

Quantitative Analysis of Automobile Parking at Airports

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Abstract

Automobile parking demand is a derived demand that is increasing in many airports around the world due to the growth in the number of passengers and aircraft movements. Hence, forecasting future parking demand is becoming a significant issue for many airports around the world. Using Seattle Airport as a case study, a spreadsheet model to estimate parking demand was generated and reported in this paper. This simple user-friendly spreadsheet model is a useful tool for airport planners and managers to optimize scarce resources and minimize land and construction costs.

Introduction

Over the last three decades of the twentieth century, the worldwide long-term growth rate in the number of airline passengers was about 6 percent a year (de Neufvill & Odoni, 2003). Although the airline industry suffered a setback following the 9/11 attack, the industry is finally recovering. Some predictions for the next two decades indicate that the world's air passenger and freight demand will grow by an average annual rate of 4% to 5% (Janic, 2004).

The predicted growth in air travel is expected to have a strong effect on some of the busiest airports in the world. To accommodate this growth, many airports must add new facilities and/or make better use of existing facilities. If the facilities provided do not keep pace with the growth in demand, then capacity and service problems may occur. In a large airport, there are many individual functional components that often interact to provide service to passengers. If any component is not functioning efficiently, it will have an effect overall capacity.

One of these important components is the automobile parking service. Parking areas consist of surface lots or multilevel garages used to store vehicles of air passengers and visitors (Brink et al., 1987). The market for parking has five distinct segments: short-term parking, structured parking, long-term or remote parking, rental car parking and employee parking (de Neufville & Odoni, 2003). For planning purposes, parking can be divided into two or three general categories: short-term, long-term, and remote (Brink et al., 1987). Since the focus of this paper is on parking for passengers, it will examine only the short-term, structured and remote parking demands.

Short-term parking is usually located close to the terminal buildings and serves mainly motorists who remain at the airports for less than 3 hours. Since most of these motorists are dropping off or picking up travelers, they want spaces close to the passenger building so that they do not have to carry their luggage for a long distance. Short-term parking provides airport operators with two significant benefits. It relieves crowding at the curbside in front of the passenger building and provides a revenue source that is highly profitable since motorists are often willing to pay for the convenience.

Structured parking serves passengers who leave their vehicles at the airport while they travel. It usually has a lower turnover rate and longer duration of stay. The demand for convenient space next to the terminal building is high, so multilevel garages are generally necessary at busy airports. This kind of garages is expensive and can easily cost about \$12000 per space. Thus, structured parking normally serves passengers on short trips or business travelers who can afford this more expensive facility.

Remote or long-term parking consists of parking lots that are located away from the airport terminal buildings. Often buses or vans may be available to transport passengers to the terminal. This type of parking provides less expensive parking suitable for long-term stays. At some airports these parking facilities are called shuttle lots or holiday lots.

Worldwide surveys indicate that major airports typically provide between 200 and 1200 parking spaces per million total passengers a year, plus 250—500 spaces per thousand employees (de Neufville & Odoni, 2003). Large airport in the world usually provide thousands of parking spaces. For examples, Dallas/Fort Worth provides about 30000 spaces while Chicago/O'Hare and Los Angeles/International provide around 20000 spaces each (ACI-NA, 2001). As the airline industry grows, there is a corresponding increase in the demand for parking at airports.

Basically, there are two ways to meet the increasing demand for parking. The first way is to expand the physical parking capacity. For examples, Vantaa International Airport built an underground parking structure with 2000 parking spaces besides the terminal configuration (Fang, 2005) whereas Phoenix Airport hoisted 'Y' columns at the parking garage to expand the capacity (Scotte & Cliff, 2000). Although these structures can increase the total parking capacity, the costs are usually very high. Another way to meet the increasing demand for parking spaces is to moderate parking demand among different parking facilities. For example, airport managers may decrease the parking fees to attract more passengers to use more remote parking lots.

One thing that should be kept in mind is that the number of parking spaces required to provide an adequate service level is greater than the total parking spaces demanded for large parking facilities due to the difficulty in finding last few empty spaces. Thus, a large parking facility is usually considered full when 85% to 95% of the spaces are occupied. Ignoring this difference will lead to congestion and a longer queue at the facility which can cause great inconvenience for some passengers who may be pressed for time.

