APPLICABILITY OF INFORMATION TECHNOLOGIES IN PARKING AREA CAPACITY OPTIMIZATION

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ABSTRACT

Parking area is a complex system consisting of adequate system components and of their inter-dependence; it is therefore necessary prior to analysing and planning of parking capacities to define the model of parking. The main goal of this paper is analyze the role and prove the applicability of information technologies in the function of design optimal parking area capacity. The working hypothesis is set: Applying the information technologies in optimization of parking area capacity the optimal number of servers (ramps) and the required capacity (number of parking spaces) in closed parking areas can be defined. Scientific methods applied in confirming this hypothesis are based on waiting-line models and information modelling method. The use of information technologies in optimization parking area capacity will be presented on an example of the "Delta" parking area in the City of Rijeka. A particular merit of the model is its universal applicability because the presented methodology can be applied to any other closed parking area, i.e. parking area with ramps in current or future, changed conditions.

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1. INTRODUCTION

The research problem of importance for this work stems from the fact that the demand for parking services is not constant. Changeability and dynamism of the demand for parking services are the main problem in determining the required size of parking facilities. The lines at the entrance to the parking lot, especially in peak periods, a daily occurrence. Accordingly, this paper will try to answer the following questions: What is the demand for parking services, according to which should be to design the optimal capacity of the parking lot?, Acceptable percentage of under capacity of the parking area?, How to provide service to park at a time of increased demand?. To find answers to these questions and prove set hypothesis using Excel spreadsheets to construct a realistic model of the theory of queues, which will support an open single-channel and multichannel queuing model.

2. RELEVANT CHARACTERISTICS PARKING AREA AS AN OPEN SINGLE-CHANNEL OR MULTICHANNEL QUEUING SYSTEM

According to the classification system of queues, queues all systems are based on the number of servicing channels are divided into two groups, as follows: Single and multi-channel systems. According to the number of potential clients, all queuing systems are also divided into two groups, namely: open and closed systems of queues. The common feature of all these models is that their clients Poisson input flow stream, and that their output stream of clients and serving time is exponentially distributed.

Typical symbols of the model are (Barković et al.;1986,213):

λ - mean number of arrivals per time period

μ - mean number of people or items served per time period

S – number of service facilities

P_0 – Probability of 0 units in the system (that is, the service unite is idle)

Pn – probability of n units in the system

Wq – average time a unit spends waiting in the queue

Ws – average time a units spends in the system (waiting time plus service time)

Lq – average number of units waiting in the queue

Ls – average number of units (customers) in the system (waiting and being served)

If the $\lambda < \mu$, individual values of the waiting line in single-channel system can be calculated from the following formulas (Heizer & Render; 2004, 715):

$$Ls = \frac{\lambda}{\mu-\lambda} \qquad Wq = \frac{\lambda}{\mu(\mu-\lambda)}$$

$$Ws = \frac{1}{\mu - \lambda} \qquad \rho = \frac{\lambda}{\mu}$$

$$Lq = \frac{\lambda^2}{\mu(\mu - \lambda)} \qquad P_0 = 1 - \frac{\lambda}{\mu}$$

Some values of the waiting line in multi-channel system can be calculated from the following formulas:

$$P_0 = \frac{1}{\left[\sum_{n=0}^{M-1} \frac{1}{n!}\left(\frac{\lambda^n}{\mu}\right)\right] + \frac{1}{M!}\left(\frac{\lambda^M}{\mu}\right)\frac{M\mu}{M\mu - \lambda}} \quad za M\mu > \lambda$$

$$Ls = \frac{\lambda\mu(\lambda/\mu)^M}{(M-1)!(M\mu - \lambda)^2} Po + \frac{\lambda}{\mu}$$

$$Ws = \frac{\mu(\lambda/\mu)^M}{(M-1)!(M\mu - \lambda)^2} Po + \frac{1}{\mu} = \frac{Ls}{\lambda}$$

$$Lq = Ls - \frac{\lambda}{\mu}$$

$$Wq = Ws - \frac{1}{\mu} = \frac{Lq}{\lambda}$$

If the number of inbound ramps to the parking area one, than we talking about the single-channel system, otherwise we are talking about multi-channel system. When the parking area fills up, entry ramps automatically prevent new vehicles from entering into the parking area, i.e. the drivers trying to enter are signalled that the parking area is complete and this initiates the creation of a line of vehicles trying to enter into the parking area. Parking area represents a queuing system with the following structure: customers are vehicles forming (or not) a waiting line (depending on the current situation) in order to be served (parked) in a parking section and after the service has been completed (certain length of parking time), they exit the system. Parking system servicing is defined as an open system of queues because with him the intensity of input flow does not depend on the state system, ie the number of users in the system, because the source populations located outside the system and users of the city roads (outside the park) come in observed the system queues.

