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Ibrahim KHLIEFAT[1]

PREDICTION OF PARKING ACCUMULATION FOR DIFFERENT LAND USES IN ABU DHABI CITY FROM AN EXISTING SURVEY

Summary. Parking accumulation profiles are time-dependent quantities at car parks that need data from longitudinal observational surveys. Car parks can be grouped into clusters based on the similarity in the shape of their accumulation profiles. This study investigates factors affecting parking accumulation and attempts to devise a methodology to construct parking accumulation profiles for different land uses in Abu Dhabi city. The study uses data available from Dubai city, which has a similar land-use type and distribution pattern as Abu Dhabi. A snapshot survey was conducted to observe the portion of the sampled car parks to calibrate the predicted parking accumulation. The estimation of parking accumulation profiles based on different land uses in Abu Dhabi city was done using the planning of the survey conducted in Dubai. The results suggest that a preliminary parking survey can help determine the initial accumulation profile and predict a robust parking accumulation profile that is applicable across different land-use types in Abu Dhabi.

1. INTRODUCTION

Over the past four decades, the Emirate of Abu Dhabi has viewed transformative development to boost social and economic growth, such as the traffic development and parking issues that were extreme for businesses and residents [1]. The 2030 Abu Dhabi Surface Transport Master Plan was published by the Department of Transport in 2009 to develop the transport elements of the 2030 plan. The plan established a fundamental aspect of the congestion management strategy through effective parking management and development control. In 2009, for Abu Dhabi, land and parking use surveys were conducted in 46 sectors, mainly in central business districts (CBDs), where parking congestion had been witnessed [2]. The parking survey showed that the parking demand was much higher in some sectors than the available spaces for on-street parking. This established the need to predict parking limitations and suggest actions for elevating the parking supply and mitigating parking demand.

The estimation of the parking demand is a complex subject [3,4]. Al-Sahili and Hamadneh [3] reported that parking trips are considered for evaluating the transportation network requirement, directing the right use of land, and accommodating the maximum traffic volume. Within the United Arab Emirates (UAE), the traffic system of the Emirate of Abu Dhabi has undergone substantial transformation backed by social and economic development. This, along with the increasing population, has made parking a serious issue not only for the residents but also for businesses [5]. Specifically, the population grew by a compounded average of 4.57% annually between 2001 and 2006, and similar growth was expected to occur by 2020 when the population was expected to reach over 3 million. Although some growth is attributable to the geographic expansion of the emirate, the majority of growth is occurring on or adjacent to Abu Dhabi.

Many cities have mitigated the problem of increasing parking shortages by ensuring that all new developments take measures to meet their parking needs. One of the aims of traffic impact studies is to end the parking shortfalls in Abu Dhabi and ensure that new developments address their parking needs.

[1] Al-Balqa Applied University, Faculty of Engineering, Civil Engineering Department; 2PF8+XPM, As-Salt, Jordan; e-mail: khliefat@bau.edu.jo; orcid.org/0000-0003-1051-8228

Parking requirements ensure that on-site parking demands are assessed and adequate parking is provided to prevent the creation or aggravation of parking problems in the area. The capacity analysis of car parks is complicated for several reasons. First, the demand pattern for arterial roads varies throughout the day. Second, the adequate capacity is variable and dependent on the parking duration of cars, although the number of parking spaces available fixes the static capacity of the car park. Therefore, various factors influence the time-dependent parking demand pattern and accumulation profile. It is necessary to collect hourly parking accumulation data during the day from 7:00 a.m. to 10:30 p.m. to determine the parking accumulation profiles for any individual car parks.

The amount of parking used at a given time, location, and duration is referred to as parking analysis. It is determined by factors like vehicle ownership, trip rate, method of transportation, duration, location, and land use. Parking demand typically follows daily, monthly, and even yearly patterns. Parking demand, for example, is highest throughout the week in office-business zones and lowest on weekends in markets, restaurants, and theatres. Furthermore, parking demand is affected by transportation, land use, and population trends. Suppose a building is converted from residential to industrial or office use. In that case, the density and neighbourhood layout may be altered, as may the quality of transportation service, which would impact parking demand and duration. The parking period varies depending on the purpose of the journey. Commuters require parking for more extended periods and, thus, are more price sensitive. In light of the foregoing, effective parking management solutions are needed at the policy level, particularly in CBDs, where space is restricted and demand is high. Visitors who park their cars for a set length of time (called parking duration) before returning to their original location produce a significant parking demand in CBDs [6]. Effective parking demand management, particularly in big city centres, is a continuous difficulty due to competing aims and ever-increasing needs for space [6]. Each emirate in the UAE has standards for the minimum amount of parking required for new developments written into its zoning code. Generally, these requirements are based on the Dubai Manual for Trip Generation and the parking requirement rates developed by Dubai Municipality. The manual was intended to be used in conjunction with information concerning the local conditions in Dubai. This conjunction facilitates the assessments of developments undertaking TIS and parking designs and assists in determining the amount of parking required for each new development. The Dubai Manual provides the best data for application to other emirates since no other data is available within the UAE. However, the variance in the local conditions from one emirate to another should be considered concerning the generic implementation of the Dubai Manual, as it may not reflect the exact conditions of other emirates.

