

MODELING CURBSIDE VEHICULAR TRAFFIC AT AIRPORTS

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ABSTRACT

We describe the use of discrete event simulation in modeling the curbside vehicular traffic at airports. The dynamic nature of vehicular traffic poses a challenge in developing a discrete event simulation model to represent roadway operations. We present our simulation methodology in modeling the new Austin-Bergstrom International Airport and address the use of simulation in the design as well as the operational planning issues. We share our experience in overcoming many challenges in this modeling effort.

1 INTRODUCTION

Airport passenger terminals are typically very crowded with thousands of passengers, well-wishers, greeters, employees, and vendors entering or leaving the terminal through some mode of ground transportation. The terminal curbside, used by all ground transportation modes, is one of the most congested areas of an airport. Most major airports have experienced significant traffic congestion problems and therefore require improvements in their ground transportation access systems. Simulation has been a useful technique in modeling vehicular traffic at terminal curbside to analyze the impact of changes in operating conditions (Carson, 1997; Bender and Chang, 1997).

We present an airport roadway simulation application and describe the methodology in modeling the curbside vehicular traffic. The simulation model provides a platform for *what-if* type analysis and is used to evaluate several design scenarios to identify a good curbside transportation mode allocation. In this paper, we also share our experiences as to the unique nature of roadway modeling using discrete event simulation.

In the next section, we specify the purpose of the modeling effort. We then describe the roadway system that is modeled in this study, followed by the identification of simulation model architecture. The model input parameters and output measures are then presented,

followed by a brief discussion on the results. Throughout this project we faced many challenges and we discuss these issues. We end this paper by highlighting our conclusions.

2 PURPOSE OF THE MODELING

The City of Austin is redeveloping a former Air Force Base into its new International Airport. As such, the property is being completely transformed and there does not exist operational data on how the new facilities will perform at the new airport. The city wants to be sure that facilities will be sufficient for opening day and beyond and this is a primary motivation for the modeling.

Additionally, there exists a Ground Transportation Coordinating Committee which advises the city on technical matters relating to ground transportation facilities at the existing and new airport. The committee raised questions about the allocation of various transportation segments to available curb parking areas and indicated a general level of concern about the operational capability of the facilities as designed. To address these concerns, the city initiated the modeling and will include alternative scenarios to directly answer the questions of the committee.

The SABRE Group (*SABRE*) was contracted by the Austin airport authorities to develop a computer simulation model of the curbside roadways, including vehicular traffic as well as the pedestrian flow entering and exiting the terminal building and the parking garage.

3 THE MODEL

We now describe the roadway system, present the simulation model architecture, specify the model input parameters, identify the model performance measures, and discuss our findings.

3.1 System Description

The Austin-Bergstrom International Airport (ABIA) is being constructed on the site of the old Bergstrom Air Force base. It is scheduled to open in 1999, and will serve over 20,000 passengers daily. With an annual passenger volume growth of 4.5%, it is estimated that in summer 2004, the airport will serve over 27,000 passengers daily. The terminal has two levels with a separate access roadway for each one.

By far, the largest mode of travel to the airport in Austin is by private vehicle. As the dominant mode, this creates a high demand for curb parking adjacent to the terminal building and strongly influences the overall traffic patterns in the curbside area. Although the city is considering encouraging other modes of travel to the airport, there is no guarantee that these modes will substantially reduce the demand for private vehicle space at the curb.

The upper level – as depicted in Figure 1 – is dedicated to departing passengers who are leaving the airport via their outbound flights. Ticketing and security access to gates are located at the upper level. Departing passengers as well as their well-wishers use the upper roadway to access the terminal. There is one entry to and one exit from the upper roadway with one-way vehicular traffic flow. All parking garage traffic is diverted to the garage before the entrance

ramp to the upper roadway. There are two curbs on the upper roadway. The inner curb, which consists of four lanes, is primarily dedicated to the use of private vehicles although other modes of transportation are allowed. The outer curb, called the median, is dedicated solely to commercial traffic, and is served by three lanes. The total length of the upper curb is 675 feet, of which 75 feet is allowed for crosswalks. With an average vehicle size of 25 feet, there are 24 curbside parking positions.