3. STATISTICAL DATA

Table 1 shows the number of vehicles arrived into the "Delta" parking area in 2009.

Table 1: Number of vehicles arrived into the "Delta" parking area in 2009 by days and months

Day	Month												Σ
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	
1.	0	0	0	1683	0	1797	1505	801	1733	1798	0	1561	10878
2.	1544	1385	1591	1395	1180	1826	1520	0	1645	1839	1589	1733	17247
3.	778	1310	1566	1764	0	1667	1537	1777	1859	1032	1522	1821	16633
4.	0	1493	1264	1051	1654	1645	892	1744	1746	0	1161	1400	14050
5.	1755	1425	1254	0	1764	1780	0	0	1194	1744	1595	1094	13605
6.	0	1615	1768	1818	1671	1005	1545	1566	0	1686	1309	0	13983
7.	1613	940	946	1671	1750	0	1628	1548	2046	1650	1050	1739	16581
8.	1432	0	0	1707	1717	1805	1555	841	1848	0	0	1037	11942
9.	1462	1613	1487	1693	1147	1752	1602	0	1771	1809	1614	1879	17829
10.	930	1264	1620	1664	0	1759	1656	1695	1733	942	1785	1853	16901
11.	0	1546	1499	1157	1676	0	1058	1835	1888	0	1642	1878	14179
12.	1624	1581	1635	0	1724	2020	0	1568	1093	1336	1729	1057	15367
13.	1586	1678	1751	0	1873	967	1645	1445	0	1711	1804	0	14460
14.	1256	0	965	1790	1978	0	1560	1778	1806	1590	1007	1742	15472
15.	1647	0	0	1744	1951	1766	1519	0	1937	1721	0	1752	14037
16.	1646	1588	1672	1754	1192	1732	1387	0	1693	1802	1703	1800	17969
17.	957	1568	1645	1751	0	1795	1433	1729	2070	1045	1714	1759	17466
18.	0	1450	1583	1114	1697	1541	756	1372	2047	0	1653	1849	15062
19.	1429	1600	1510	0	1591	1631	0	1294	1120	1756	1706	0	13637
20.	1563	1537	1514	1831	1574	671	1599	1208	0	1727	1755	0	14979
21.	1202	1060	940	1881	1532	0	1433	1427	1869	1619	1043	1520	15526
22.	1536	0	0	1709	1704	0	1437	927	1749	1491	0	1315	11868
23.	1652	1595	1663	1587	1055	1950	1376	0	1802	1530	1498	2161	17869
24.	972	1458	1277	1698	0	1905	1301	1667	1965	977	1681	1463	16364
25.	0	1589	1548	1085	1555	0	1126	1652	2060	0	1661	0	12276
26.	1663	1641	1547	0	1466	1972	0	1576	1086	1742	1687	0	14380
27.	1385	1744	1522	1724	1563	1054	1535	1547	1	1658	1601	0	15334
28.	1565	1122	1061	1675	1662	0	1415	1550	1824	1658	940	2105	16577
29.	1561	0	0	1570	1782	1807	1351	1085	1734	1717	0	1880	14487
30.	1604	0	1722	1546	804	1705	1263	0	1739	1812	1537	1623	15355
31.	997	0	1466	0	0	0	1536	1784	0	1245	0	463	7491
Σ	35359	33802	38016	40062	39262	37552	38170	35416	45058	40637	37986	38484	459804

Note: Number "0" denotes holidays, i.e. days (Sunday and national holidays) when parking fee was not charged or months with less than 31 days.