2. LITERATURE REVIEW

Studies regarding parking accumulation profiles have addressed various aspects of this issue, namely data collection issues and parking policies as a travel demand management strategy. For instance, Banu and Rahman [7] stated that about 60% of street parking developments introduced as a part of advancing the roadway capacity fail to meet adequate parking requirements. Douglass and Abley [8] showed that spaces per 100 m^2 gross floor area (GFA) serve as the most practical method for overcoming seasonal traffic and parking variations. Bu and Pershouse [9] presented the parking choice model for remote parking behaviour in Australia. The variables considered include parking space availability and parking cost.

Axhausen and Polak [10] used a stated preference approach for collecting disaggregate data on travellers responses towards changes in parking attributes and showed that journey purposes strongly impact the value of time and subsequent parking choices. Marsden [11] provided an interesting review of the literature related to the behavioural responses of drivers to a series of real or hypothetical parking policies. The study concluded that the assumption that parking constraints make centres less attractive and discourage economic development was not confirmed and needs to be challenged. Morency and Trépanie [12] presented a method for constructing parking accumulation profiles using travel survey data. Since parking accumulation profiles are derived from individual trip data in urban origin-destination surveys, they can be used for various population segments to identify similar patterns of land use, activity, and parking types. The average duration of parking events can also be estimated. Shatnawi

[13] re-examined the minimum parking standards for various uses in Abu Dhabi city and introduced recommendations for maximum parking requirements. The study mentioned that "providing flexibility in minimum parking can be accomplished either by allowing the relevant permitting authority discretion to reduce the number of spaces required based on certain considerations and factors, or by establishing more specific criteria/policies that will allow for reductions in required parking". Boamah [14] designed an economic model of parking behaviour to consider the relationship between costs and benefits in meeting parking demands on an urban university campus at Minnesota State University. The study concluded that there was an over-supply of some types of parking spaces and an under-supply of other types when parking demand was determined only by expected permit purchases without considering the peak use of parking facilities.

Sen et al. [15] conducted a case study on on-street parking demand estimation for four-wheelers in urban CBDs. Two areas, such as the largest shopping and office area, were selected to develop a parking demand model to estimate parking demand using age, vehicle ownership, parking duration, annual family income, and the distance between origin and destination as input parameters. The data for the determined variables were obtained from various field surveys like in-out surveys and questionnaires. Similarly, Silva [16] studied the development of a prediction method for on-street parking space availability using only historical occupancy data collected from on-street multi-space parking meters and added attributes like weather conditions and holidays, which provided additional context and comprehension.

2.1. Parking Demand Models

A static parking generation rate model was established in 1994 based on land use. Equation 1 presents the simplest form of the parking generation rate model. In addition, a parking searching algorithm and static parking generation rate model were developed to analyse the factors influencing urban parking. A parking generation rate model undertakes several attributes, including parking price impact coefficient, motor vehicle growth, level of service (LOS) of the parking facility, parking lot occupancy, and average turnover rate. (Equation 2). In this regard, the LOS value was undertaken randomly by 85%, regardless of considering the factors identified for defining the LOS for a specific parking facility. Thereby, Equation 2 has been expanded by Sen et al. [15] to consider the cost factor of public transit. They used the analytical hierarchy process for formulating the LOS equation, undertaking parking attributes, safety attributes, and design attributes as selection criteria for the parking lot.

It is not common to use parking accumulation profiles to validate parking demand models, whereas several different parking demand models have been presented previously [17]. For instance, Bates et al. [18] validated the Traffic Restraint Analysis Model by collecting data from roadside interview surveys and household interview surveys. This paper prepared the methodology at car parks for projecting the entire day parking accumulation profile for different vehicle types in various districts. It was observed that parking accumulation profiles can further be utilised for other objectives, such as the progression of real-time parking information systems, regardless of the validation of parking demand models [19]. In addition, information on car parking accumulation profiles is beneficial for assessing different traffic management strategies. For instance, planners are usually interested in the effects of parking restraint policies on traveller behaviour.

3. MATERIALS AND METHODS

Parking accumulation profiles summarise the number of vehicles requiring parking spaces on any particular day. It also indicates the maximum number of parking spaces needed for a facility. Generally, parking accumulation is dependent on different factors (Fig. 1).

3.1. Study Area

In the present study, the downtown area of Abu Dhabi was chosen as the study area. Abu Dhabi is the largest of the UAE's seven emirates. With 1,493,000 residents, Abu Dhabi, the UAE's capital,

represents 86.7% of the state's total surface area. The emirate has the world's sixth-largest known oil reserves, is the main oil producer in the UAE, and controls 90% of the country's oil and natural gas [20].

