ENHANCEMENTS TO AIRFIELD SIMULATION OF LONDON GATWICK AIRPORT

Issue Date: June 2011

Abstract—*This paper describes four enhancements to the US Federal Aviation Administration's (FAA's) airport and airspace simulation model (SIMMOD) program that have been recently developed for use on Bechtel's project at London's Gatwick Airport (LGW). Gatwick is the busiest single-runway airport in the world, and the tools typically available in SIMMOD do not generally address a number of significant airfield issues. Bechtel Civil's airport planning team added capabilities to account for (1) busing/coaching operations, (2) towing of aircraft to and from stands, (3) pushback operations, and (4) arrival/departure shifts to minimize aircraft taxi delays. The simulation enhancements have been used to analyze potential expansion projects at the airport under four different traffic scenarios and to assist the client in assessing and selecting projects based on optimal airfield performance.*

Keywords—*airport, airfield, congestion, delay, Gatwick Airport (LGW), runway, simulation, SIMMOD, taxiway*

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INTRODUCTION

Bechtel is assisting Global Infrastructure Partners (GIP) with developing and managing London's Gatwick Airport (LGW), which is the busiest single-runway commercial airport in the world with about 130,000 operations per year and 36 million passengers per annum (mppa). Bechtel assisted in reviewing and revising the airport's capital development program and has made a number of recommendations to adjust the program's scope, schedule, and cost. As part of this work, Bechtel, assisted by Greg Bradford of Airport Tools, has used the US Federal Aviation Administration's (FAA's) airport and airspace simulation model (SIMMOD) to conduct extensive airfield analysis to assess potential projects and their impacts on the airfield.

SIMMOD is a widely recognized standard for airfield and airspace simulation. Although this program is quite powerful, SIMMOD was not capable of adequately addressing several specific issues at Gatwick. To resolve these gaps, Bechtel added several enhancements to SIMMOD that have made it possible to fully analyze the airport's unique conditions.

BACKGROUND

As shown in **Figure 1**, the airport consists of two independent terminals, the South terminal and the North terminal. The South terminal includes Piers 1, 2, and 3 and 32 contact gates, and the North terminal includes Piers 4, 5, and 6 and 32 contact gates. Several clusters of remote stands add another 45 gates. The airport currently handles a high volume of aircraft operations and achieves a very high throughput (more than 50 operations per hour) on its single active runway. In contrast, other United Kingdom (UK) airports typically achieve only about 40 operations per hour.

The airfield area is quite constrained for an airport with such intensive aircraft activity, and several limitations inhibit the flow of aircraft. The most notable limitation is that, although Gatwick technically has two parallel runways, only one can be used at a time because the separation distance between them is inadequate to allow simultaneous operations. As a result, northern runway 08L/26R is typically used only as a taxiway or for emergency back-up. In other parts of the airfield, particularly around Piers 1, 2, 3, and 4, single taxiways create long cul-de-sacs that significantly limit the free flow of aircraft in and out of the pier stands and contribute to potential congestion and delays.

Another significant factor is that access to the threshold on runway 26L, which handles approximately 70% of all operations, is quite constrained and can lead to long departure queues during peak-hour operations. These queues can sometimes become so long that

Each crossing is a potential conflict point that could significantly impede the free flow of aircraft on the taxiways and create departure delays due to late arriving coaches or trolleys.

ABBREVIATIONS, ACRONYMS, AND TERMS

A-D-A	arrival-departure-arrival
A-D-D-A	arrival-departure-departure-arrival
A-T-D	arrival-tow-departure
A-T-O	arrival-tow-overnighting
CAA	UK Civil Aviation Authority
Code C	size of aircraft such as the Boeing 737
Code E	size of aircraft such as the Boeing 747
Code F	size of aircraft such as the Airbus 380
FAA	US Federal Aviation Administration
GIP	Global Infrastructure Partners
LGW	London Gatwick Airport
MARS	multiple aircraft ramp system
mppa	million passengers per annum
nm	nautical mile
OTD	overnighting-tow-departure
SID	standard instrument departure
SIMMOD	FAA's airport and airspace simulation model program
UK	United Kingdom
UK NATS	United Kingdom National Air Traffic Services
US	United States
08R/26L	runway 08 right/26 left
08L/26R	runway 08 left/26 right

they back up onto the adjacent taxiways, significantly affecting the flow of arriving and departing aircraft.

