MODELING PASSENGER AND BAGGAGE FLOW AT VANCOUVER AIRPORT

Mike Lazzaroni

Vancouver Airport Authority
3211 Grant McConachie Way
Richmond, BC V7B 1Y7, CANADA

ABSTRACT

The Vancouver Airport Authority developed a simulation model to analyze the flow of passengers and baggage that are arriving, departing, and connecting through Vancouver International Airport (YVR). The purpose of the simulation model is to assess demand at various process points, and in turn determine capacity requirements which meet defined service levels.

Using an extensive database of passenger and flight profiles, the model is designed to forecast passenger demand and determine capacity requirements using interchangeable flight schedules. Results from a custom report are to be used by various airport contractors including passenger screening, baggage handling, border protection agencies, and customer service.

This modeling approach is part of YVR's latest initiative named eYVR (efficient YVR), aimed at optimizing airport operations.

1   KEY DRIVERS

The following Vancouver Airport Authority corporate values were the key drivers at the heart of this project.

1.1   Collaboration and Teamwork

The Airport Authority sought input and ideas from appropriate stakeholders over the years. These include customs officials, security screeners, baggage handlers, and of course airline carriers. YVR recognized the importance in obtaining "buy-in" from all stakeholders, both internal and external, in order to make this project successful. Collaboration has been key in achieving corporate results.

1.2   Creativity

Alternative solutions were sought in order to improve upon the status quo. The airport business is constantly changing due to market demand, and adapting to it is the key in maintaining an excellent reputation. Striving for originality and creativity, issues were analyzed, technology was leveraged, and most importantly stakeholders have shown adaptability in managing change.

1.3   Accountability

A commitment to achieving results by optimizing airport operations was stated from the beginning. Allowing stakeholders to take ownership of various aspect of the project leads to a natural path of self-motivation. Accordingly, stakeholder feedback was engaged in order to establish trust, build realistic expectations, manage execution of the project, and of course provide the ability to make sound decisions.

Performance measures and targets were also published in the corporate business plan. These serve as targets by which the simulation results are measured.

1.4   Passion for Results

All stakeholders shared a common desire and passion to achieving results. At stake is the profitability of the business while maintaining or improving service levels at world-class levels. Successful projects rarely occur by accident and without a great deal of passion. Rather, passion is the fuel that motivates one to keep striving for solutions to a problem.

2   MODELING APPROACH

Simio[TM] modeling software was used to simulate the model, while Excel along with VBA automation was used for reporting the results. AutoCAD[TM] drawings of the various termination levels were imported into Simio as bitmap images to provide working backgrounds for the model. Images, such as the one in Figure 1, were then scaled and calibrated appropriately in order for walking distances to be accurately calculated.
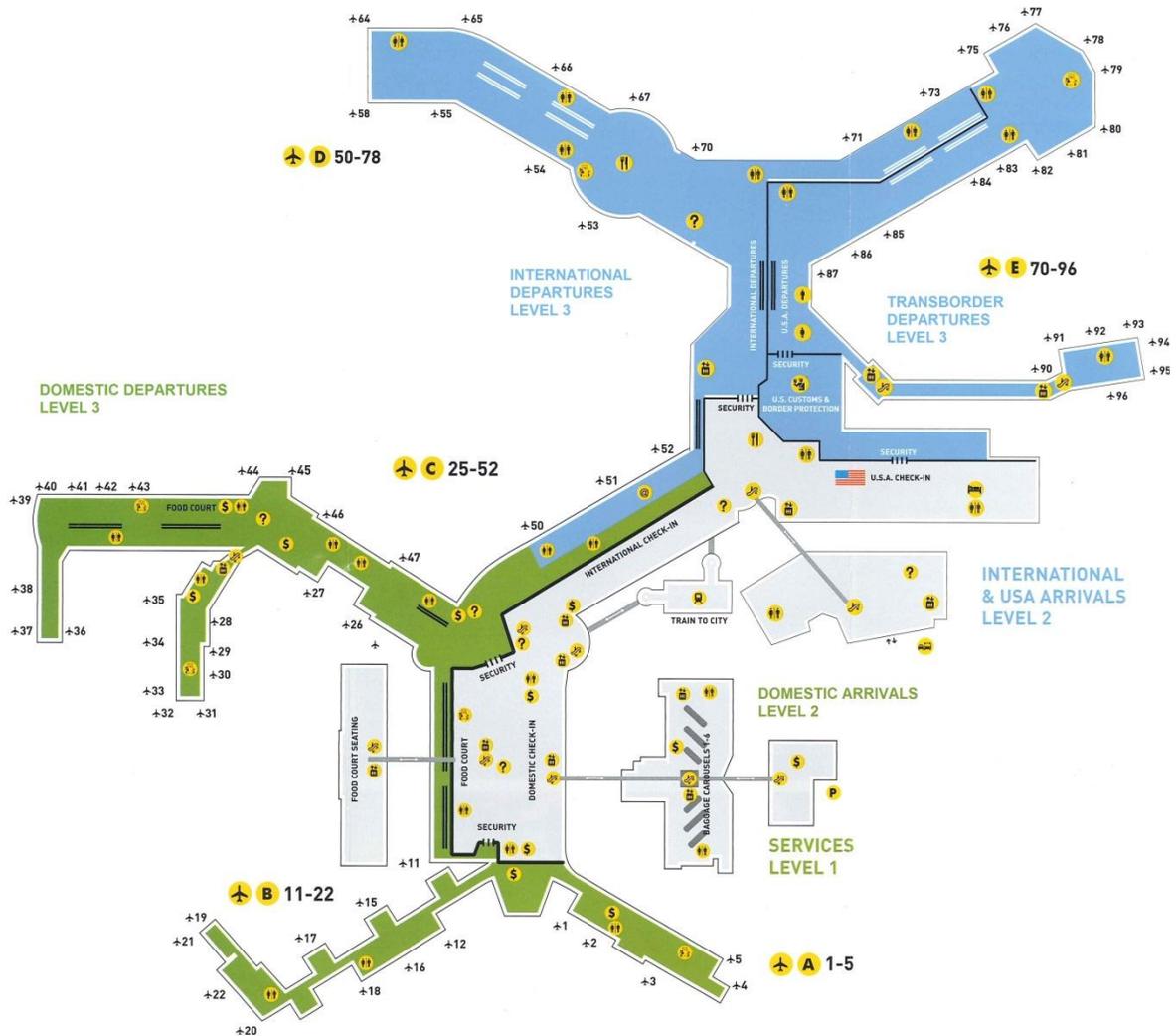

