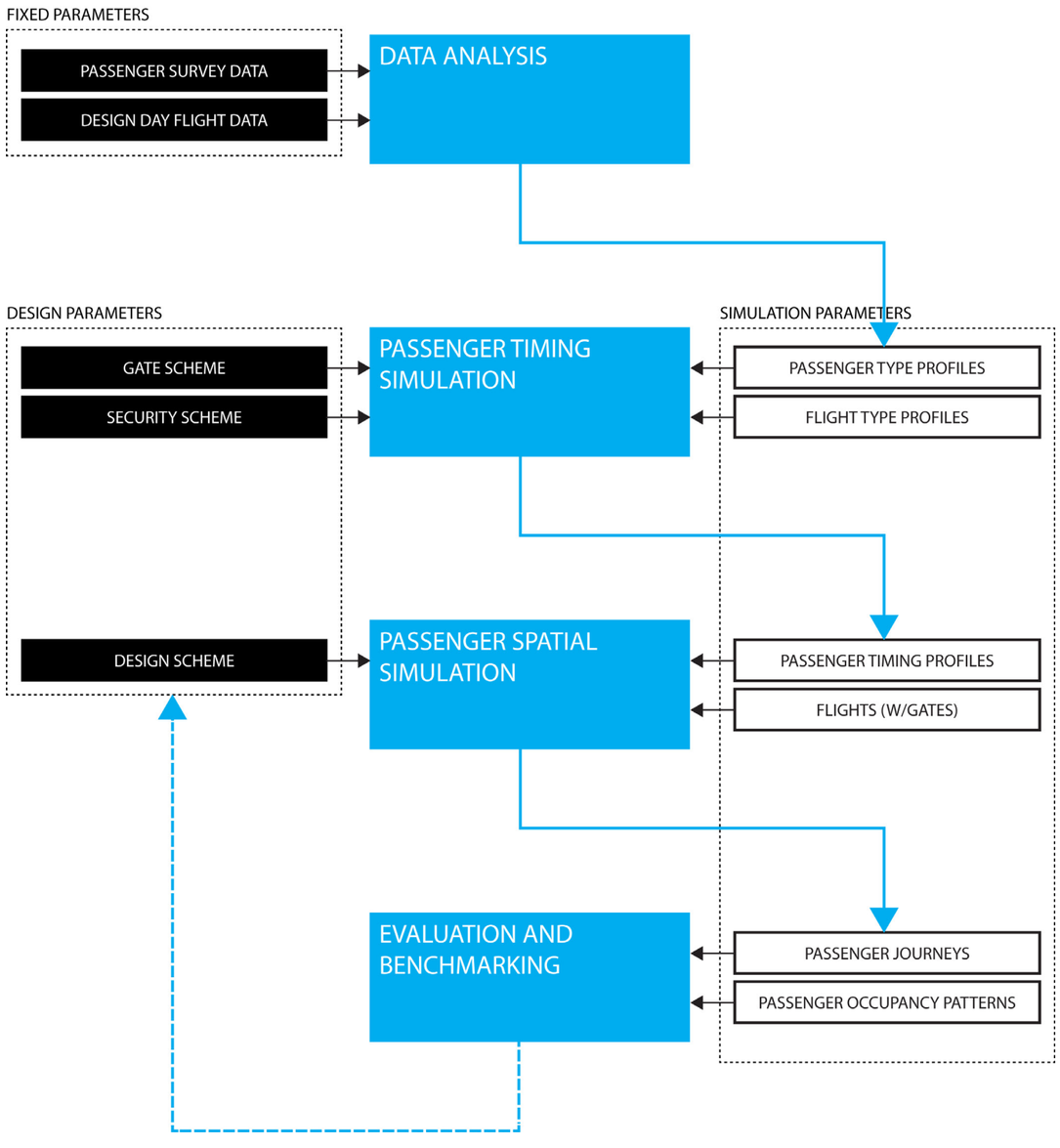
SUPERSPACE

Aviation simulation

A system for air-side passenger behavior simulation



Index

01 - Data Analysis:

- Passenger type distribution and profile generation
- Aircraft type and flight profile generation

02 - Passenger Timing Simulation:

- Gate packing optimisation and spatial configuration
- Curbside - departure passenger timing event generation

03 - Passenger Spatial Simulation:

- Passenger behavior
- Passenger Movement
- Passenger Density

04 - Evaluation and Benchmarking

- Output analysis
- Optimization metrics
- Performance comparison

01

Data Analysis

PASSENGER
Type : leisure.domestic.departing Gender : F bags : false isPreCheck : true isTransfer : false Flight Name : AA to Los Angeles, Boeing 737-800 Timing Profile : brshop / shop : 52 /22 brfood / food : 73 / 51

Preliminary data collection and analysis of key metrics for building airport specific passenger and flight profiles.

Specifications for passenger types:

- Propensities towards air-side behavioral patterns (buying from duty-free, F+b, etc...)
- Propensities towards land-side behavioral patterns (bag-check, global entry, pre-check, etc...)
- Arrival patterns

Specifications for flight types:

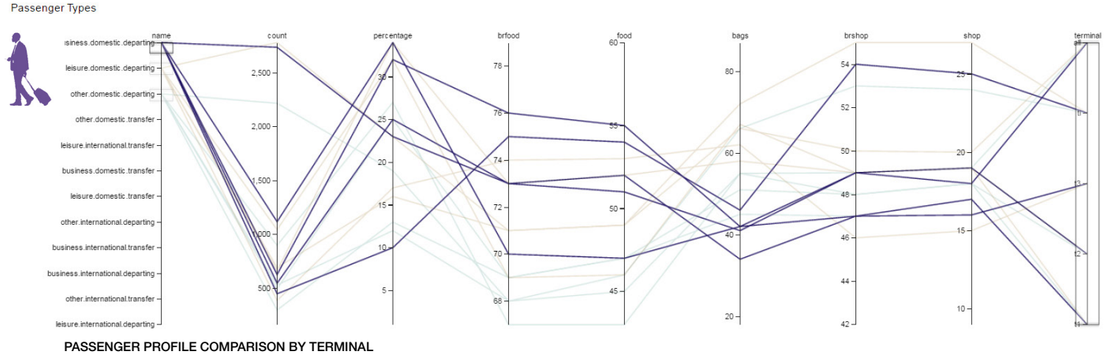
- Propensities towards passenger type distributions
- Current/expected turnaround times by airline/aircraft
- Design day flight schedule/gate scheme
- Load factor

DATA ANALYSIS

PASSENGER TYPE DISTRIBUTION AND PROFILE GENERATION

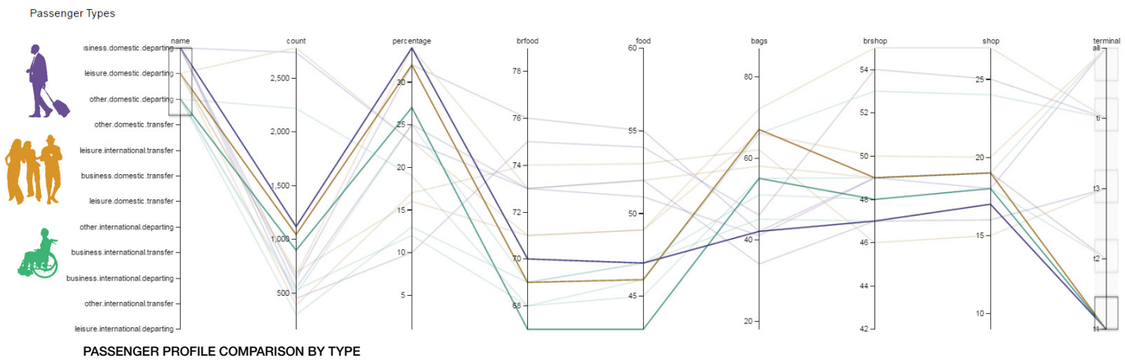
In order to accurately simulate the behavioral patterns of passengers in the airport, preliminary work was done to distill passenger data into distinct types. An analysis of ~15000 reponses to passenger satisfaction surveys conducted by SFO over the last 4 years (weighted by SFO to reflect actual customer traffic disbursement), in addition to prior research done by the ARCP, led to 12 distinct types (and underlaying sub-types) which were used to build a holistic picture of passenger behavioral patterns in the airport:

BUSINESS | LEISURE | OTHER / DOMESTIC | INTERNATIONAL / DEPARTING | TRANSFER



PASSENGER PROFILE COMPARISON BY TERMINAL

Output data from the analysis is an interactive graphic allowing for relative comparisons between occupancy patterns filtered by type, by terminal, or by propensity. The image above is a snapshot showing the purchasing propensities and total percentages of business.domestic.departing passengers (purple) for all 4 terminals of the San Francisco International Airport, as well as average propensities accross all terminals. In addition, the green and orange represent equivalent propensities for leisure.domestic.departing and other.domestic.departing respectively for comparison.

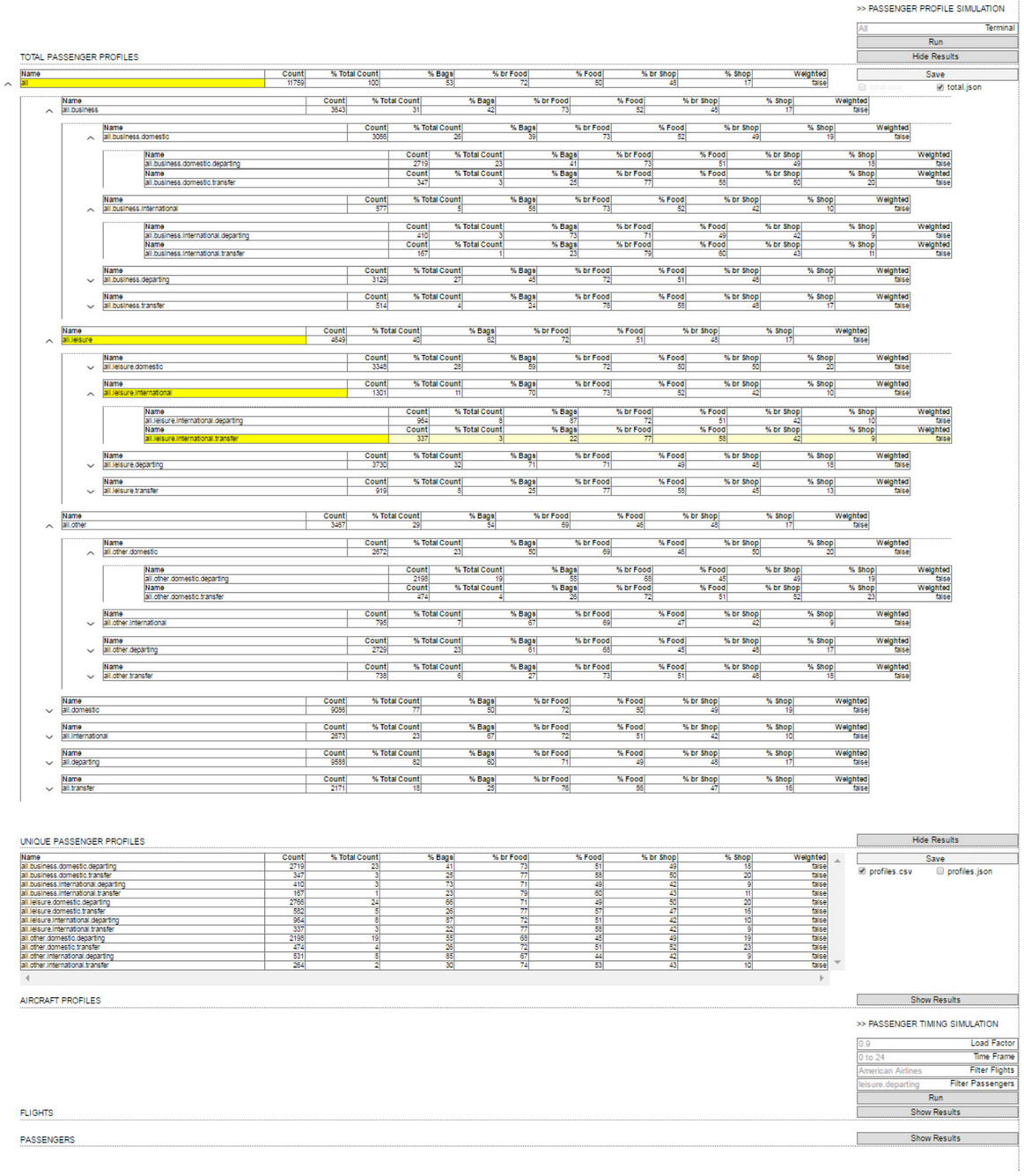


PASSENGER PROFILE COMPARISON BY TYPE

The image above shows the relative comparisons of all three types of domestic passenger, filtered to display for terminal 1 only.

Passenger propensities towards un-measured variables were complemented by existing data sets for similar airports. In this case, the propensity of a passenger to browse a shop was not accounted for in the survey data. However. the Denver International Airport reported a set of data that showed a clear correlation between passenger browsing propensities and passenger buying propensities. Statistical linear regression was used to apply this correlation to the browsing propensity of SFO passengers.

In addition, some assumptions were needed regarding the frequency of passenger bathroom breaks, walking speeds and the propensity to revisit certain concessions. This information could easily be inbedded within the simulation if it were available.

