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Modeling Airside Operations at Major Airports for Strategic Decision Support

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Abstract

Tens of billions of dollars are spent each year worldwide on airport infrastructure to promote safe, efficient, and environmentally friendly operations. Airport layouts, allocations of gates to carriers, and the manner of deploying ground equipment or personnel can dramatically affect passenger delays, fuel consumption, and air and noise pollution. Airport planners require reliable information about how different spheres of airport activity interact and how system performance would change with alterations to physical infrastructure or operating practices. We developed a discrete-event simulation model that can be used for strategic decisions regarding the provision and effective utilization of infrastructure needed for airside operations at major airports. We calibrated the model with detailed activity data for an entire year, verified its ability to represent essential spheres of activity, and illustrated its application to study system performance under several operating scenarios.

Keywords

airport operations, decision support, simulation modeling

Disciplines

Civil Engineering

MIDWEST TRANSPORTATION CENTER MTC

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tech transfer summary

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MTC RESEARCH PROJECT TITLE
Modeling Airside Operations at Major Airports for Strategic Decision Support

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The Midwest Transportation Center (MTC) is a regional University Transportation Center (UTC). Iowa State University, through its Institute for Transportation (InTrans), is the MTC lead institution.

MTC's research focus area is State of Good Repair, a key program under the 2012 federal transportation bill, the Moving Ahead for Progress in the 21st Century Act (MAP-21). MTC research focuses on data-driven performance measures of transportation infrastructure, traffic safety, and project construction.

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Background

Major commercial airports rely on multiple parties for safe and efficient operations. Air traffic controllers coordinate approaches to the airport, aircraft movements on the ground, and departures from the airport. Airline personnel coordinate activities on the parking ramps and at passenger gates. Third parties may service aircraft at gates or at designated stations (e.g., for de-icing).

In recent years, major airlines in the US have altered their route structures and schedules to concentrate their flight activity at a few mega-hubs. Consolidation of this sort and hub operations of express freight carriers strain some airports while other airports now have excess capacity.

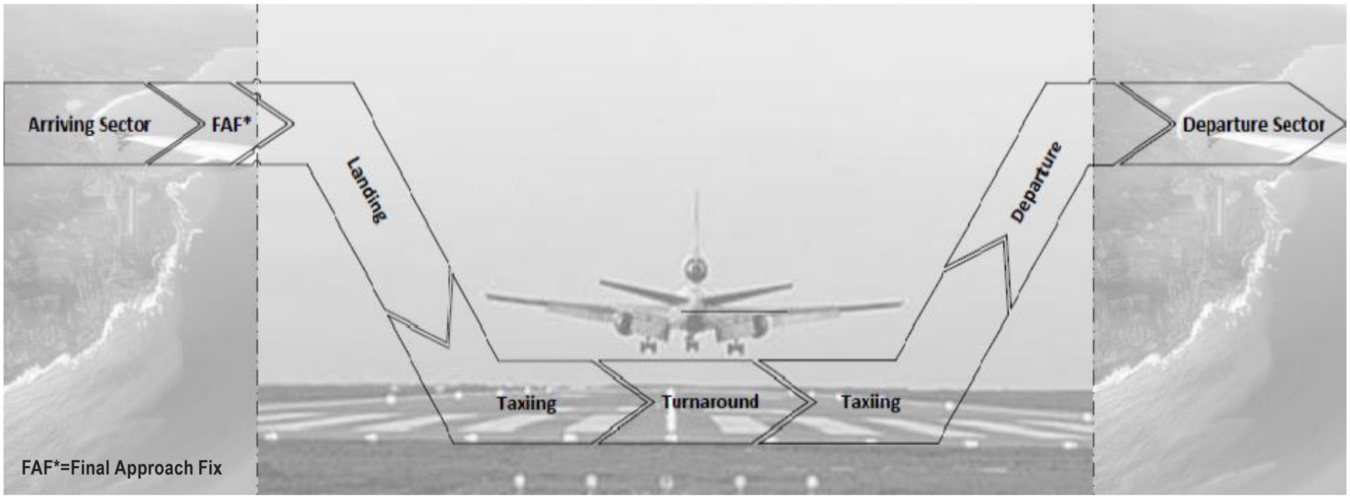
System performance is affected by the concentration of airline flight schedules, activities of air express carriers, taxiway and ramp layouts, resources allocated for gate operations, air traffic control (ATC) procedures, adverse weather conditions, and traffic backups at major connecting hubs.

Problem Statement

Tens of billions of dollars are spent each year worldwide on airport infrastructure to promote safe, efficient, and environmentally friendly operations. Airport layouts, allocations of gates to carriers, and the manner of deploying ground equipment or personnel can dramatically affect passenger delays, fuel consumption, and air and noise pollution.