Figure 1: Airport Layout

3 MODELED PROCESSES

Key processes such as check-in, security screening, customs declaration, and baggage claim were modeled for all arriving and departing flights as shown in Figure 2. These are by no means exhaustive, but meant to provide an overall snapshot and interaction between sectors.
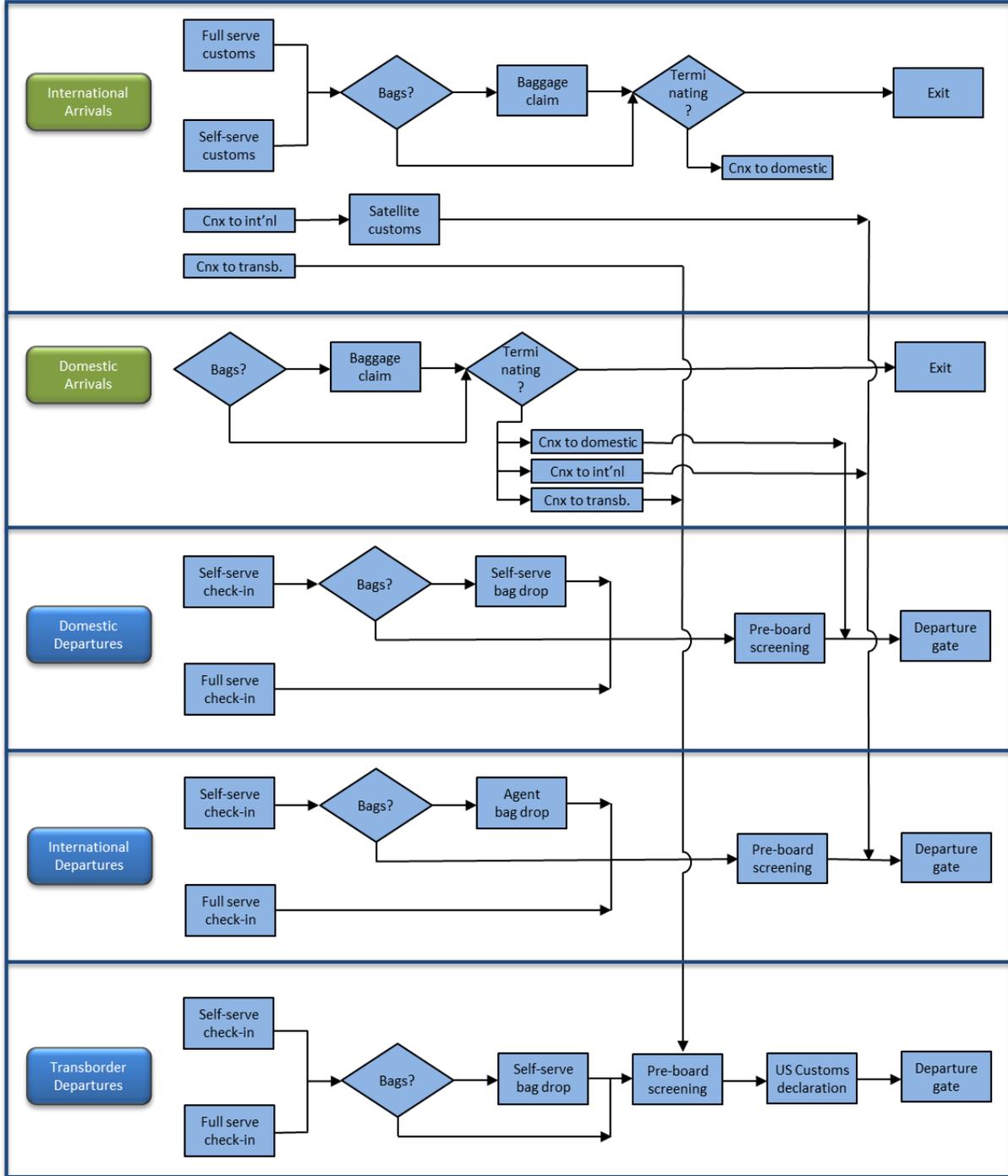

