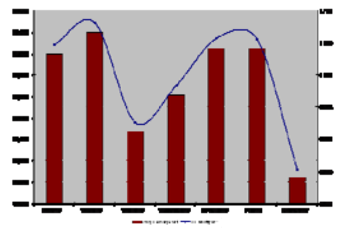
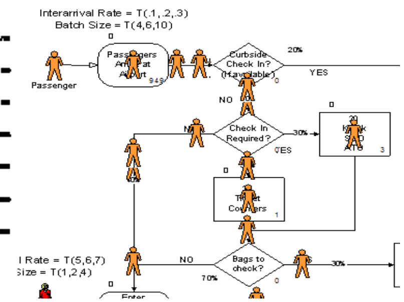
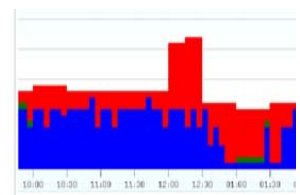
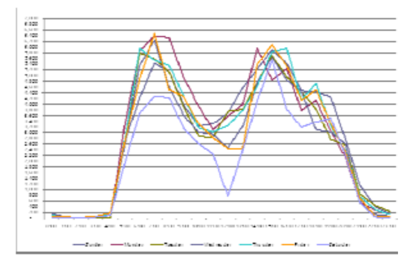
SIMULATION-BASED MANPOWER PLANNING WITH OPTIMIZED SCHEDULING IN A DISTRIBUTED MULTI-USER ENVIRONMENT





David Kalasky - IBM Corporation
Michael Coffman - Transportation Security Administration
Melanie De Grano - IBM Corporation
Kevin Field - ProModel Corporation





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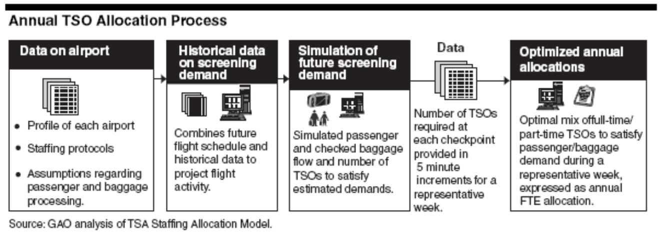
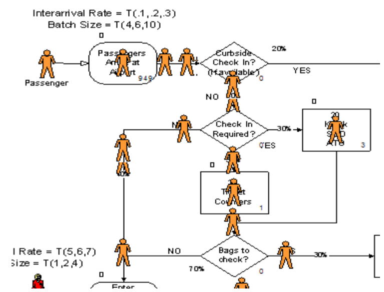
AGENDA

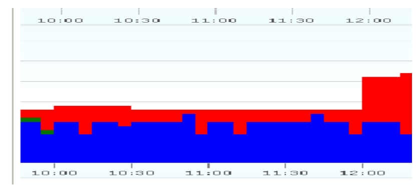
Overview of ESM process



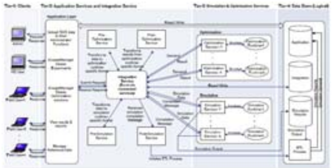
Use of simulation engine to determine requirements



Overview of scheduling optimizer



Benefits of ESM simulation-based scheduling system



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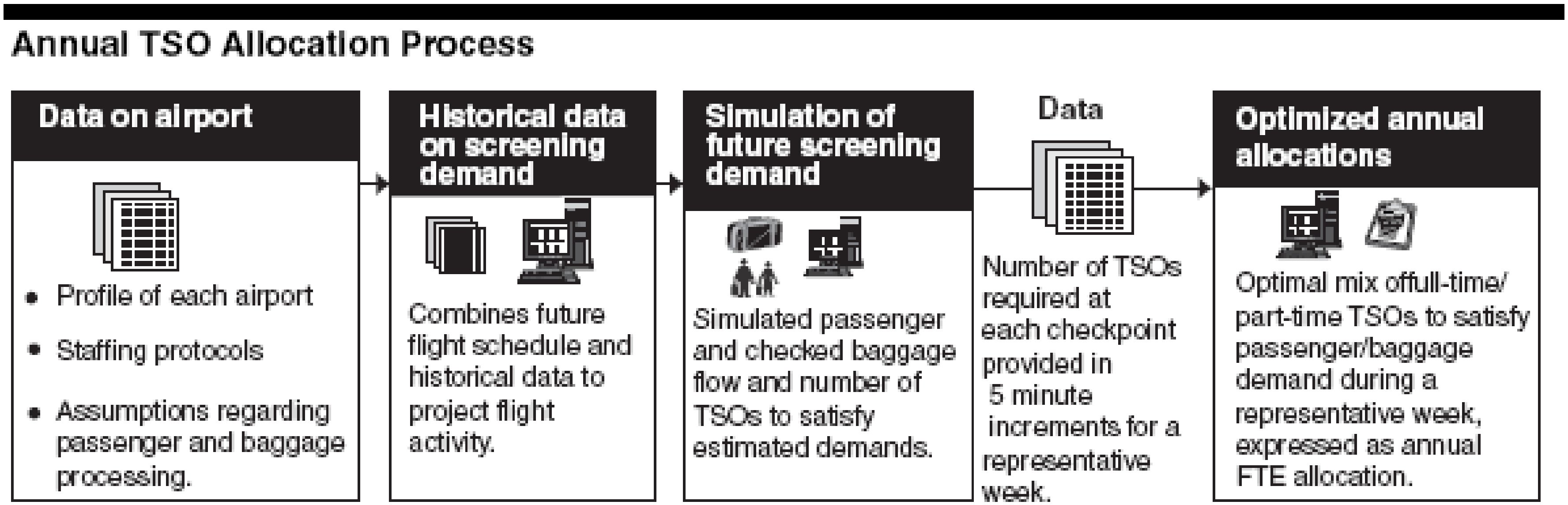
Enhance Staffing Model (ESM) allocates airport staff based on unique airport screening, equipment, facility layout, and scheduling requirements



Source: GAO analysis of TSA Staffing Allocation Model.