Source: Statistical data of the "Delta" database

The number of spaces in the waiting line: total length of space appointed to the waiting of the vehicles in order to be able to enter into the parking area is 80 m; if the average length of a vehicle in the waiting line is 5 m, it follows that the maximum of 16 automobiles can be present on the reserved space in one moment, i.e. $m = 16$. Therefore, the observed servicing process is classified as a queuing problem with finite number of vehicles in the waiting line, $M/M/S/16$. Every next vehicle (17th one) in the waiting line will be cancelled from the waiting line because the line of vehicles would otherwise continue on the roads intended for the circulation of motor vehicles.

The intensity of the vehicles' arrival flow: the calculation will use the average number of vehicles arriving daily into the parking area in 2005; $\lambda = 1{,}569$ vehicles per day (with 14-hour working time and 293 days a year because the rest of the days are holidays and the parking fee is not charged) or the average of 112 vehicles/hour, i.e. 302 vehicles/hour in peak hours and maximum load of the parking area.

Intensity of servicing: the intensity of servicing (μ) is obtained in the calculation as a reciprocal value of the average servicing time ($\bar{t}_{usl}$ = arithmetic mean of the servicing time); if the servicing time represents the time necessary for the driver (parking area customer) to stop its vehicle in front of the entry terminal, to take the parking ticket and to enter into the parking area and it amounts to an average of 15 s, then $\bar{t}_{usl} = 15\ s = 0.0041666$ hours (Maršanić,2008,356), and the intensity of servicing

$$\mu = 1/\bar{t}_{usl} = 240 \text{ vehicles/hour.}$$

4. COMPUTER SUPPORTED WAITING LINE MODEL

The most common case of queuing problems involves the single-channel, or single-server, waiting line. In this situation, arrivals from a single line to be serviced by a single station. In the table 2 set a model for problem solving using Excel spreadsheets.

Table 2: Using Excel for Queing M/M/1 model

	A	B	C	D	E	F
6	**Data**			**Results**		
7	Arrival rate (λ)	112		Average server utilization(ρ)	0,466667	=B7/B8
8	Service rate (μ)	240		Average number of customers in the queue(L_q)	0,408333	=B7*B7/(B8*(B8-B7))
9				Average number of customers in the system(L)	0,875	=B7(B8-B7)
10				Average waiting time in the queue(W_q)	0,003646	=B7(/(B8*(b8-B7))
11				Average time in the system(W)	0,007813	=1/(B8-B7)
12				Probability (% of time) system is empty (P_0)	0,533333	=1-E7
15	**Probabilities**					
16	Number	Probability	Cumulative Probability			
17	0	0,533333	0,533333	Probability		
18	1	0,248889	0,782222	B17=1-B7/B8		
19	2	0,116148	0,898370	B18=B16*B7/b8		
20	3	0,054202	0,952573	B19=B17*B7/B8		
21	4	0,025294	0,977867			
22	5	0,011804	0,989671			
23	6	0,005509	0,995180			
24	7	0,002571	0,997751			
25	8	0,001200	0,998950			
26	9	0,000560	0,999510			
27	10	0,000261	0,999771			
28	11	0,000122	0,999893			
29	12	0,000057	0,999950			
30	13	0,000027	0,999977			
31	14	0,000012	0,999989			
32	15	0,000006	0,999995			
33	16	0,000003	0,999998			
34	17	0,000001	0,999999			
35	18	0,000001	0,999999			

All data obtained for the average number of vehicles that are serviced during the day, indicating that it is sufficient only one ramp that is capable serviced all vehicles arrived. Probability that there is no vehicle in the queuing system is 53.33% that is in line only one vehicle is 78.22% that is in line two vehicles 89.83% (...).

Now it is evident that the peak hours, comes more vehicles per unit of time in respect of their serving with only one entrance ramp. Based on the definition of basic parameters in the parking lot, "Delta" as a system servicing a limited length of the queue (M/M/S/16) gets to be $\rho = \lambda / \mu = 302/240 = 1.25833$. Accordingly, the question whether increasing the number of input ramp increases/decrease the value of indicators parking system? In order to get an answer to this question in the table 3 set a multi-channel model.