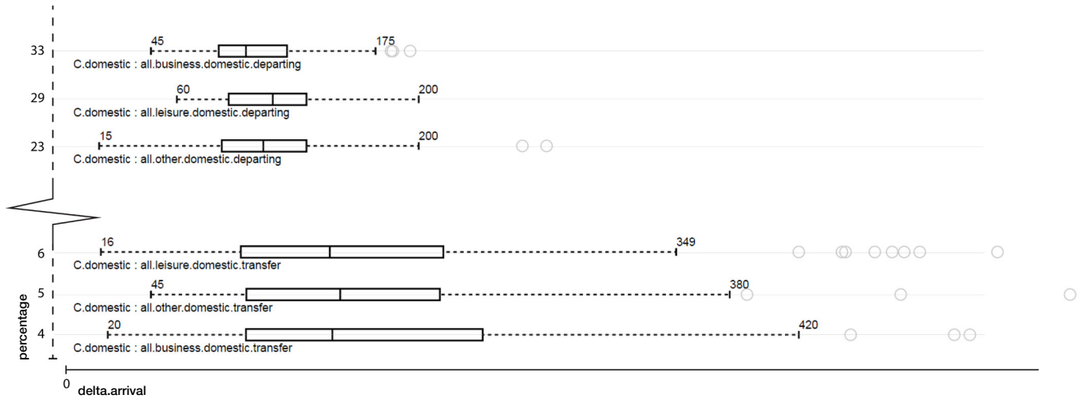


PASSENGER PROFILE TREE AND UNIQUE PASSENGER TYPES (WITH PROPENSITIES)

DATA ANALYSIS

AIRCRAFT TYPE AND FLIGHT PROFILE GENERATION

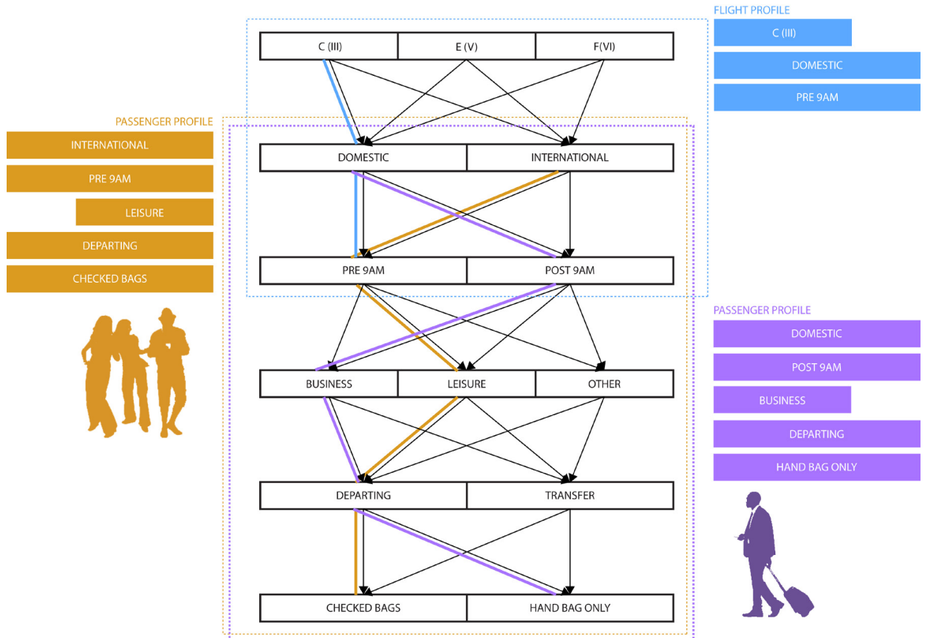
Cross referencing passenger survey data with a database of existing and past departing flights, and information about carrier, aircraft and turnaroud times results in a set of flight profiles that store replicatable simulation information regarding passenger type disbursement, arrival rates and other key information needed to generate a set of passengers for each flight, specific to that flight's profile.



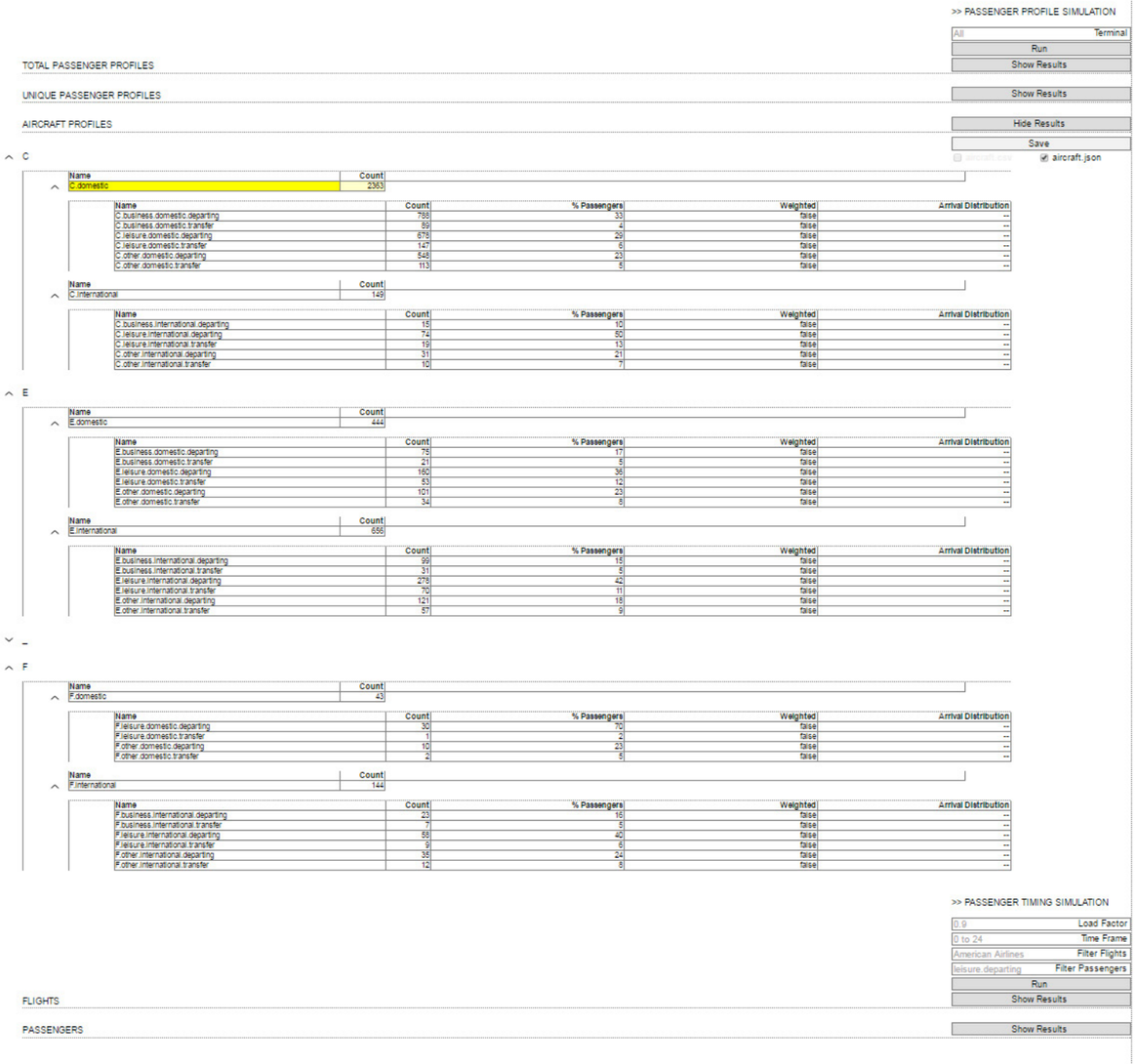
DOMESTIC TYPE C FLIGHT PROFILE

As a methodology to distill and categorize the data, flight and passenger profiles belong to a tree of possible attribute permutations. Each attribute's distinct nature eliminates passenger/flight crossover between types (e.g. passengers cannot be domestic and international), and provides a framework by which to label passenger profiles for simulation and propensity assignment.

In addition, passenger types that resulted in little to no respondents were culled from the flight profiles - either due to incompatable types (e.g. F.international : domestic.leisure.transfer), or minimal percentages (e.g. C.international : international.business.transfer).



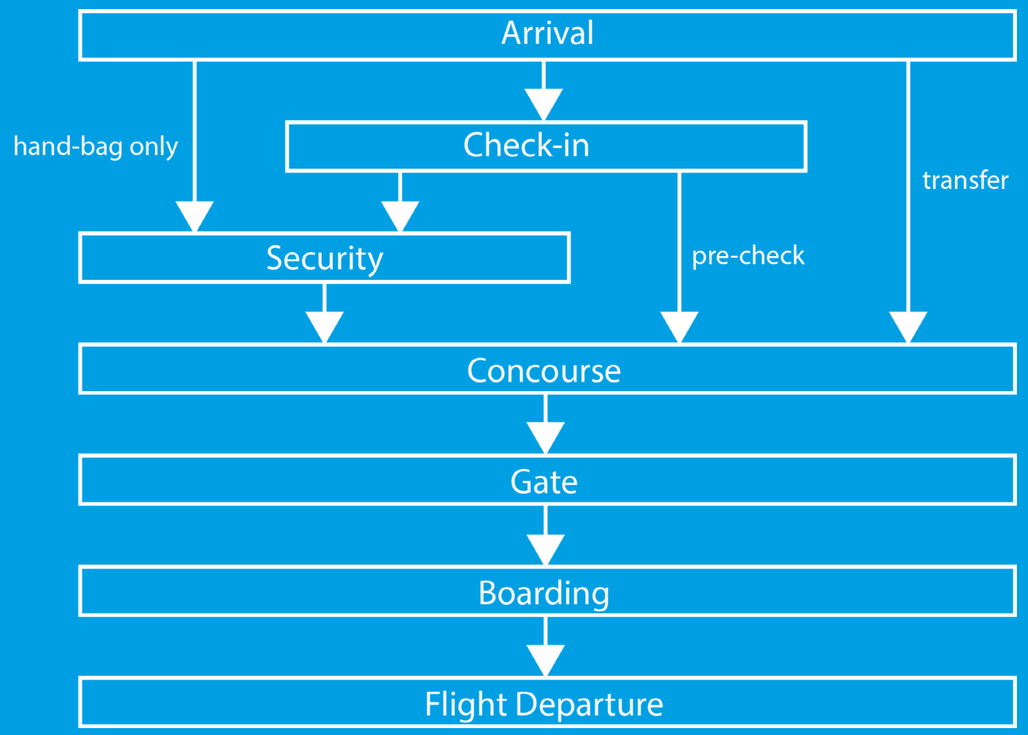
PASSENGER TYPE AND FLIGHT TYPE PERMUTATION TREE



AIRCRAFT PROFILE TREE AND PASSENGER TYPE DISTRIBUTIONS

02

Passenger Timing Simulation



The passenger timing model generates timing profiles for all passengers from curbside to departure using passenger profiles, arrival rates and flight type distributions. These journeys are split into a series of timing events that feed into the passenger spatial simulation.

The system outputs a series of passengers with corresponding timings, as well as :

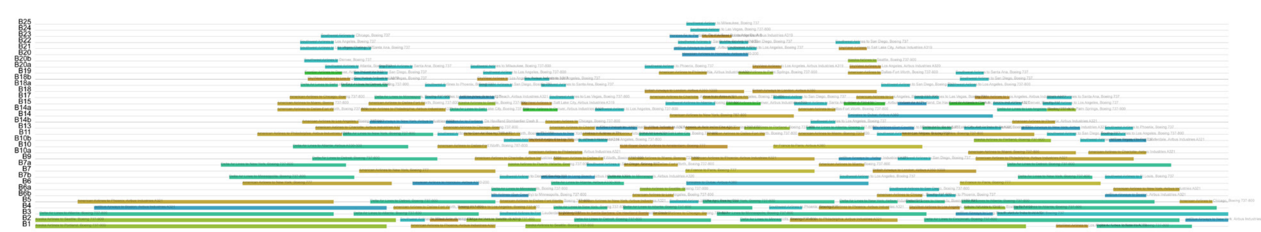
- Information about arrival rates and queuing times based on the current design scheme and flight schedule
- Optimized gate allocation (if none present) based on the airport specific flight profiles, allowing the spatial simulation to be linked to a CAD plan for the simulation of concession usage on the given design day.