Airport planners require reliable information about how different spheres of airport activity interact and how system performance would change with alterations to physical infrastructure or operating practices.

Strategic decision support is needed to provide ways of better utilizing existing assets in some environments, intelligently expanding them in others, and selectively removing assets from service where costly excess capacity exists.



Scope of modeled activity for the project

Project Results

For this project, we developed and calibrated a discrete-event simulation model that captures essential interactions of "airside" activity at commercial airports.

Our model, calibrated with detailed flight and gate data for an entire year's activity at Lambert - St. Louis International Airport, represents the interactions of key system components with sufficient granularity to study the effects of different planning scenarios and operating rules.

Project Description

We modeled airport operations using Arena software by moving simulated aircraft through a network of staged queues—some physical, others conceptual.

- Ground movements are controlled by signals and routings that consider capacities of ramps and taxiway segments.

- Aircraft arrivals are generated by a Statistical Analysis System (SAS) pre-processor and placed in conceptual queues at the final approach fix (FAF) for an active runway.

- Scenarios are defined by active runways for takeoffs and arrivals, weather in airspace sectors through which arrivals and departures take place, and conditions at major hub airports.

- Movements of aircraft are simulated using lognormal distributions from point to point until the designated flight's activity at the airport is completed (with termination at the gate, or, if continuing to another destination, after turnaround and departure).

- Statistical models for individual airlines are used to set the probability of delay and duration of delay at the gate dependent on time of day and whether the flight is originating or continuing.

- Entities for flights that terminate at the airport are removed from the simulation after reaching the gate and the gate is then made available for originating flights that are generated by the model according to schedule (with random perturbation if desired) or for a new arrival.

- Dispatching strategies are imposed by routing aircraft among staging points on the airport surface and releasing them with dynamic priorities that reflect the decision rules in force.

- Detailed logs are created for each simulated event and statistical analysis and reporting of simulated performance are accomplished externally using SAS.

Calibration and validation of the model required integration of gate data maintained by individual airlines and flight data that are maintained by ATC systems for aircraft that operate under instrument flight rules (IFRs).

We demonstrated the application of the model to investigate the effects of different operating conditions and dispatching strategies upon delays, ramp time, and taxi time for individual airlines.

Implementation Readiness and Benefits

Our simulation prototype was created to facilitate the analysis of airport ground operations with due consideration of the major intersecting spheres of activity and responsibility. It captures essential characteristics of the system in each operational sphere and links them with staged queues at the interfaces.

Optimizing heuristics may be embedded in portions of the Arena simulation model and the effects of their solutions may be tested with consideration of stochastic system behavior. Solutions from deterministic optimizing models may also be driven through the model to see their effects on other aspects of the operation and to examine whether promised gains from their use are achievable in a stochastic environment.

The simulation prototype was originally constructed to represent traffic in the dominant operating environment at Lambert - St. Louis International Airport (using runways 30L and 30R for departures and arrivals) and behavior was validated using complementary flight data for just a few weather scenarios.

Direct observations of ramp activity were conducted with the airport planning manager. Each of the research associates gained further experience with SAS for multivariate modeling of system performance and estimating dynamic model parameters. We added detail to the Arena simulation model that allows analysis of activity on all Lambert - St. Louis International runways.

Focus of analysis shifted to address questions about the possible effects of using runways differently—namely segregating propeller traffic from turbine traffic for arrivals and directing the former to runway 06-24 while utilizing runway 11-29 for departures. This alternative was simulated while parallel air traffic controllers experimented with these strategies in the actual operating environment.

In the course of this project, the model was extended and calibrated for opposite traffic flows (using runways 12L and 12R), occasional traffic on runway 06-24 when strong crosswinds require such use, and use of runway 11-29 for occasional westerly departures from Terminal 1 and occasional easterly arrivals to Terminal 1. Continued streaming of data for flight operations to the university will enable us to compare changes of performance in the operating environment with predicted changes in performance from the simulation model.

Models for fuel burn considering taxi time and idle times under power could be appended to the report generators to estimate fuel burned and emissions generated under alternative airport configurations and operating practices. Further refinements estimating stop-and-go behavior on runways and taxiways, depending on congestion levels, could provide better estimates.

In sum, our modeling approach provides a balance between the highly detailed engineering simulations of airspace and airports with microscopic detail, on one hand, and operations research models designed for strategic optimization of parts of the system, on the other hand. It incorporates necessary details of the operating environment and avoids the “flaw of averages” when studying system behavior.

Our approach is sufficiently efficient that complementary groundside operations (such as crossdocking facilities for cargo carriers) could be added. Furthermore, it would be possible to add details of flight activity at connected hub airports to examine the consequences of airline scheduling practices on individual airlines.