Figure 2: Modeled processes

4   GENERATION OF PASSENGER AND BAGGAGE ENTITIES

4.1   Flight Schedule

The flight schedule in Figure 3 lists all the arriving and departing flights as identified as "A" or "D" in the "Leg" field. It also consists of 3 sectors: domestic (D), international (I), and transborder (T). The latter sector consists of flights from Vancouver to the United States of America.

Load factors represent the percentage of the aircraft seats that are occupied. A 90% load factor on a 100-seat aircraft, for instance, results in the presence of 90 passengers. Where these passengers are introduced in the model however, depends on individual connecting rates. The last three fields in Figure 3 indicate the following connecting rates: Domestic (DomCnx), International (IntCnx), and Transborder (TBCnx).

DateTime	Flt No	Leg	Sector	Carrier	Via 1	Actype	Gate	Seats	LF	DomCnx	IntCnx	TbCnx
8/17/12 0:58	XY151	D	D	XY	YYZ	319	42	100	90.0%	20.0%	10.0%	5.0%
8/17/12 5:49	XY8050	A	D	XY	YYJ	DH3	41	50	85.0%	57.2%	17.3%	7.4%
8/17/12 6:00	XY136	D	D	XY	YYZ	319	37	120	87.0%	10.1%	5.9%	2.2%
8/17/12 6:20	AB8190	D	D	AB	YKA	DH3	35	50	100.0%	58.0%	9.7%	4.3%
8/17/12 6:22	XY8410	A	D	XY	YCD	DH3	22	50	100.0%	85.8%	4.4%	2.4%
8/17/12 6:25	XY201	A	D	XY	YYC	E90	16	93	92.5%	13.3%	22.0%	5.9%
8/17/12 6:53	XY233	A	D	XY	YEG	E90	21	93	94.0%	17.1%	27.7%	6.9%
8/17/12 6:53	5Y8411	A	D	5Y	YLW	DH3	44	50	84.0%	52.0%	10.0%	6.5%
8/17/12 6:53	XY8189	A	D	XY	YKA	DH3	20	50	45.0%	58.0%	9.7%	4.3%
8/17/12 6:55	3M8351	A	D	3M	YYF	DH3	26	50	75.0%	54.5%	5.4%	7.7%
8/17/12 7:00	XY8410	D	D	XY	YLW	DH3	24	50	88.0%	52.0%	10.0%	6.5%
8/17/12 7:00	XY232	D	D	XY	YEG	E90	23	93	100.0%	17.1%	27.7%	6.9%
8/17/12 7:00	XY202	D	D	XY	YYC	E90	11	93	100.0%	13.3%	22.0%	5.9%
8/17/12 7:00	XY108	D	D	XY	YYZ	320	146	146	100.0%	10.1%	5.9%	2.2%
8/17/12 7:00	XZ586	D	D	XZ	YYZ	73H	4	166	81.8%	3.2%	1.4%	2.1%
8/17/12 7:00	6Z230	A	D	6Z	YQQ	BE1	22	18	81.9%	61.5%	3.8%	4.1%

Figure 3: Flight Schedule (note that carrier names are fictitious to preserve confidential data)

