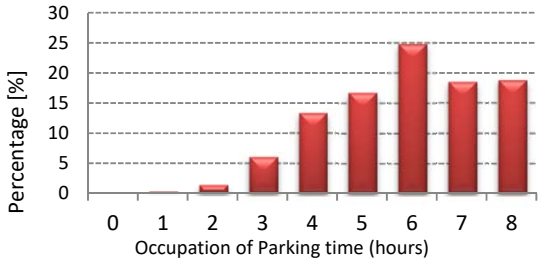


Fig. 5 Sunday group parking time percentage

III. Data Distributions

The Easy Fit program was used to determine the distribution of the data collected such the distribution of cars entering and departing the selected parking along with processing time distribution.

Based on the Easy Fit, the arrival data followed a Poisson distribution with $\lambda = 8.6182$. This means that the time between successive events follows an exponential distribution with $\lambda = 1.16$, as shown in Fig. 7.

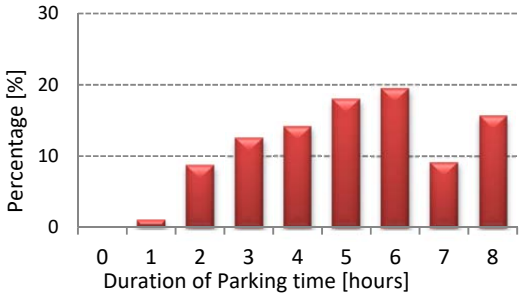
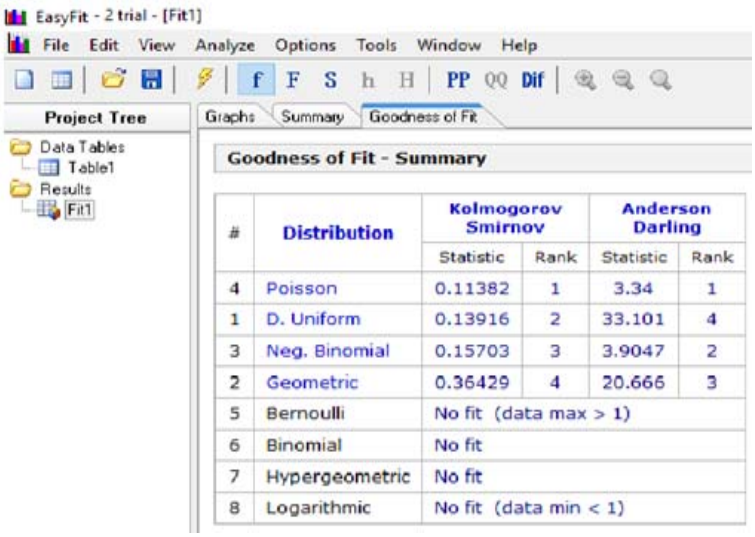


Fig. 6 Monday group processing time percentage



#	Distribution	Kolmogorov Smirnov		Anderson Darling	
		Statistic	Rank	Statistic	Rank
4	Poisson	0.11382	1	3.34	1
1	D. Uniform	0.13916	2	33.101	4
3	Neg. Binomial	0.15703	3	3.9047	2
2	Geometric	0.36429	4	20.666	3
5	Bernoulli	No fit (data max > 1)			
6	Binomial	No fit			
7	Hypergeometric	No fit			
8	Logarithmic	No fit (data min < 1)			

Fig. 7 Arrival distribution provided by easy fit program, for Sunday, Tuesday and Thursday

The parking service time was fitted based on Easy Fit software. For the Sunday, Tuesday and Thursday group, the service time followed a normal distribution with a mean of 5.84 hours and standard deviation of 1.65 hour.

For the Monday and Wednesday group, the service time followed a normal distribution with a mean of 5.3146 and a standard deviation of 1.9094 (Fig. 8).

IV. Simulation

A. Modeling with Arena

Arena simulation software was used for analyzing the parking system at the university under study. The parking system consists of different elements that play a major role in the performance and daily use of the parking lots. First, the vehicles that occupy the lot, and which arrive at different times, stay for various lengths of time in the lot, and then depart at separately. The vehicle will be represented using an entity that mimics real life. Second, the parking lot, which will be represented using a server that receives different entities and times; the server's capacity will be represented by the parking lot capacity. When a vehicle departs the parking lot, it will be modeled as the entity leaves; it goes to dispose and quits the system. Dispose is a function defined in Arena software to absorb the leaving customers (cars in this case) [9].

