ACRP Report 40
Airport Curbside and Terminal Area Roadway Operations

Appendix B

BIBLIOGRAPHY

This appendix presents an annotated bibliography of documents reviewed during the literature search for this research project on airport curbside and terminal area roadway operations, with an emphasis on those documents that describe analytical procedures and performance measures. The documents are organized under the following topics:

- General landside access
- Performance measures
- Terminal area roadways
- Analytical tools
- Simulation models
- Curbside operations

GENERAL LANDSIDE ACCESS

The following documents provide a general overview of airports including their planning, design, and operations. They describe the major components of an airport landside sector, and how they interrelate with each other and with the airside sector. These documents provide a foundation for the material contained in subsequent sections of this bibliography as they explain the purpose and function of the airport landside sector, the general configuration and operations of terminal curbsides, and the types and functions of terminal-area roadways.

Textbooks

1. Ashford, Norman and Paul H. Wright, ***Airport Engineering, Third Edition***. John Wiley & Sons, 1992.

   References curbside analysis procedures published by Cherwony and Zabawski (see reference #20 under Analytical Tools).

2. Ashford, Norman, H.P. Martin Stanton' and Clifton A. Moore, ***Airport Operations, Second Edition***. McGraw-Hill, 1997.

   A basic reference on all aspects of airport operations. Airport access chapter presents nomographs for estimating curbside lengths in terms of passenger volumes.

3. De Neufville, Richard and Amedeo Odoni. ***Airport Systems: Planning, Design, and Management*** McGraw-Hill, October 2002.

The most recent textbook on airport systems planning, design, and management. Describes full range of computer-based tools and methodology. Terminal buildings chapter provides overview of curbside operation, configurations, and a formula for approximating curbside requirements.

4. Hart, Walter. ***The Airport Passenger Terminal.*** Krieger Publishing Company, January 1992.

A general resource textbook that provides information specific to passenger terminals. Provides case studies of eight airport terminals, with associated discussions of ground transportation facilities provided at those terminals.

5. McKelvey, Francis X. and Robert Hornjeff. ***Planning & Design of Airports***, ***Fourth Edition***. McGraw-Hill, 1994

A well respected reference covering all aspects of airport planning and design that briefly addresses circulation roadways.

6. Shapiro, Phillip S., Marcy G. Katzman, Warren E. Hughes, Joseph McGee, Matthew Coogan, M. Allen Hoffman, Emily Van Wagner, and Peter B. Mandle. ***Intermodal Ground Access to Airports: A Planning Guide.*** U.S. Department of Transportation, Federal Aviation Administration. December 1996.

Paraphrased from the article abstract: Shortly after passage of the Intermodal Surface Transportation Efficiency Act of 1991, the Federal Highway Administration and the Federal Aviation Administration recognized that very little guidance was available for airport operators and metropolitan planning organizations to use in planning intermodal access to U.S. airports. The ***Intermodal Ground Access to Airports: A Planning Guide*** was developed to provide guidance to states, metropolitan planning organizations, and airport operators on the types of analyses that should be performed when planning airport access. The airport access planning process and procedures for performing the analyses are described.

During development of the Guide, relationships were developed between numbers of originating passengers at U.S. airports and the characteristics of airport access and landside facilities. The types of characteristics that were related to originating passengers included public parking, vehicle trips, terminal curbside design, and mode of access. With respect to curbside and terminal area roadways, the Guide presents examples of the

sizes, configurations, and layouts of airport curbsides and terminal area roadways and provides metrics for evaluating their capacities and forecasting future needs.

7. Transportation Research Board, National Research Council. ***Special Report 215: Measuring Airport Landside Capacity.*** Washington, D.C., 1987.

   From the Special Report synopsis: "Reviews existing capacity assessment techniques and recommend guidelines that can be used by airport operators, planners, and others who must measure airport landside capacity. Congestion at airport terminal buildings, access roads, and parking areas increasingly threatens the capability of airports to serve additional passengers and air cargo. Measuring the capacity of these airport landside facilities and services is becoming critical. No generally accepted standards exist for gauging the level of service provided by landside facilities and their operations. The report concludes that current knowledge about the performance of various airport landside components is inadequate to support airport landside service standards at this time. Instead, the report recommends a process for measuring airport landside capacity that takes an important first step toward developing such standards."

   With respect to curbside and terminal area roadways, Special Report 215 provides a suggested model for estimating curbside requirements obtained from ***Airport Curbside Planning and Design,*** by Mandle, Whitlock, and LaMagna (see reference #25 under Analytical Tools).

Published Articles and Presentations

8. Leiner, Craig, Massachusetts Port Authority. "Airport Terminal Roadway and Curbside Simulation Models: State of the Practice." ***Annual Transportation Research Board Meeting***, January 2005.

   Summarizes the terminal roadway and curbside simulation models and analytical tools commonly used by selected airport operators and consultants. Describes curbside level of service measures and case studies regarding application of available analytical tools and simulation models.