The lower level is dedicated to arriving passengers who are coming to the airport via their inbound flights. Baggage claim is located at the lower level. Arriving passengers as well as their greeters use the lower roadway. There is one entry to and one exit from the lower roadway with one-way vehicular traffic flow. There are two curbs on the lower roadway. The inner curb, which consists of four lanes, is primarily dedicated to the use of private vehicles although other modes of transportation are allowed. The outer curb is dedicated solely to commercial traffic, and is served by three lanes. No parking is allowed on the outer most lanes of inner curb and the median curb. There are 24 curbside parking positions at both the inner and the outer curbs.

Pedestrians use the four crosswalks to reach the median and the two crosswalks to reach the parking garage. Crosswalks are currently unregulated, pedestrians have immediate right-of-way and all vehicular traffic yields to pedestrians.

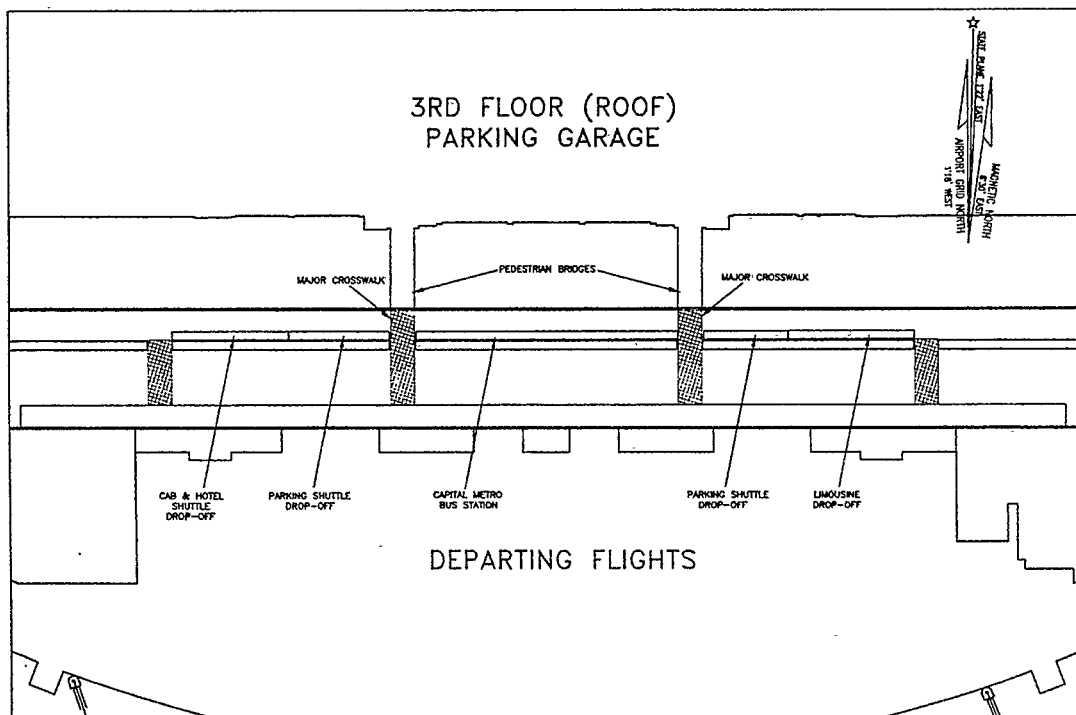


Figure 1: Austin-Bergstrom International Airport Departures Layout

3.2 Simulation Model Architecture

The curbside roadway simulation model includes five major logic components.

- *Vehicle Movement* – Moves vehicles forward while checking for any blockages or interference from other vehicular or pedestrian traffic. Necessary lane changes are performed, provided that enough vehicle separation is maintained for safety reasons.
- *Parking Space Selection* – Determines the parking position of vehicles based on the desired parking zone and availability. Vehicles are assumed to park at the available zone closest to their desired terminal entrances. If no single-lane parking position is available, vehicles are allowed to double-park and triple-park to drop-off and pick-up passengers.
- *Passenger Drop-off* – Ensures that passengers are dropped-off at designated zones. The unloading time delay is sampled from the corresponding unloading time distributions based on the transportation modes.
- *Passenger Pick-up* – Matches deplaning passengers with their corresponding transportation modes, and samples from the corresponding loading time distributions.
- *Pedestrian Crossing* – Ensures that roadway traffic yields to pedestrians crossing to and from the parking garage.