PASSENGER TIMING SIMULATION

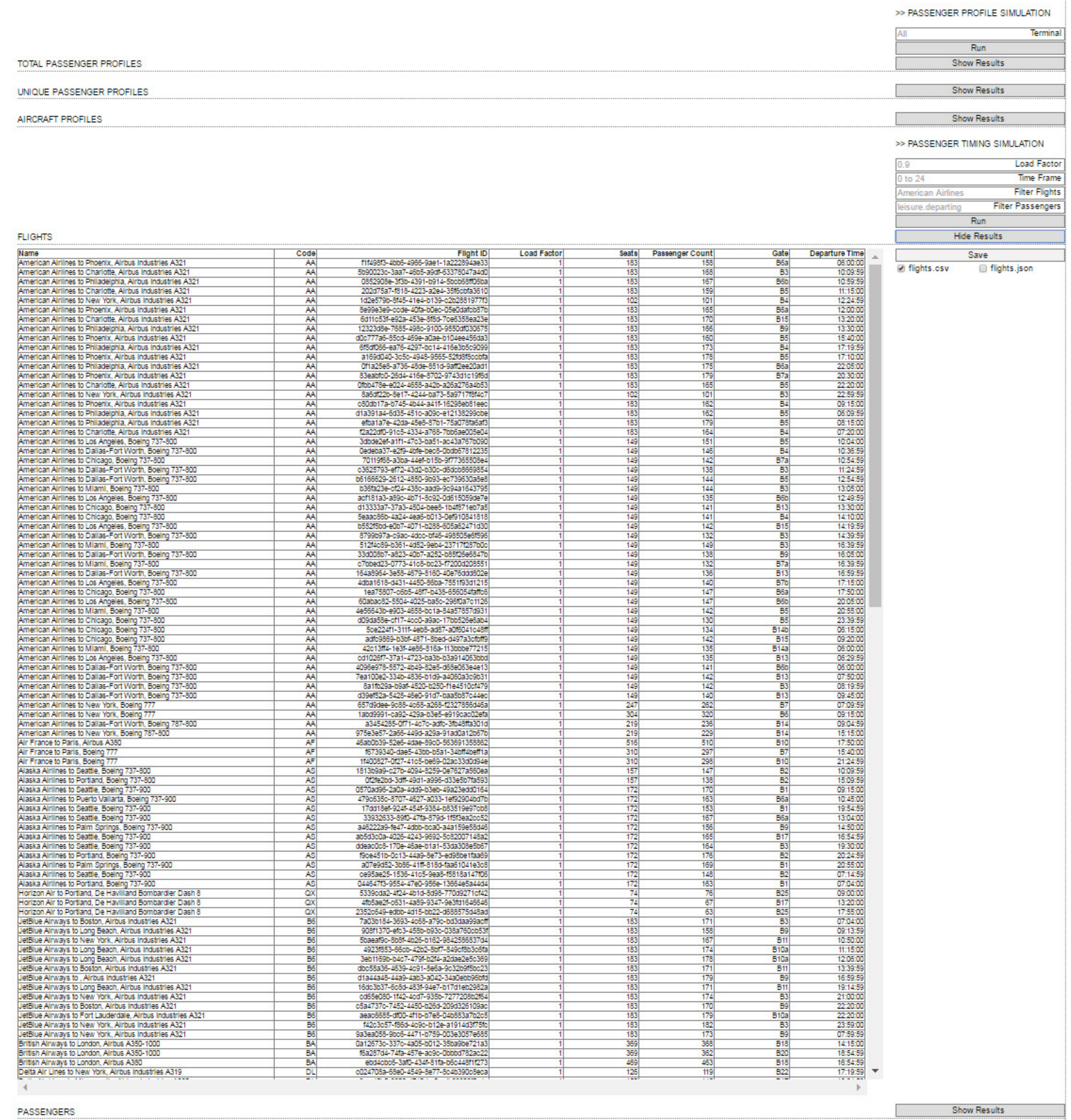
GATE PACKING OPTIMIZATION AND SPATIAL CONFIGURATION

For the output from the passenger timing simulation to be linked to an existing design scheme, peak design day flight schedule input is required as a measure of passenger flow. In this case, the schedule included all desired flights out of SFO on a maximum capacity day in 2023. This data was then filtered by terminal to include flights strictly for Terminal 1.

CLUSTER PACKING



OPTIMIZED SPACE PACKING



SIMULATED FLIGHT OUTPUT WITH GATE ALLOCATIONS AND PASSENGER COUNT

Given that flights from the design day have not been assigned a gate, and in order to tie the simulation to the plan of a test fit during the design phase, two kinds of gate packing are implemented to simulate passenger flow through the concourse. Both account for Multi Aircraft Ramping System (MARS) gates, gate capacity and design group restrictions during flight allocation. A database of turnaround times by aircraft, and by airline were used allong with aviation industry standards for time padding on interval extents in order to allocate the nessessary amount of time for each flight.

- Optimized space packing assigns flights to gates as closely as possible, potentially eliminating unnecessary gates. Airlines are distributed without location preferences on the concourse and there is no attempt to keep flights from a single airline together.

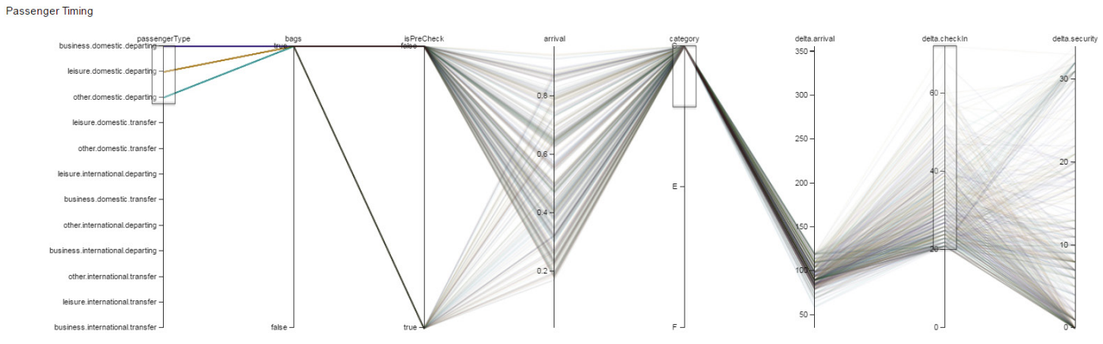
- Cluster packing is slightly less optimal, but maintains groups of airlines together as well as specific gate allocations to airlines.

PASSENGER TIMING SIMULATION

CURBSIDE - DEPARTURE PASSENGER TIMING EVENT GENERATION

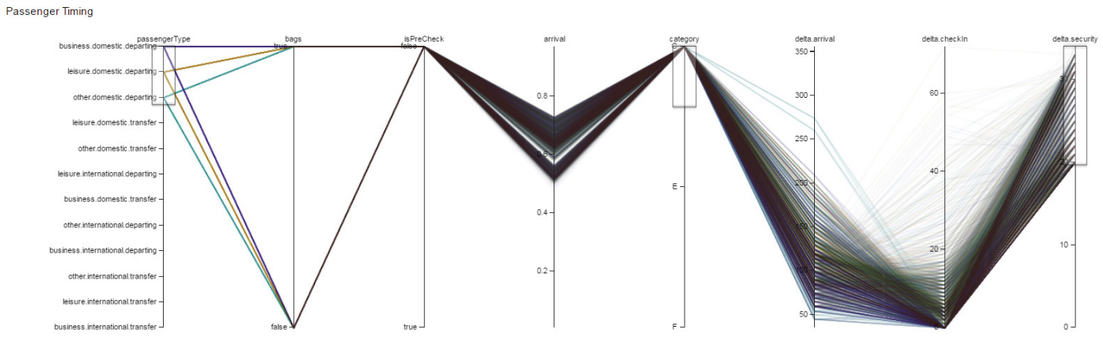
Using the pre-computed passenger types and aircraft types specific to the airport, and coupled with the design day flight schedule and design scheme variables, the preliminary passenger timing simulation produces a set of passengers with journey events for every flight out of the airport over the course of the design day:

ARRIVAL | CHECK-IN | SECURITY | CONCOURSE | GATE | BOARDING | DEPARTURE



DOMESTIC TYPE C PASSENGER TIMING FILTERED BY CHECK-IN TIME

Passenger check-in times are algorithmically computed using bespoke in-house Superspace methods, and are a function of the ARCP's LoS standards for accepatble queuing times and processing rates at check-in kiosks. This could be used to test various combinations of check-in kiosks and the corresponding effect on queuing times. Passenger arrival distribution rates and the percentage of passengers checking in bags versus carry-on only are derived from the pre-computed profiles specific to the flight type (i.e. domestic type C / international type F), load factor, and time of day (pre 9AM vs post 9AM).



DOMESTIC TYPE C PASSENGER TIMING FILTERED BY SECURITY TIME

Similarly, passenger security times are driven by passenger flow from check-in to security for all emplaning flights at a given time slice delta, as well as the current design scheme's security unit capacity. Flow rates are assumed to be around 140 passengers per hour per security unit (ARCP), or 1 passenger every 140/(60*n units) * delta. Variable security unit counts are implemented, as the current SFO design scheme provides a base of 10 security units for all passengers, with an additional 6 available to passengers without checked bags.

delta.change rates are not reflective of actual times from check-in to security. They are representative of the cumulative delay to passengers assuming a regular flow rate and walk times between events, so how much longer from 0 minutes the passenger will wait. For example, a passenger with an average security processing time of 30 sec, 5 min walk to security, and a **delta.security of 4 min** would have an actual time of 9.5 min from check-in to concourse.