The first flight in this schedule indicates 100 seats with a load factor of 90%. The passenger load is calculated as follows and resulting in 90 passengers:

$$Passenger\ Load = Seats\ x\ LF$$

Of the 90 passengers, the model needs to distribute them among originating at check-in (in this case, for a departure flight), and connecting from one of the domestic, international, and transborder sectors using the following formulas

$$Originating\ Passenger\ Load = Seats\ x\ LF\ x\ (1 - DomCnx - IntCnx - TBCnx)$$
$$Domestic\ Connecting\ Passengers = Seats\ x\ LF\ x\ DomCnx$$
$$International\ Connecting\ Passengers = Seats\ x\ LF\ x\ IntCnx$$
$$Transborder\ Connecting\ Passengers = Seats\ x\ LF\ x\ TBCnx$$

In the above example, the model generates 59 originating passengers at check-in, 18 passengers connecting from a domestic flight, 9 passengers connecting from an international flight, and 4 passengers connecting from a transborder flight.

4.2   Connecting Rates

Connecting rates play a large role in determining the distribution of passengers at various points in the terminal. Furthermore, connecting passengers require less terminal processing upon arrival and depar-

ture. Generally upon arrival from a flight, connecting passengers can simply proceed to their departing gates rather than queue up for check-in at the departure concourse. Connecting baggage might also be transferred from one aircraft to another, without ever entering the terminal or using baggage conveyors.

Figure 4 shows connecting rates to and from various destinations for a given carrier. The actual destination names have been replaced with fictitious names to conceal sensitive carrier-specific market data.

Domestic Connecting Rates	2011-01	2011-02	2011-03	2011-04	2011-05	2011-06	2011-07	2011-08	2011-09	2011-10	2011-11	2011-12
6M - Air Ease												
6M - Greenview (YAA)	86.4%	88.1%	86.9%	92.2%	91.9%	90.9%	91.6%	92.7%	91.8%	90.2%	88.0%	90.2%
Domestic	74.5%	76.0%	71.8%	81.3%	82.5%	82.7%	84.8%	85.8%	81.4%	79.4%	77.8%	82.1%
International	5.9%	3.6%	5.5%	4.8%	4.2%	5.0%	3.8%	4.4%	7.0%	5.2%	4.3%	3.7%
Transborder	6.0%	8.5%	9.6%	6.1%	5.3%	3.3%	3.0%	2.4%	3.4%	5.5%	5.8%	4.4%
6M - Eden Falls (YBB)	32.1%	37.0%	32.4%	33.4%	41.0%	44.8%	47.2%	49.7%	48.3%	41.7%	33.8%	36.8%
Domestic	29.6%	32.6%	28.9%	27.8%	35.5%	39.2%	43.0%	45.0%	40.9%	36.5%	30.7%	33.6%
International	2.5%	2.6%	1.8%	3.1%	3.6%	4.1%	2.7%	3.7%	6.1%	3.3%	0.9%	2.5%
Transborder		1.7%	1.7%	2.5%	1.9%	1.5%	1.5%	1.1%	1.3%	1.8%	2.2%	0.7%
6M - Greendale (YCC)	58.3%	59.9%	57.3%	62.2%	50.1%	48.8%	47.5%	51.8%	46.8%	49.8%	51.7%	50.5%
Domestic	15.5%	13.3%	14.6%	14.1%	14.5%	14.7%	16.3%	17.1%	15.8%	17.0%	15.5%	20.3%
International	25.2%	23.6%	24.1%	24.3%	26.2%	27.4%	23.0%	27.7%	24.5%	23.4%	23.1%	21.5%
Transborder	17.7%	22.9%	18.6%	23.8%	9.5%	6.7%	8.1%	6.9%	6.5%	9.4%	13.2%	8.8%
6M - Flora (YDD)	54.6%	59.4%	57.6%	64.9%	66.5%	68.2%	72.9%	72.0%	69.2%	68.6%	59.3%	61.6%
Domestic	31.8%	37.6%	39.6%	47.2%	53.9%	57.5%	60.0%	58.0%	54.5%	55.6%	43.6%	47.0%
International	11.8%	7.9%	6.2%	5.6%	5.7%	5.6%	6.2%	9.7%	9.1%	6.2%	6.3%	7.2%
Transborder	11.0%	13.9%	11.8%	12.1%	6.9%	5.2%	6.7%	4.3%	5.6%	6.7%	9.3%	7.4%
6M - Roxborough (YEE)	58.4%	60.3%	63.0%	65.7%	62.2%	62.9%	67.8%	68.5%	61.5%	61.5%	55.5%	59.9%
Domestic	30.0%	32.3%	34.0%	37.7%	44.4%	45.6%	50.3%	52.0%	44.7%	44.5%	37.2%	41.3%
International	14.8%	12.0%	12.4%	10.4%	10.2%	11.5%	11.3%	10.0%	10.5%	9.2%	9.3%	11.4%
Transborder	13.5%	15.9%	16.6%	17.5%	7.5%	5.7%	6.2%	6.5%	6.3%	7.8%	9.1%	7.1%