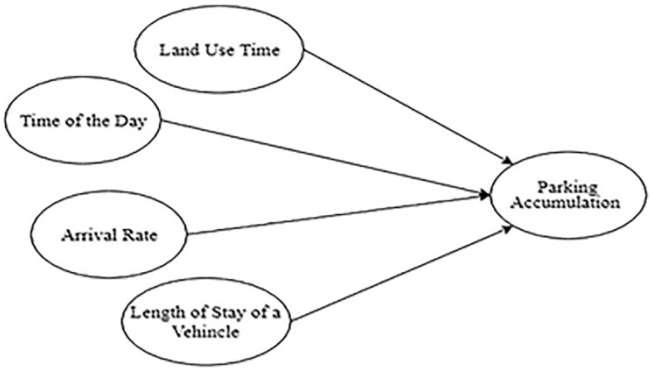


Fig. 1. Parking Accumulation Factors

3.2. Sampling Frame

Parking inventories from 1998 were used as the sampling frame for the survey. The inventories were adequately planned and converted into an open geographic information system format for facilitating easy implementation with the predefined structure of a proposed transport information system. Information was comprised in the car park inventory regarding the building name and address of the car park, the land use type that the car park is aimed to serve, the building type, and the proportion of parking space of each class assigned for public or private use. All car parks were geo-coded so that their accurate locations were known. Commercially operated car parks used majorly by visitors to the area were included even though car parks were normally used for ownership-based parking and are considered for usage-based parking. The inventory stores information on the parking space class and the location of groups of parking spaces. Each cluster of parking spaces was assumed to be a car park in the survey.

3.3. Sampling Method

Much data on parking attributes can be retrieved automatically at car parks and stored in computer databases because of the automation of car park management systems. However, the experience of this study was that most operators of privately owned car parks were not willing to disclose explicit information about the usage attributes of their car parks. Thereby, surveyors manually gathered most of the data needed for this study. The survey was carried out on weekdays in 1998 during September and October. Daily or monthly variations in parking accumulation were not considered, as each car park was surveyed only once. The parking accumulation was not considered for Saturdays and Sundays.

3.4. Modelling Technique

A typical parking accumulation profile is created by conducting a series of parking surveys for different land-use types while performing a parking accumulation study. Then, a typical curve is used as a proxy for different sizes of developments for the same or similar land use. In this study, information for trip generation and parking requirements was derived from the 'Dubai Trip Generation and Parking Rates Manual' based on surveys undertaken in 1998 [21]. The Dubai manual contains two independent variables used to generate the parking accumulation profile for each proposed development (i.e. the GFA and number of employees) and utilised for office developments. The manual provides trip rates for each variable for the three peak periods (morning peak hour, afternoon peak hour, and evening peak hour). In addition, the manual provides parking rates for each variable. Moreover, this data is important for developing parking accumulation for Abu Dhabi city, similar to Dubai city concerning its land-use type and distribution. The suggested technique for collecting one-day statistics uses trained neural networks to detect occupancy states based on visual cues collected from parking spaces [22].

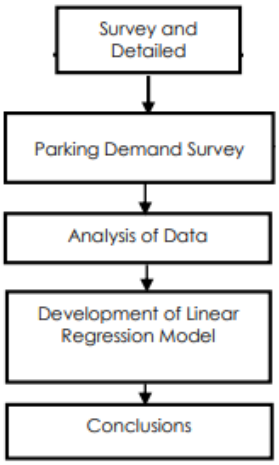


Fig. 2. Research study procedure/method

4. RESULTS AND DISCUSSION

4.1. Parking Accumulation for an Office Building (Class 201- Dubai Manual)

Considering the derivation of parking accumulation for land-use class 201, an office building in Abu Dhabi's CBD is shown in Table 1. The cars' in/out parking rates are considered the initial points for the three peak hours (Tables 2a and 3a). Additional data can be inserted into the table based on the assumption that the parking rate is zero from 9:00 p.m. to 7:00 a.m. (Table 2b and Fig. 2b). Missing points are obtained by assuming that a straight-line connection is used between 9:00 a.m. and 1:00 p.m. Also, the accumulation results after 9:00 p.m. must ensure that there are no remaining vehicles in the car park. Therefore, between 3:00 p.m. to 7:00 p.m., the parking rate must be based on the assumption that the number of parked vehicles is zero after 9:00 p.m. This value can be calculated from the number of remaining vehicles if this time is left blank. Table 3 presents the parking accumulation based on land-use 201.

Table 3 shows that 1.39 vehicles remain after 9:00 p.m. based on the initial values. However, the number of remaining vehicles should be zero, and thus, a value of – (1.39/4) can be set between 4:00 p.m. and 7:00 p.m. (Table 4). This profile review suggests that it is an adequate proxy for parking accumulation concerning office use. However, there are two issues to consider further: First, the parking rate is based on all vehicles in the peak hours requiring parking, which is not realistic. The parking requirement is 4.87 based on the figures derived above, whereas the Dubai Manual suggests a parking rate of 2.43 for this land use. Second, the same value is used for both hours within the two-hour peak period, which is also unrealistic.

Considering the second point, a realistic approach appears to use a moving average based on the initial figures. This means the maximum value occurs only in one peak hour and results in a smooth profile similar to the time series analysis. It is suggested that a moving average of more than two values would cause a substantial change; therefore, only two values are used. Although a forward-moving average has been used, the backward-moving average is also appropriate. However, further research into parking in Abu Dhabi is conducted to ascertain the best methodology. Table 5 and Figs. 3a and 3b present the parking rate and accumulation, respectively.