Although increasing parking facilities can bring significant revenue to the airports, it will also increase vehicle traffic which may result in more traffic congestion near the terminal buildings. On the other hand, using efficiency improvement measures, such as increasing the parking fees to discourage people from using the parking lots near the terminal buildings, may make better use of the facilities and reduce

congestion, but it may reduce revenue as well. Therefore, operators have to choose an optimal balance between these two approaches.

The optimization of parking facilities is therefore a significant issue on airport design and management, especially for large busy urban airports where land and construction costs are very high. In optimizing the parking facilities, we need to recognize that there is a strong relationship between public parking demand on the one hand and air passenger volume and mix on the other. Failure to understand this relationship will lead to an over or under design of the parking capacity, resulting in a waste of capital and space or offering an inadequate level of service.

Therefore, the aim of this study is to develop a simple spreadsheet model to forecast the demand for automobile parking at airports to provide planners and managers with important information to optimize the use of scarce resources. Spreadsheet model is chosen because it is simple to use, requires less data than econometric models, and easy to re-calibrate for applications to other airports. Although the accuracy of spreadsheet model is not as high as many of the econometric forecasting models, it is deemed to be sufficient for this purpose.

Overview of the Model

The tool used in this paper for the analysis of automobile parking at airports is spreadsheet model. Spreadsheet model can be a mix of analytical models and simulation models. Using deterministic analytical formulas, it is possible to model multiple processes and quickly obtain the number of vehicles in the parking lot using a deterministic approach. Spreadsheet model are quick to build, simple to understand and easy to expand (de Neufville et al, 2002).

Using Seattle airport as a case study, the spreadsheet model was generated based on the data provided. The main idea behind this model is to use the historical data and other information that are already known to estimate the future demand for the automobile parking at the airport. From a user perspective, the model consists of

two major parts, data input area and data output area, which is shown in Figure 1.

Time	Occupancy	Occupancy	Date	Day of the week	Passenger driving profile (vehicles/passenger)	Parking profile	Airline information
00:00	0	0	2007-8-30	Thursday	0.178657075	General parking	US Airways
00:05	0	0			0.1864089	4th floor parking	Delta Air Lines
00:10	0	0				1hr	Delta Connection/Atlantic Southeast
00:15	0	0				2hrs	Delta Air Lines
00:20	0	0				3hrs	Delta Air Lines
00:25	0	0				4hrs	Delta Air Lines
00:30	0	0				5hrs	Delta Air Lines
00:35	0	0				6hrs	Delta Air Lines
00:40	0	0				7hrs	Delta Air Lines
00:45	0	0				8hrs	Delta Air Lines
00:50	0	0				9hrs	Delta Air Lines
00:55	0	0				10hrs	Delta Air Lines
01:00	0	0				11hrs	Delta Air Lines
01:05	0	0				12hrs	Delta Air Lines
01:10	0	0				1/2day to 1day	Delta Air Lines
01:15	0	0				2days	Delta Air Lines
01:20	0	0				3days	Delta Air Lines
01:25	0	0				4days	Delta Air Lines
01:30	0	0				5days	Delta Air Lines
01:35	0	0				6days or more	Delta Air Lines
01:40	0	0					Delta Air Lines
01:45	0	0					Delta Air Lines
01:50	0	0					Delta Air Lines
01:55	0	0					Delta Air Lines
02:00	0	0					Delta Air Lines
02:05	0	0					Delta Air Lines
02:10	0	0					Delta Air Lines
02:15	0	0					Delta Air Lines
02:20	0	0					Delta Air Lines

Figure 1: Spread sheet model.

The most important information in the data output area is the predicted demand for automobile parking in five minute intervals. An example of this forecast is 14,508 lots on the 4th floor parking lot would be occupied at 11:55 a.m. on July 19th, 2008. The only input data that is normally required is the date. Users could extract forecast that they desired simply by changing the date.

More advanced users also have the ability to get customized forecasts of the demand if they have the required information for the airport or data from different airports. The way to calibrate the model will be discussed in the next section.