Figure 4: Connecting Rates (with fictitious destinations)

4.3 Baggage Rate Distributions

Weighing heavily in the infrastructure needs of airports is the handling of checked baggage. Behind the scenes and out of sight of the travelling public is a maze of baggage conveyors, which not only move baggage from one part of the terminal to another, but also convey them in and out of security screening devices. Ensuring that baggage is delivered in a timely fashion is essential to the success of an airport.

The amount of check baggage has a direct impact on process times and capacity requirements. The check-in process for instance, is accelerated in the absence of checked baggage. Passengers need simply obtain boarding cards and forego the process of having their bags registered, tagged, and inducted on baggage conveyors. However, the absence of checked baggage usually translates in the presence of additional carry-on baggage. This will in turn slow down the passenger screening process at pre-board screening.

Given the importance of baggage modeling in assessing capacity requirements, detailed historical data was obtained to determine the precise amount of baggage per passenger. This amount varies greatly by sector and by type of passenger (for example, originating versus connecting). Short-haul passengers who fly domestically for instance, are less prone to checking in baggage than those who fly internationally. Accordingly, the average number of baggage checked in by domestic passengers is much lower than for international passengers.

Figure 5 below indicates ratios of baggage per passenger, sorted by sector and passenger type. These were computed by dividing the total amount of baggage by the total amount of passengers. It must be noted that ratio includes passengers with no baggage.

5

Vancouver International Airport Bags per Passenger Ratios				
Sector	0 Bags	1 Bag	2 Bags	Ratio Bags/Pax
Domestic				
Originating	25.0%	54.0%	21.0%	0.96
Connecting from Domestic	25.0%	55.0%	20.0%	0.95
Connecting from International	25.0%	17.0%	58.0%	1.33
Connecting from Transborder	25.0%	57.0%	18.0%	0.93
International				
Originating	25.0%	9.0%	66.0%	1.41
Connecting from Domestic	25.0%	23.0%	52.0%	1.27
Connecting from International	25.0%	17.0%	58.0%	1.33
Connecting from Transborder	25.0%	27.0%	48.0%	1.23
Transborder				
Originating	25.0%	51.0%	24.0%	0.99
Connecting from Domestic	25.0%	61.0%	14.0%	0.89
Connecting from International	25.0%	36.0%	39.0%	1.14
Connecting from Transborder	25.0%	37.0%	38.0%	1.13

Figure 5: Baggage Ratios

The remainder 75% of passengers that have checked baggage, are then distributed among those that have 1 bag and those who have 2. Overall, the ratio of baggage per passenger is computed as follows:

$$Ratio\ of\ baggage\ per\ passenger = (Perc\ of\ passengers\ with\ 1\ bag) + (2\ x\ Perc\ of\ passengers\ with\ 2\ bags)$$

4.4 Passenger Arrival Distributions

The generation of passengers and baggage for departing sectors is based on sector specific distributions of passenger arrivals at the airport. Certain factors will determine how early passengers arrive at the airport, such as self-service versus full-service check-in. Furthermore, some passengers might check-in online prior to arriving at the airport, and may not require any baggage to be tagged. In such cases, these passengers will tend to arrive closer to departure time.

Accordingly, passengers departing on a 1:00 p.m. domestic flight are likely to arrive on average 70 minutes prior to departure. On the other hand, the passenger arrival times prior to departure are 100 minutes for those departing on an international flight and 120 minutes for those on a transborder flight.

The transborder sector with its pre-clearance process, requires passengers to arrive at the airport earlier. Departing from Vancouver to the United States, passengers undergo a US Customs and Border Protection inspection prior to their flight. Upon arrival in the United States, passengers deplane and proceed as if arriving on a domestic flight.

The following are some factors to be considered when determining passenger arrival time at the airport:

- Departing sector
- Number of bags, if any
- Type of check-in (web, self-serve kiosk, agent)
- Time of day

5   SUMMARY MODELING RESULTS

5.1   Business Plan Targets and Results

Simulation results, as shown in Figure 6, are rated against performance targets established in the annual Vancouver Airport Authority Business Plan. These results allow management to track its business plan progress against a number of measurable targets. The success rate is a measure of the percentage of passengers completing a segment with the allotted time, as defined by its level of service.