The curbside model is developed using the simulation modeling tool ARENA. The run time of one replication of the model is slightly under 5 minutes on Intel Pentium 200 megahertz machine running Windows NT operating system.

3.3 Model Inputs

The model is driven by a number of parameters which include:

- Flight schedules
- Commercial vehicle access frequencies
- Distribution of
 - passenger group size
 - number of well-wishers
 - number of bags per passenger
 - pedestrian walking speed
 - passenger arrival time pattern
 - loading/unloading times for vehicles
- Parking garage usage percentages
- Transportation mode split and curbside allocation of
 - Private autos
 - Taxicabs
 - Limousines
 - Hotel/Motel courtesy shuttles
 - Shared ride
 - City buses

- Charter busses
- Parking shuttles
- Maximum passenger occupancy by vehicle types
- Airline zone identification at curbside

These input parameters together with several rules that control the vehicle and pedestrian movement define the input space for the simulation model.

We collected data on-site to estimate the distribution of loading/unloading times for different modes of transportation. Other model input parameters were obtained from previous studies. These include the passenger group size, number of well-wishers, number of bags per passenger, pedestrian walking speed, and passenger arrival pattern distributions. The current flight schedules were obtained from the Official Airline Guides and future demand for the year 2004 is estimated based on a 4.5% annual growth. Other model parameters have been provided by the *New Airport Project Team* of the City of Austin.

3.4 Model Outputs

The model provides a large number of performance measures that are important in assessing the roadway operating conditions. These are listed below:

- The number of vehicles present at the inner curb and the median by time of the day, and the overall average and maximums,
- The number of single-, double- and triple-parked vehicles by airline parking zones and by time of the day, and the overall average and maximums,
- Overall average time vehicles spend at the curb from the roadway entrance to the roadway exit,
- The time vehicles spend waiting to access a parking space and road segments (as a percentage of total time spent at the roadway),
- Number of vehicles that could not find a parking position at the curbside and had to re-circulate,
- Count of pedestrians crossing each crosswalk by time of day,
- Distance traveled by pedestrians

The simulation output contains a detailed summary report for the statistics pertaining to the performance measures. The model also provides a detailed animation which proved to be very useful in debugging the model and assessing the model capabilities.

3.5 Results

At the time when this paper is written, the project is ongoing. There are several scenarios that we plan to analyze and compare to a base case. We have completed a base case model and preliminary results are described below. At completion of this project, the performance of several other scenarios will be analyzed.

The upper roadway (dedicated to departing passengers) has enough capacity to serve the vehicles arriving to the terminal. Even at peak times, there is excess capacity at both the median and the curbside. More than 85% of the passengers were dropped-off at the single-parking lane. Less than one percent of the vehicles were unable to find a parking position and re-circulated around the airport. These results indicate that the level of service at the upper roadway is very good. However, the curbside capacity is not being used uniformly. Curbside in front of one of the four terminal entrances is being used heavily as compared to the others. This result suggests that signage may be used to distribute the traffic evenly at the curbside. However, knowledgeable passengers will still prefer to park closer to the door so the benefit of improved signage may only be marginal.

The lower roadway (dedicated to arriving passengers) experiences some congestion, especially in the evening peak hour when passengers are returning to Austin. Vehicles frequently double- and triple-park to pick-up arriving passengers, which causes congestion and delays. Less than 40% of the passengers were picked-up at the single-parking lane. This indicates that the lower roadway is more congested than the upper roadway. There are several factors that affect the lower roadway traffic congestion. The unregulated pedestrian crosswalks significantly impact the lower roadway capacity and one recommendation from this study is for the city to manage these crosswalks more actively. Traffic flow control and parking violations also have significant impacts on congestion. Currently, vehicles are not allowed to park and wait for passengers for more than 5 minutes. This rule has a direct impact on the roadway congestion; applying a rule where only active loading is allowed will significantly reduce the congestion.