As part of development efforts for the UK Civil Aviation Authority's (CAA's) fifth quinquennium (Q5) (the fifth 5-year airport regulatory period, from April 2008 to March 2013) and to improve capacity, there are several ongoing airport development programs involving:

- Pier 5 reconfiguration
- Pier 1 and Pier 2 redevelopment
- Northwest apron (ramp)

In addition to the issues involving aircraft congestion identified above, there are additional issues related to the operation of the airfield. First, the airport must rely on a fairly significant number of remote passenger operations because of the limited number of contact gates. Remote operations entail moving large numbers of passenger coaches and baggage trolleys to and from the terminals and the remote aircraft positions. These coaches and trolleys must, at different points on the airfield, cross active taxiways to reach their destinations. Each crossing is a potential conflict point that could significantly impede the free flow of arriving and departing aircraft on the taxiways and create aircraft departure delays due to late arriving coaches or trolleys.

Second, because of the regulatory requirement to achieve certain pier service level targets, it has also been necessary to implement a towing program to shift aircraft between the remote

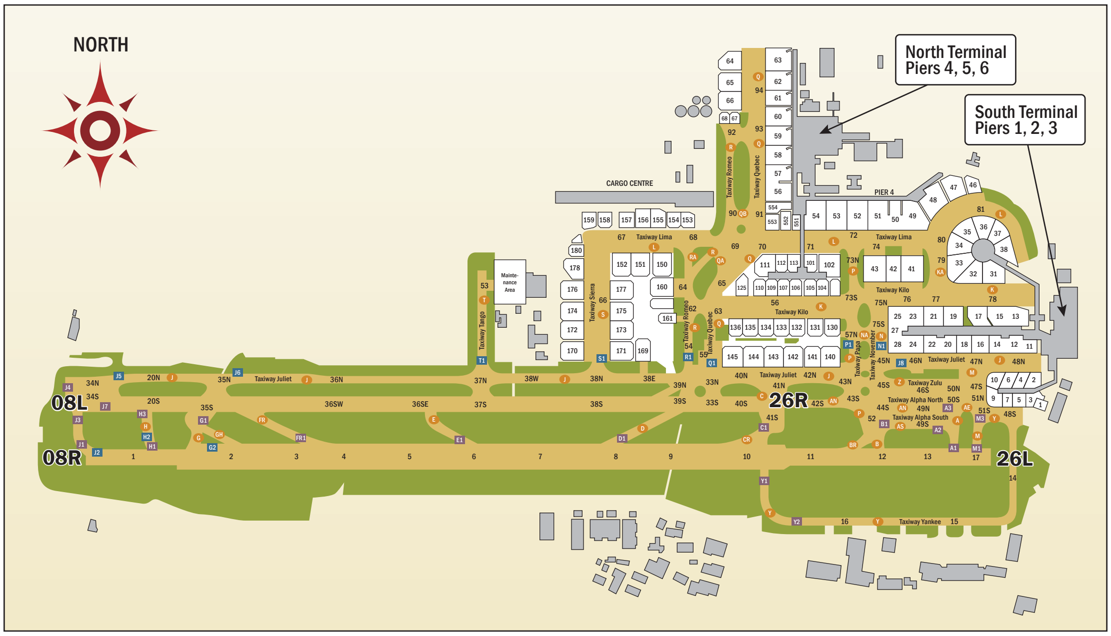

Figure 1. Layout of Gatwick Airport

stands and the piers. This program allows pier service targets to be increased and use of the limited number of contact gates to be optimized. However, towing aircraft can also disrupt airfield operations, since towed aircraft are typically moved at much slower speeds than piloted aircraft.