Segment	Target	Simulation Results				
			Cycle Times			Success
		Total Pax	Min.	Avr.	Max.	Rate
Arrivals (Destined)						
Domestic Arrivals	30 min.	11269	0:05:10	0:07:42	0:10:13	100.0%
International Arrivals	45 min.	14582	0:05:50	0:33:44	1:05:13	84.2%
Departures (Originating)						
Domestic Departure	30 min.	10784	0:03:45	0:12:05	0:31:08	99.9%
International Departure	40 min.	7465	0:09:47	0:21:38	0:43:31	97.8%
Transborder Departure	75 min.	7087	0:10:09	0:24:33	0:31:25	100.0%
Connections						
Domestic to International	15 min.	1410	0:09:00	0:10:56	0:13:29	100.0%
Domestic to Transborder	10 min.	703	0:10:19	0:15:12	4:14:49	0.0%
International to International	10 min.	33	0:04:00	0:04:00	0:04:00	100.0%
International to Transborder	15 min.	165	0:08:04	0:12:47	0:16:38	90.3%
Int'nl/Transborder to Domestic	75 min.	1738	0:26:10	0:55:31	1:33:52	93.2%
Transborder to International	15 min.	276	0:04:00	0:04:00	0:04:00	100.0%

Figure 6: Business plan targets and results

5.2   Process Results

Figure 7 indicates detailed modeling results for individual processes. Given a defined amount of available resources (i.e. check-in desk, check-in kiosks, pre-board screening lanes, etc.) and a desired level of service (LOS) with stated maximum wait times, the model will determine the optimal amount of resources required during the entire simulation period.

Process results indicate the following:
- Utilized resources required to meet the LOS
- Wait times (average, maximum, and standard deviation)
- Queue lengths
- Periods of time above the LOS threshold
- Success rate.

The success rate is a measure of the percentage of passengers completing a process within an allotted time, as defined in a level of service.

Resource	Available Resources	Wait Time Threshold (min)	Utilized Resources		Actual Wait Times			Maximum QL	Minutes above Threshold	Success Rate
			Avr *	Max	Avr *	Std Dev *	Max			
International Arrivals										
ABC Kiosks	12	1	2.6	10	0:00:00	0:00:00	0:00:00	0	0	100%
DVO	3	1	1.0	1	0:00:03	0:00:05	0:00:27	1	0	100%
RR PIL Agents	10	15	6.2	10	0:15:00	0:09:29	0:42:02	400	327	77%
Vis PIL Agents	12	15	7.2	12	0:16:16	0:10:51	0:43:57	471	355	75%
Domestic Departures										
North bag drops	3	2	1.3	3	0:01:02	0:00:37	0:02:21	19	25	98%
South bag drops	2	2	1.1	2	0:00:32	0:00:35	0:02:28	15	10	99%
North PBS	8	5	3.5	7	0:03:34	0:00:39	0:05:25	46	2	100%
South PBS	5	5	3.1	5	0:05:03	0:05:17	0:24:16	202	155	89%
International Departures										
PBS	8	5	5.2	8	0:07:54	0:07:27	0:27:57	190	200	86%
Transborder Departures										
Bag drops	4	2	1.2	4	0:00:33	0:00:23	0:01:20	20	0	100%
PBS	10	5	4.2	10	0:03:40	0:00:39	0:05:16	87	5	100%
US CBP	15	10	5.8	14	0:08:10	0:00:54	0:10:18	148	11	99%
Int'nl and Domestic to Transborder (ITPCF)										
PBS	2	5	1.0	2	0:00:37	0:00:59	0:04:23	12	0	100%
US CBP	3	10	1.2	2	0:00:15	0:00:39	0:03:15	8	0	100%

Figure 7: Process results

6   DEMAND GRAPHS

Passenger and baggage demand graphs are generated at the following process points
- Check-in
- Self-serve baggage drop
- Passenger screening (PBS)
- Baggage claim
- Customs
- Transit points
- Inbound baggage induction

Demand is measured as a rolling rate in term of entities per time unit, and updated every minute. Depending on the type of entity, demand is measured in passengers per hour, passengers per 15 minutes, baggage per 15 minutes, or baggage per minute.