9. Mandle, Peter B., Frank LaMagna, and E.M. Whitlock. ***Air Passenger Processing—From Home to Gate.*** Airport Systems Planning and Design, Tenth Annual Short Course at University of California at Berkeley. June 1981.

   An overview of airport landside operations, including discussion on the function of the airport terminal, air passenger characteristics, planning for passenger processing and passenger terminals, design criteria for selection of passenger ground transportation elements, future airport planning considerations, and case studies.

10. Shapiro, P.S. and M. Katzman. "Relationships between Airport Activity and Ground Transportation Needs." ***Transportation Research Record, No. 1622, Air Transportation***, 1998.

    Summarizes the ***Intermodal Ground Access to Airports: A Planning Guide*** (see reference #6 above). Describes relationships between originating passenger activity and airport access and the demand for landside facilities, including access and circulation roadways, curbsides, parking, and commercial vehicle facilities. Presents some of the relationships that were developed, how they were developed, and their importance to airport access planning. Additional relationships that should be developed are suggested.

11. Vumbaco, Brenda J., ed. ***Airport Landside Operations and Air Service. Transportation Research Record No. 840.*** Transportation Research Board, National Research Council. Washington, D.C., 1982.

    Includes various articles on landside operations (e.g., an analysis of the New Orleans airport ground transportation system, guidance for airport curbside planning and design, and air service (e.g., a time-series analysis of intercity air travel volumes and economic justification of air service to small communities).

PERFORMANCE MEASURES

The following documents describe measures for evaluating the performance and adequacy (i.e., levels of service) of airport curbsides and terminal area roadways. Additional measures are presented in references under Analytical Tools and Simulation Models below.

12. Correia, Anderson and S.C. Wirasinghe. "Evaluating Level of Service at Airport Passenger Terminals: Review of Research Approaches." ***Transportation Research Record, No. 1888.*** Transportation Research Board, National Research Council. Washington, D.C., 2004.

    From the article abstract: "Establishing measures to evaluate the level of service (LOS) at airport passenger terminals is of interest to airlines and airport operators. Airport LOS has been evaluated at individual airports, but no standard method or reporting system exists…various approaches developed by different agencies and researchers are reviewed. In 1986, FAA commissioned TRB to study ways to measure airport capacity. The resulting study recognized that capacity cannot be evaluated without defining acceptable level of service values, but that little agreement exists on methods to measure LOS for terminal buildings. This paper reviews various approaches developed by others to assist professionals interested in applying one of the methods previously developed but not having access to all published information, especially the new approaches. The

intent of this review is to motivate new research on the subject, which would facilitate integration of various existing methods or the development of new approaches." The paper contains an extensive list of references.

13. Mumayiz, S.A. "Evaluating Performance and Service Measures for the Airport Landside." ***Transportation Research Record, No. 1296.*** Transportation Research Board, National Research Council. Washington, D.C., 1991.

    This paper presents a method for evaluating passengers' attitudes and their perceptions of and satisfaction with the quality of service at airport terminal facilities. By using this method, levels of service for airport facilities can be determined for different service measures associated with system performance. When used in connection with capacity assessment techniques (e.g., simulation), this method can facilitate evaluation of the operational performance of airport facilities.

TERMINAL AREA ROADWAYS

The following articles describe the planning, design, operation, and management of terminal area roadways, including analytical tools and simulation models. Several articles describe the causes of terminal area roadway congestion and offer mitigation measures. The effects of weaving—or excessive vehicle movements across traffic lanes, exclusive of typical merging and diverging operations—are also discussed.

14. Duncan, Gavin. "Airport Roadways: Why Congestion Occurs, Mitigation Tools." Landside Operations Workshop. San Francisco, California, April 11, 2002.

    Presents overview of airport roadway operations, how they vary from urban and rural roads, the causes and results of congestion, and potential mitigation measures and their applicability.

15. Gosling, Geoffrey D., ed. ***Ground Access to Airports.*** Proceedings of two workshops sponsored by the FAA. Institute of Transportation Studies, University of California at Berkeley. December 1994.

16. Iqbal, Muhammad Shahid. "Analytical Models of Weaving Area Operations under Nonfreeway Conditions." ***Institute of Transportation Engineers Journal***, July 1995, pp. 60-65.

    Describes the evaluation of nine analytical models to determine nonfreeway weaving.

17. McGlashan, Jason and James Krzeminski, HDR Engineering. "Weaving Operations at Orlando International Airport—A Comparative Evaluation of Analysis Methods." ***Institute of Transportation Engineers, 2001 Annual Meeting***. 2001.

Speed and volume data were collected from two weaving areas to evaluate the accuracy of analytical weave models used at Orlando International Airport. The paper provides a survey of five analytical weave models (2000 ***Highway Capacity Manual***, 1997 ***Highway Capacity Manual***, 1985 ***Highway Capacity Manual***, New Jersey Institute of Technology model, and Fazio lane shift model) and compares their applicability to Orlando International Airport. The authors concluded that, while many models may be applicable to nonfreeway weave sections, none appear to be universal in their application to different weaving scenarios.