End result is the airport's FTE allocation used to guide hiring and as a measure of each airport's performance

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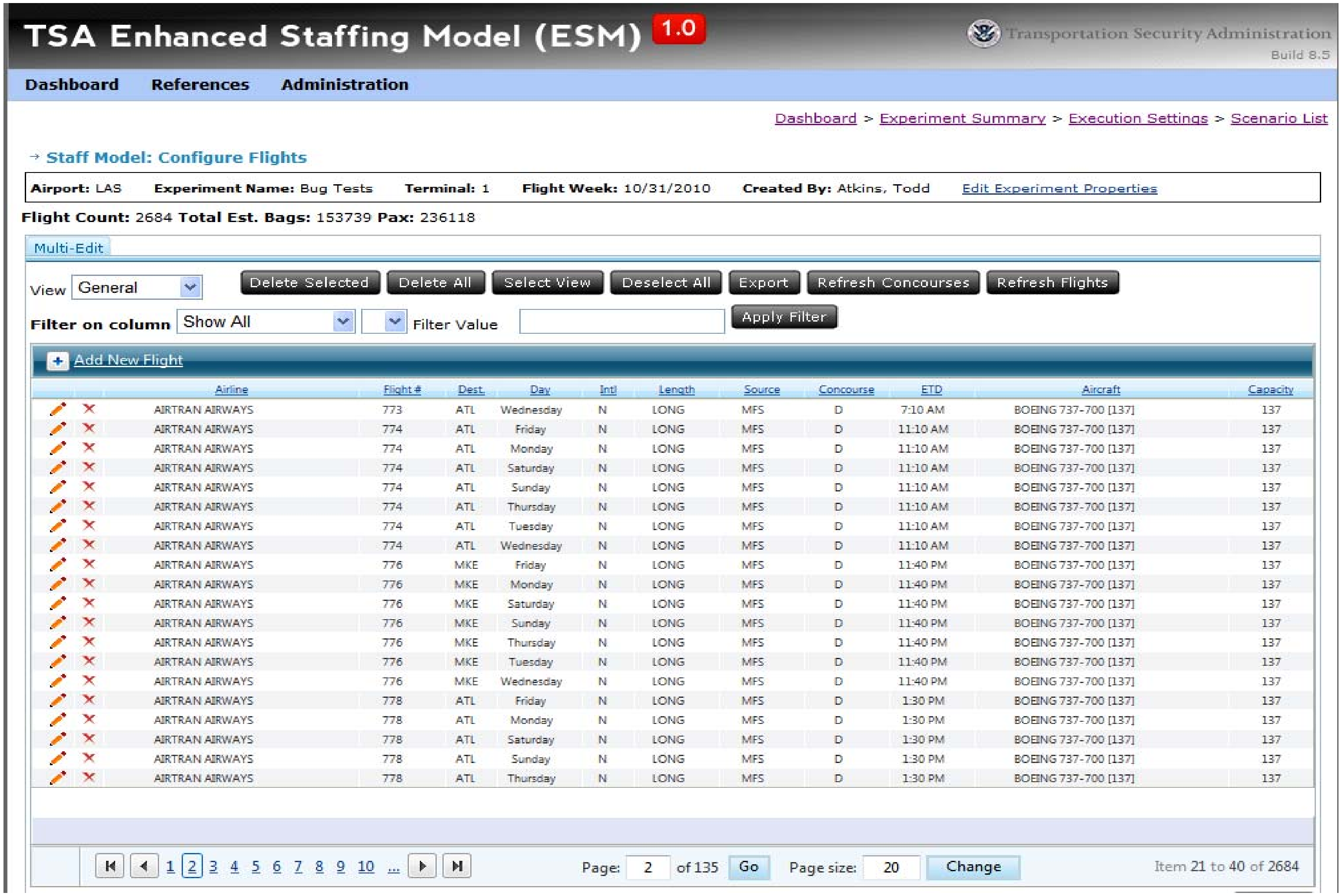
Screening requirements are generated in the application as flight instances based on a combination of data provided by OAG (Official Airline Guide) and BTS (Bureau of Transportation Statistics)



Airline	Flight #	Dest.	Day	Intl	Length	Source	Concourse	ETD	Aircraft	Capacity
AIRTRAN AIRWAYS	773	ATL	Wednesday	N	LONG	MFS	D	7:10 AM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	774	ATL	Friday	N	LONG	MFS	D	11:10 AM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	774	ATL	Monday	N	LONG	MFS	D	11:10 AM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	774	ATL	Saturday	N	LONG	MFS	D	11:10 AM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	774	ATL	Sunday	N	LONG	MFS	D	11:10 AM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	774	ATL	Thursday	N	LONG	MFS	D	11:10 AM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	774	ATL	Tuesday	N	LONG	MFS	D	11:10 AM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	774	ATL	Wednesday	N	LONG	MFS	D	11:10 AM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	776	MKE	Friday	N	LONG	MFS	D	11:40 PM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	776	MKE	Monday	N	LONG	MFS	D	11:40 PM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	776	MKE	Saturday	N	LONG	MFS	D	11:40 PM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	776	MKE	Sunday	N	LONG	MFS	D	11:40 PM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	776	MKE	Thursday	N	LONG	MFS	D	11:40 PM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	776	MKE	Tuesday	N	LONG	MFS	D	11:40 PM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	776	MKE	Wednesday	N	LONG	MFS	D	11:40 PM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	778	ATL	Friday	N	LONG	MFS	D	1:30 PM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	778	ATL	Monday	N	LONG	MFS	D	1:30 PM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	778	ATL	Saturday	N	LONG	MFS	D	1:30 PM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	778	ATL	Sunday	N	LONG	MFS	D	1:30 PM	BOEING 737-700 [137]	137
AIRTRAN AIRWAYS	778	ATL	Thursday	N	LONG	MFS	D	1:30 PM	BOEING 737-700 [137]	137