The demand needs to also be segmented by its originating points. The domestic departures passenger demand in Figure 8 for instance, indicates demand for passengers that are originating and those that are connecting from the domestic, international, and transborder sectors. Of interest, for the purpose of proving adequate check-in capacity, is the originating demand. That is why the original demand is emphasized in 3d with a bright color, while the connecting demand is in 2d with muted gray colors.
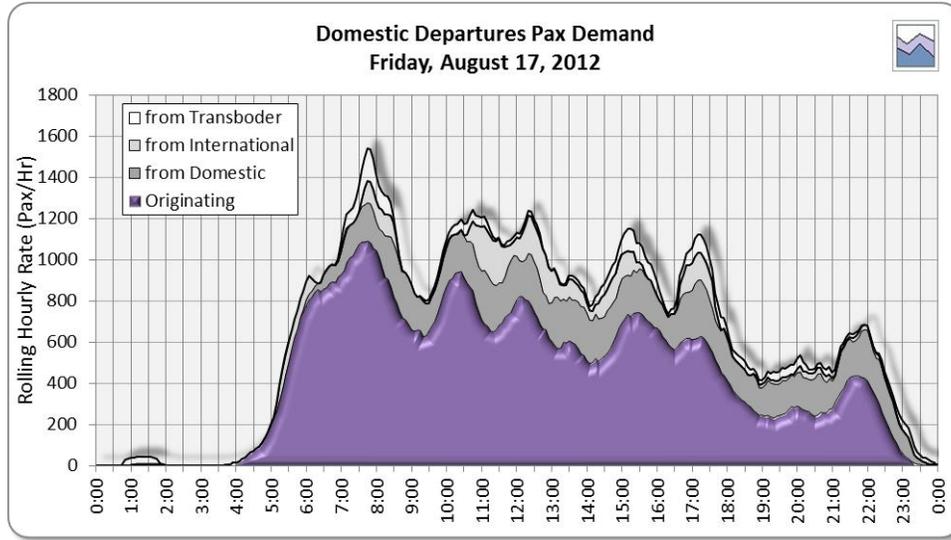
Figure 8: Typical Passenger Demand Graph

7   CAPACITY REQUIREMENTS

The capacity requirement graphs indicate needed resources for attaining the chosen level of service (LOS) thresholds.   Resource availability however, is capped and may not be sufficient to deliver the chosen LOS. In Figure 9 below for example, the graph indicates the amount of lanes required to process returning residents at the customs primary inspection line (PIL).

Model inputs specified 10 available lanes for the processing of returning residents at PIL, with a desired level of service with wait times not exceeding 15 minutes. The model adjusts capacity requirements throughout the day in order to ensure that the level of service is met. At approximately 11:00 however, the model sets capacity at 10 lanes and maintains that level for over 3 hours. It cannot increase capacity due to the stated limitations. As we will see further, service levels will not be met during this period.
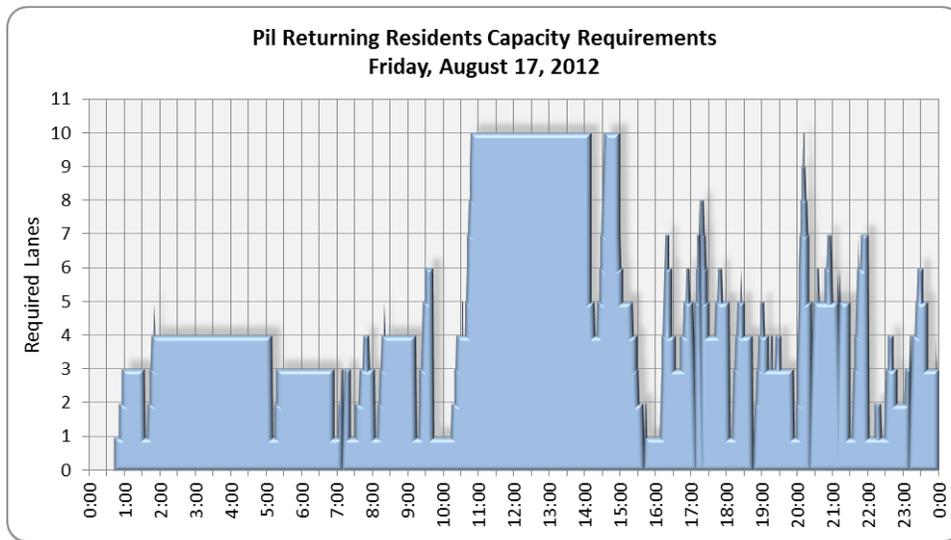
Figure 9: Typical Capacity Requirement Graph

8   WAIT TIMES AND QUEUE LENGTHS

Wait times are measured from the moment entities enter a process queue to the moment processing begins. In the case of a long snaking queuing area, wait time calculations do not begin when entities enter the queue but rather when they encounter blockage.

Following the example in the previous section, we established a level of service with wait times of less than 15 minutes for returning residents processed at the primary inspection line (PIL). As previously noted however, maximum available capacity is 10 lanes for the processing of returning residents. Given that demand exceeded capacity for a substantial period of time, we see in Figure 10 that wait times have exceeded the 15 minute level of service threshold.