18. Peterson, D.W. "Simulation of Airport Land-side Circulation Using Path-based Vehicle Routing." ***Institute of Transportation Engineers***, 2000.

From the article abstract: "Planning and management of ground access is both important and required in a competitive environment. Airport access delays have three components: regional access problems (shared use of principal arterials with other travel destinations or transit based operating delay), on-airport access problems (shared use of primary and secondary roads amongst different terminals, frontages, cargo and terminal service operations by different users such as passenger cars, taxis and limos, rental car and hotel vans, and various bus operations), and finally, frontage utilization problems (e.g., space allocation amongst users and modes interference amongst areas and modes, parking inefficiencies, flight schedule based surges in demand, bunching, and level of enforcement). This paper focuses on the second category, on-airport planning, and touches upon the third, frontage utilization. It describes a series of tools developed to facilitate access planning at a major multiterminal international airport in the Northeastern United States planning undergoing significant growth in terminal capacity and changes in mode usage due to construction of an inter-terminal and regional rail access system."

19. Van Burgsteden, Marco C., Paul E. Joustra, Michiel R. Bouwman, Incontrol Business Engineers, and Mark Hullegie, Amsterdam Airport Schiphol. "Modeling Road Traffic on Airport Premises." In ***Proceedings of the 2000 Winter Simulation Conference***, ed. J.A. Joines, R.R. Barton, K. Kang, and P.A. Fishwick, pp. 1,154-1,163.

From the article abstract: "This paper describes the development of a traffic-modeling tool as an Arena template and two applications of it: one to evaluate alternative designs for the road network on the premises of

Amsterdam Airport Schiphol and one to assess the effects of traffic signaling on a junction. The tool uses discrete event simulation, very suited for modeling traffic in areas where there are a lot of interactions other than car-following. Generation of the O/D matrix was done automatically by a custom-made application."

ANALYTICAL TOOLS

The following articles present analytical tools or methods for calculating requirements for analyzing the operations of airport curbsides and terminal-area roadways, exclusive of simulation models. The analytical tools presented were most frequently used in (1) estimating roadway and curbside demand requirements; (2) evaluating the relationship between aviation demand and curbside demands; and (3) curbside planning, design, and operations.

20. Cherwony, Walter, Abrams-Cherwony & Associates and Frank A. Zabawski, Booz, Allen & Hamilton. "Airport Terminal Curbfront Planning." Transportation Research Board, National Research Council. August 1982.

    Presents suggested method to analyze transportation supply and demand characteristics for airport curbside passenger loading and unloading. The suggested method defines curbfront demand and supply in terms of a time-distance variable of foot-minutes, which is a composite measure of vehicle length and dwell time. Describes the computational procedures for defining transportation demand and capacity. Provides lane utilization factors considering the number of lanes available and nomographs for determining the impact of lane utilization as a function of demand and available length and methods for calculating a volume/capacity ratio.

21. Hillsborough County Aviation Authority, "Terminal Curbfront Demand Modeling." ***Tampa International Airport Master Plan Update***, Workshop #3, undated.

    PowerPoint presentation of curbside model input parameters and results developed for Tampa International Airport. Describes existing terminal curbside and roadways, actions of airline passengers at the terminal frontage, and analyses for curbside assignment and roadway activity.

22. JHK & Associates. "Washington Dulles International Airport Main Terminal Expansion: Technical Memorandum, Curbside Activity and Capacity." 1998.

    Reviews activity at the Washington Dulles International Airport main terminal curbside, and provides a method for calculating curbside capacity.

23. KPMG Peat Marwick, Airport Consulting Services. ***Estimates of Terminal Curbside Frontage Requirements, Newark International Airport, The Port Authority of New York and New Jersey.*** August 1989.

Describes the methodology used to calculate terminal curbside requirements for Newark Liberty International Airport. A spreadsheet model was used.

24. LaMagna, F., Peter B. Mandle, and E.M. Whitlock, Wilbur Smith and Associates. "Guidelines for Evaluation of Airport Landside Vehicular Traffic and Pedestrian Characteristics." ***Fifty-Eighth Annual Meeting, Transportation Research Board***, January 1979.

From the article abstract: "Data are presented describing passenger and vehicular characteristics observed during an extensive study of the landside sectors of Miami International, Denver's Stapleton, and New York's LaGuardia Airports, and one terminal in New York's John F. Kennedy International. Vehicular and pedestrian flow rates at all terminal buildings, curbside, parking, and airport entrances and exits were measured simultaneously and related to the air passenger activity levels, using enplanements and deplanements as indices, which occurred during the same time intervals. Additionally, processing time and service rates were sampled at several locations, including ticket counters, car rental areas, passenger security check points, parking cashier operations, and other locations within the terminal. This paper presents a compendium of these processing times observed at these three airports. Representative pedestrian and vehicular flow rates per passenger and processing times are presented for use as planning tools."