While SIMMOD is a very powerful and sophisticated tool for analyzing airfield issues, its ability to address the kinds of issues identified above, especially those specific to Gatwick, is limited. As a result, Bechtel developed several SIMMOD enhancements to analyze these specific concerns as part of the analysis of Gatwick's airfield.

SIMMOD ENHANCEMENTS

Passenger Coaches and Baggage Trolleys

SIMMOD does not typically include the ability to analyze coaching and baggage operations or to integrate these operations with aircraft movements on an airfield. The following actions were taken to analyze these issues:

- Quantify and simulate the number of coaches, trolleys, and tugs (special vehicles used to push aircraft back) required for each flight using the same flight schedule used to drive the aircraft simulation
- Assess the coach routes and their impacts on taxiway crossing points
- Calculate loading/unloading times for coaches and trolleys to assess the impacts on departure delays
- Add a graphic element to SIMMOD to visually demonstrate the interaction of aircraft and ground service traffic (see **Figure 2**)

Aircraft Towing

SIMMOD typically addresses aircraft towing (as shown in **Figure 3**) by sending aircraft to an undefined virtual apron in the simulation and retrieving them only when the aircraft are being actively towed to a contact gate. Hence, towed aircraft typically appear and disappear from the virtual apron in the simulation and typically only account for single one-way towing operations. However, towing operations at Gatwick are more complicated, and a single aircraft may undergo multiple towing operations—upon arrival, to and from remote stands, upon departure, and to and from contact gates. Furthermore, the slow speed of the towing operation and its potential impact on the airfield are not typically a concern or focus. The enhancement includes the ability to:

- Track towed aircraft to and from specific stands—not virtual aprons—at actual towing speeds
- Account for all towing possibilities such as arrival-tow-departure (A-T-D), arrival-tow-overnighting (A-T-O), and overnighting-tow-departure (O-T-D)
- Automate the towing event in SIMMOD to allow aircraft to be tracked interactively with other airfield activity

Pushback Operations

SIMMOD typically assigns precedence to aircraft operations on a first-in/first-served basis and does not allow more than one aircraft to occupy a given block of taxiway. However, given the number of single taxiways at Gatwick, this frequently leads to situations in which a single aircraft being pushed back blocks access to an entire taxiway for multiple aircraft and triggers major delays. In addition, at times multiple aircraft at Gatwick

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Figure 2. Coaches Integrated with Airfield

Figure 3. Path of Towed Aircraft (Shown in Purple)

Figure 4. Multiple Pushback Operations and Queuing at Threshold (Departure Aircraft Shown in Blue)

It was necessary to add an arrival holding stack so that arriving aircraft could be held "in the air" to allow the proper rules for sequencing and wake vortex separation.

are pushed back from a single pier and moved as a group to the runway threshold (see **Figure 4**). Since SIMMOD typically does not allow such operations to occur, the simulation was adjusted to:

- Provide rules of precedence other than first-in/first-served to determine which aircraft should have priority in operation
- Allow multiple simultaneous pushbacks and multiple departures using the same taxiway
- Set a maximum time limit on delays in aircraft arrivals triggering the use of "push and hold" stands for aircraft departures to minimize congestion

Arrival/Departure Shifts

Gatwick's air traffic control tower is managed by the UK National Air Traffic Services (NATS). NATS has achieved unusually high throughput on Gatwick's single runway by actively and innovatively managing the runway and airfield. Some of the NATS procedures are, in fact, unique to Gatwick. One of these procedures involves adjusting arrival and departure sequences to increase the number of hourly operations achieved while simultaneously decreasing airfield congestion. SIMMOD does not typically allow sequence shifting equal to the rapidity and flexibility of the NATS's runway operation adjustments. As a result, a NATS recommendation was encoded into the simulation to:

- Shift the departure/arrival sequence from A-D-A to A-D-D-A to accelerate departures (see **Figure 5**)
- Trigger the shift dynamically when departing aircraft taxi times reach 20 minutes and runway holding queues begin to form
- Reduce arriving aircraft delays by decreasing the length of departing aircraft queues at the threshold

In addition, to achieve this shift, it was also necessary to add an arrival holding stack so that arriving aircraft could be held virtually "in the air" to allow the proper rules for sequencing and wake vortex separation (minimum distance between aircraft to prevent accidents due to turbulence that forms behind an aircraft as it passes through air) to be applied.