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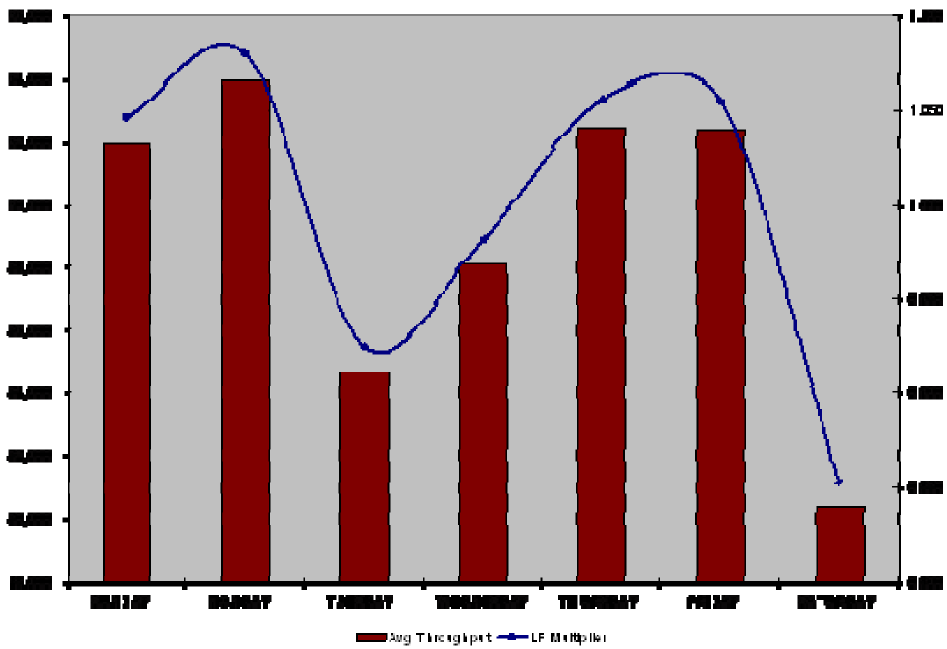
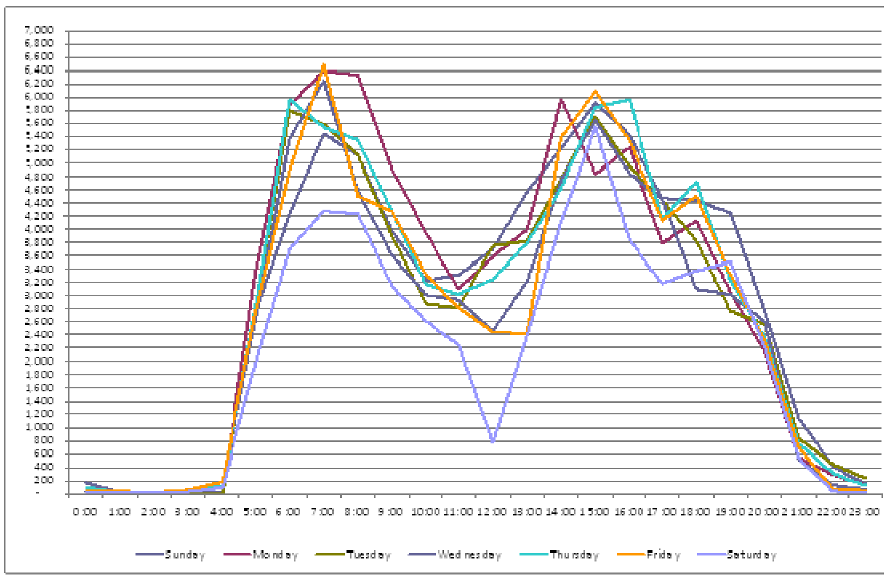
Building the ESM simulation model first required a thorough understanding of passenger and bag generation as well as variability



Day of Week Variability



Origination Factors by Time of Day

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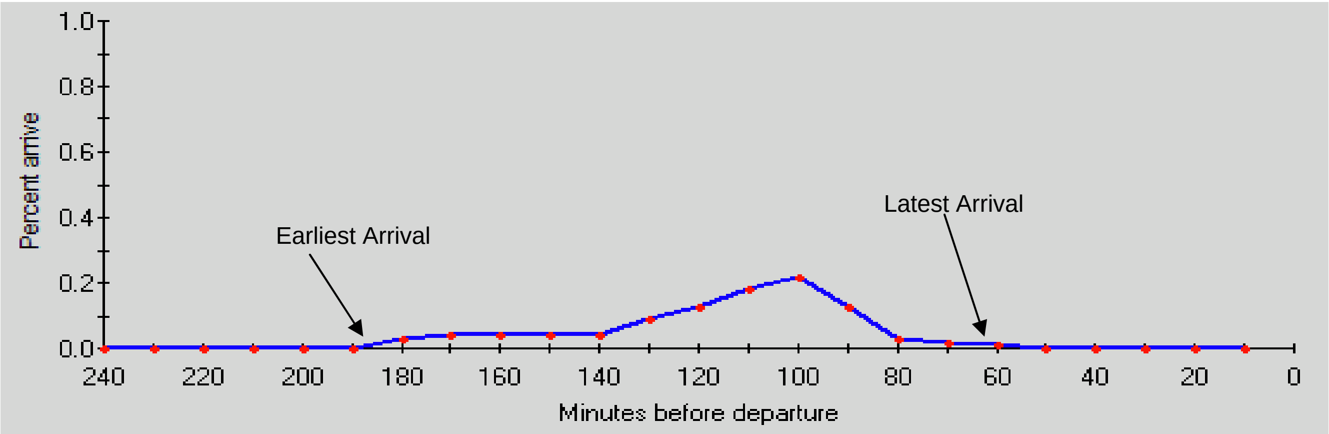
Building the ESM simulation model first required a thorough understanding of passenger and bag generation as well as variability

*Expected # of passengers = aircraft capacity * origination factor * load factor*

Passengers are distributed using empirical distributions based on time of day, flight duration, and individual airport characteristics



Example arrival distribution for peak domestic flight

The number of checked bags is modeled as a discrete distribution ranging from zero to six bags and is a function of the flight type (Intl, Domestic, Low Cost, Legacy).

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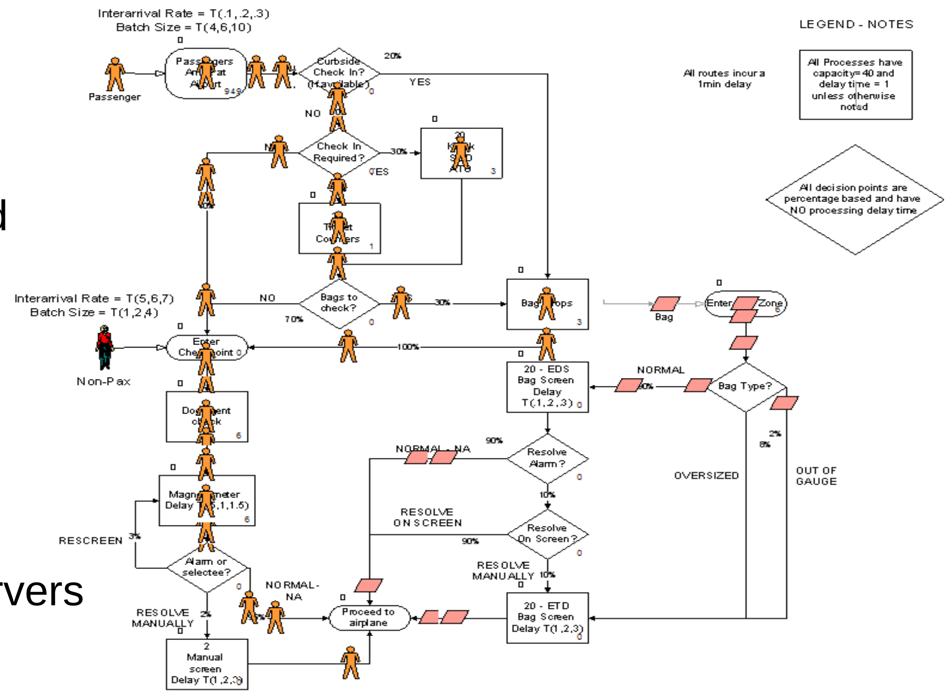
The model logic was initially designed as a prototype including three functional areas: concourse, checkpoint, and bag zone