>> PASSENGER PROFILE SIMULATION

All — Terminal

Run

TOTAL PASSENGER PROFILES — Show Results

UNIQUE PASSENGER PROFILES — Show Results

AIRCRAFT PROFILES — Show Results

>> PASSENGER TIMING SIMULATION

0.9 — Load Factor

0 to 24 — Time Frame

American Airlines — Filter Flights

leisure.departing — Filter Passengers

Run

FLIGHTS — Show Results

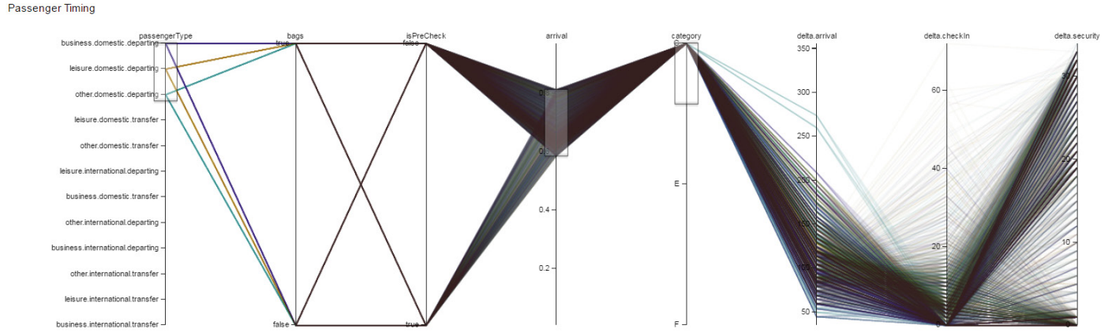
PASSENGERS — Hide Results

Save

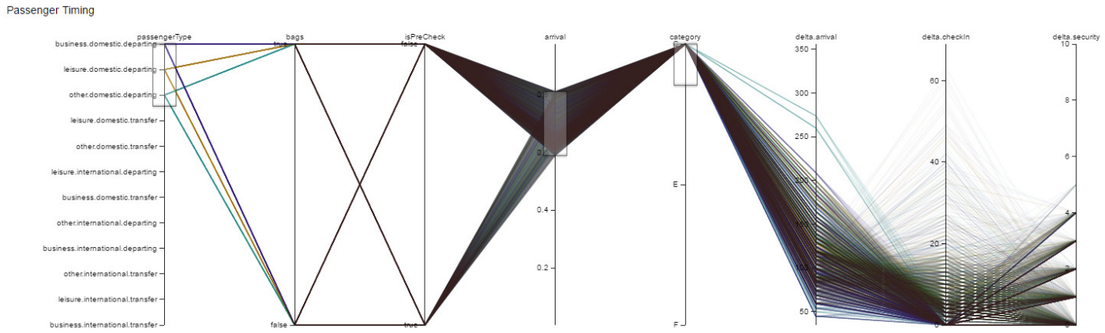
passengers.csv passengers.json

Name	Gender	Bags	Pre Check	Flight ID	Arrival	Security	Concourse	Gate	Boarding	Departure
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	05:06:00	05:06:00	05:14:00	05:39:00	05:38:00	06:00:00
all.business.domestic.departing	M	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	05:01:00	05:01:00	05:01:00	05:37:00	05:47:00	06:00:00
all.business.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	05:00:00	05:00:00	05:06:00	05:44:00	05:48:00	06:00:00
all.business.domestic.departing	F	true	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	05:00:00	05:04:00	05:04:00	05:40:00	05:48:00	06:00:00
all.business.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:54:00	04:54:00	04:58:00	05:27:00	05:45:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:51:00	04:51:00	04:55:00	05:27:00	05:40:00	06:00:00
all.business.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:51:00	04:51:00	04:56:00	05:42:00	05:42:00	06:00:00
all.business.domestic.departing	F	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:46:00	04:46:00	04:46:00	05:39:00	05:48:00	06:00:00
all.business.domestic.departing	F	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:45:00	04:45:00	04:45:00	05:39:00	05:42:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:41:00	04:41:00	04:44:00	05:37:00	05:47:00	06:00:00
all.business.domestic.departing	F	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:40:00	04:40:00	04:40:00	04:40:00	05:48:00	06:00:00
all.business.domestic.departing	M	true	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:39:00	04:54:00	04:54:00	05:42:00	05:45:00	06:00:00
all.business.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:37:00	04:50:00	04:54:00	05:41:00	05:43:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:36:00	04:36:00	04:36:00	04:36:00	05:48:00	06:00:00
all.business.domestic.departing	M	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:35:00	04:38:00	04:35:00	05:25:00	05:47:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:30:00	04:30:00	04:33:00	04:33:00	05:39:00	06:00:00
all.business.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:30:00	04:38:00	04:41:00	05:29:00	05:45:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:30:00	04:30:00	04:34:00	05:40:00	05:47:00	06:00:00
all.business.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:30:00	04:40:00	04:44:00	05:33:00	05:43:00	06:00:00
all.business.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:26:00	04:26:00	04:28:00	05:41:00	05:45:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:26:00	04:26:00	04:26:00	05:37:00	05:44:00	06:00:00
all.business.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:24:00	04:36:00	04:36:00	05:35:00	05:45:00	06:00:00
all.business.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:22:00	04:32:00	04:34:00	05:43:00	05:48:00	06:00:00
all.business.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:21:00	04:26:00	04:26:00	05:44:00	05:49:00	06:00:00
all.business.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:21:00	04:30:00	04:33:00	05:35:00	05:44:00	06:00:00
all.business.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:20:00	04:24:00	04:24:00	05:35:00	05:49:00	06:00:00
all.business.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:15:00	04:25:00	04:23:00	05:40:00	05:48:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:15:00	04:15:00	04:15:00	05:42:00	05:48:00	06:00:00
all.business.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:09:01	04:15:00	04:17:00	05:39:00	05:43:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:09:01	04:09:01	04:10:01	05:39:00	05:39:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:04:59	04:04:59	04:04:59	05:32:00	05:46:00	06:00:00
all.business.domestic.departing	M	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:04:59	04:04:59	04:04:59	04:04:59	05:43:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:04:59	04:04:59	04:05:59	05:36:00	05:44:00	06:00:00
all.business.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:03:00	04:03:00	04:03:00	05:27:00	05:48:00	06:00:00
all.business.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:01:00	04:01:00	04:02:00	05:41:00	05:44:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:01:00	04:01:00	04:01:00	05:33:00	05:46:00	06:00:00
all.business.domestic.departing	M	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:00:00	04:00:00	04:00:00	05:22:00	05:46:00	06:00:00
all.business.domestic.departing	M	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:00:00	04:00:00	04:00:00	05:20:00	05:48:00	06:00:00
all.business.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:55:01	03:55:01	03:55:01	03:55:01	05:48:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:54:01	03:54:01	03:54:01	05:43:00	05:46:00	06:00:00
all.business.domestic.departing	F	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:49:01	03:49:01	03:49:01	05:29:00	05:40:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:46:00	03:46:00	03:46:00	05:41:00	05:48:00	06:00:00
all.business.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:45:00	03:49:01	03:49:01	03:49:01	05:45:00	06:00:00
all.business.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:40:59	03:44:00	03:44:00	05:34:00	05:48:00	06:00:00
all.business.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:39:59	03:39:59	03:39:59	05:31:00	05:41:00	06:00:00
all.business.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:34:59	03:34:59	03:36:59	05:43:00	05:47:00	06:00:00
all.business.domestic.departing	F	true	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:30:00	03:34:00	03:34:00	05:38:00	05:48:00	06:00:00
all.business.domestic.departing	M	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:29:00	03:29:00	03:29:00	05:30:00	05:49:00	06:00:00
all.business.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:26:00	03:26:00	03:26:00	05:28:00	05:40:00	06:00:00
all.business.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:21:00	03:26:00	03:26:00	03:26:00	05:40:00	06:00:00
all.business.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:15:00	03:18:00	03:18:00	05:36:00	05:47:00	06:00:00
all.business.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:04:01	03:08:01	03:08:01	03:08:01	05:44:00	06:00:00
all.business.domestic.departing	M	true	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	02:54:00	02:56:00	02:56:00	05:24:00	05:43:00	06:00:00
all.business.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	02:45:00	02:45:00	02:46:00	05:44:00	05:47:00	06:00:00
all.business.domestic.transfer	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:21:00	03:21:00	03:21:00	05:39:00	05:48:00	06:00:00
all.business.domestic.transfer	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	02:02:00	02:02:00	02:02:00	02:02:00	05:45:00	06:00:00
all.business.domestic.transfer	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	01:44:00	01:44:00	01:44:00	05:32:00	05:47:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	05:00:00	05:07:00	05:16:00	05:34:00	05:48:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:51:00	05:04:00	05:10:00	05:42:00	05:46:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:46:00	05:00:00	05:05:00	05:42:00	05:46:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:45:00	04:57:00	05:03:00	05:03:00	05:43:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:40:00	04:54:00	04:57:00	05:36:00	05:39:00	06:00:00
all.leisure.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:36:00	04:36:00	04:40:00	04:40:00	05:49:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:36:00	04:49:00	04:53:00	05:17:00	05:40:00	06:00:00
all.leisure.domestic.departing	F	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:36:00	04:36:00	04:36:00	05:42:00	05:48:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:33:00	04:41:00	04:44:00	05:41:00	05:48:00	06:00:00
all.leisure.domestic.departing	M	true	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:30:00	04:36:00	04:36:00	04:36:00	05:44:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:30:00	04:46:00	04:49:00	05:43:00	05:43:00	06:00:00
all.leisure.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:30:00	04:30:00	04:33:00	05:34:00	05:48:00	06:00:00
all.leisure.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:26:00	04:26:00	04:27:00	05:17:00	05:48:00	06:00:00
all.leisure.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:21:00	04:21:00	04:24:00	05:44:00	05:44:00	06:00:00
all.leisure.domestic.departing	F	true	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:21:00	04:29:00	04:29:00	05:31:00	05:48:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:20:00	04:27:00	04:29:00	05:34:00	05:43:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:15:00	04:22:00	04:24:00	05:24:00	05:49:00	06:00:00
all.leisure.domestic.departing	M	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:15:00	04:15:00	04:17:00	04:17:00	05:44:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:09:01	04:19:00	04:20:00	05:38:00	05:48:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:09:01	04:19:00	04:19:00	05:41:00	05:47:00	06:00:00
all.leisure.domestic.departing	M	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:09:01	04:09:01	04:09:01	04:09:01	05:46:00	06:00:00
all.leisure.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:06:59	04:14:00	04:15:00	05:29:00	05:46:00	06:00:00
all.leisure.domestic.departing	F	false	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:04:59	04:04:59	04:04:59	04:04:59	05:48:00	06:00:00
all.leisure.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:01:00	04:09:01	04:10:01	05:42:00	05:48:00	06:00:00
all.leisure.domestic.departing	F	true	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:01:00	04:13:00	04:13:00	05:41:00	05:42:00	06:00:00
all.leisure.domestic.departing	F	false	true	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:00:00	04:00:00	04:00:00	04:00:00	05:48:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:00:00	04:08:59	04:08:59	05:40:00	05:40:00	06:00:00
all.leisure.domestic.departing	M	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	04:00:00	04:08:01	04:08:01	05:39:00	05:45:00	06:00:00
all.leisure.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:59:00	04:01:00	04:02:00	05:30:00	05:48:00	06:00:00
all.leisure.domestic.departing	F	true	false	f1f49f5-4bb6-4966-9ae1-1a222894e33	03:54:01	03:58:00	03:58:00	05:43:00	05:47:00	06:00:00

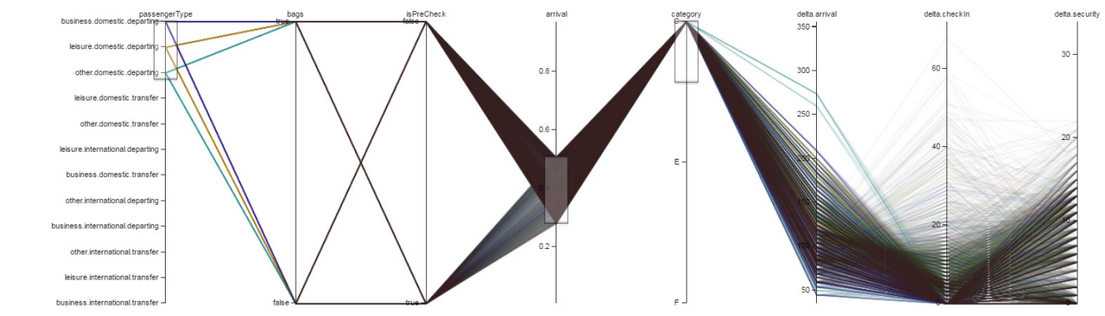
SIMULATED PASSENGER OUTPUT WITH EVENT TIMINGS AND PROFILE ATTRIBUTES



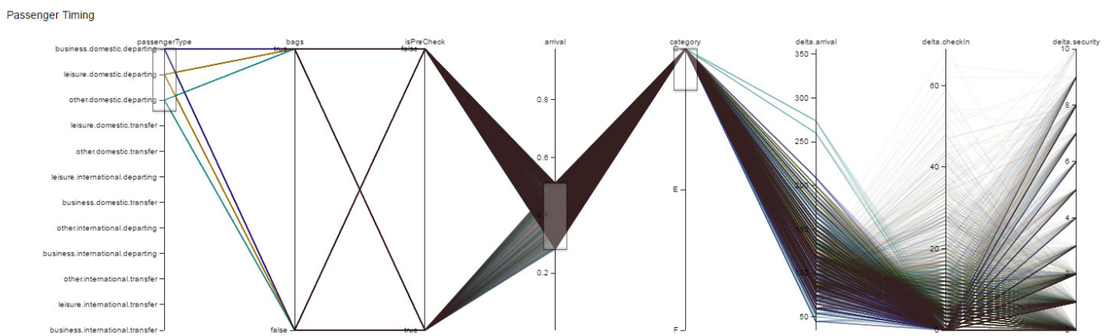
DOMESTIC PASSENGER SECURITY TIMES | AFTERNOON PEAK - SCHEME I (10/12 SECURITY LINES)



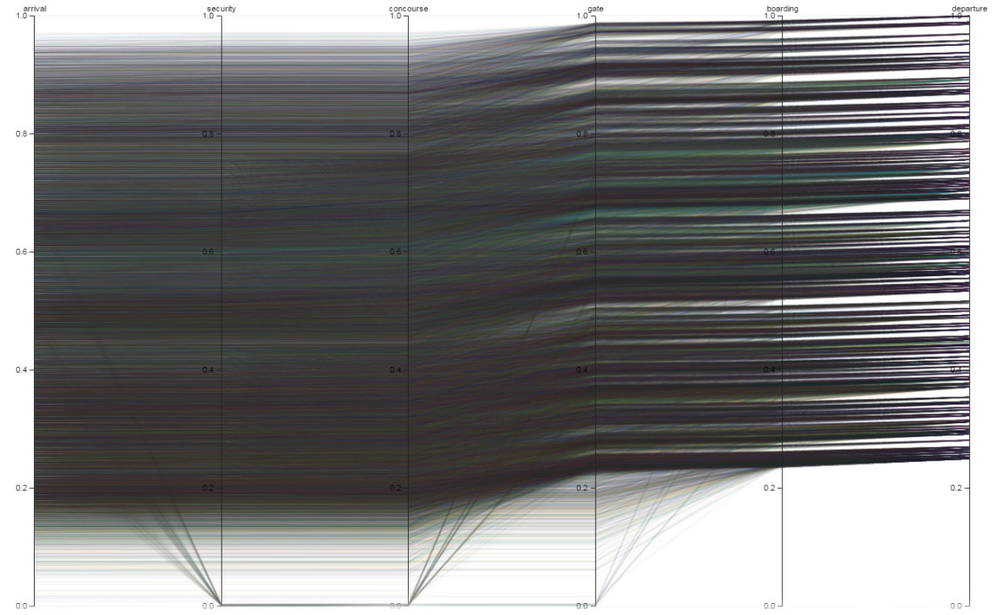
DOMESTIC PASSENGER SECURITY TIMES | AFTERNOON PEAK - SCHEME II (10/16 SECURITY LINES)



DOMESTIC PASSENGER SECURITY TIMES | MORNING PEAK - SCHEME I (10/12 SECURITY LINES)

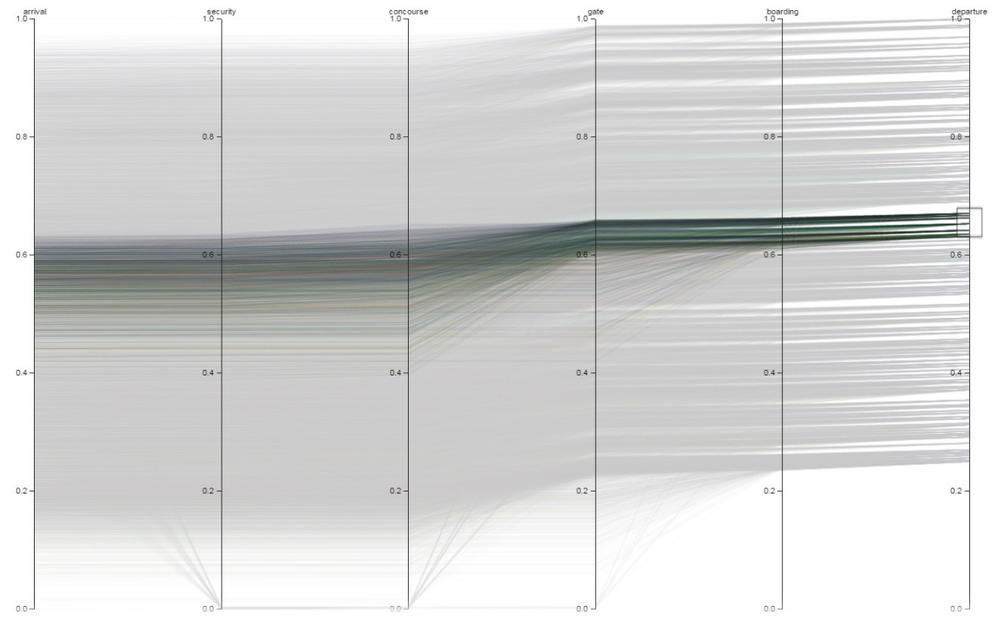


DOMESTIC PASSENGER SECURITY TIMES | MORNING PEAK - SCHEME II (10/16 SECURITY LINES)