AIRFIELD SIMULATION

After the simulation model with enhancements was developed, it was possible to demonstrate to the NATS, the airlines, and other stakeholders that the model was credible and accurate in reflecting actual conditions at the airport.

The next step was to apply the model to proposed capital projects to determine the impacts on airfield operations. In particular, the effort focused on analyzing a proposed extension to Pier 6. As shown in **Figure 6**, the Pier 6 extension

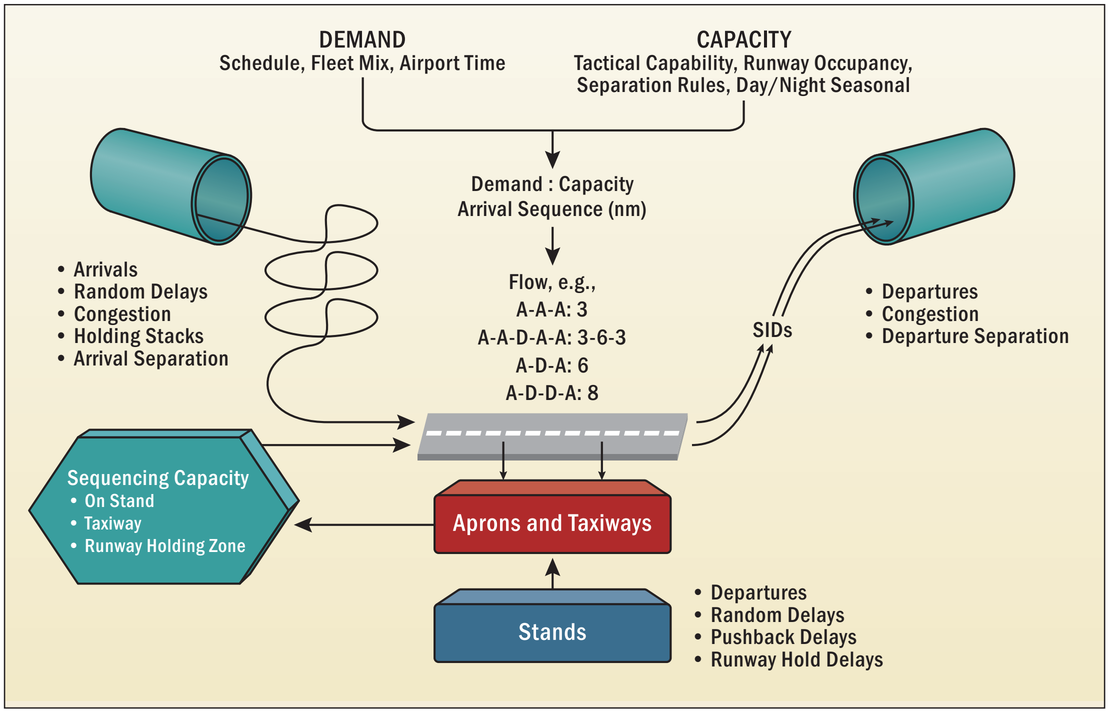

Figure 5. Diagram Showing Logic of the Arrival/Departure Shift

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Pier 6 Extension Project

The new Pier 6 extension will be located south of the existing Pier 6 and linked to it by a connecting corridor. The project has been divided into two phases: Phase 1 coincides with development (by