When modeling the system through the Arena program, the model first creates an entity (vehicle) that goes through the model and conducts different actions such as entering the server (the parking lot) and leaving it. This will provide the model with the different entities at different times, which needs the arrival and distribution data. Based on the fitted data, the arrival time of the entity follows an exponential with a mean of 1.16 minutes. Afterwards, entities enter a block representing the parking lot. The fitted service time (duration of parking) was given based on the group of days (Sunday, Tuesday and Thursday, or Wednesday and Monday) to this block. Then, a path has been selected for the entity; the first group had normal distribution of mean 5.8373 hours and standard deviation of 1.6475, while the second group had

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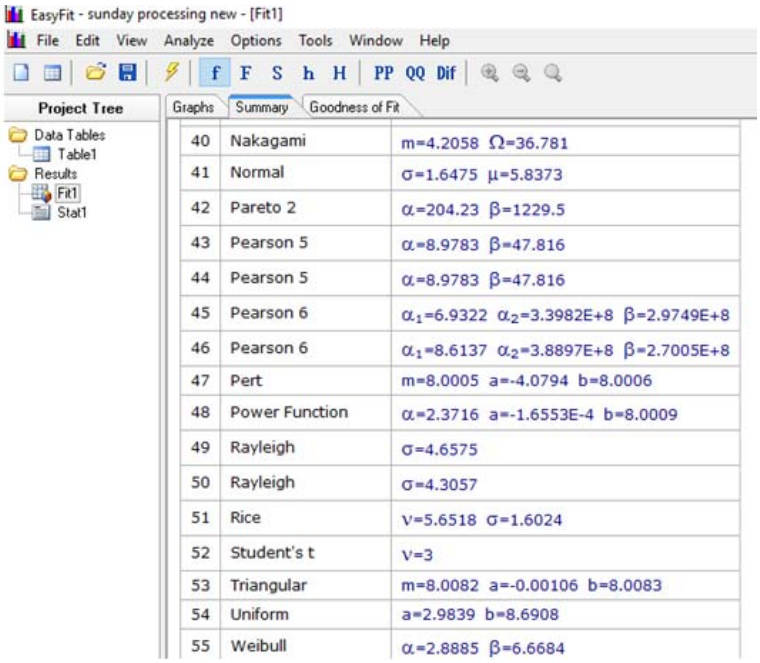
normal distribution of mean 5.1346 hours and a standard deviation of 1.9094 hours.

The simulation was run for eight hours a day and five days. Ten replicates were considered for the model. Results show that the average number of vehicles in the system was 1,939 per week. The average service time of each of the vehicles was about 2.5 hours (152.99 min). The minimum average between the 10 replications was 2.41 hours (144.62 min), and the maximum average was 2.68 hours (161.32 min). The results of the Arena simulation are presented in Fig. 9.



40	Nakagami	m=4.2058 Ω=36.781
41	Normal	σ=1.6475 μ=5.8373
42	Pareto 2	α=204.23 β=1229.5
43	Pearson 5	α=8.9783 β=47.816
44	Pearson 5	α=8.9783 β=47.816
45	Pearson 6	α_1=6.9322 α_2=3.3982E+8 β=2.9749E+8
46	Pearson 6	α_1=8.6137 α_2=3.8897E+8 β=2.7005E+8
47	Pert	m=8.0005 a=-4.0794 b=8.0006
48	Power Function	α=2.3716 a=-1.6553E-4 b=8.0009
49	Rayleigh	σ=4.6575
50	Rayleigh	σ=4.3057
51	Rice	ν=5.6518 σ=1.6024
52	Student's t	ν=3
53	Triangular	m=8.0082 a=-0.00106 b=8.0083
54	Uniform	a=2.9839 b=8.6908
55	Weibull	α=2.8885 β=6.6684

Fig. 8 Processing time of the second group, Monday and Wednesday

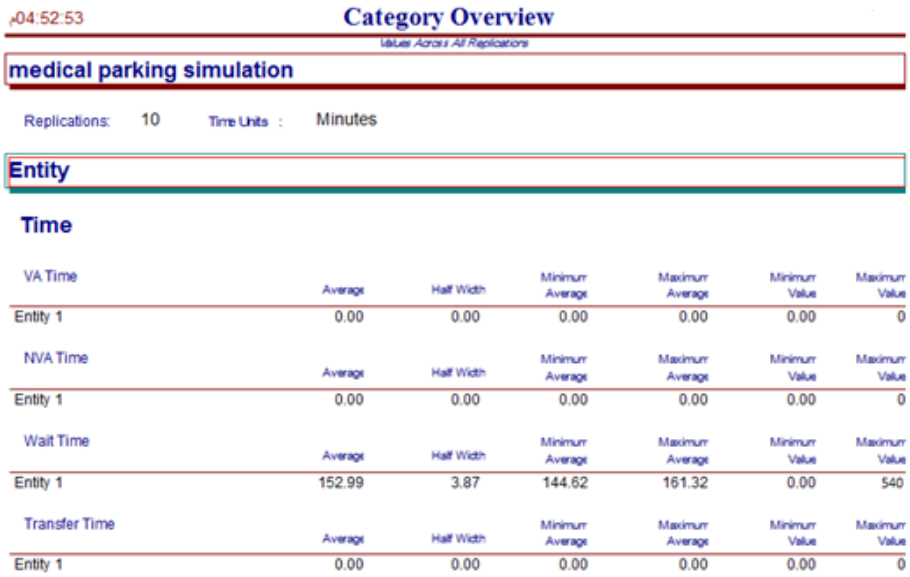


Fig. 9 Time results provided by selected entities

Fig. 10 shows the resources results, which shows that the longest service time was 9 hours. The utilization of the parking lot was 96%, the minimum average utilization per 10 replications was 95%, and the maximum average of utilization per 10 of the replications was 96.5%. The maximum value of utilization was 100%, which means that the parking lot reached its full capacity.