Development and Calibration of Model

The airline information is entered into the spreadsheet and shown in Figure 2. For each flight, there is a start date and end date, departure

time, and availability for each day of the week. A flight is available if there is a number showing under specific day of the week.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Airline information											
2	Airline	From Date	To Date	Departure time	Mon	Tue	Wed	Thur	Fri	Sat	Sun	Origination
3	US Airways	2007-7-8	2007-9-4	8:15	1	2	3	4	5		7	82
4												
5	Delta Air Lir	2007-7-1	2007-7-31	6:45	1	2	3	4	5	6	7	142
6	Delta Air Lir	2007-7-1	2007-7-31	8:30	1	2	3	4	5	6	7	141
7	jetBlue Airw	2007-7-1	2007-7-31	12:50	1	2	3	4	5	6	7	129
8	jetBlue Airw	2007-7-1	2007-7-31	22:15	1	2	3	4	5	6	7	132
9	jetBlue Airw	2007-7-1	2007-7-31	23:50	1	2	3	4	5	6	7	129
10												
11	Delta Air Lir	2007-7-1	2007-7-31	8:00	1	2	3	4	5	6	7	237
12	Delta Conn	2007-7-1	2007-7-31	11:20	1	2	3	4	5	6	7	42
13	Delta Air Lir	2007-7-1	2007-7-31	19:46	1	2	3	4	5	6	7	
14	Delta Air Lir	2007-7-1	2007-7-31	21:33	1	2	3	4	5	6	7	
15	Delta Air Lir	2007-7-1	2007-7-31	6:15	1	2	3	4	5	6	7	142
16												
17	Delta Air Lir	2007-7-1	2007-7-31	7:30	1	2	3	4	5	6	7	141
18	Delta Air Lir	2007-7-1	2007-7-31	11:40	1	2	3	4	5	6	7	154
19	Delta Air Lir	2007-7-1	2007-7-31	12:51	1	2	3	4	5	6	7	154
20	Delta Air Lir	2007-7-1	2007-7-31	14:07	1	2	3	4	5	6	7	155
21	Delta Air Lir	2007-7-1	2007-7-31	15:35	1	2	3	4	5	6	7	126
22	Delta Air Lir	2007-7-1	2007-7-31	17:00	1	2	3	4	5	6	7	116
23	Delta Air Lir	2007-7-1	2007-7-31	18:25	1	2	3	4	5	6	7	126
24	Delta Air Lir	2007-7-1	2007-7-31	21:41	1	2	3	4	5	6	7	
25	Delta Air Lir	2007-7-1	2007-7-31	23:00	1	2	3	4	5	6	7	145
26												

Figure 2: Airline Information

The next step is to apply pivot table to calculate the number of passengers departing every five minutes on that day. Pivot table is used because it can easily add the number of passengers from different flights at the same time and day. In order to use the pivot table, a list of time schedule needs be set up. The flight schedules should be settled from 00:00 to 23:55, since we are using five minute intervals, so that the pivot table could be integrated (see Figure 3).

Although airline departure times are recorded and user requests are entered to the nearest minute, the forecasting model is developed using five minute intervals to minimize the number of times with no flights and simplify the computation. It should be noted that the choice of a 5-minute interval is arbitrary and users can select other intervals in their recalibration of the model.

	A	B	C	D	E	F
1	AIRLINE	Time	Time	Passenger		1979-12-31
2		0.003472222				
3			00:00			10062
4			00:05			3
5			00:10			4
6			00:15			
7			00:20			
8			00:25			
9			00:30			
10			00:35			
11			00:40			
12			00:45			
13			00:50			
14			00:55			
15			01:00			
16			01:05			
17			01:10			
18			01:15			

Figure 3: Times in 5-minute Interval

The flight information is then added to the pivot table after the time schedule (see Figure 4). In this table, column A is the name of the airlines, column B is the real time of departure. Data for columns A and B is directly copied from the airline information shown in figure 2.

Column C is the 5-minute equivalent of column B. To convert the departure time or requested time into 5 minute blocks, the Excel formula “Round” is used to get rid of the residue for each time and the result is multiplied by the cardinal number 0.003472 [i.e., $5/(60 \times 24)$]. The Excel formula used is “Round (‘Time’/ ‘cardinal number’, 0) * ‘cardinal number’”. Through this way, anytime like 8:46 could be changed to its five minute equivalent, 8:45, and would be ready for use in the pivot table and output system.