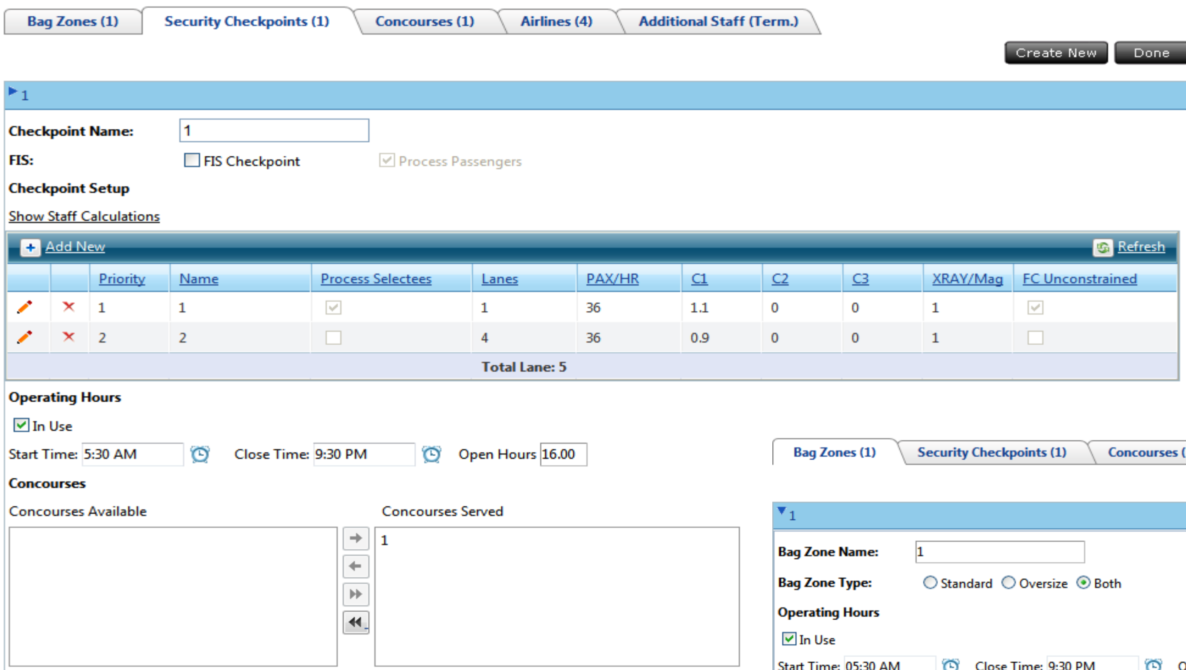
The concourse is a single location with probabilities and delays for arrival patterns, check-in and bag check

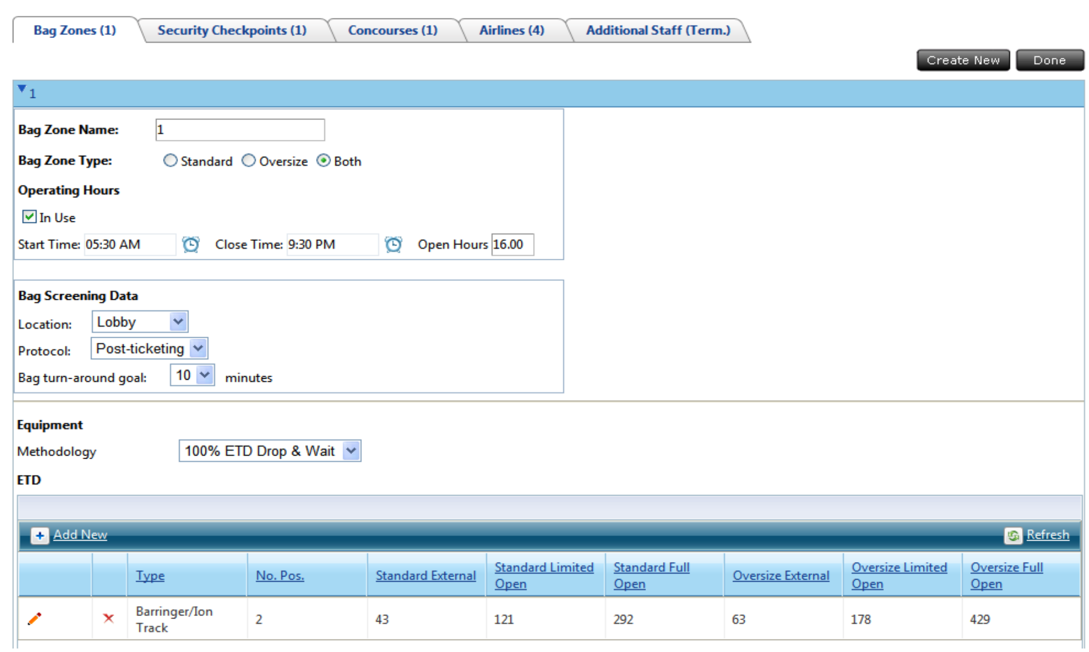
The checkpoint is a single queue with multiple servers (lanes) that can be opened and closed

The bag zone is the same as checkpoint with additional secondary screening queue and servers



Passenger and bag screening equipment data, hours of operation, and facility layout configurations are edited by the user for each airport





The logic for determining checkpoint and bag zone equipment requirements is based on the number in queue, equipment processing rate and MOE

Model first observes # in queue and determines the time needed to process the queue:

Time to Clear Queue = # in Queue / Processing Rate

Model determines the number of servers needed to meet the user-defined measure of effectiveness (MOE):

Number of servers = Time to Clear Queue / MOE

This provides an estimate of checkpoint lanes and bag screening equipment needed to support the MOE

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Airports of different sizes and configurations were tested against TSA-approved statistics

	Reported Statistic
Checkpoint	Sum of passengers processed
	Sum of non-passengers processed
	Max processing time for all Checkpoints (minutes)
	Max passengers in queue for all Checkpoints
	Average processing time (Average Queue Time) in Minutes
	Total Checkpoint Utilization
	% of passengers waiting over 10 minutes
	Total # of lanes open for all priority groups
Bag Zone	Count of bag entered across all Bag Zones
	Count of bags processed across all Bag Zones
	Count of alarmed bags across all Bag Zones
	Count of alarms resolved across all Bag Zones
	Max processing time for all Bag Zones in Minutes
	Max bags in queue for all Bag Zones
	Average bag TAT (average delay) in minutes
	% of bags with TAT greater than 10 minutes
	Utilization of EDS primary systems
	Utilization of ETD alarm resolvers

Prototype logic was tested for robustness using results from the original model statistics

After results were verified, the prototype was made “generic” so that it could solve *any* airport model

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ESM results provide staffing requirements for checkpoints and bag zones, as well as any additional staff required

Airport Abbrevation:	ORD	**Terminal Name:**	1
Experiment Name:	ORD_RAJA	**Start Date:**	
Comments:	This is a test comment entered for ORD_RAJA!		