Additional scenarios that will be modeled include reallocating curbside parking areas based on input from the city's Ground Transportation committee. This reallocation will provide a direct comparison of the level of service provided by the alternative scenarios. The goal of the city will be to provide the best possible level of service to most of the passengers. Comparison of the output metrics from case to case will provide a strong guide to the level of service that each provides.

4 ISSUES

Given the complex nature of the airport curbside roadway and the interactions of pedestrian walkways, developing an analytical model to represent this problem is impossible. The use of simulation in this project was very fruitful and provided many useful answers. However, we faced many challenges. In this section we share these challenges and tell what we have done to overcome those.

4.1 Limitations of Discrete Event Simulation

Representing the vehicular motion through discrete events was one of the most challenging components of the roadway simulation modeling. Roadway traffic flow is more of a continuous process where the state of the system changes instantaneously and continuously. Our efforts in discretizing this almost continuous process had some drawbacks and created severe computational burden. We have modeled the motion such that vehicles claim road segments ahead and move in 25 foot increments. Based on the posted roadway speed, vehicles travel through 25 foot roadway segments under one second. To better model the continuous movement, the roadway segments can be further reduced, perhaps at a segment size of one foot. This will improve the model precision at a high computational cost. After experimenting with different values, we have found that 25 foot segments provided sufficient resolution.

4.2 Modeling Human Behavior

Another significant challenge in simulating the curbside operations was modeling human behavior. Given the large percentage of passengers using private vehicles to access the airport, human behavior becomes a substantial issue. For example, how many people will take the first available curb parking space rather than risk not finding a space ahead? How many people will double-, triple- or quadruple-park and under what conditions will they do this? Although there are certain rules that describe the driving process, each driver is unique in his or her decisions as to where and when to park, as well as when to pass the vehicle blocking the road ahead. For the selection of parking positions, we assumed that the drivers park at a spot closest to their desired terminal entrance, if one is available. If all parking positions are occupied, they will double- or triple-park if necessary. However, in reality, driver parking selection logic is much more complex than our simple rule. There may be drivers that choose to park at other terminal entrances to avoid the traffic congestion in front of the desired entrance.

We have faced a similar difficulty in modeling the pedestrian crossing between the terminal and the parking garage. At Austin airport, the crosswalks are not regulated by traffic signals and passengers generally have the right-

of-way. In our first attempt, we modeled the crosswalks such that pedestrians always had immediate right-of-way and vehicular traffic immediately yielded to pedestrians. This created unacceptable and unrealistic waiting times for the vehicles since streams of pedestrians kept the roadway occupied for extended periods. In reality however, pedestrians may adjust their walking speed to create "groups" for crossing the busy roadway and this will prevent the roadway from being blocked by a stream of pedestrians. We updated our pedestrian crossing logic to model the grouping effect and obtained more realistic vehicular and pedestrian waiting times.

Although we have spent a significant amount of time observing the curbside vehicular and pedestrian traffic to be able to understand and model the relevant human behavior, we believe that these behavioral issues should be studied in more detail to provide a basis for preparing models such as this. It is quite a difficult task to represent human behavior with a set of rules that can be included in a simulation model. Although a set of rules may apply to the majority of passengers and drivers, there will always be others who behave differently. It is a challenge for simulation consultants to gauge the sensitivity of their models with respect to human behavior.

4.3 Output Analysis

There are a large number of output measures in our model, each addressing a specific issue in the roadway model. It is not a straightforward task to statistically analyze a model that has several important output measures. The average number of vehicles present at the curbside is not a useful measure since the demand is driven by flight schedules, which follow a cyclical pattern with peak hours in the morning and in the afternoon. The maximum number of vehicles present by time of day is a more interesting measure and is used in determining the roadway performance. The challenge for the simulation consultant is to decide which replication to report. In this case, we made enough replications to narrow down the confidence interval around an average performance and then choose a typical busy day (75th percentile based on the average performance) and report the corresponding maximum vehicular occupancy. In addition, we used many histograms to display the output measures and they were very useful in assessing the roadway conditions.

5 CONCLUSIONS

The simulation model of the curbside vehicular traffic and pedestrian flow of the Austin-Bergstrom International Airport proved to be very useful in planning and design of the new airport. It provides numerical results as well as graphical animations of the roadway. Several design issues

as to the allocation of curbside space to different transportation modes are addressed with this model.

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