A	B	C	D	E	F	G
281		23:10				
282		23:15				
283		23:20				
284		23:25				
285		23:30				
286		23:35				
287		23:40				
288		23:45				
289		23:50				
290		23:55				
291 US Airway	8:15	8:15	82	true		
292	0	0:00	0	FALSE		
293 Delta Air L	6:45	6:45	142	true		
294 Delta Air L	9:30	9:30	141	true		
295 JetBlue Air	12:50	12:50	139	true		
296 JetBlue Air	22:15	22:15	132	true		
297 JetBlue Air	23:50	23:50	129	true		
298	0	0:00	0	FALSE		
299 Delta Air L	8:00	8:00	237	true		
300 Delta Conn	11:20	11:20	42	true		
301 Delta Air L	19:46	19:45	0	true		
302 Delta Air L	21:33	21:35	0	true		
303 Delta Air L	6:15	6:15	142	true		
304	0	0:00	0	FALSE		
305 Delta Air L	7:30	7:30	141	true		
306 Delta Air L	11:40	11:40	154	true		
307 Delta Air L	12:51	12:50	154	true		
308 Delta Air L	14:07	14:05	155	true		
309 Delta Air L	15:35	15:35	126	true		
310 Delta Air L	17:00	17:00	116	true		
311 Delta Air L	18:25	18:25	126	true		
312 Delta Air L	21:41	21:40	0	true		
313 Delta Air L	23:00	23:00	145	true		

Figure 4: Pivot Table for Flight Information

Column D is the expected number of passengers on this flight, and column E is the criteria to decide whether column D is applicable or not. Since some airlines do not have flights departing everyday in a week, the model must recognize the day of the week for each date for which the forecast is desired. In other words, when users input a date, the system should output the day of week and uses it to determine the flights available for this date. To do this, the model calculates the difference in the number of days between the original set up date and the date that the user input. This difference is then divided 7 and the residue represents the days after the set up day. For example, if the set up date is Sunday, 1979-12-30 and a user input a date of 2008-07-31, the difference in the number of days between these two dates is 10441, with a residual of 4. Then the day of the week of 2008-07-31 is Thursday (four days after Sunday).

Column E is mainly used to test if there is an air flight available on this day. If yes, the output would be “true”. Otherwise the output will be “FALSE”. If the day of the week DW=4, which is Thursday, then

the formula for the first air flight, US airways, will be as follow:
 “IF(DW=E3, "true", IF(DW=F3, "true", IF(DW=G3, "true", IF(DW=H3, "true", IF(DW=I3, "true", IF(DW=J3, "true", IF(DW=K3, "true", "FALSE"))))))”). Because DW=4, the output of this formula will be “true”. Otherwise, if DW=6, the output will be “FALSE” since there is no record would match 6.

Column D is used to decide if the air flight is available and output the number of passengers. Suppose DATE=2007-07-20, the formula in column D for the first airline, US airways, would be: “IF(DATE>=B3, IF(DATE<=C3, IF(E291="true", L3,0),0),0)”. Because 2007-07-20 is between the date of 2007-07-08 and 2007-09-04, and the output of testing the day of week is “true”, the output of this formula for the first airline would be 82. Otherwise, the output will be 0.

Using the function of pivot table, the content discussed above could be easily transferred to a table with number of passengers departing at each five minutes. The command “Sumproduct” can be used to combine the flight departure information and passenger arrival (going to airport for departure) profile to generate the numbers of passengers arriving at the airport at five minute intervals. Multiply this list with passenger driving profile, a new list of numbers of vehicles arriving at the airport for each five minutes could be built.

What the airport managers need is information on the occupancy in the parking lot, but not the number of vehicles arriving for each period of time. Thus, there is one more step the model has to do. Since different passengers park their vehicles for different duration, a parking profile is needed. For example, with 10 vehicles at 12:05 p.m., our data suggests that 50% will stay for 1 hour, 30% will stay for 2 hours, and 20% have a duration time of 3 hours. Then 5, 3, and 2 vehicles will be put in the category of 1 hour, 2 hours, and 3 hours, respectively. The same procedure should be implemented on all other times (see Figure 5).