TOTAL SIMULATED DESIGN DAY 2023 FLIGHT PASSENGERS - FLOW FROM CURBSIDE TO DEPARTURE

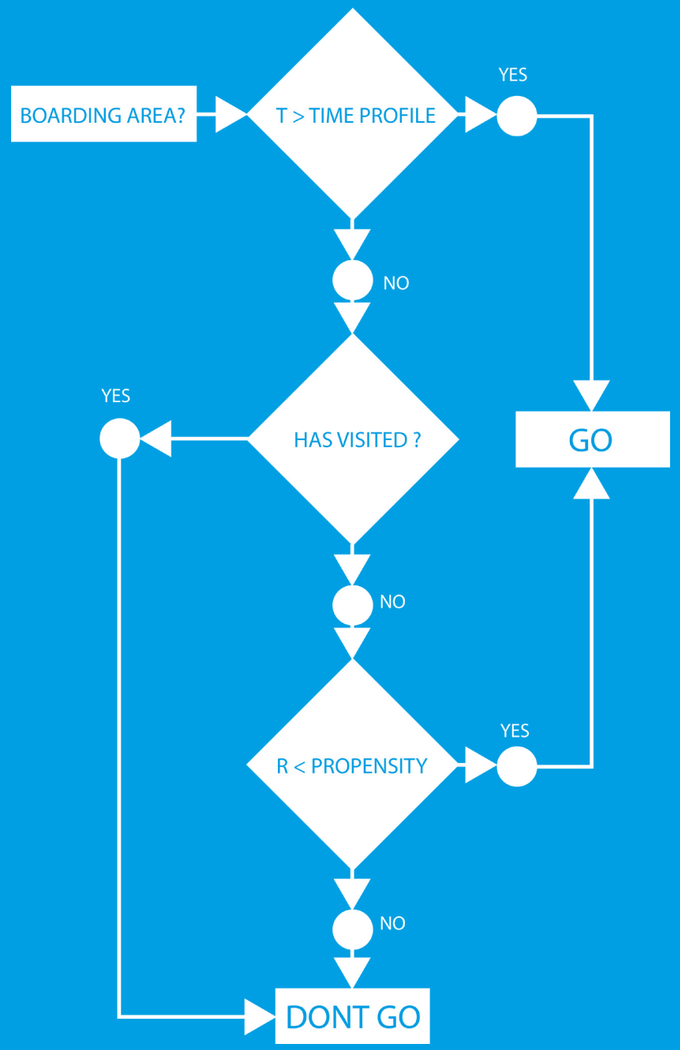
The images on the left show the changes in security times between two different schemes - one with a base 10 + 2 units, and the other with a base 10 + 6 units (current scheme). The top two images are filtered to afternoon peak hours, and the bottom are filtered to morning peak hours. The images above and below are total passenger flow through the airport for the current design scheme and design day flights.



PASSENGERS FILTERED BY DEPARTURE TIME - FLOW FROM CURBSIDE TO DEPARTURE

03

Passenger Spatial Simulation



The passenger spatial model simulates occupational patterns and behaviors on the air-side of a given airport design scheme configuration.

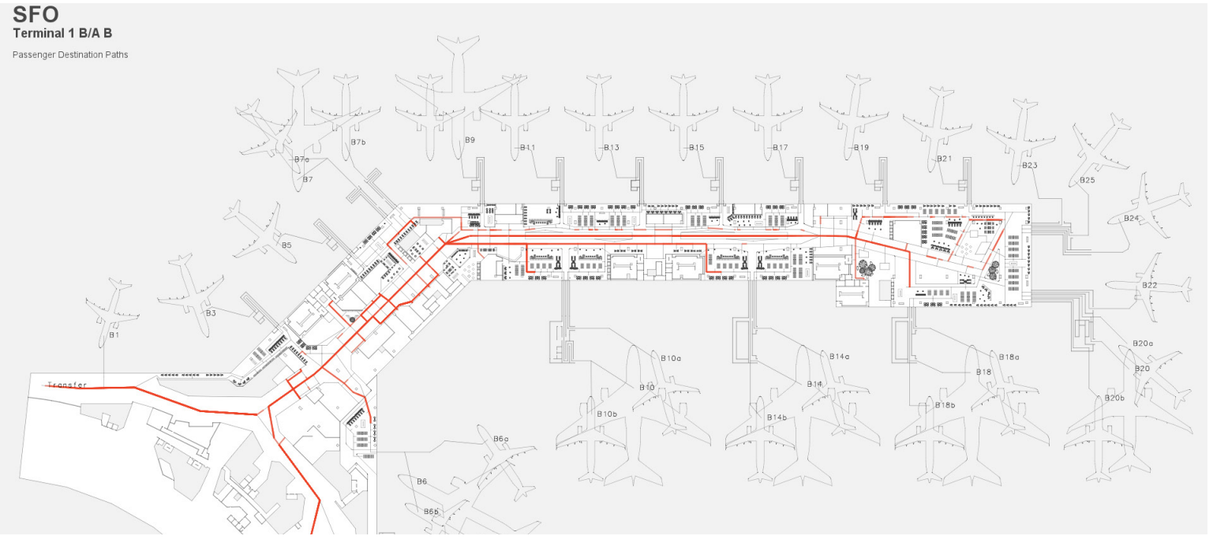
Using the timing profiles for each passenger's overall airport journey events, and the specifications for each unique passenger type, the system outputs a spatial representation of the total occupation and usage of the design layout for:

- Seating configurations
- Retail/concessions/F&B
- Bathrooms
- Access/pathways
- Hold room occupancy/arrival rates
- Visibility/distances

PASSENGER SPATIAL SIMULATION

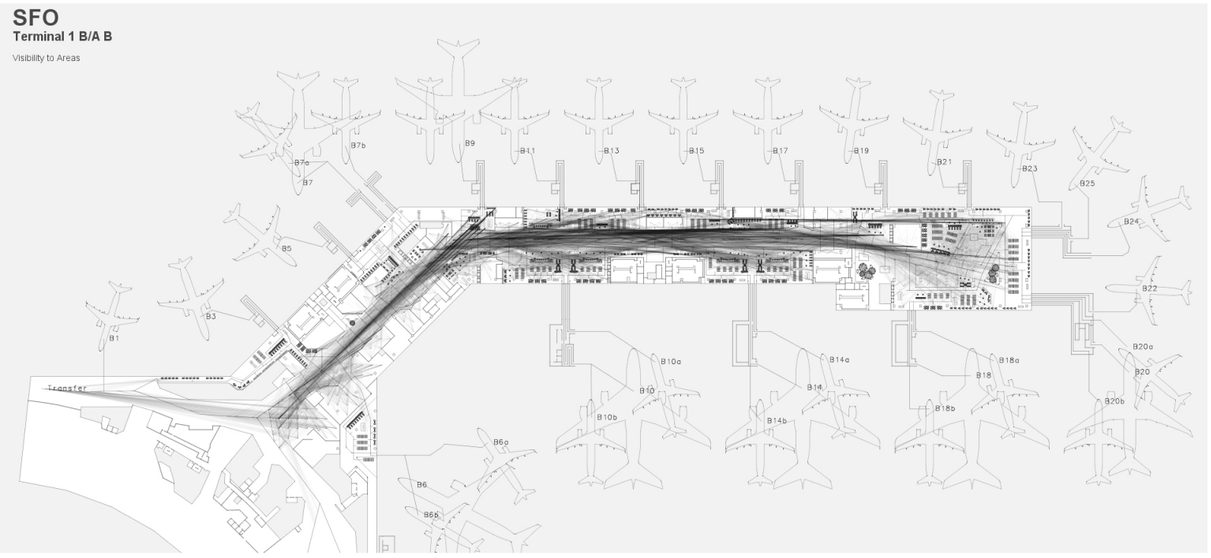
PASSENGER BEHAVIOR

With a spatial graph representation of the scheme, and using the generated timing profiles, more detailed behaviors for each passenger can be simulated moving through the departure lounge. The combination of passenger type definitions with inherent spatial properties such as visibility, distance to destination and shortest path are used to improve the agent decision making process.

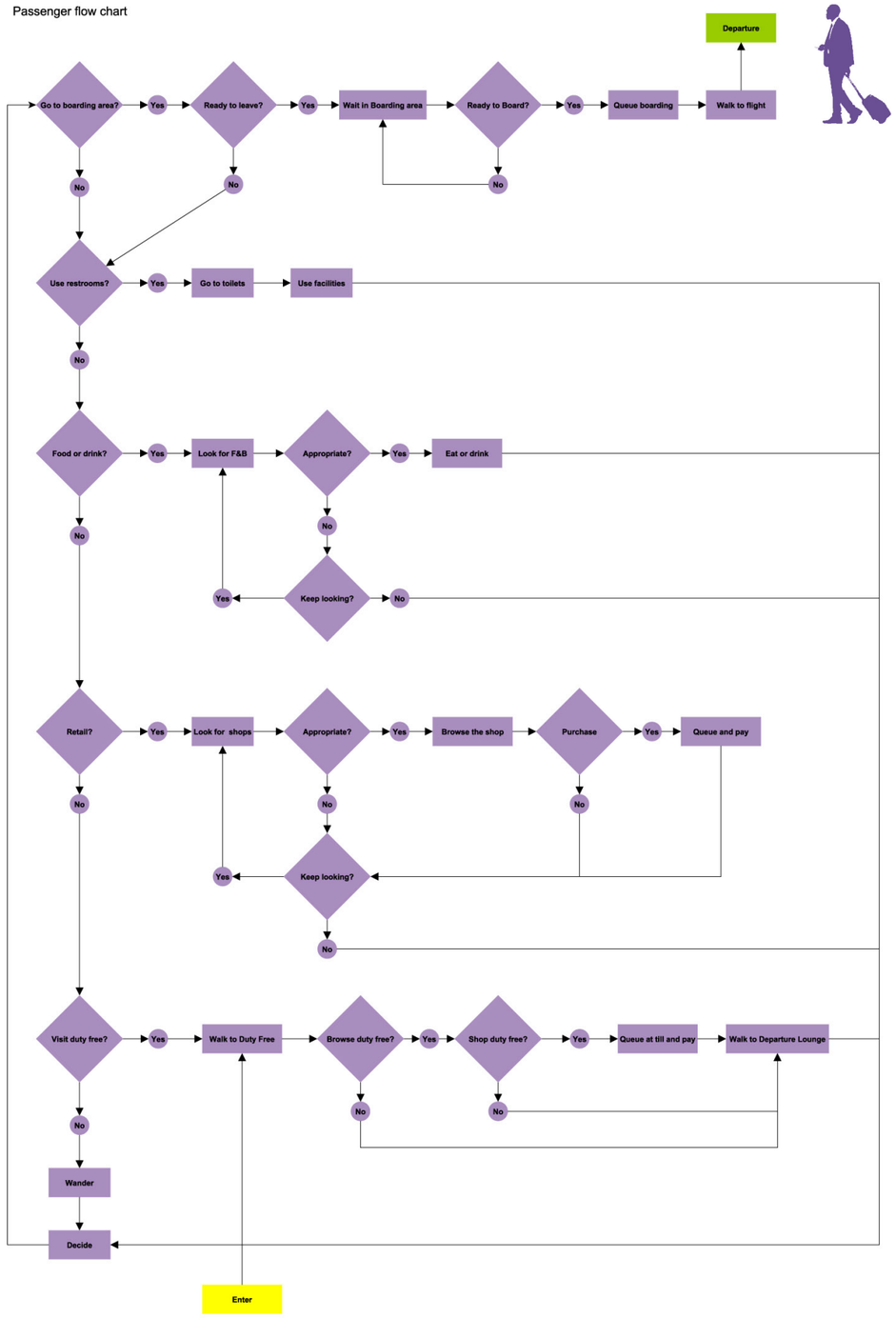


DESIGN SCHEME SPATIAL GRAPH AND PASSENGER DECISION PATHS

The image to the right is an example of a passenger journey flow chart. The individual journey is determined according to passenger type, generic behaviour, and spatial conditions. Diamond nodes represent individual decisions that the passenger can make. Round nodes represent potential outcomes of that decision (boolean yes | no), and rectangles represent action resulting from that decision. For each desision, an evaluation of the passenger profile and propensities is used to weight the best outcome.