SUNDAY

Checkpoint3 - CheckPointStaff - Either

Time	Either	Male	Female	Staff Multiplier	Total Staff
2:00 PM	9	4	4	1	17
3:00 PM	7	3	3	1	13
4:00 PM	7	3	3	1	13
5:00 PM	7	3	3	1	13
6:00 PM	7	3	3	1	13
7:00 PM	3	1	1	1	5
8:00 PM	0	0	0	1	0
9:00 PM	0	0	0	1	0
10:00 PM	0	0	0	1	0
11:00 PM	0	0	0	1	0
Maximum by Day	9	4	4	1	17

CheckpointFIS 1 - CheckPointStaff - Either

Time	Either	Male	Female	Staff Multiplier	Total Staff
12:00 AM	0	0	0	1	0
1:00 AM	0	0	0	1	0
2:00 AM	0	0	0	1	0
3:00 AM	3	1	1	1	5
4:00 AM	3	1	1	1	5
5:00 AM	3	1	1	1	5
6:00 AM	3	1	1	1	5

TSA Enhanced Staffing Model Page 11 of 84 Printed 9/27/2010 4:42:18 PM

Schedules are created from these staffing requirements

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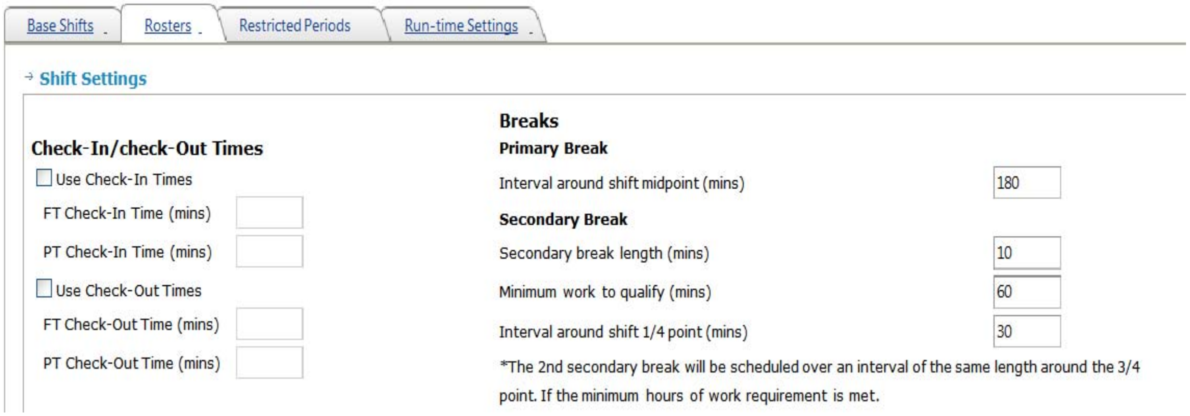
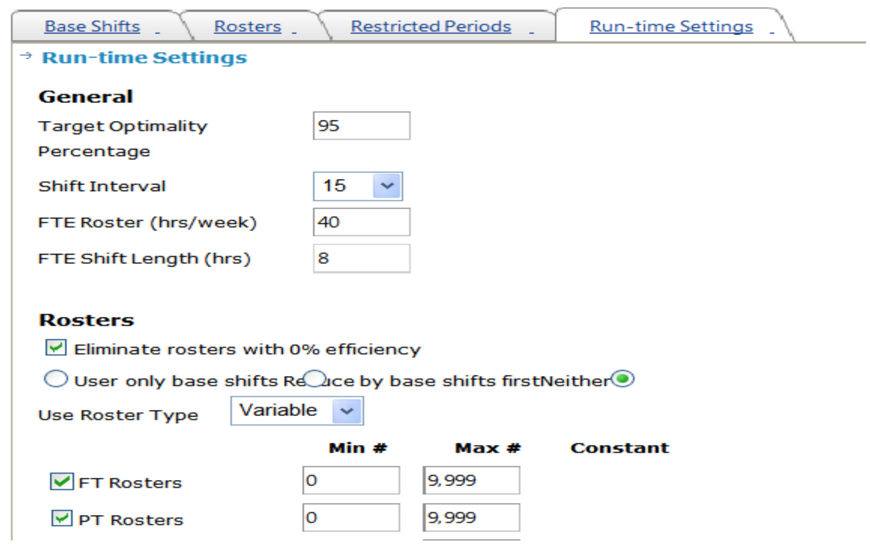
The optimization engine exports the staffing requirements from ESM into a CPLEX-based scheduling optimizer



The user can edit shift intervals, breaks, rosters, and run-time settings before optimization



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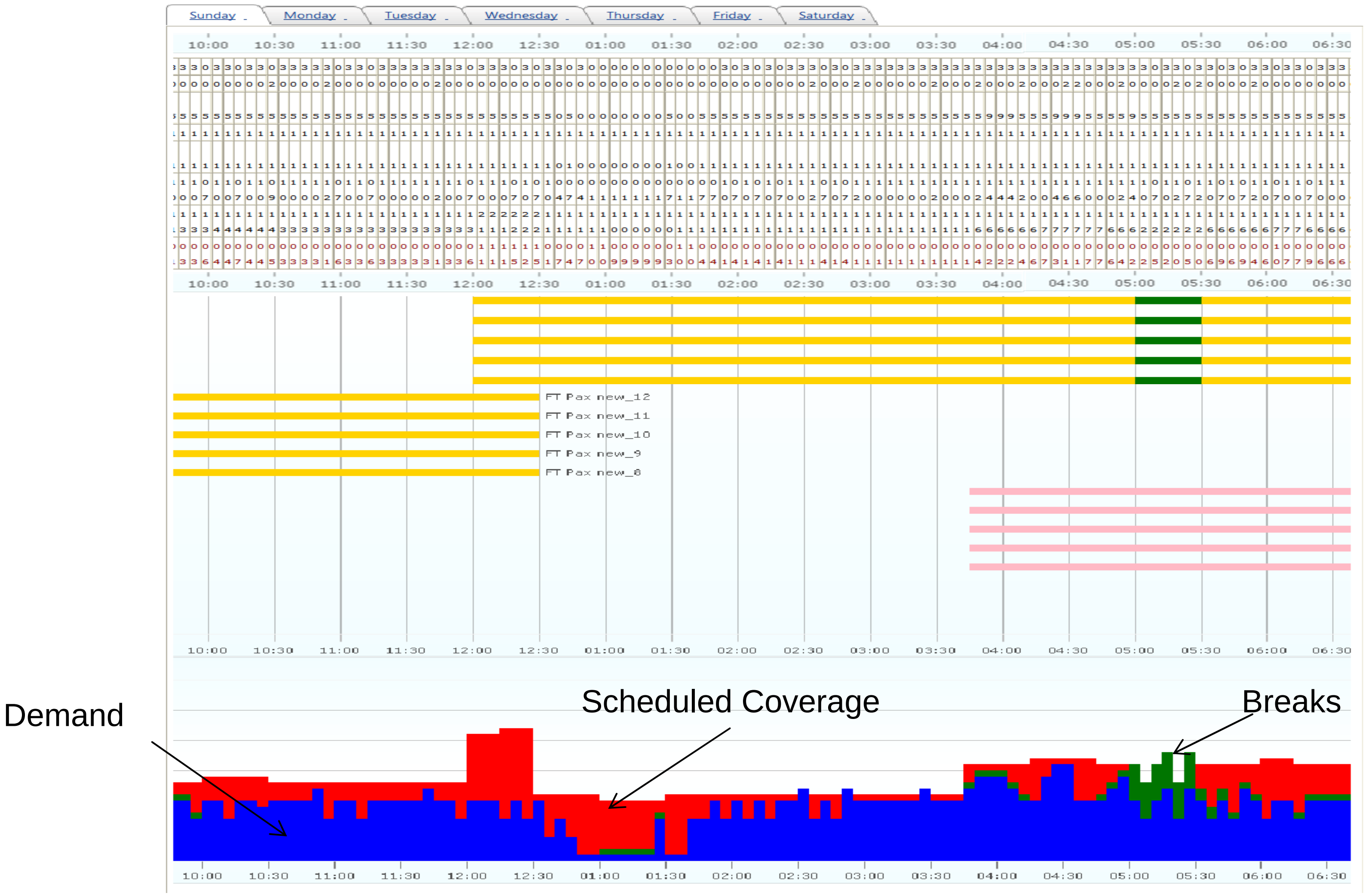
Established staffing rules are validated in the optimization engine, and a deployable schedule with FTE requirements is generated