Reflecting on the first point, the number of vehicles requiring parking can be adjusted to obtain a maximum parking requirement of 2.43 (as detailed in the Dubai Manual). This is achieved by assuming that 50% of the arriving vehicles require parking (Table 6). Also, Fig. 4 presents the parking rate (moving average) of the vehicle. The parking rate profile is still derived from the initial values, but the moving average relates to the 50% value. The parking accumulation at 50% is shown in Fig. 4b. The data now give a parking accumulation consistent with the Dubai Manual's data.

Table 1

Office Inner-CBD Class 201 (Independent Variable of GFA)

Trip Rates (Average Weekday)				Units	Directional Distribution (%)							
PH of Adj Street (07:00-09:00)	PH of Adj Street (12:00-14:00)	PH of Adj Street (17:30-20:00)	PH of Generator		PH of Adj Street (07:00-09:00)		PH of Adj Street (12:00-14:00)		PH of Adj Street (17:30-20:00)		PH of Generator	
					IN	OUT	IN	OUT	IN	OUT	IN	OUT
3.5	2.67	3.29	4.69	Per 100 Sqm GFA	70%	30%	43%	57%	45%	55%	n. a	
Parking Rate		2.43		Generation Rate	2.45	1.05	1.15	1.52	1.48	1.81		
			In-Out (Parking Rate)			1.40		0.37		0.33		

Table 2

Parking Arrival Rates for Offices (a) Before adjustment (b) after adjustment

(a) Parking Arrivals (Before Adjustment)				(b) Parking Arrivals (After Adjustment)			
Time Interval		Hour	Parking Rate	Time Interval		Hour	Parking Rate
a.m.	0:00 to 1:00	1		a.m.	0:00 to 1:00	1	0
	1:00 to 2:00	2			1:00 to 2:00	2	0
	2:00 to 3:00	3			2:00 to 3:00	3	0
	3:00 to 4:00	4			3:00 to 4:00	4	0
	4:00 to 5:00	5			4:00 to 5:00	5	0
	5:00 to 6:00	6			5:00 to 6:00	6	0
	6:00 to 7:00	7			6:00 to 7:00	7	0
	7:00 to 8:00	8	1.4		7:00 to 8:00	8	1.4
	8:00 to 9:00	9	1.4		8:00 to 9:00	9	1.4
	9:00 to 10:00	10			9:00 to 10:00	10	
	10:00 to 11:00	11			10:00 to 11:00	11	
	11:00 to 12:00	12			11:00 to 12:00	12	
p.m.	12:00 to 1:00	13		p.m.	12:00 to 1:00	13	
	1:00 to 2:00	14	-0.37		1:00 to 2:00	14	-0.37
	2:00 to 3:00	15	-0.37		2:00 to 3:00	15	-0.37
	3:00 to 4:00	16			3:00 to 4:00	16	
	4:00 to 5:00	17			4:00 to 5:00	17	
	5:00 to 6:00	18			5:00 to 6:00	18	
	6:00 to 7:00	19			6:00 to 7:00	19	
	7:00 to 8:00	20	-0.33		7:00 to 8:00	20	-0.33
	8:00 to 9:00	21	-0.33		8:00 to 9:00	21	-0.33
	9:00 to 10:00	22			9:00 to 10:00	22	0
	10:00 to 11:00	23			10:00 to 11:00	23	0
	11:00 to 12:00	24			11:00 to 12:00	24	0

Based on the accumulation profile, it could be argued that the profile for Dubai would be expected to show a reduction before 12:00 pm, followed by an increase in the afternoon before dropping in the evening. It should be noted that this is only an assumption at this point, and surveys need to be

undertaken to establish a typical profile. Several assumptions were made when establishing the above profile: a moving average would give a better result, a straight line is assumed between 9:00 a.m. and 1:00 p.m., and values between 3:00 p.m. and 7:00 p.m. will be the same. Maximum parking accumulation should agree with the Dubai Manual values. In the following analysis, it has been assumed that there is no straight line between 9:00 a.m. and 1:00 p.m., and the effect of choosing different values can be seen in the graphs below. The table of values is presented in Table 7. It should be noted that the values between 9:00 a.m. and 1:00 p.m. were approximated values to derive a different value for the parking accumulation and are not based on facts.

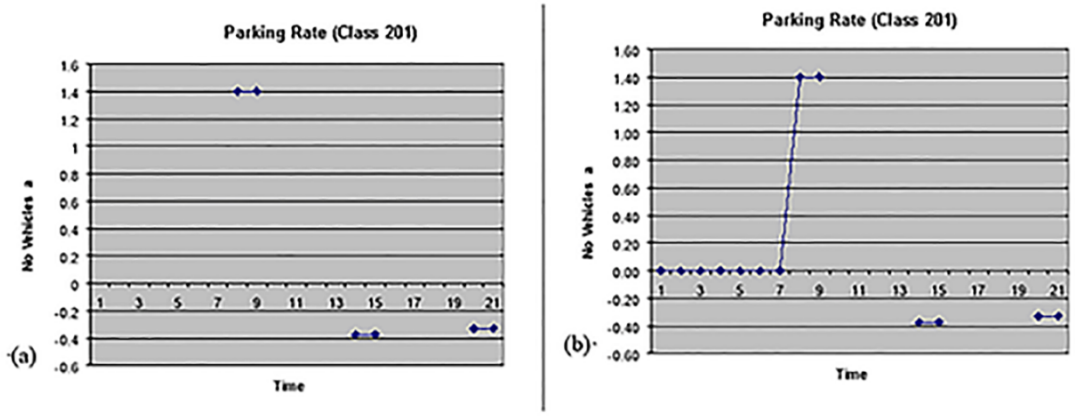


Fig. 3. Graphs of Parking Arrivals: (a) Initial parking arrivals and (b) expected parking arrivals