DESIGN SCHEME VISIBILITY FROM GRAPH NODE LOCATIONS

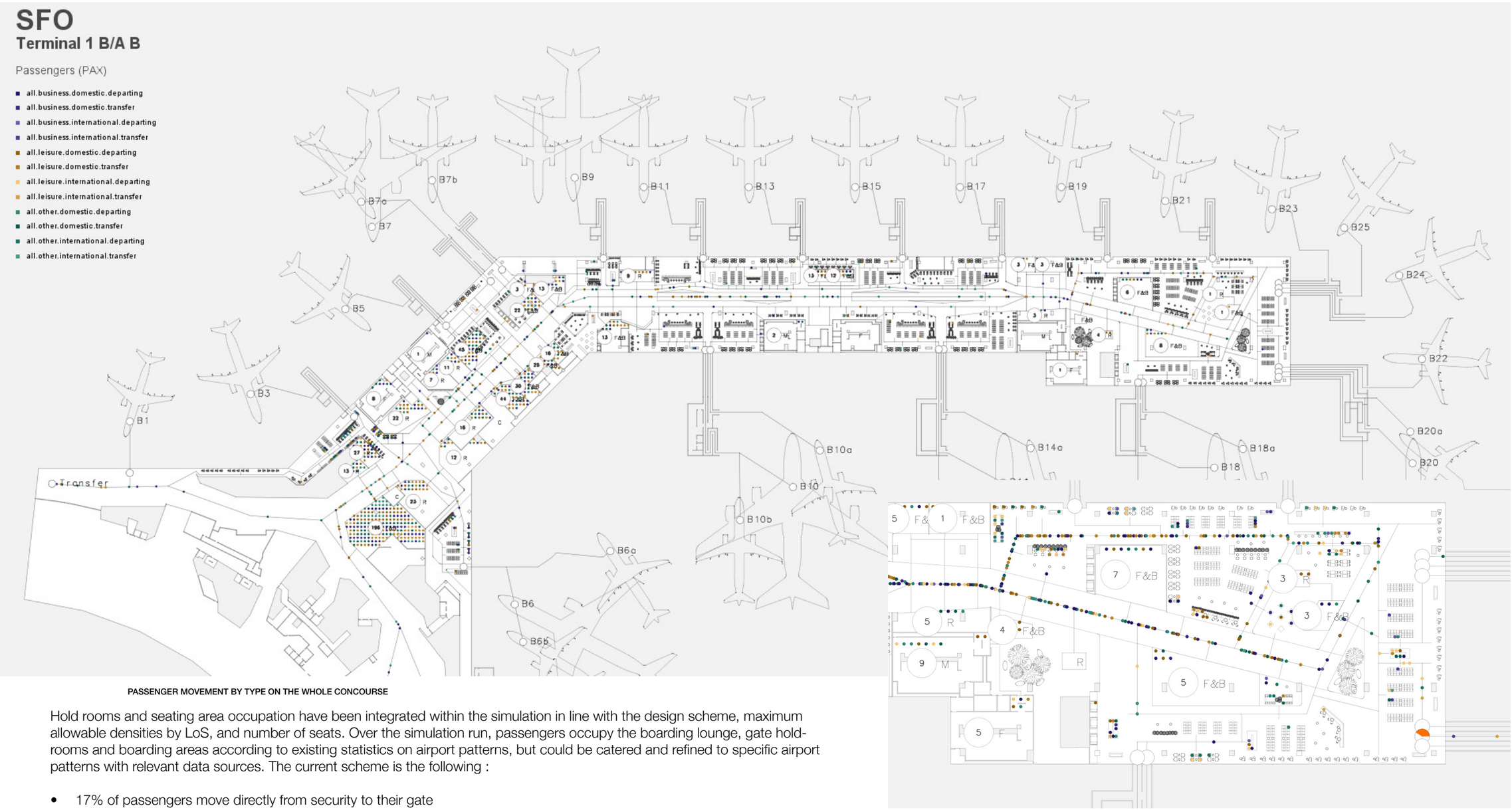


INTERNATIONAL.BUSINESS.DEPARTING JOURNEY FLOW CHART

PASSENGER SPATIAL SIMULATION

PASSENGER MOVEMENT

Passenger movement and spatial usage on the air-side of the design scheme can be visualized by passenger type and retail type. Propensities of different passengers towards different retail/FnB/concessions allows for a visualization of possible occupation patterns for a given gate scheme/design day flight schedule.



PASSENGER MOVEMENT BY TYPE ON THE WHOLE CONCOURSE

Hold rooms and seating area occupation have been integrated within the simulation in line with the design scheme, maximum allowable densities by LoS, and number of seats. Over the simulation run, passengers occupy the boarding lounge, gate holdrooms and boarding areas according to existing statistics on airport patterns, but could be catered and refined to specific airport patterns with relevant data sources. The current scheme is the following :

- 17% of passengers move directly from security to their gate
- 29-50% of passengers are at their gate 5 min prior to the first call for boarding

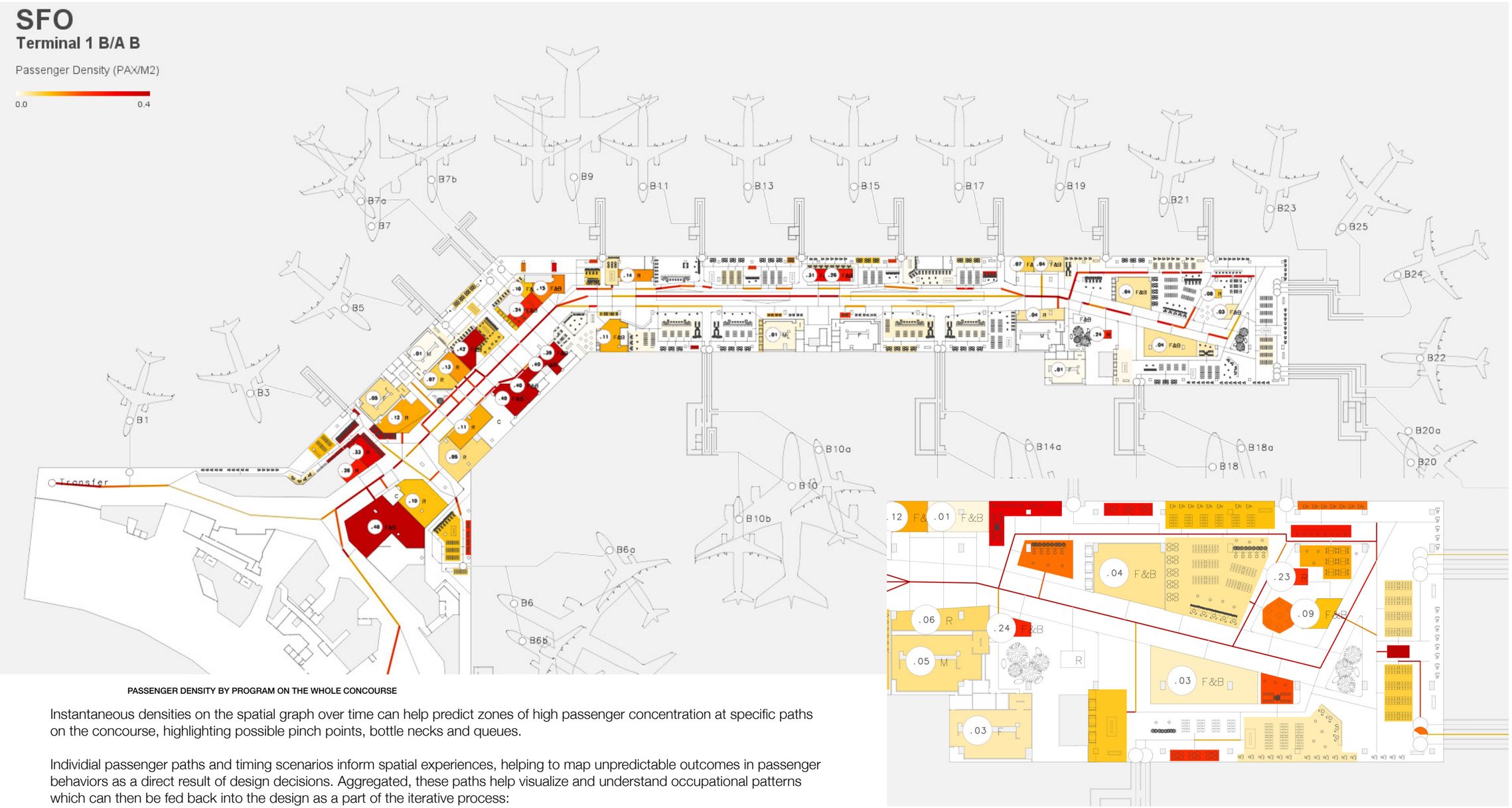
Residual passenger gate and boarding arrival rates are computed using a Weibull distribution. Passenger concession/bathroom and amenity usage are profile driven and based on type, propensity, location and remaining time until departure.

PASSENGER MOVEMENT BY TYPE ON THE END OF CONCOURSE

PASSENGER SPATIAL SIMULATION

PASSENGER DENSITY

Concession usage ouput statistics include total average and instantaneous values on passenger occupancy densities. By standard LoS measures of acceptable square footage per person, this is capped at a 0.4 persons per m2 during simulation. Average density per amenety can reflect adequate program sizing (seating, holdrooms, bathrooms), and inform retail and F&B placement optimization strategies.



PASSENGER DENSITY BY PROGRAM ON THE WHOLE CONCOURSE

PASSENGER DENSITY BY PROGRAM ON THE END OF CONCOURSE

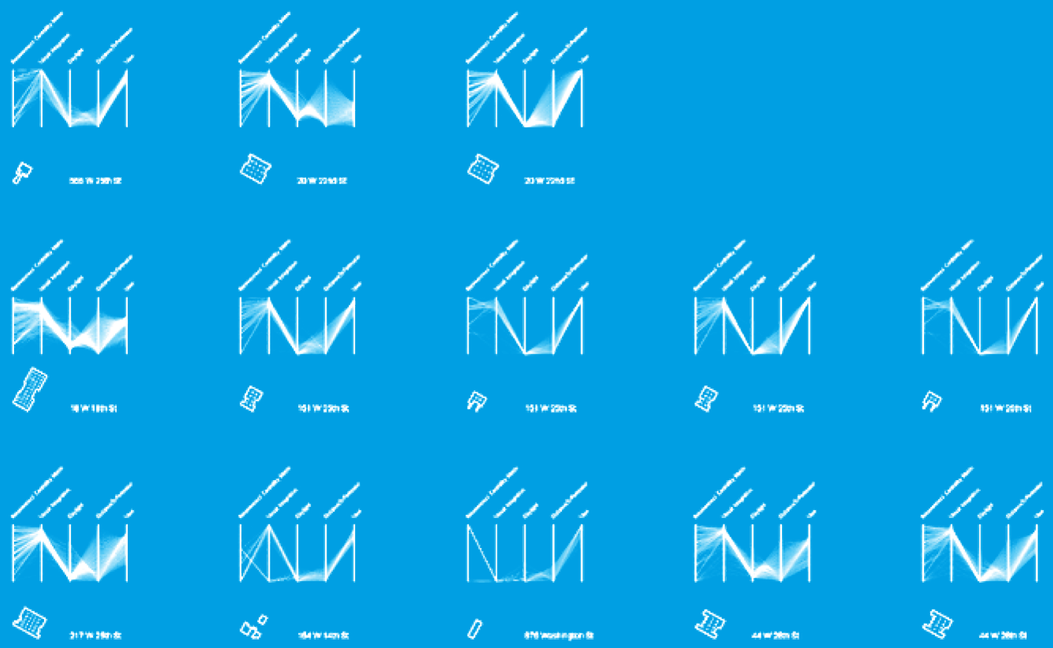
Instantaneous densities on the spatial graph over time can help predict zones of high passenger concentration at specific paths on the concourse, highlighting possible pinch points, bottle necks and queues.

Individial passenger paths and timing scenarios inform spatial experiences, helping to map unpredictable outcomes in passenger behaviors as a direct result of design decisions. Aggregated, these paths help visualize and understand occupational patterns which can then be fed back into the design as a part of the iterative process:

- Time spent at specific ammeneties by passenger/flight type
- Average/min/max distance covered
- Spatial experience in terms of visibility

04

Evaluation and Benchmarking



Post processing evaluation of the simulation data across multiple schemes can determine performative differences relative to changes in program.

Simulation output analysis for program elements builds a picture of the occupational changes for each element over the course of the design day. These changes can also be viewed by passenger type in order to build an understanding of the overall usage of the space for each type.