The screenshot shows an Excel spreadsheet titled "Parking model with macro.xls". The table contains data for various time slots and vehicle counts. The columns are labeled A through O, and the rows are numbered 1 through 178. The data is organized into a grid where each row represents a specific time slot and each column represents a different category of vehicle count or duration.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	12:00	7	4	1	0	0	0	0	0	0	0	0	0	2	5
148	12:05	6	3	1	0	0	0	0	0	0	0	0	0	2	5
149	12:10	6	3	1	0	0	0	0	0	0	0	0	0	2	5
150	12:15	6	3	1	0	0	0	0	0	0	0	0	0	2	5
151	12:20	6	3	1	0	0	0	0	0	0	0	0	0	2	4
152	12:25	6	3	1	0	0	0	0	0	0	0	0	0	2	4
153	12:30	6	3	1	0	0	0	0	0	0	0	0	0	2	4
154	12:35	6	3	1	0	0	0	0	0	0	0	0	0	2	5
155	12:40	6	3	1	0	0	0	0	0	0	0	0	0	2	5
156	12:45	6	4	1	0	0	0	0	0	0	0	0	0	2	5
157	12:50	6	4	1	0	0	0	0	0	0	0	0	0	2	5
158	12:55	7	4	1	0	0	0	0	0	0	0	0	0	2	5
159	13:00	7	4	1	0	0	0	0	0	0	0	0	0	2	5
160	13:05	7	4	1	0	0	0	0	0	1	0	0	0	2	5
161	13:10	7	4	1	0	0	0	0	0	1	0	0	0	2	5
162	13:15	7	4	1	0	0	0	0	0	1	0	0	0	2	6
163	13:20	7	4	1	0	0	0	0	0	1	0	0	0	2	6
164	13:25	7	4	1	0	0	0	0	0	1	0	0	0	2	6
165	13:30	7	4	1	0	0	0	0	0	1	0	0	0	2	5
166	13:35	7	4	1	0	0	0	0	0	1	0	0	0	2	5
167	13:40	7	4	1	0	0	0	0	0	0	0	0	0	2	5
168	13:45	7	4	1	0	0	0	0	0	0	0	0	0	2	5
169	13:50	7	4	1	0	0	0	0	0	0	0	0	0	2	5
170	13:55	6	3	1	0	0	0	0	0	0	0	0	0	2	5
171	14:00	6	3	1	0	0	0	0	0	0	0	0	0	2	5
172	14:05	6	3	1	0	0	0	0	0	0	0	0	0	2	5
173	14:10	6	3	1	0	0	0	0	0	0	0	0	0	2	5
174	14:15	6	3	1	0	0	0	0	0	0	0	0	0	2	4
175	14:20	6	3	1	0	0	0	0	0	0	0	0	0	2	4
176	14:25	6	3	1	0	0	0	0	0	0	0	0	0	2	4
177	14:30	6	3	1	0	0	0	0	0	0	0	0	0	2	4
178	14:35	6	3	1	0	0	0	0	0	0	0	0	0	2	4

Figure 5: Parking Profile and Vehicle Numbers

When the table showed in Figure 5 has been computed, the total number demand can be estimated by simply adding the demand for each time slot. For instances, in order to calculate the occupancy at 14:00, the model would add numbers in category of 1 hour between 13:05 and 14:00, plus numbers in category of 2 hours between 12:05 and 14:00, plus numbers in category of 3 hours between 11:05 and 14:00, and so on and so forth. Although the data in this table is only for one day, the model builds up pivot tables for 7 days, and uses all the results for calculating the occupancy. Then the categories would spread from “1 hour” to “6 days or more”. Of course, using more days would improve the forecast but using only 7 days is expected to result in a very small error.

Finally, since Excel can not refresh the data for the pivot tables by itself, the model also provides a function to update the data. In order to refresh data, a macro button is provided, and users can refresh the data at anytime simply by clicking the macro button. The macro button uses the “Visual basic editor” function, and the code used is shown below.

```

Private Sub RefreshDataButton_Click()
Sheets("SheetName1").PivotTables("PivotTableName1").
    RefreshTable
Sheets("SheetName2").PivotTables("PivotTableName2").
    RefreshTable
.....
Sheets("SheetNameN").PivotTables("PivotTableNameN").
    RefreshTable
End Sub

```

Conclusion

The aim of this study is to develop a spreadsheet model to forecast the demand for automobile parking at airports that could be used by anyone with the widely available software Microsoft Excel. Although the model is calibrated using information from Seattle Airport, users can easily calibrate the model using similar data from any airport. This tool will be very useful to airport designers and planners given the current boom in the aviation industry to optimize the development of new landside equipments and facilities as well as to improve the efficiency of the existing facilities.

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