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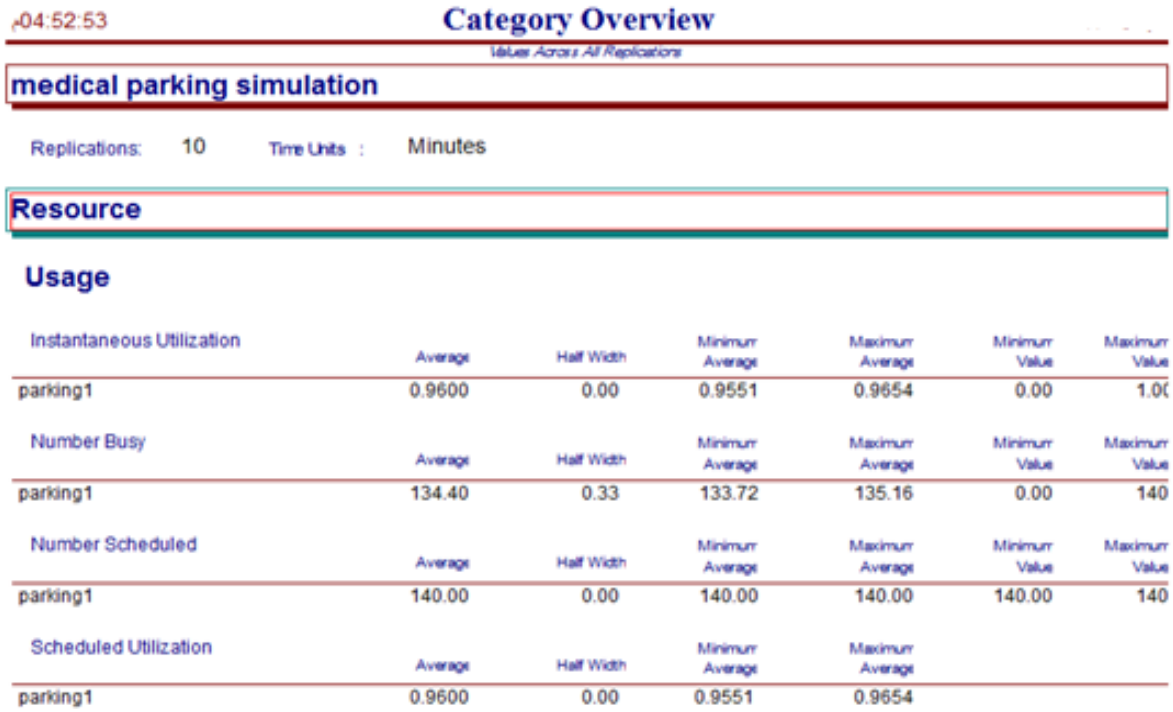
04:52:53

Category Overview

Values Across All Replications

medical parking simulation

Replications: 10 Time Units : Minutes

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
parking1	0.9600	0.00	0.9551	0.9654	0.00	1.00

Number Busy	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
parking1	134.40	0.33	133.72	135.16	0.00	140

Number Scheduled	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
parking1	140.00	0.00	140.00	140.00	140.00	140

Scheduled Utilization	Average	Half Width	Minimum Average	Maximum Average
parking1	0.9600	0.00	0.9551	0.9654

Fig. 10 Schedule and utilization results provided by resources

V. Conclusions

In this paper, a parking system was molded using Arena software. One parking lot in a university was considered (the medical college parking lot). Results of simulating this parking scenario allow the university to determine the rush hours for each parking lot. By determining the rush hours, it allows the university to reschedule lectures so that the peak number of arrival cars can be distributed over more than one hour. The academic classes in the university are divided into two groups, the first is Sunday, Tuesday and Thursday classes, and the other one includes Monday and Wednesday. The results clearly show that the parking lot was very crowded during the rush hours for the days of the first group, while for the second group the parking lot did not fill to maximum capacity. One solution to relieve congestion on certain days would be for the university can add more classes on those days (Monday and Wednesday) when parking is not used to capacity. In this way, the overall parking utilization will be improved, which in turn makes the process of finding a parking space easier and faster for students.

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