Table 3

Parking Accumulation based on land-use 201 before adjustment

Time Interval		Hour	Parking Rate	Calculation / Parking Accumulation
a.m.	0:00 to 1:00	1	0	0
	1:00 to 2:00	2	0	0
	2:00 to 3:00	3	0	0.00
	3:00 to 4:00	4	0	0.00
	4:00 to 5:00	5	0	0.00
	5:00 to 6:00	6	0	0.00
	6:00 to 7:00	7	0	0.00
	7:00 to 8:00	8	1.40	1.40
	8:00 to 9:00	9	1.40	2.80
	9:00 to 10:00	10		2.80
	10:00 to 11:00	11		2.80
	11:00 to 12:00	12		2.80
p.m.	12:00 to 1:00	13		2.80
	1:00 to 2:00	14	-0.37	2.43
	2:00 to 3:00	15	-0.37	2.05
	3:00 to 4:00	16		2.05
	4:00 to 5:00	17		2.05
	5:00 to 6:00	18		2.05
	6:00 to 7:00	19		2.05
	7:00 to 8:00	20	-0.33	1.72
	8:00 to 9:00	21	-0.33	1.39
	9:00 to 10:00	22	0	1.39
	10:00 to 11:00	23	0	1.39
	11:00 to 12:00	24	0	1.39

Table 4

Parking Accumulation with Adjustments

Time Interval		Hour	Parking Rate	Parking Accumulation	Parking Accumulation
a.m.	0:00 to 1:00	1	0	0	0
	1:00 to 2:00	2	0	0	0
	2:00 to 3:00	3	0	0	0
	3:00 to 4:00	4	0	0	0
	4:00 to 5:00	5	0	0	0
	5:00 to 6:00	6	0	0	0
	6:00 to 7:00	7	0	0	0
	7:00 to 8:00	8	1.4	1.4	1.4
	8:00 to 9:00	9	1.4	2.8	2.8
	9:00 to 10:00	10	1.05	3.85	3.85
	10:00 to 11:00	11	0.69	4.54	4.54
	11:00 to 12:00	12	0.34	4.87	4.87
p.m.	12:00 to 1:00	13	-0.02	4.85	4.85
	1:00 to 2:00	14	-0.37	4.48	4.48
	2:00 to 3:00	15	-0.37	4.1	4.1
	3:00 to 4:00	16	-0.86	3.24	3.24
	4:00 to 5:00	17	-0.86	2.38	2.38
	5:00 to 6:00	18	-0.86	1.52	1.52
	6:00 to 7:00	19	-0.86	0.66	0.66
	7:00 to 8:00	20	-0.33	0.33	3.78
	8:00 to 9:00	21	-0.33	0	3.45
	9:00 to 10:00	22	0	0	3.45
	10:00 to 11:00	23	0	0	3.45
	11:00 to 12:00	24	0	0	3.45

Table 5

Parking Rate and Parking Accumulation

Time Interval		Hour	Parking Rate	CALCULATION	RESULTS	
				Parking Accumulation	Parking Rate (Moving Average)	Parking Accumulation
					100.00%	
a.m.	0:00 to 1:00	1	0	0	0	0
	1:00 to 2:00	2	0	0	0	0
	2:00 to 3:00	3	0	0.00	0.00	0.00
	3:00 to 4:00	4	0	0.00	0.00	0.00
	4:00 to 5:00	5	0	0.00	0.00	0.00
	5:00 to 6:00	6	0	0.00	0.00	0.00
	6:00 to 7:00	7	0	0.00	0.00	0.00
	7:00 to 8:00	8	1.40	1.40	0.70	0.70
	8:00 to 9:00	9	1.40	2.80	1.40	2.10
	9:00 to 10:00	10		2.80	0.70	2.80

	10:00 to 11:00	11		2.80	0.00	2.80
	11:00 to 12:00	12		2.80	0.00	2.80
p.m.	12:00 to 1:00	13		2.80	0.00	2.80
	1:00 to 2:00	14	-0.37	2.43	-0.19	2.61
	2:00 to 3:00	15	-0.37	2.05	-0.37	2.24
	3:00 to 4:00	16		2.05	-0.19	2.05
	4:00 to 5:00	17		2.05	0.00	2.05
	5:00 to 6:00	18		2.05	0.00	2.05
	6:00 to 7:00	19		2.05	0.00	2.05
	7:00 to 8:00	20	-0.33	1.72	-0.16	1.89
	8:00 to 9:00	21	-0.33	1.39	-0.33	1.56
	9:00 to 10:00	22	0	1.39	-0.16	1.39
	10:00 to 11:00	23	0	1.39	0.00	1.39
	11:00 to 12:00	24	0	1.39	0.00	1.39