25. Mandle, Peter, E.M. Whitlock, and F. LaMagna. "Airport Curbside Planning and Design." ***Transportation Research Record No. 840***, Transportation Research Board, National Research Council. Washington, D.C., 1982.

From the article abstract: "A method of estimating airport curbside demand and procedures for adjusting this demand for various service levels and operating conditions are discussed. Data are presented describing the effects of passenger and vehicular activity at the airport curb areas. Operational problems that typically occur at an airport curb are discussed. Factors influencing operational problems at the curb are addressed, as well as a means of determining curb frontage requirements, demands, and relating these to levels of service, based on observations at six major U.S. airports. This approach affords airport planners an opportunity to measure the degree of use of the curbside area and to correlate curbside requirements to the effective length of curb. Volumes of originating and terminating passengers were found to be of prime importance in forecasting demand as contrasted to total enplanements and

deplanements. The enforcement level of parking regulations and corresponding vehicle dwell time was found to strongly influence curbside capacity. Design considerations such as roadway and sidewalk widths that affect the efficiency of the curb are presented, and criteria are recommended."

26. Parizi, M.S. and J.P. Braaksma. "Dynamic Capacity of Airport Enplaning Curbside Areas." ***Transportation Research Record, No. 1373, Airport Landside Planning and Operations***, 1992.

    From the article abstract: "An analytical model based on the theory of time-space was developed to calculate the dynamic vehicular capacity of the enplaning curbside area at airport passenger terminal buildings. The enplaning curbside area was considered as a system, and most of the variables that affect the capacity of this system were taken into account. To calculate the practical capacity, two distribution functions were developed. First, the traffic distribution around the doors of the terminal building was analyzed, on the basis of drivers' parking space preference, in the form of a binomial function. Second, weighting functions were developed and calibrated on the basis of users' door preference for unloading, in the case of more than one door, in the form of a modified binomial distribution. Using these functions, the percentage of distribution of traffic as well as the practical dynamic capacity of the enplaning curbs were found."

27. Piper, Heinz Peter, Prof. Dipl.-Ing. "Calculation method for the number of short-term carpark spaces at airport terminals." ***Airport Forum***, 1993, pp. 52-53.

    The article discusses passenger walking distance as a performance measure, and provides a method for determining the number of short-term spaces—i.e., spaces along the curbside—required in front of an airport terminal. The ***Airport Forum*** editors also provide a description of the Advanced Landside Performance System (ALPS) model.

28. Tilles, Richard, et al. "Curb Space at Airport Terminals," ***Traffic Quarterly***, pp. 563-582, October 1973.

    The article presents methods of curb length computation at airports, an analysis of factors that determine such lengths, and commentary on considerations of curb design and cost. Regarding curb length computation, the author discusses rules of thumb and simulation, and asserts that a statistical process using queuing theory is better suited to most airport design requirements. A statistical analysis methodology is discussed. Factors affecting curb length requirements are presented, as follows: (a) vehicle arrival rate and (b) total time a vehicle remains at a

curb (mean service time). Finally, design and cost considerations are described, including the use of one or two levels, width of the roadway, length of the curb, and imposing charges on users of the curb area.

29. URS Greiner, "Curbside Needs Evaluation for Port Columbus International Airport." undated.

    URS Greiner conducted a demand/capacity needs evaluation of the curbside conditions at the terminal. This memorandum summarizes the inventory surveys, specific analyses, and the results.

30. Whitlock, E.M. and E.F. Cleary, Wilbur Smith and Associates. "Planning Ground Transportation Facilities for Airports." Presented at the 48th ***Annual Meeting of Committee on Passenger Transportation Economics***, undated.

    Paraphrased from the article abstract: This article summarizes expected changes in air travel characteristics. Broad considerations also are suggested for improving airport utility and ground transportation systems. The authors evaluated transportation facilities at San Francisco International, Boston Logan International, and Detroit Metropolitan Wayne County airports. Correlations were established for modal split, traffic variation, passenger and vehicle relationships, curb use, and parking characteristics and needs. The following changes in airline travel are expected to influence ground transportation requirements: (a) introduction of larger aircraft; (b) reduction in per capita travel costs; (c) shift from predominantly business travel by air to more recreational travel; (d) large increases in goods movements by air; (e) cheaper per-ton costs of good movements; and (f) more pronounced peak-hour traffic.

SIMULATION MODELS

The following documents discuss simulation of airport curbsides and roadway operations, including (1) the presentation of new simulation models; (2) the evaluation of the effectiveness of existing models; and (3) the discussion of case studies conducted using curbside simulation models at various airports. The following documents are organized by model, as follows:

- Advanced Landside Performance System
- Leigh Fisher Associates Curbside Traffic Simulation (LFACTS)
- Mobility Analysis and Simulation Tools (MAST)
- Terminal, Roadway, and Curbside Simulation (TRACS)
- VISSIM
- Other simulation models

Advanced Landside Performance System™ (ALPS2000)

The JKH Mobility Services division of Kimley-Horn and Associates, Inc., developed the ALPS model to simulate complex multimodel transportation environments, including airport landside systems. The following documents relate to the model's underlying assumptions, features, and uses:

31. Lott, J. Sam, Kimley-Horn and Associates, Inc. "Hybrid Simulation Techniques for the Analysis of Landside and Terminal Capacity Issues." PowerPoint Presentation. ***FAA/NASA/Industry Airport Planning Workshop***. September 12, 2006.