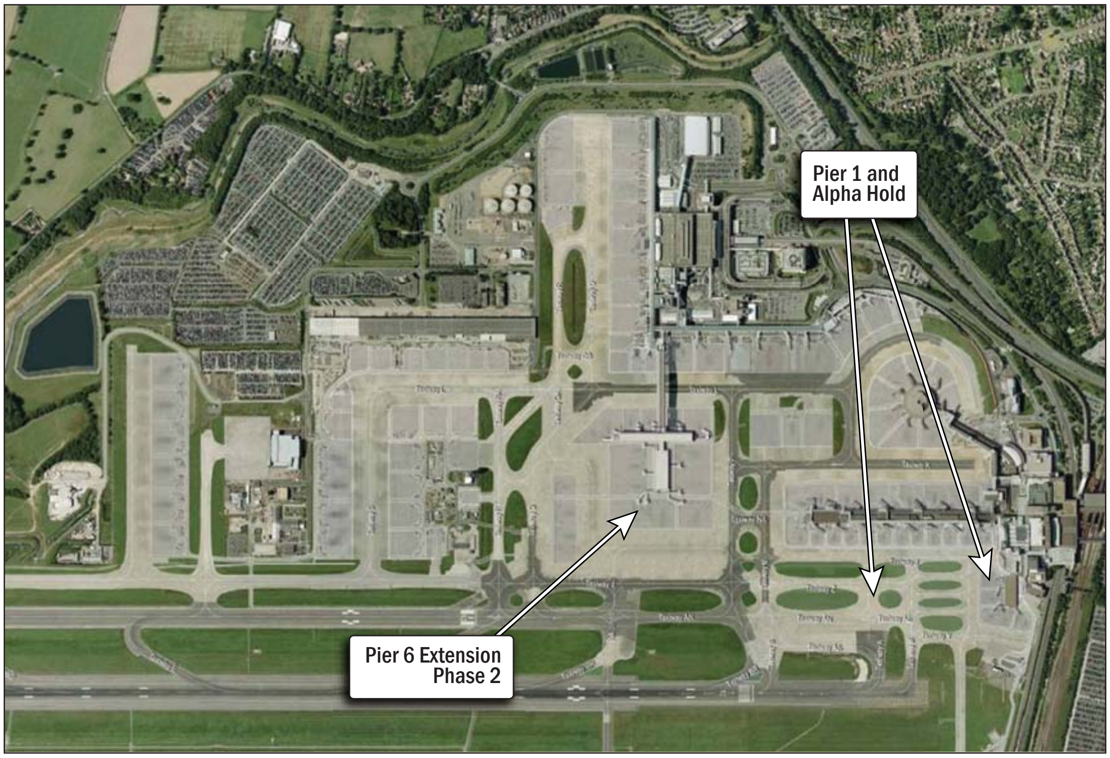


Figure 6. Location of Pier 6 Extension Project

2014) of four aircraft stands consisting of two gates for Code F aircraft and two gates for Code E aircraft, which are located on the east and south sides of the new pier. Phase 2 (shown in **Figure 7**), which is planned to be completed by 2017, will add an additional three gates for Code E aircraft along the west side. All of these new stands will use the multiple aircraft ramp system (MARS) to also accommodate Code C aircraft, making the new pier very flexible.

Accommodating Code F aircraft such as the Airbus A380 is a significant challenge, since Gatwick cannot currently handle such large planes at contact positions.

The project has been laid out and integrated with the existing airfield taxiway system. A new Code F aircraft taxilane south of and parallel to Taxiway J is planned to provide a through route between Taxiways Q and P. The Phase 2 airfield will add a Code E aircraft taxiway along the western side of the pier to provide access to new contact gates and several remote stands at the edge of the apron.

Accommodating Code F aircraft such as the Airbus A380 is a significant challenge to the airfield, since Gatwick cannot currently handle such large planes at contact positions. Hence, the project also represents the potential to allow Gatwick to serve new airlines and markets in Asia and the Middle East.

Forecast Scenarios

The Pier 6 extension project was simulated using four forecasts corresponding to different expectations about the future growth rate at the airport over the next several years:

- 2013 Low Growth
- 2013 High Growth
- 2017 Low Growth
- 2017 High Growth

The forecasts provided a range of traffic levels—from a low of 38 mppa to a high of 44 mppa—and incorporated various expectations about aircraft mixes, airline shifts, and possible changes to the markets served by the airport.