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The move from PC-based to network model provides benefits to the user while meeting the required end-user functionality

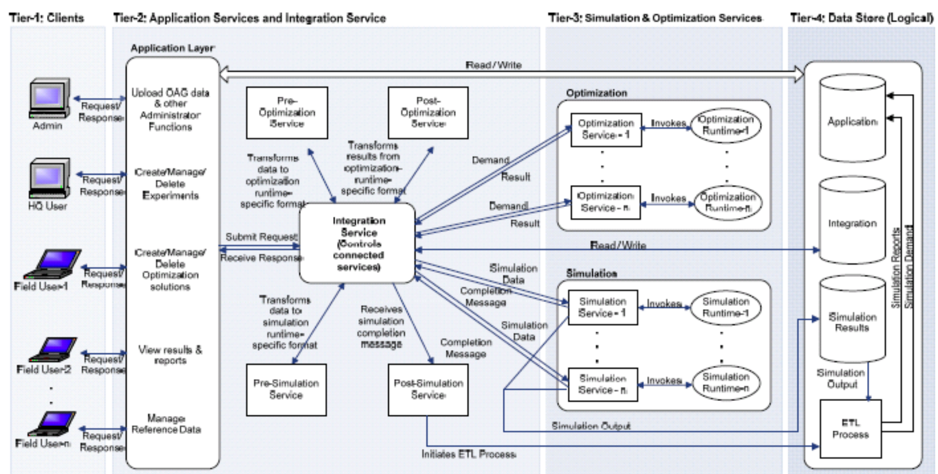
Network efficiency is improved due to single data repository, centralized end-user support, and instant access to model and data upgrades

Users are more productive due to faster simulation run time and ability to run simultaneous models

Reduced help desk support and TCO

Access to TSA SOA IT infrastructure & support

Improved security



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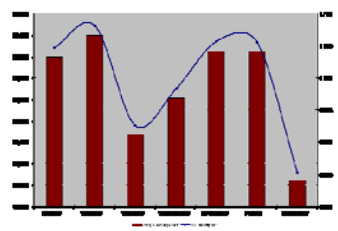
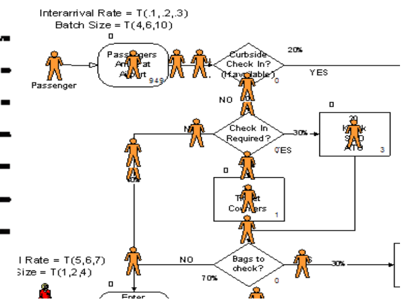
SIMULATION-BASED MANPOWER PLANNING WITH OPTIMIZED SCHEDULING IN A DISTRIBUTED MULTI-USER ENVIRONMENT





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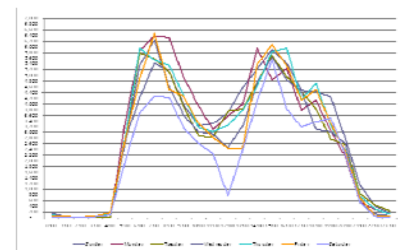

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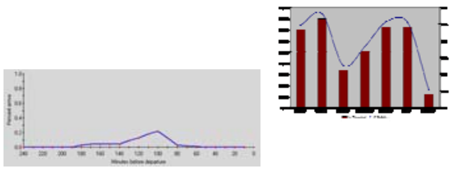
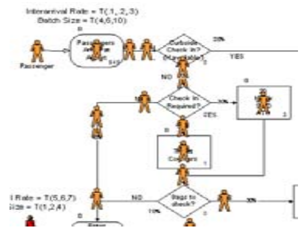
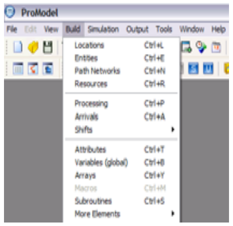
The ESM simulation engine was built in steps



Gain thorough understanding of passenger/bag generation and variability

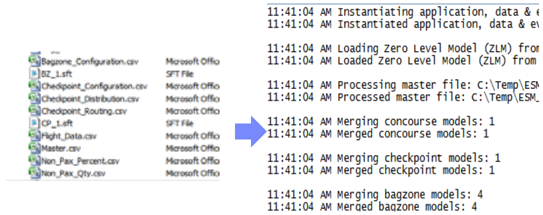


Build a prototype with prototypical data

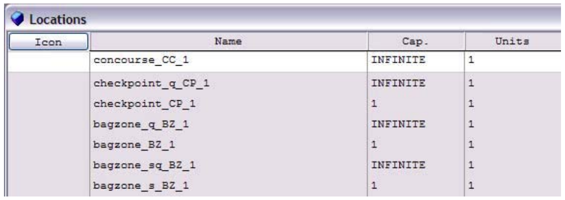


Decompose prototype into generic submodels

Test submodels and logic for robustness, “harden”



Coordinate design and use of external data files



Develop schema for programmatic model builds

Test, test, test!