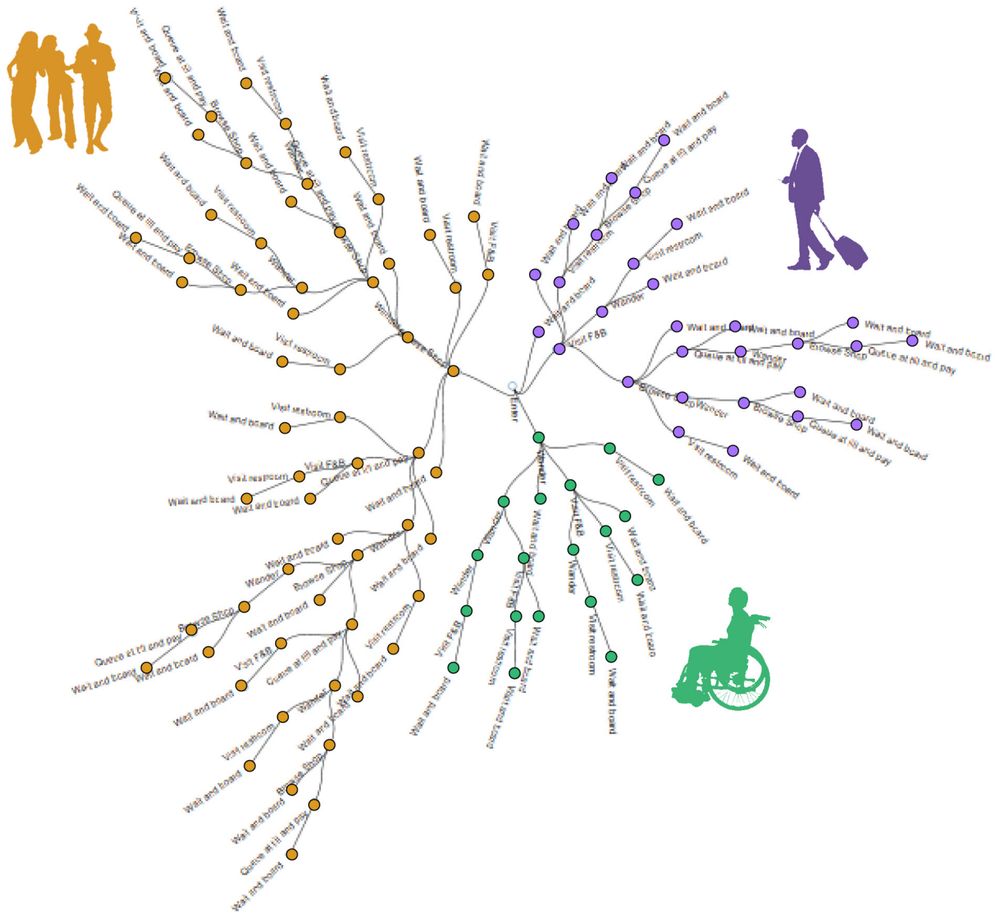
Benchmarking and comparing these discrepancies either within a scheme or between airports can further design goals by creating a set of reference points on which to optimize occupancy objectives.

EVALUATION AND BENCHMARKING

OUTPUT ANALYSIS

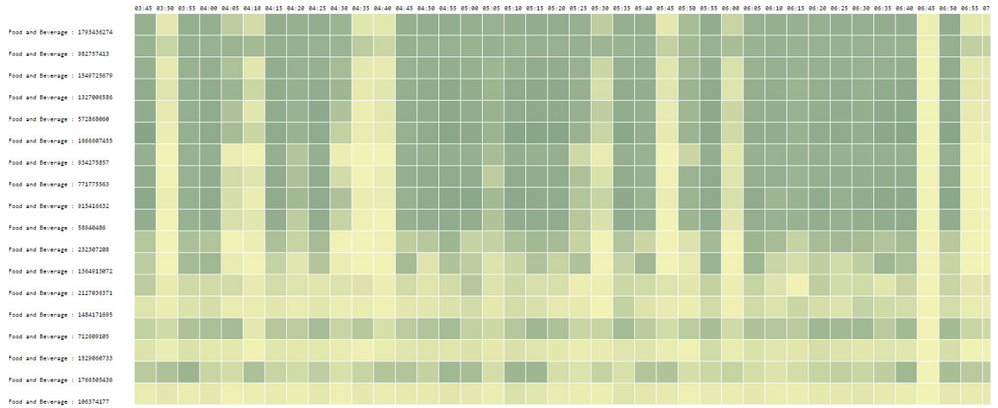
The passenger spatial simulation outputs a series of datasets regarding usage of the air-side spatial cofiguration that can be analyzed to identify the trends and occupation of each space. Spatial density is measured over time for any element of the program, including gate seating allocations, individual F&B and retail concessions, flow through gates and security. Minimum, Maximum and Mean values for each time interval are computed for all passenger types.

The resulting data infers trends in concession usage for all passenger types and relative to the spatial graph, resolving itself in a usage profile that can be modified to optimize for sizing, program placement and peak passenger density on any part of the concourse at a given time.

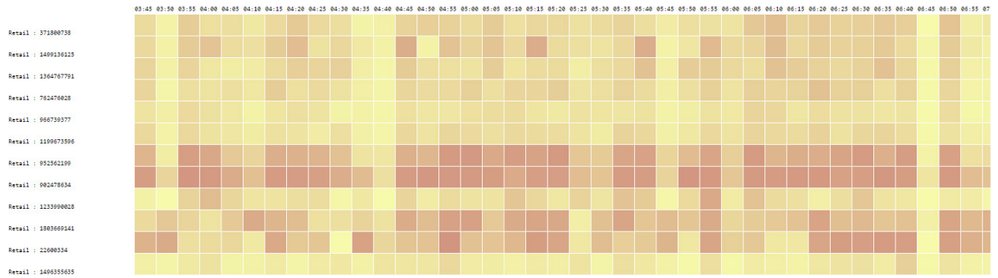


PASSENGER TYPE DECISION/JOURNEY TREE

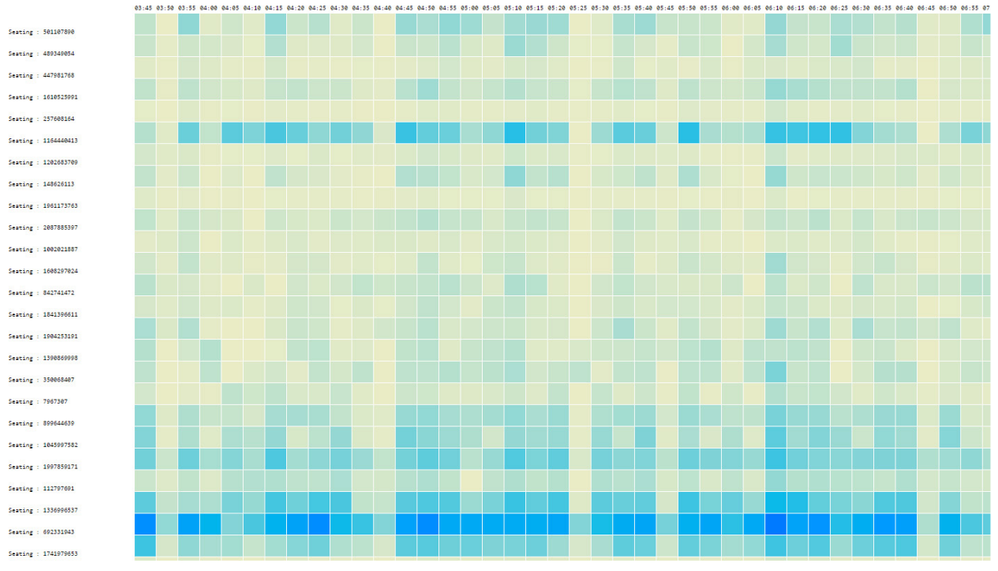
Journey information for each passenger is stored as a series of data points, which can be used to examine spatial usage by profile type across the entire design scheme. The propensities of passenger types tomake different decisions directly affects their journeys, and different profiles will occupy different features and concessions based on their location. The passenger journey tree above shows all possible combinations of decisions taken by various types over the course of a simulation.



PASSENGER FOOD AND BEVERAGE DENSITIES OVER TIME



PASSENGER RETAIL DENSITIES OVER TIME

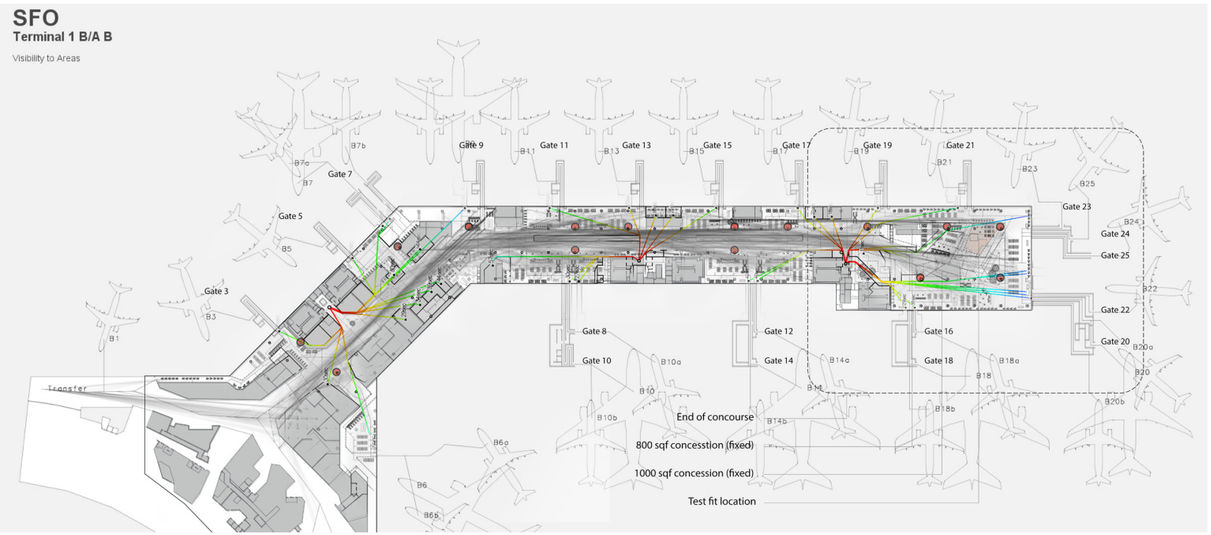


PASSENGER GATE SEATING DENSITIES OVER TIME

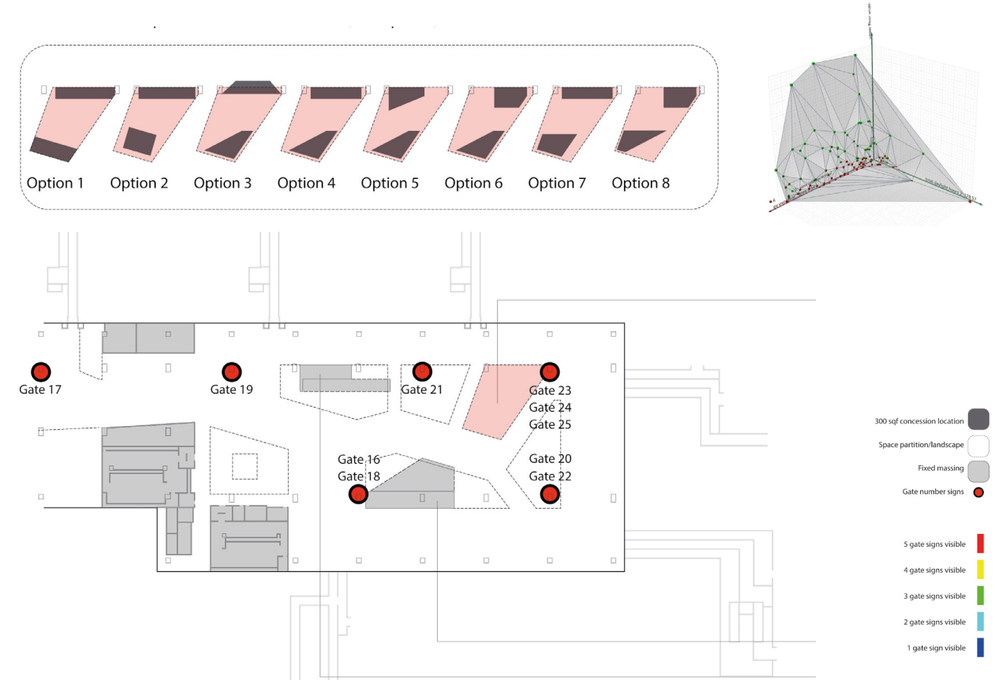
EVALUATION AND BENCHMARKING

OPTIMIZATION METRICS

Optimizing program location can be achieved through a recursive analysis of spatial conditions (e.g visbility, access, egress, distance to bathrooms) and/or simulation results (e.g. occupant density, estimated revenue). Single-objective optimization suggests a potential potential maximum fitness output within a test scope, without looking at the larger contextual model.

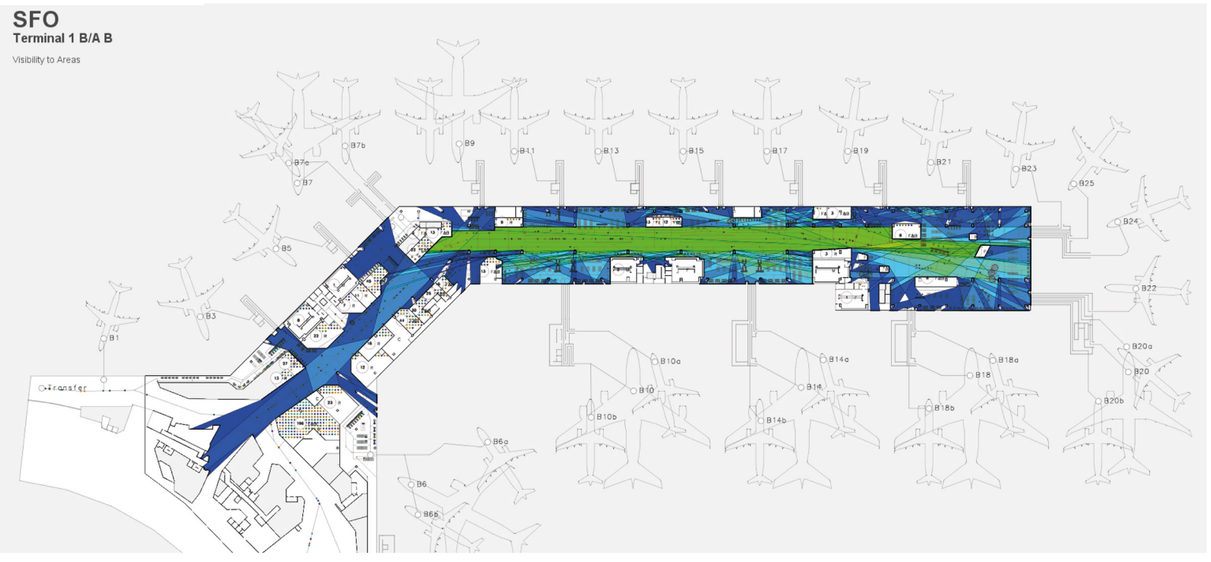


CONCOURSE WAYFINDING LOCATIONS AND SHORTEST DISTANCE PATHS FROM GATE TO NEAREST BATHROOM.