    Describes the holistic methodology of the ALPS2000 model, and presents methods for hybrid simulation modeling—i.e., focusing higher processing power on locations where significant analytical benefits would result. The objective is faster, more-efficient simulation of airport ground transportation systems. Case studies from previous simulation efforts are presented.

    "ALPS2000™ is a set of computer simulation tools used to evaluate the airport landside operations, especially on the roadways and terminal curbsides. ALPS2000 allows the modeler to create micro simulations that encompass the pedestrian and vehicular movements within the terminal roadway system.

    "Fundamental to the ALPS concept is the ability to generate passenger demands based on airline flight schedules. Passenger characteristics, such as visitor characteristics and trip timing, are applied to the flight schedules to generate the passenger demands throughout a 24-hour period. Then vehicular characteristics, such as mode split and vehicle occupancy, are applied to the passenger demands to generate the vehicular activity.

    "Once the vehicular activity is generated, the individual vehicles are routed through the roadway network and stop at their respective curbsides. The ALPS program allows visualization of roadway and curbside operations, including congestion levels, and captures many quantitative results such as travel times. The model is able to simulate all airport roads, parking facilities, curbsides, toll plazas, pedestrian ways and transit systems (such as LRT and APM systems).

    "One of the major features of ALPS2000 is that it is a highly visual tool. All of the results can be displayed to show the detailed movement of people and vehicles. This feature allows for all stakeholders in the airport environment to better understand the results of the analysis. Additional features of the model are its ability to (1) evaluate passenger flow aspects for an entire day (24 hours), (2) differentiate among types of vehicles on the roadway, (3) coordinate with other transportation models, (4) depict

visualizations of bottlenecks and trapped vehicles, (5) identify forced vehicle recirculation at the curbsides, and (6) [identify] conflicts due to pedestrians crossing curbside roadways."

Leigh Fisher Associates Curbside Traffic Simulation (LFACTS)

The LFACTS model was developed by Leigh Fisher Associates (now Jacobs Consultancy) to simulate traffic operations at airport curbsides. The following documents prepared by Leigh Fisher Associates' staff relate to the model's underlying assumptions, features, and uses.

32. Duncan, W. Gavin R. and Hugh Johnson. "Development and Application of a Dynamic Simulation Model for Airport Curbsides." ***The 2020 Vision of Air Transportation. Engineering Issues and Innovative Solutions.*** Proceedings of the 26th International Air Transportation Conference, 2000., American Society of Civil Engineers

    From the article abstract: "The paper describes a proprietary model, Leigh Fisher Associates' Curbside Traffic Simulation (LFACTS), developed to simulate vehicular traffic operations on airport curbsides. The model results can be used to evaluate alternatives and to help airport operators deal with existing and anticipated airport ground traffic congestion problems. The basic theory and assumptions behind LFACTS are provided in the paper. Also provided are examples of how LFACTS has been used to answer specific questions at four United States airports."

33. Hoffman, M. Allen. "Planning and Design of Airport Curbsides." Conference on the Optimal Design and Management of Airport Curbs, Airport Ground Transportation Association and BusCon 2001, September 10, 2001.

    PowerPoint presentation that describes curbside requirements and analysis, selection of appropriate analysis methodology, and potential curbside solutions. In relation to curbside analysis, manual / spreadsheet procedures and their limitations are listed. The presentation describes LFACTS simulation modeling, and lists typical simulation applications.

Mobility Analysis and Simulation Tools (MAST)

34. MAST, developed by DMJM Aviation / AECOM has been used in several airport ground access studies to help evaluate future ground transportation improvements. MAST is an integrated set of computer programs that can be used to model the traffic conditions on roadways and curbs at medium to large airports, including the time of day variations and complex traffic variations associated with multiple-terminal airports.

Terminal, Roadway, and Curbside Simulation (TRACS)

The TRACS model is a discrete-event simulation model developed by Trans Solutions to model airport curbsides and terminal area roadways. The following documents describe the model's underlying assumptions, features, and uses.

35. Bender, Gloria G. and Kuo-Yang Chang. SABRE Decision Technologies. "Roadway and Curbside Traffic Simulation for Las Vegas McCarran International Airport." Presented at the ***American Society of Civil Engineers International Conference on Airport Modeling and Simulation***, May 1997.