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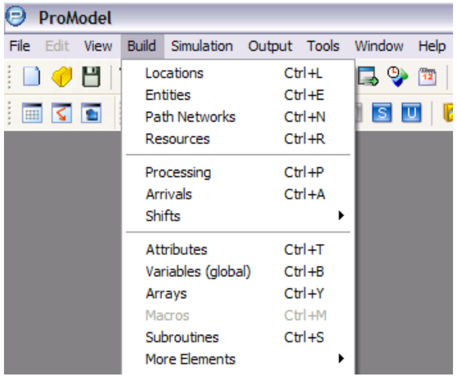
The prototype was used to create generic concourse, checkpoint and bag zone submodels along with a base “zero-level” model



The zero-level model (ZLM) contains the attributes, global variables, data arrays, subroutines, and statistical distributions inherent in every model

The concourse submodel has processing records for passengers (arrival delay, check-in, bag divesting , routing) and for bags (generation, determine standard or oversize, routing to bag zone)

The checkpoint submodel has processing records used at the checkpoint queues for the processing of passengers and non-passengers

The bag zone submodel is similar to the checkpoint submodel but also has another queue with infinite capacity and multiple server locations for secondary processing of the bags

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Screening requirements are based on average weekly enplanements for the peak month of travel for each airport

Month	Monthly Enplanements	Days	Avg Weekly Enplanements
Jan	254168	31.00	8199
Feb	238635	28.00	8523
Mar	302462	31.00	9757
Apr	282966	30.00	9432
May	314311	31.00	10139
Jun	315088	30.00	10503
Jul	330806	31.00	10671
Aug	308251	31.00	9944
Sep	267968	30.00	8932
Oct	310840	31.00	10027
Nov	284867	30.00	9496
Dec	269556	31.00	8695

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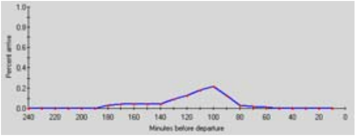
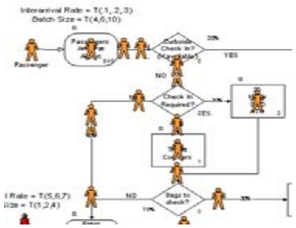
The ESM simulation engine was built in steps

Gain thorough understanding of passenger/bag generation and variability





Build a prototype with prototypical data

Decompose prototype into generic submodels and test for robustness

	Reported Statistic
Checkpoint	Sum of passengers processed
	Sum of non-passengers processed
	Max processing time for all Checkpoints (minutes)
	Max passengers in queue for all Checkpoints
	Average processing time (Average Queue Time) in Minutes
	Total Checkpoint Utilization
	% of passengers waiting over 10 minutes
	Total # of lanes open for all priority groups
Bag Zone	Count of bag entered across all Bag Zones
	Count of bags processed across all Bag Zones
	Count of alarmed bags across all Bag Zones
	Count of alarms resolved across all Bag Zones
	Max processing time for all Bag Zones in Minutes
	Max bags in queue for all Bag Zones
	Average bag TAT (average delay) in minutes
	% of bags with TAT greater than 10 minutes
	Utilization of EDS primary systems
	Utilization of ETD alarm resolvers

Coordinate design and use of external data files

Bagzone_Configuration.csv	Microsoft Offic
BZ_1.sft	SFT File
Checkpoint_Configuration.csv	Microsoft Offic
Checkpoint_Distribution.csv	Microsoft Offic
Checkpoint_Routing.csv	Microsoft Offic
CP_1.sft	SFT File
Flight_Data.csv	Microsoft Offic
Master.csv	Microsoft Offic
Non_Pax_Percent.csv	Microsoft Offic
Non_Pax_Qty.csv	Microsoft Offic

```
11:41:04 AM Instantiating application, data & e
11:41:04 AM Instantiated application, data & ev

11:41:04 AM Loading Zero Level Model (ZLM) from
11:41:04 AM Loaded Zero Level Model (ZLM) from

11:41:04 AM Processing master file: C:\Temp\ESM
11:41:04 AM Processed master file: C:\Temp\ESM_

11:41:04 AM Merging concourse models: 1
11:41:04 AM Merged concourse models: 1

11:41:04 AM Merging checkpoint models: 1
11:41:04 AM Merged checkpoint models: 1

11:41:04 AM Merging bagzone models: 4
11:41:04 AM Merged bagzone models: 4
```

Develop schema for programmatic model builds

Locations

Icon	Name	Cap.	Units
	concourse_CC_1	INFINITE	1
	checkpoint_q_CP_1	INFINITE	1
	checkpoint_CP_1	1	1
	bagzone_q_BZ_1	INFINITE	1

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The prototype was then designed and tested as generic concourse, checkpoint and bag zone submodels along with a base "zero-level" model

After submodels were tested, external data files were incorporated

All airport data was handled within ProModel as Arrays, User Distributions, and Shift files

Distributions

Data arrays

Shift Files

Name	Type
Airline_OS_Bagzone.csv	Microsoft Office Excel Comma Separated Values File
Airline_Reg_Bagzone.csv	Microsoft Office Excel Comma Separated Values File
Arrival_Distribution.csv	Microsoft Office Excel Comma Separated Values File
Bag_Distribution.csv	Microsoft Office Excel Comma Separated Values File
Bagzone_Configuration.csv	Microsoft Office Excel Comma Separated Values File
BZ_1.sft	SFT File
Checkpoint_Configuration.csv	Microsoft Office Excel Comma Separated Values File
Checkpoint_Distribution.csv	Microsoft Office Excel Comma Separated Values File
Checkpoint_Routing.csv	Microsoft Office Excel Comma Separated Values File
CP_1.sft	SFT File
Flight_Data.csv	Microsoft Office Excel Comma Separated Values File
Master.csv	Microsoft Office Excel Comma Separated Values File
Non_Pax_Percent.csv	Microsoft Office Excel Comma Separated Values File
Non_Pax_Qty.csv	Microsoft Office Excel Comma Separated Values File

A subroutine is called at initialization of the model to read each of the files to populate the three main data arrays for Flight Data, Checkpoint, and Bag Zone Configuration

ESM programmatically builds each unique airport model from the input files

ESM begins by loading the zero-level model

Based on the unique airport configuration information, submodels are merged (concourses, checkpoints and bag zones) to model the airport

Using this schema, an airport with one concourse, one checkpoint and one bag zone would generate a Locations table as shown below