Results of the Modeling

Table 1 shows the simulated taxi times for the 2013 and 2017 high growth forecasts and actual taxi times observed in 2007 to 2009. The data has been sorted to provide a pier-by-pier summary of the taxi times. This table shows that the simulated taxi times for both arrivals and departures compare quite favorably with historic data, indicating roughly equivalent airfield performance between the simulated times and the actual historic times.

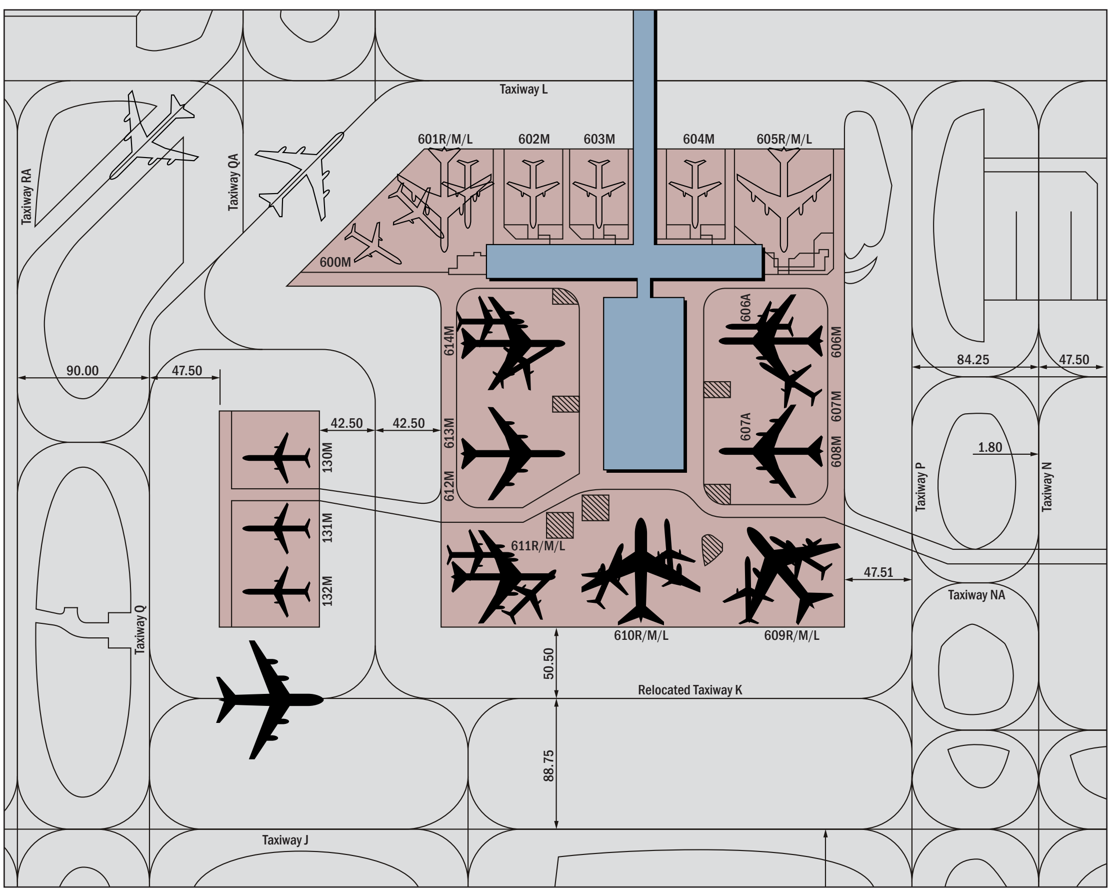


Figure 7. Pier 6 Extension Project at Completion of Phase 2

Table 1. Results of the Simulation (Taxi Times in Minutes)