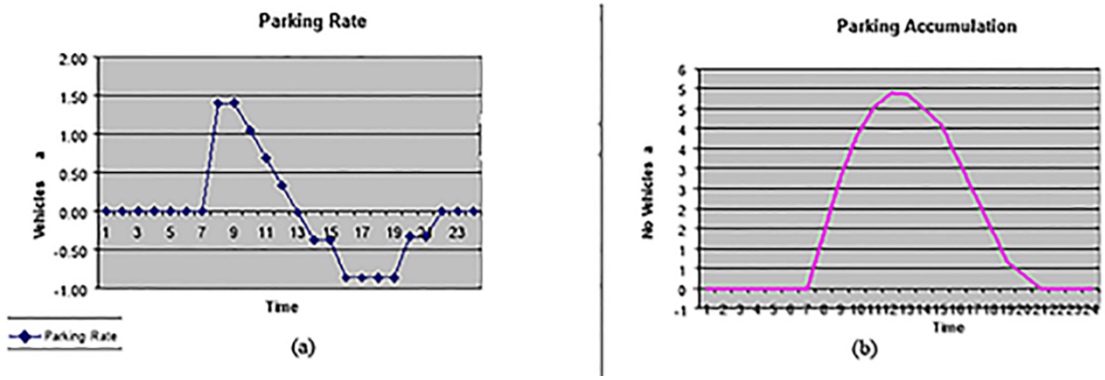


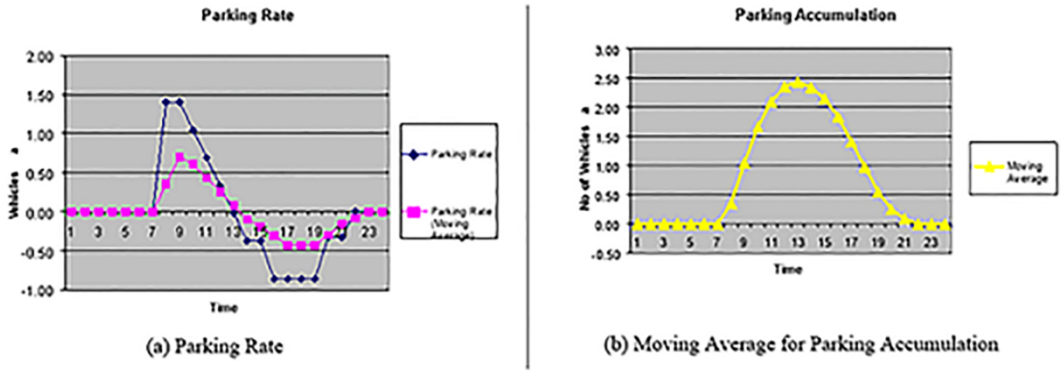
Fig. 4. Graphs of Parking Arrivals and Accumulation

Table 6

Parking Accumulation Assuming 50% of Vehicles Arriving Require Parking

Time Interval		Hour	Parking Rate	Parking Accumulation (Adjusted)	Parking Accumulation	Results	
						Parking Rate (Moving Average) 50.00%	Parking Accumulation
a.m.	0:00 to 1:00	1	0	0	0	0	0
	1:00 to 2:00	2	0	0	0	0	0
	2:00 to 3:00	3	0	0	0.00	0.00	0.00
	3:00 to 4:00	4	0	0	0.00	0.00	0.00
	4:00 to 5:00	5	0	0	0.00	0.00	0.00
	5:00 to 6:00	6	0	0	0.00	0.00	0.00
	6:00 to 7:00	7	0	0	0.00	0.00	0.00
	7:00 to 8:00	8	1.40	1.40	1.40	0.35	0.35
	8:00 to 9:00	9	1.40	2.80	2.80	0.70	1.05
	9:00 to 10:00	10	1.05	3.85	3.85	0.61	1.66
	10:00 to 11:00	11	0.69	4.54	4.54	0.43	2.10
	11:00 to 12:00	12	0.34	4.87	4.87	0.26	2.35
p.m.	12:00 to 1:00	13	-0.02	4.85	4.85	0.08	2.43
	1:00 to 2:00	14	-0.37	4.48	4.48	-0.10	2.33
	2:00 to 3:00	15	-0.37	4.10	4.10	-0.19	2.15
	3:00 to 4:00	16	-0.86	3.24	3.24	-0.31	1.84
	4:00 to 5:00	17	-0.86	2.38	2.38	-0.43	1.41
	5:00 to 6:00	18	-0.86	1.52	1.52	-0.43	0.98
	6:00 to 7:00	19	-0.86	0.66	0.66	-0.43	0.54

	7:00 to 8:00	20	-0.33	0.33	3.78	-0.30	0.25
	8:00 to 9:00	21	-0.33	0	3.45	-0.16	0.08
	9:00 to 10:00	22	0	0	3.45	-0.08	0.00
	10:00 to 11:00	23	0	0	3.45	0.00	0.00
	11:00 to 12:00	24	0	0	3.45	0.00	0.00