Locations

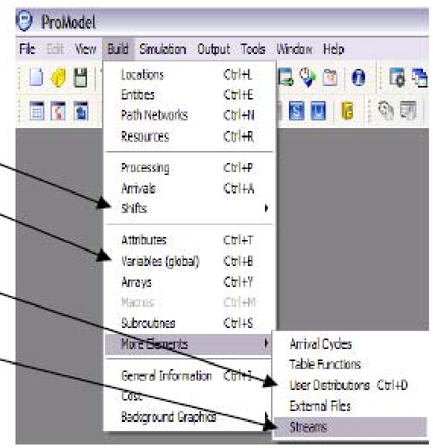
Icon	Name	Cap.	Units
	concourse_CC_1	INFINITE	1
	checkpoint_q_CP_1	INFINITE	1
	checkpoint_CP_1	1	1
	bagzone_q_BZ_1	INFINITE	1
	bagzone_BZ_1	1	1
	bagzone_sq_BZ_1	INFINITE	1
	bagzone_s_BZ_1	1	1

Shifts defined

Variables defined and initialized

User distributions

Random number streams



Automatically-applied suffixes are used in order to differentiate among multiple submodels with the same name

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After ZLM and submodels are successfully merged, the remaining configuration data is read in

The ProModel application programming interface (API) populates the remaining configuration and operational data including secondary bag screening equipment counts and screening rates

Lastly, shifts, variables, user distributions and random number streams are added programmatically and the model is run

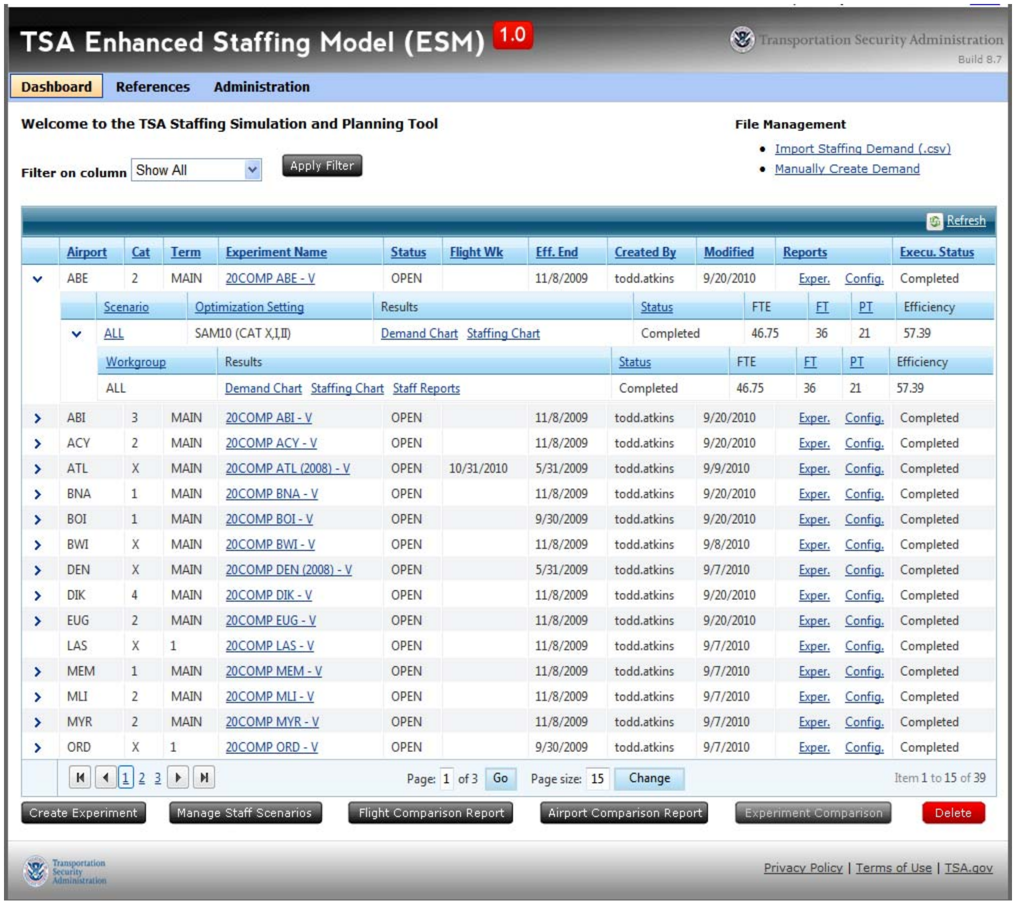
Simulation_Process - Notepad

File Edit Format View Help

```
9/20/2010 11:41:52 AM Saving and populating merged model: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\MMB.MOD
9/20/2010 11:41:52 AM Saved and populated merged model: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\MMB.MOD

9/20/2010 11:41:52 AM Parsing locations table to verify successful merge of all sub-models
9/20/2010 11:41:52 AM Parsed locations table to verify successful merge of all sub-models

9/20/2010 11:41:52 AM Updating array & external file table for flights from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Flight_Data.csv
9/20/2010 11:41:52 AM Updated array & external file table for flights from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Flight_Data.csv

9/20/2010 11:41:52 AM Updating array & external file table for airline master from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Airline_Maste
9/20/2010 11:41:53 AM Updated array & external file table for airline master from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Airline_Master

9/20/2010 11:41:53 AM Uploading arrival distributions from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Arrival_Distribution.csv
9/20/2010 11:41:53 AM Uploaded arrival distributions from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Arrival_Distribution.csv

9/20/2010 11:41:53 AM Uploading bag distributions from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Bag_Distribution.csv
9/20/2010 11:41:53 AM Uploaded bag distributions from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Bag_Distribution.csv

9/20/2010 11:41:53 AM Uploading checkpoint distributions from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Checkpoint_Distribution.csv
9/20/2010 11:41:53 AM Uploaded checkpoint distributions from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Checkpoint_Distribution.csv

9/20/2010 11:41:53 AM Updating array & external file table for checkpoint configuration from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Che
9/20/2010 11:41:53 AM Updated array & external file table for checkpoint configuration from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Checl

9/20/2010 11:41:53 AM Updating routing table for concourse-checkpoint from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Checkpoint_Routing.cs
9/20/2010 11:41:53 AM Updated routing table for concourse-checkpoint from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Checkpoint_Routing.csv

9/20/2010 11:41:53 AM Updating array & external file table for concourse-checkpoint routing from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575
9/20/2010 11:41:53 AM Updated array & external file table for concourse-checkpoint routing from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\

9/20/2010 11:41:53 AM Uploading shift file for checkpoint_CP_1 from file: CP_1.sft
9/20/2010 11:41:53 AM Uploaded shift file for checkpoint_CP_1 from file: CP_1.sft

9/20/2010 11:41:53 AM Updating array & external file table for non-passenger percentage from file: C:\Temp\ESM_SimulationFiles\Files\RequestID_575\Non
```

Example Simulation Process Log

ESM overcame many unique modeling challenges



Data-driven model builds for 450 unique airports

Data and model integrity for 450 unique end-users (non-simulationists)

Integration with network GUI and optimizer

File interchange via .CSV files

Naming conventions and passing strings

Improved speed vs. compiled language code

Transportation Security Administration

IBM

ProModel
Visualize Analyze Optimize VAO