Pier	Activity	Simulated		Historic		
		2013	2017	2007	2008	2009
1	Arrival Departure	8.3 5.3	8.6 5.5	10.0 10.0	N/A 8.2	N/A 6.7
2	Arrival Departure	9.5 7.9	9.8 9.0	10.5 11.0	N/A 9.9	N/A 8.2
3	Arrival Departure	11..1 10.8	12.5 11.8	11.3 12.0	N/A 11.1	N/A 9.9
4	Arrival Departure	11.7 12.6	11.1 12.4	10.5 11.0	N/A 11.2	N/A 10.3
5	Arrival Departure	9.7 12.6	10.4 13.2	8.5 12.0	N/A 10.5	N/A 9.3
6	Arrival Departure	8.0 9.6	7.7 11.6	8.5 11.0	N/A 11.8	N/A 10.6

As a result of the modeling, the questions about negative impacts on the airfield due to the new project were largely answered and the decision to proceed with further design development was made. An additional future step in the process will be to consider how best to stage the project during construction. Further simulation will be carried out to analyze how best to close taxiways sequentially during construction and reroute aircraft circulation to minimize further impacts.

CONCLUSIONS

Gatwick is the busiest single-runway airport in the world. By adding several enhancements to SIMMOD, it has been possible to accurately model the airfield's complex and sometimes unique operations and fully analyze a variety of specific conditions.

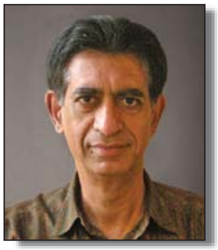
This credible and powerful simulation model was used to simulate several proposed expansion projects at the airport and assess their potential impacts on aircraft delay and congestion. As part of Bechtel's continuing work at the airport, the successful projects will be incorporated into the airport's ongoing capital development program and further analyzed as they move into the design and construction stages. ■

BIOGRAPHIES

Jim Denton-Brown is the manager of planning for Bechtel Civil Aviation and Infrastructure in San Francisco, California. He has been involved in planning transportation infrastructure megaprojects around the world, including in North America, Europe, Asia, and the Middle East. He is responsible for industrial planning, port planning, and aviation planning projects and has also supported joint development efforts in Bechtel's Oil, Gas & Chemicals (OG&C) and Mining & Metals (M&M) Global Business Units for projects in Asia and the Middle East.

Jim is a member of the American Planning Association (APA) and is a registered professional planner through the American Institute of Certified Planners (AICP). He has authored 10 articles on airport free trade zones, airport master planning, and other project types, including seaports and industrial complexes. He has been a guest speaker at the Department of Civil and Environmental Engineering, University of California, Berkeley, as well as a speaker at the American Society of Civil Engineers (ASCE), San Francisco section.

Jim received an MBA in Management and Economics from the University of Maryland, College Park, Maryland, and a BA in Humanities and Sciences from Stanford University, Palo Alto, California. He also did BS/MS studies in Environmental Design and Planning at California Polytechnic University, San Luis Obispo, California. He has also received a certificate in Airport Master Planning from the Singapore Aviation Academy and a certificate in Airport Systems Planning from the Massachusetts Institute of Technology.



Farzam Mostoufi, a senior planning and simulation specialist with Bechtel Civil, has more than 20 years of experience at Bechtel in planning and designing transportation and material handling facilities, including international airport terminals, railroads, transit systems, bulk and container ports, and mining and metals production complexes. He is highly experienced in conducting technical simulation studies and economic analyses as well as in designing, developing, and using specialized transportation and logistics models.

Farzam has developed economic models and participated in feasibility studies to test the impact of projected operations and designed facilities on revenues, capital expenditures, and maintenance costs. He is currently supporting the Gatwick Airport project with a focus on airfield simulation, terminal throughput analysis, and ground access issues.

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Farzam received an MBA in Finance from Golden Gate University, San Francisco, California; has a BS in Economics and Insurance from Tehran College, Tehran, Iran; and has completed course requirements in the Doctor of Business Administration (DBA) program at Golden Gate University. As a lecturer at Golden Gate University, he taught graduate and undergraduate courses in computer modeling, simulation, and quantitative analysis. Farzam also holds a certificate in Airport Systems Planning from the Massachusetts Institute of Technology, Cambridge, Massachusetts.