    From the article abstract: "Simulation modeling is a useful tool to study the capacity and operation of the airport ground transportation access system (GTAS). This paper compares simulation analysis to other analytical methods and then provides a case study to illustrate how simulation modeling was used as an effective GTAS planning tool at Las Vegas McCarran International Airport. Since most state-of-the-art traffic simulation models either do not have curbside parking and pedestrian crossing logic or the logic does not provide appropriate resolution to answer the questions necessary to support detailed planning, SABRE developed a stochastic, discrete-event simulation model to replicate the behavior of vehicles on the airport curbside roadway. The paper describes the simulation model of the curbside roadways at the LAS main terminal and, among other things, describes the impacts of curbside control measures."

36. Chang, Kuo-Yang. "A Simulation Model for Analyzing Airport Terminal Roadway and Traffic and Curbside Parking." Dissertation submitted to the Faculty of the Graduate School of the University of Maryland, College Park in partial fulfillment of the requirements for a Doctor of Philosophy degree, 2001.

    From the article abstract: This article "…proposes a computer simulation model that helps airport planners and managers conduct operational analyses of airport terminal roadway traffic and curbside vehicle parking activities. The major logic components built into the model include those for vehicular traffic generation, vehicle movement, lane selection and changing, curbside parking space selection, and pedestrian crosswalks. The major output statistics generated by the model, which also demonstrate the model's performance capability, include vehicle system time, number of vehicles entering and leaving the terminal roadway, number of vehicles parked along the curbside, number of vehicles queued at the terminal roadway entry, number of vehicles that cannot find a curbside parking space due to congestion, and vehicle delays."

37. Chang, Kuo-Yang, A. Haghani, and G.G. Bender. "Traffic Simulation at Airport Terminal Roadway and Curbside." ***The 2020 Vision of Air Transportation. Engineering Issues and Innovative Solutions.*** Proceedings of the

26th International Air Transportation Conference, 2000., American Society of Civil Engineers

From the article abstract: "The paper presents a working simulation model that can be used as a tool to assist airport planners, decision makers, and operators to evaluate the performance of airport curbside parking facilities. The model validation results show accurate traffic flow predictions for both arrival and departure areas. Also, the results show that the model can predict both exit flow and vehicles' time spent in the curbside facilities. This model can easily be embedded in a decision support system for airport planners and decision makers to examine different scenarios during planning and design stages."

38. Hargrove, B. and E. Miller. "TRACS—Terminal, Roadway, and Curbside Simulation—A Total Airport Landside Operations Analysis Tool." ***Airport-Airspace Simulations: A New Outlook***, ***Transportation Research E-Circular***, Transportation Research Board, National Research Council. 2002.

"TRACS—Terminal, Roadway, and Curbside Simulation—is a flexible planning tool that can be linked to other simulation products to provide a comprehensive assessment of terminal performance and its interaction with the airspace, airfield, and roadways systems."

39. Siow, B.T., O. Kivanc, G. Bender, R. Evlioglu, and C. Tunasar. "Managing Airport Traffic Disruptions during Construction." ***Designing, Constructing, Maintaining, and Financing Today's Airport Projects,*** Proceedings of the Twenty-Seventh International Air Transportation Conference, American Society of Civil Engineers, 2002.

From the article abstract: "The George Bush Intercontinental Airport / Houston (IAH) has multiple construction projects planned for the next several years. All of these projects will involve a temporary closure of roadways or traffic lanes, as well as changing traffic operations in and around the airport. Two separate, but correlated simulation models are used to represent the vehicular traffic operations at IAH. The Terminal and Curbside Roadways are modeled using a discrete event simulation model, the TRACS (TransSolutions' proprietary terminal, roadway, and curbside simulation tool), which allowed a detailed representation of vehicle parking to accommodate passenger loading and unloading, pedestrian crossing, and vehicle re-circulation. TRACS' trip generator and model logic is validated through extensive field data. Airport Access Roadways and Regional Freeways covering 25 square miles are modeled by CORSIM, a microscopic traffic simulation model developed by the Federal Highway Administration. This paper presents the methodology in identifying the critical construction phases to be studied, the modeling framework, and how it is used to assess and manage construction impact."

40. Tunasar, Cenk, Gloria Bender, The SABRE Group, and Holland Young, City of Austin. "Modeling Curbside Vehicular Traffic at Airports." Proceedings of the 1998 Winter Simulation Conference, ed. D.J. Medeiros, E.F. Watson, J.S. Carson, and M.S. Manivannan, pp. 1,113-1,117.

    The article describes the use of discrete event simulation in modeling curbside vehicular traffic at airports. Simulation results are described in terms of level of service.

VISSIM

VISSIM was developed by the German company Planung Transport Verkehr AG (PTV) to simulate various ground transportation scenarios, and is known throughout the industry for its 3-D visualization features. The model has been applied to airport landside systems. The following documents provide a comparison of VISSIM and other roadway simulation models and describe airport applications of VISSIM plus its underlying assumptions, features, and uses.

41. Choa, Fred, Ronald T. Milam, and David Stanek. "CORSIM, PARAMICS, and VISSIM: What the Manuals Never Told You." Proceedings of the Ninth Transportation Research Board Conference on the Application of Transportation Planning Methods. Baton Rouge, Louisiana. April 6-10, 2003.