(a) Parking Rate (b) Moving Average for Parking Accumulation

Fig. 5. Parking rate (moving average) of the vehicle

Table 7

Parking Accumulation in Abu Dhabi

Time Interval		Hour	CALCULATION		RESULTS	
			Parking Rate	Parking Accumulation	Parking Rate (Moving Average)	Parking Accumulation
					50.00%	
a.m.	0:00 to 1:00	1	0	0	0	0
	1:00 to 2:00	2	0	0	0	0
	2:00 to 3:00	3	0	0.00	0.00	0.00
	3:00 to 4:00	4	0	0.00	0.00	0.00
	4:00 to 5:00	5	0	0.00	0.00	0.00
	5:00 to 6:00	6	0	0.00	0.00	0.00
	6:00 to 7:00	7	0	0.00	0.00	0.00
	7:00 to 8:00	8	1.40	1.40	0.35	0.35
	8:00 to 9:00	9	1.40	2.80	0.70	1.05
	9:00 to 10:00	10	-0.80	2.00	0.15	1.20
	10:00 to 11:00	11	-0.80	1.20	-0.40	0.80
	11:00 to 12:00	12	0.15	1.35	-0.16	0.64
p.m.	12:00 to 1:00	13	0.15	1.50	0.08	0.71
	1:00 to 2:00	14	-0.37	1.13	-0.06	0.66
	2:00 to 3:00	15	-0.37	0.75	-0.19	0.47
	3:00 to 4:00	16	-0.02	0.73	-0.10	0.37
	4:00 to 5:00	17	-0.02	0.71	-0.01	0.36
	5:00 to 6:00	18	-0.02	0.68	-0.01	0.35
	6:00 to 7:00	19	-0.02	0.66	-0.01	0.33
	7:00 to 8:00	20	-0.33	0.42	-0.09	0.25
	8:00 to 9:00	21	-0.33	0.09	-0.16	0.08
	9:00 to 10:00	22	0	0.09	-0.08	0.00
	10:00 to 11:00	23	0	0.09	0.00	0.00
	11:00 to 12:00	24	0	0.09	0.00	0.00

4.2. Parking Accumulation for a Hotel Building (Class 401)

A similar principle can be used when developing a parking accumulation profile for a hotel. The trip generation table and parking figures are shown in Table 8.

Table 8

Hotel Non-CBD Class 401 (Independent Variable No of Rooms Occupied)

Trip Rates (Average Weekday)				Units	Directional Distribution (%)							
PH of Adj Street (07:00 - 09:00)	PH of Adj Street (12:00-14:00)	PH of Adj Street (17:30-20:00)	PH of Generator		PH of Adj Street (07:00-09:00)		PH of Adj Street (12:00-14:00)		PH of Adj Street (17:30-20:00)		PH of Generator	
					IN	OUT	IN	OUT	IN	OUT	IN	OUT
0.69	1.03	1.19	2.27	Per Occupied Room	58%	42%	55%	45%	56%	44%	59%	41%
					0.40	0.29	0.57	0.46	0.67	0.52		
						0.69		1.03		1.19		

The results presented in Table 9 depict that the maximum parking requirement for a hotel occurs at night. Therefore, the overnight parking was 1.43 (from the Dubai Manual). It is observed in Table 9 that overnight accumulation exceeds 1.43. However, the new table assumes an overnight accumulation of 1.00 and a 50% parking requirement, as shown in Table 10.

Table 9

Parking Rate and Accumulation

Time Interval		Hour	CALCULATION	
			Parking Rate	Parking Accumulation
a.m.	0:00 to 1:00	1	0	1.43
	1:00 to 2:00	2	0	1.43
	2:00 to 3:00	3	0	1.43
	3:00 to 4:00	4	0	1.43
	4:00 to 5:00	5	0	1.43
	5:00 to 6:00	6	0	1.43
	6:00 to 7:00	7	0	1.43
	7:00 to 8:00	8	0.11	1.54
	8:00 to 9:00	9	0.11	1.65
	9:00 to 10:00	10	0.11	1.76
	10:00 to 11:00	11	0.11	1.87
	11:00 to 12:00	12	0.11	1.97
p.m.	12:00 to 1:00	13	0.10	2.08
	1:00 to 2:00	14	0.10	2.18
	2:00 to 3:00	15	0.10	2.28
	3:00 to 4:00	16	-0.28	2.00
	4:00 to 5:00	17	-0.28	1.71
	5:00 to 6:00	18	-0.28	1.43
	6:00 to 7:00	19	-0.28	1.14
	7:00 to 8:00	20	0.14	2.43
	8:00 to 9:00	21	0.14	2.57
	9:00 to 10:00	22	0	2.57
	10:00 to 11:00	23	0	2.57
	11:00 to 12:00	24	0	2.57

The results presented in Table 10 appear to be the best fit for the parking accumulation profile based on the figures in the Dubai Manual. Again, Table 11 is achieved by removing the straight-line relationship between 9:00 a.m. and 1:00 p.m. and substituting values. The table clarifies the applicable parking rate and parking accumulation.