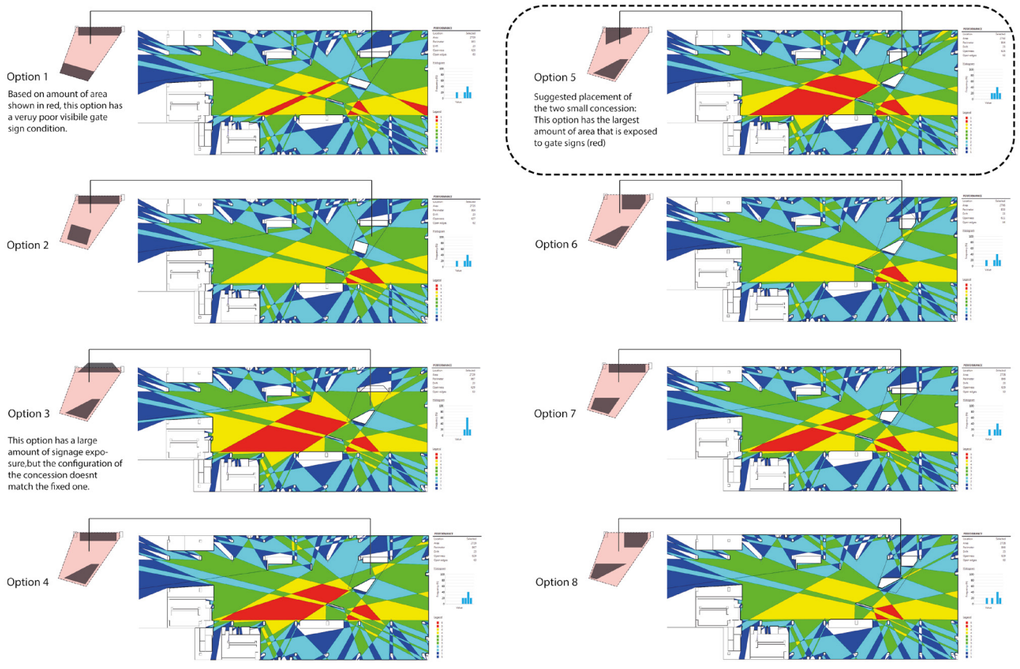


END OF CONCOURSE CONCESSION LOCATION OPTIMIZATION

Multi-objective optimization assumes and tracks the effects of every variable design parameter in the design space, and attempts to configure best case scenarios on a pareto front in the case of counter productive outcomes.(e.g. changes that benefit visibility may negatively effect egress and daylighting). Given appropriate constraints, both methods can highlight opportunities for data-drivent design decisions.



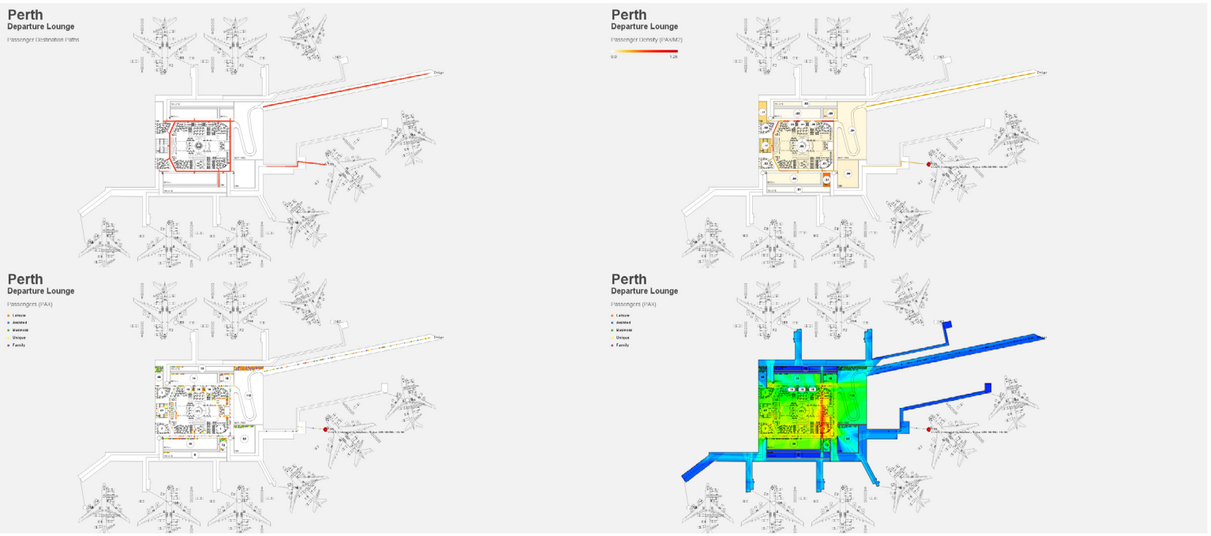
VISILITY FROM WAYFINDING LOCATIONS



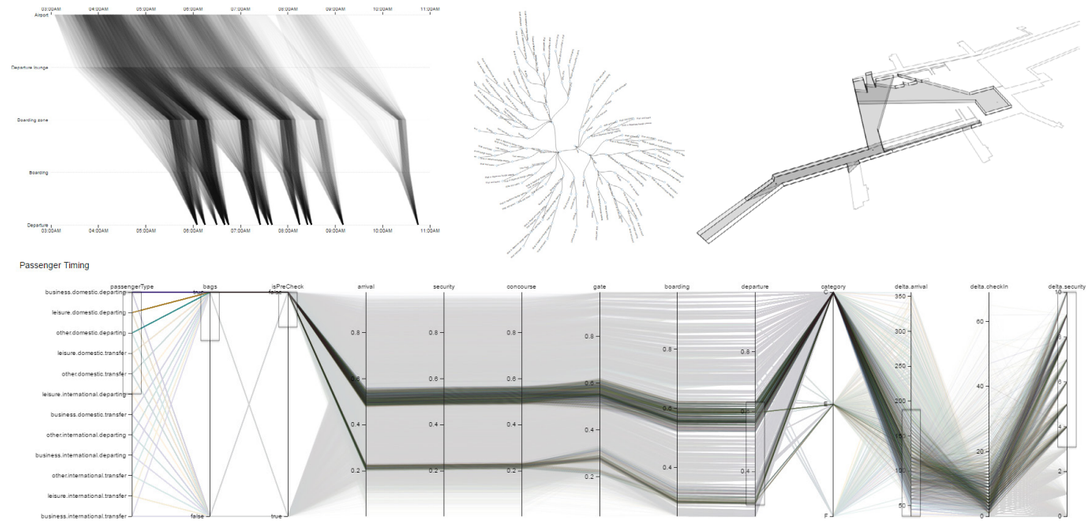
ISOVIST VIEWS TO WAYFINDING POINTS FOR POTENTIAL CONCESSIONS

EVALUATION AND BENCHMARKING
PERFORMANCE COMPARISON

Measuring output accross multiple airports can improve future design implementations by building a database of airport specific performance statistics and correlating them with their design schemes. Through machine learning algorithms, desired occupational patterns or spatial properties can be detected and quantifed, associating them with programmatic configurations.

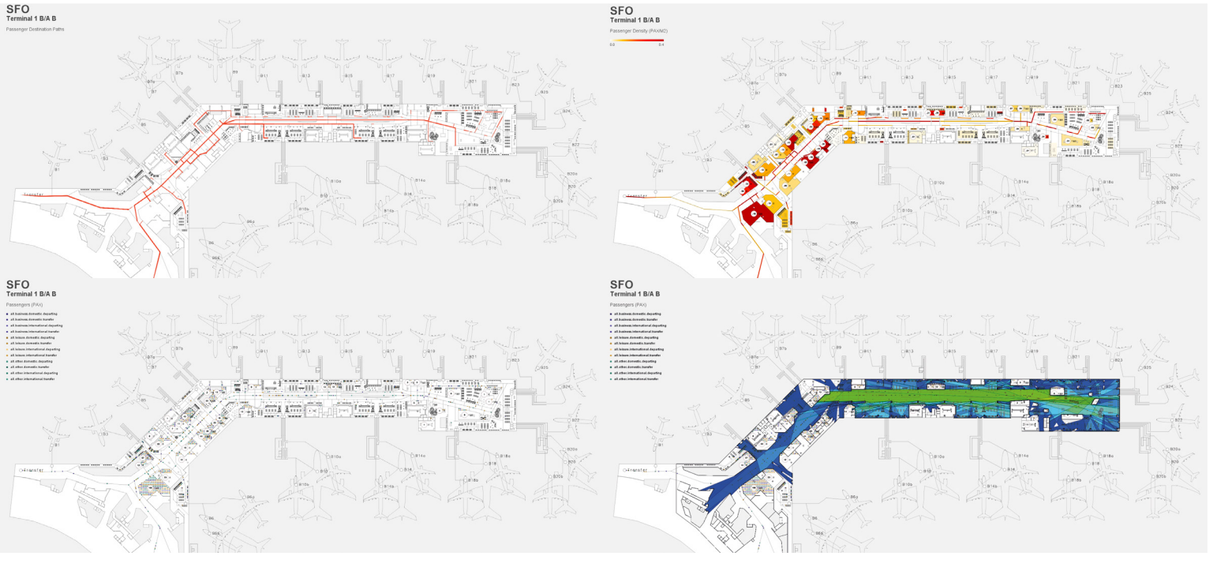


PERTH AIRPORT PASSENGER SPATIAL SIMULATION OUTPUT

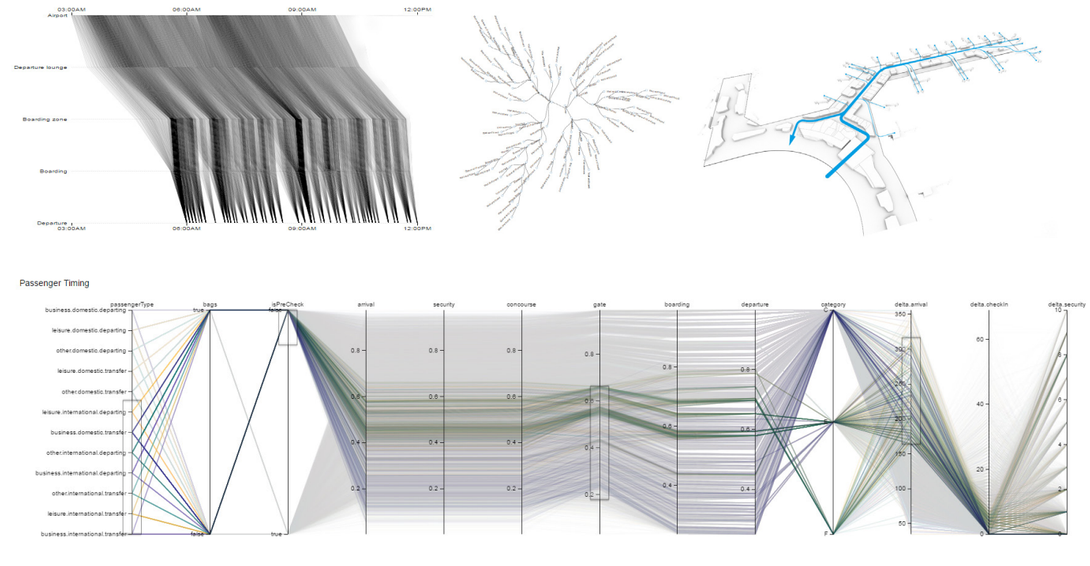


PERTH AIRPORT PASSENGER TIMING SIMULATION OUTPUT AND PASSENGER JOURNEY TREE

Rather than designing using assumptions about passenger experience and interaction with space, benchmarking occupational patterns allows them to be a generative parameter in design, similar to daylighting or visibility. Quantifying underlaying similarities accross multiple projects with ideal real world results can then be used to accurately replicate them on an as needed basis.



SAN FRANCISCO INTL AIPORT PASSENGER SPATIAL SIMULATION OUTPUT



SAN FRANCISCO INTL AIRPORT PASSENGER TIMING SIMULATION AND PASSENGER JOURNEY TREE

SAN FRANCISCO INTL. AIRPORT

TERMINAL 1 REDEVELOPMENT - BOARDING AREA B