    From the article abstract: "With the increasing use of microsimulation traffic software in operations analysis, the need to identify which tool to use and the ability of the software to provide traditional traffic engineering measures of effectiveness consistent with the 2000 ***Highway Capacity Manual*** (2000HCM) has become a major area of debate. This paper provides a comparison of the three major traffic simulation software programs in use today and the results of the evaluation matrix developed by the authors for a freeway and interchange improvement project involving unique geometrics, ramp controls, and weaving constraints. The three simulation programs considered in the paper are listed as follows: (1) CORSIM, developed by the Federal Highway Administration (FHWA), is one of the most commonly used micro-simulation programs for modeling vehicle traffic operations. (2) PARAMICS, developed by Quadstone Limited, a Scottish company, is a software program used to model the movement and behavior of individual vehicles and transit on local arterial and regional freeway networks. (3) VISSIM, developed by Planung Transport Verkehr (PTV), a German company, is one of the most sophisticated microsimulation software programs available and provides significant enhancements in terms of driver behavior, multi-modal transit operations, interface with planning / forecasting models, and 3-D simulation. This paper describes several key factors that may affect the decision on which software to use for a specific project involving a freeway interchange and the consistency of the model output to traditional traffic engineering measures of effectiveness."

42. Siecke, Ronald C., P.E., HNTB. "Exploring New Frontiers in the Use of VISSIM for Airport Simulation." PowerPoint Presentation. FAA/NASA/Industry Airport Planning Workshop. September 12, 2006.

    PowerPoint presentation that reviews appropriate instances for using simulation modeling, the VISSIM model, VISSIM as a component of an airport's "simulation toolbox," and challenges and opportunities in applying VISSIM to airport ground transportation issues.

43. Trueblood, Michael T. "Airport Curbside Modeling Using VISSIM." ***2006 Annual Meeting and Exhibit Compendium of Technical Papers***, Institute of Transportation Engineers. 2006.

    From the article abstract: "Recently, VISSIM has added a new feature that greatly enhances curb modeling at airports. The purpose of this paper is to promote this feature of VISSIM as a viable tool for analyzing curbside operations of airport terminals. Airport terminals can be extremely congested because of the mixture of various transportation modes (i.e., pedestrians, limos, rental car buses, and passenger vehicles). The use of VISSIM can be a great tool for showing the benefits of relocating various activities offsite to improve operations along the curb. The following VISSIM items and their importance in effectively simulating curbside modeling will be covered in the paper: (1) link and connectors; (2) pedestrian interaction; (3) dwell time by vehicle classification; and (4) selection of lane choice and curb location."

Other Simulation Models

The following documents describe the development, underlying assumptions, features, and uses of other models developed for or applied to airport landside systems.

44. Hall, Charles A. and Charles E. Dare. "A Simulation Model for an Enplaning-Passenger-Vehicle Curbside at High-Volume Airports." Undated (c. 1976/77).

    This paper describes how a simulation was used to determine the efficiency of the airport's enplaning curbside. Denver Stapleton International Airport was modeled, and the model can easily be modified for other airports. The computer simulation methodology is discussed. The model predicts effectiveness of the measures suggested to improve levels of service.

45. McCabe, L. and T. Carberry. "Simulation Methods for Airport Facilities." ***Transportation Research Board Special Report No. 159***, Transportation Research Board, National Research Council. Washington, D.C., 1975.

    From the article abstract, "The most realistic method of quantitatively approaching airport landside traffic problems appears to be computer simulation of airport landside traffic flows. This paper describes how the

simulation of the landside portion of an airport complex can be used to represent or model the airport landside system to accurately determine the flow and holding capacity and the associated delays of the airport landside. A review of existing computer simulation models indicates that the Bechtel and TAMS models are most suitable for this purpose. They can produce the required distributions of delay, queue lengths, and occupancies for the boundaries specified. The major adaptation that would appear necessary to complete the landside analysis capability would be including a model of the curbside as a server of finite capacity rater than representing the time spent at curbside as a dwell time."

46. Mumayiz, S.A. and P. Schonfeld, eds. ***Airport Modeling and Simulation: Conference Proceedings***. Arlington, Virginia, August 17-20, 1997.

    From the article abstract: "The subjects covered by these papers range from air traffic management to terminal design. Specifically, topics such as curbside traffic simulation, air traffic flow, financial modeling, modeling applications, travel forecasting, and landside simulation are covered. Aviation planners, engineers, and managers will find these proceedings of interest."

47. Verbraeck, Alexander and Edwin Valentin. "Simulation Building Blocks for Airport Terminal Modeling." ***Proceedings of the 2002 Winter Simulation Conference.*** Editors: Yucesan, Chen, Snowdon and Charnes. 2002.