Table 10

Parking Rate and Accumulation

Time Interval		Hour	CALCULATION		RESULTS	
			Parking Rate	Parking Accumulation	Parking Rate (Moving Average) 50.00%	Parking Accumulation
a.m.	0:00 to 1:00	1	0	1.03	0	1.03
	1:00 to 2:00	2	0	1.03	0	1.03
	2:00 to 3:00	3	0	1.03	0.00	1.03
	3:00 to 4:00	4	0	1.03	0.00	1.03
	4:00 to 5:00	5	0	1.03	0.00	1.03
	5:00 to 6:00	6	0	1.03	0.00	1.03
	6:00 to 7:00	7	0	1.03	0.00	1.03
	7:00 to 8:00	8	0.11	1.14	0.03	1.06
	8:00 to 9:00	9	0.11	1.25	0.06	1.11
	9:00 to 10:00	10	0.11	1.36	0.05	1.17
	10:00 to 11:00	11	0.11	1.47	0.05	1.22
	11:00 to 12:00	12	0.11	1.57	0.05	1.28
p.m.	12:00 to 1:00	13	0.10	1.68	0.05	1.33
	1:00 to 2:00	14	0.10	1.78	0.05	1.38
	2:00 to 3:00	15	0.10	1.88	0.05	1.43
	3:00 to 4:00	16	-0.28	1.60	-0.05	1.39
	4:00 to 5:00	17	-0.28	1.31	-0.14	1.24
	5:00 to 6:00	18	-0.28	1.03	-0.14	1.10
	6:00 to 7:00	19	-0.28	0.74	-0.14	0.96
	7:00 to 8:00	20	0.14	2.03	-0.04	0.92
	8:00 to 9:00	21	0.14	2.17	0.07	0.99
	9:00 to 10:00	22	0	2.17	0.04	1.03
	10:00 to 11:00	23	0	2.17	0.00	1.03
	11:00 to 12:00	24	0	2.17	0.00	1.03

Table 11

Parking Rate and Accumulation

Time Interval		Hour	CALCULATION		RESULTS	
			Parking Rate	Parking Accumulation	Parking Rate (Moving Average) 50.00%	Parking Accumulation
a.m.	0:00 to 1:00	1	0	1.00	0	1.00
	1:00 to 2:00	2	0	1.00	0	1
	2:00 to 3:00	3	0	1.00	0.00	1.00
	3:00 to 4:00	4	0	1.00	0.00	1.00
	4:00 to 5:00	5	0	1.00	0.00	1.00
	5:00 to 6:00	6	0	1.00	0.00	1.00
	6:00 to 7:00	7	0	1.00	0.00	1.00
	7:00 to 8:00	8	0.11	1.11	0.03	1.03
	8:00 to 9:00	9	0.11	1.22	0.06	1.08
	9:00 to 10:00	10	-0.38	0.85	-0.07	1.02
	10:00 to 11:00	11	-0.38	0.47	-0.19	0.83
	11:00 to 12:00	12	0.10	0.57	-0.07	0.76

p.m.	12:00 to 1:00	13	0.10	0.67	0.05	0.81
	1:00 to 2:00	14	0.10	0.77	0.05	0.86
	2:00 to 3:00	15	0.10	0.88	0.05	0.91
	3:00 to 4:00	16	-0.04	0.84	0.02	0.93
	4:00 to 5:00	17	-0.04	0.80	-0.02	0.91
	5:00 to 6:00	18	-0.04	0.76	-0.02	0.89
	6:00 to 7:00	19	-0.04	0.71	-0.02	0.87
	7:00 to 8:00	20	0.14	1.02	0.03	0.89
	8:00 to 9:00	21	0.14	1.16	0.07	0.96
	9:00 to 10:00	22	0	1.16	0.04	1.00
	10:00 to 11:00	23	0	1.16	0.00	1.00
	11:00 to 12:00	24	0	1.16	0.00	1.00

The analysis revealed commonalities in parking demand profiles, and car park classifications corresponding to different types of land utilisation nearby emerged. The study then advocated estimating parking demand based on the surrounding land use of an relevant car park based on this known demand pattern. Although the strategy was adequate for its use, subcategories of car parks may arise when parking demand is recorded for the full day. Car parks with a similar parking pattern during the day may have different features at night. As a result, research should not assume a dynamic period for parking activities but rather depend on actual data from a single day. Thorough research conducted in Abu Dhabi, UAE, re-examined the minimum parking regulations for diverse applications in Abu Dhabi city and made suggestions for maximum parking needs [23]. The study discovered that parking requirements could be reduced under certain conditions, such as due to shared parking and the presence of a close complementing attraction within walking distance.

5. CONCLUSIONS

This study mainly focused on the initial methodology for developing parking accumulation profiles. In the initial assessments, relatively basic assumptions were formed and later adjusted to influence the parking profile. Information from the Dubai Trip Generation and Parking Rate Manual can be used to develop parking accumulation profiles. The approach proposed in this study is feasible for predicting parking accumulation based on similar land use. Future improvements can be made by conducting preliminary surveys to establish an initial profile and predicate a robust parking accumulation profile for different land-use types in Abu Dhabi. Additional accurate information on parking supply and demand will facilitate the development of better travel demand models that can offer decision support for transporting planners when planning new transport infrastructures or evaluating traffic management strategies because parking availability and parking cost are essential factors affecting the behaviour of travellers. However, the results of this study are limited, as they do not consider technological advances used in modern-day parking, like multi-storey parking facilities. Therefore, future studies need to consider using modern technologies for efficient parking to become popular in most public places. The parking demand model must be implemented with the transport demand model so that engagements can be modelled more precisely regarding travellers' behaviours and supply restraint.

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