Table 3: Using Excel for Queing M/M/S model

	A	B	C	D	E
6	**Data**			**Results**	
7	Arrival rate (λ)	302		Average server utilization(ρ)	0,629167
8	Service rate (μ)	240		Average number of customers in the queue(L_q)	0,824485
9	Number of servers(s)	2		Average number of customers in the system(L)	2,082818
10				Average waiting time in the queue(W_q)	0,00273
11				Average time in the system(W)	0,006897
12				Probability (% of time) system is empty (P_0)	0,227621
13	**Probabilities**				
14	Number	Probability	Cumulative Probability		
15	0	0,227621	0,227621		
16	1	0,286424	0,514045		
17	2	0,180208	0,694253		
18	3	0,113381	0,807634		
19	4	0,071336	0,878970		
20	5	0,044882	0,923852		
21	6	0,028238	0,952090		
22	7	0,017767	0,969857		
23	8	0,011178	0,981035		
24	9	0,007033	0,988068		
25	10	0,004425	0,992493		
26	11	0,002784	0,995277		
27	12	0,001752	0,997028		
28	13	0,001102	0,998130		
29	14	0,000693	0,998824		
30	15	0,000436	0,999260		
31	16	0,000274	0,999534		
32	17	0,000173	0,999707		
33	18	0,000109	0,999816		
34	19	0,000068	0,999884		
35	20	0,000043	0,999927		

Based on data from the table 3 it is clear that a system with 2 inputs and peak load ρ is less than one, and thus satisfies the basic condition that the user (vehicle) to be serviced before or after. This is not the case in a system with only one entrance ramp. The probability that a vehicle in a system with two inputs to be immediately Served in peak periods amounts to 22.76%. On the basis of this it is easy to conclude that with only one entrance ramp significantly deteriorates the quality of servicing the vehicle with the possibility of failure in the system, while the values for the cases when placed at the entrance gate two input significantly increases the quality of servicing. It therefore follows that the two entrance ramps optimal number given the intensity of arrivals of vehicles in the parking and servicing their time entering the vehicle.

5. DESIGN CAPACITY OF PARKING AREA

Capacity is the "throughput", or the number of units a facility can hold, receive, store, or produce in a period of time. The capacity determines if demand will be met or if facilities will be idle.

The parking area capacity is expressed in the number of parking spaces, i.e. the number of vehicles which use the parking service. The optimal number of entering points, i.e. ramps, according to experts in garage facilities and closed parking areas construction, amounts to one entering point per 250 parking spaces. This is the statistical parking area capacity. The dynamical parking area capacity is calculated by also taking into account the number of vehicles entering into the parking area in a day, then the average parking time length and the total working time of the parking area using the formula

$$\sum_{PM} = \lambda \frac{t}{T}$$

where:

Σ_{PM} – total number of required parking spaces,

λ – average number of vehicles per day,

t – average parking time (hours),

T – total working time of the parking area per day (hours).

If we take into consideration the fact that there is an average of 1,569 vehicles arriving daily into the "Delta" parking area and that the average length of parking is 2 hours and the opening hours are 14 a day, the formula shows us that the required number of parking spaces is 224. Based on the obtained results and taking into account the fact that according to experts dealing with the construction of buildings and garage parking is sufficient closed one entrance to 250 parking spaces, the question of the validity of the formula. In support of these claims go and the fact that the actual number of parking spaces in the parking lot is 458. The answer to these questions should be sought in the fact that more than 40% of the parking lot occupied permanent subscribers (tenants and companies), and this is the real reason why the peak periods produce large columns stand at the door.

6. CONCLUSION

In this paper is demonstrate that by applying the information technologies the optimal number of servers (ramps) and the required capacity (number of parking spaces) in closed parking areas can be defined. After all, the verification of the set out model of planning of optimal capacity of parking area capacity upon the actual "Delta" parking area in the City of Rijeka has shown the indisputable applicability of the results of a scientific research to actual parking area capacities. Transition of the parking lot with one of two entrance ramps to shorten the queue leading to a small number of cancellation in the system and effective utilization of capacity parking lot. A particular merit of the model is its universal applicability because the presented methodology can be applied to any other closed parking area, i.e. parking area with ramps in current or future, changed conditions.

LITERATURE

1. Barković, D. et al.: (1986). Odlučivanje u marketingu, Informator, ISBN 86-301-0047-8, Zagreb.

2. Heizer, J., Render, B. (2004). Operations Management, seventh edition, Pearson Prentice Hall, ISBN 0-13-120974-4, New Jersey.

3. Maršanić, R. (2008). Parkiranje u turističkim destinacijma, IQ Plus, d.o.o., ISBN 978-953-95705-1-2, Kastav.