    From the article abstract: "Airports are an ideal application area for simulation. The processes are in a continuous state of change, are complex and stochastic, involve many moving objects, and require a good performance that can be measured using several different performance indicators. Within airports, but also between airports, the same kind of questions are answered over and over again. Often, however, new simulation models are built for each question, if possible copying some parts of previous models. Structured reuse of simulation components is rarely seen. This paper shows an approach for airport terminal modeling that departs from the assumption that reusable simulation building blocks can form the core of a powerful airport modeling tool, which is able to answer different questions at airports better and faster than traditional models. The building blocks have been implemented in the commercially available simulation language eM-Plant. Several studies carried out with this library were very successful."

CURBSIDE OPERATIONS

The following documents are related to curbside operations, and discuss (1) calculation of curbside requirements, (2) optimization of curbside allocation, (3) management of the curbside, and / or (4) other measures adopted to improve level-of-service at the airport curbside. Because these documents provided

background information, and not specific information on analytical tools or simulation models for airport curbsides and roadways, no annotations are provided.

48. Bianconi, Peter, Airport Professional Services Branch, Transport Canada. "Draft – Chapter V—Operational Needs of Transport Modes." August 15, 1984.

49. Brown, Deborah Ross, Ground Transportation Coordinator at Stapleton International Airport. "Cleaning up the Curb, Airport Planning." 58th Annual Conference and Exposition, May 21, 1986.

50. Clippinger, Susan E., Massachusetts Port Authority, and Alex Taft, Cambridge Systematics, Inc. "Managing a Scarce Resource—Massport's Recent Experience with Curbside Control." Transportation Research Board, National Research Council. January 23, 1989.

51. Hall, Richard W. and Marjorie Brink, Peat, Marwick, Mitchell and Co. "Control of Curbside Use," Institutional and Municipal Parking Congress Seminar**,** Clearwater Beach, Florida, October 28, 1983.

52. Hunnicutt, James M. "Nine Ways to Curb Landside Congestion." ***Airport Services Management***, September 1986.

53. Hoffman, M. Allen, Leigh Fisher Associates. "Airport Curbside Traffic Operations and Management." International Parking Institute, Airport Parking and Ground Transportation Operations, Las Vegas, Nevada, December 4, 1997.

54. KPMG Peat Marwick Airport Consulting Services. ***Analysis of Commercial Curbside Utilization and Private Vehicle Circulation Patterns.*** July 17, 1989.

55. KPMG Peat Marwick, Airport Consulting Services. ***Terminal Building Curbside Management Study, Boston Logan International Airport, Massachusetts Port Authority***. June 1991.

56. Mandle, Peter B., Jacobs Consultancy. "Curbside Planning and Operations," Airport Ground Transportation Planning and Operations Seminar, San Francisco, April 5-6, 2006.

57. Mandle, Peter B., Wilbur Smith and Associates. "Airport Curb Operations and Practices at Major United States Airports." 1986. Presentation before Transportation Research Board

58. Mandle, Peter B. and Jessica Wyatt, Leigh Fisher Associates. "Airport Curbsides**,**" Landside Operations Workshop, April 12, 2002.

59. Meehan, James A. "Preventing Curbside Chaos." ***Airport Forum***, Volume 20, No. 2. February 1990.

60. Rahman, A.K.A., H.O. Al-Bar, and N.A. Al-Zaitooni. "Evaluation of Curbsides' Capacity and Service Level at King Abdul Aziz International Airport (KAIA) Terminals in Jeddah, Saudi Arabia." Institute of Transportation Engineers, 1999.

61. Roberts, Bruce, Vice President and General Manager, Airport Service, Inc. "Common Curbside Problems at U.S. Airports." Airport Service, Inc., undated.

62. "St. Louis Smoothes Traffic Flow, Boosts Safety with Curbside Redesign," ***Airports***, September 3, 1991.

63. Street, Jim. "Curbing Curbside Gridlock," ***Airport Magazine***, March / April 1991.

64. Wilbur Smith and Associates. "Suggested Curb Utilization Improvement Plan for Dallas / Fort Worth International Airport." February 28, 1986.

65. Yee, Stephen, Airport Manager, Los Angeles International Airport. "Ground Transportation Program at Los Angeles International Airport." AAAE / Transport Canada Airport Management Conference, July 30, 1991.

66. Zatopek, Joan C., Leigh Fisher Associates. "Managing Commercial Ground Transportation Vehicles." Airport Ground Transportation Planning and Operations Seminar, San Francisco, April 5-6, 2006.

67. Institute of Traffic Engineers, ***Trip Generation,*** 7th Edition. Washington, D.C., 2003.

68. HCM. Highway Capacity Manual, TRB, 2000. Transportation Research Board, National Research Council. ***Highway Capacity Manual.*** Washington, D.C., 1987.

70. MUTCD. Manual of Traffic Control Devices, FHWA. Federal Highway Administration, ***Manual on Uniform Traffic Control Devices.*** Revision 2. Washington, D.C., 2007.

71. Institute of Traffic Engineers, ***Traffic Engineers Handbook,*** Washington, D.C., 2009.