Wait times which exceed LOS thresholds are not always detrimental. One needs to evaluation the duration in which this occurs. The nature of the airport business is such that it would not always be cost-effective to provide adequate capacity to meet temporary demand surges occurring at peak periods. Surges are often followed by a sudden drops in demand along with recovering levels of service. Figure 10 however, suggests that a deterioration in the level service above the 15-minute threshold is lasting for an extended period. Future iterations will be required to determine the ultimate amount of lanes to meet the level of service.
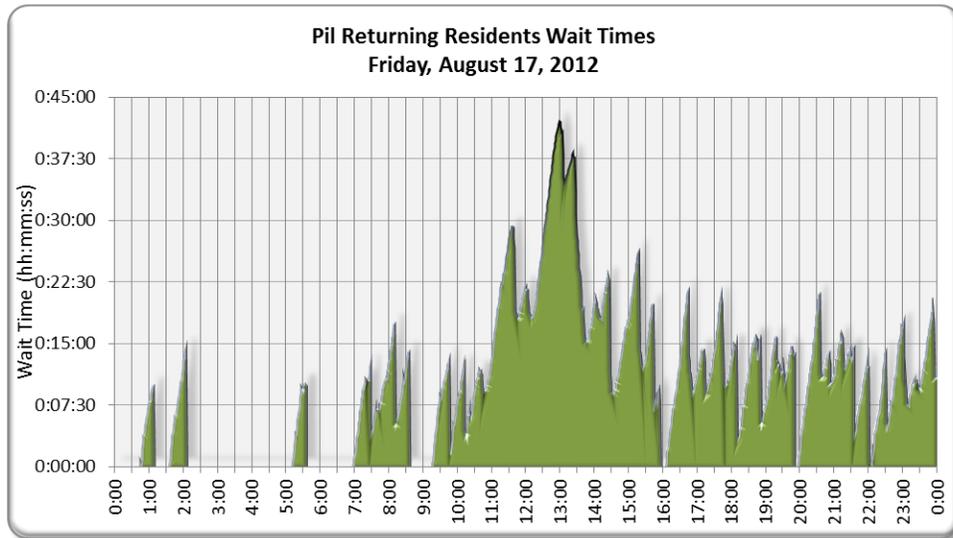
Figure 10: Typical Wait Time Graph

Another factor in determining adequate capacity is the generated queue length. Although it may be deemed acceptable for wait times to exceed a desired level of service, albeit momentarily, the physical queuing space might not be able to accommodate the amount of queued passengers. Figure 11 indicates a queue length of approximately 580 passengers shortly after 12:00.

In such cases, facility managers need to assess whether to incur additional manpower costs, to increase processing capacity, or make capital investments to expand the facility in order to accommodate queued passengers.
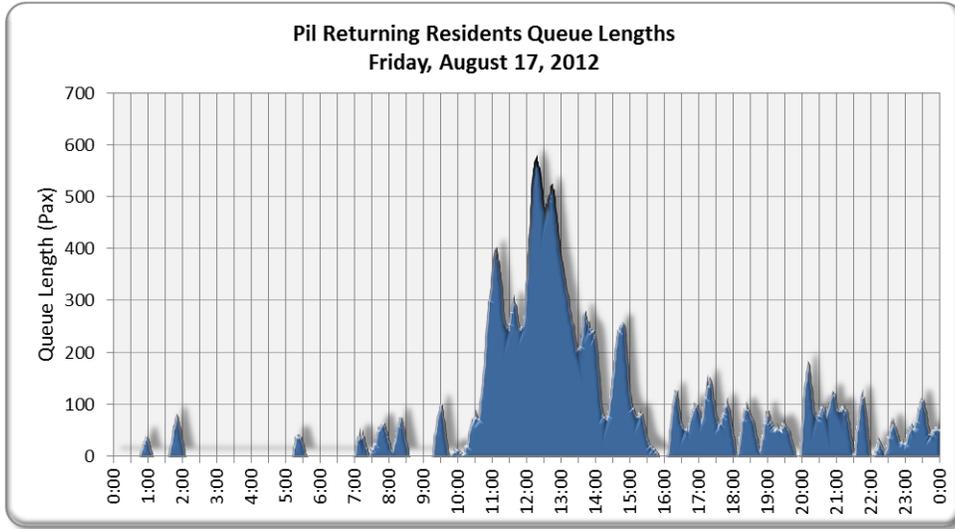
Figure 11: Typical Queue Length Graph

9   WAIT TIME DISTRIBUTIONS

We previously noted that wait times could not always be contained within a desire service level threshold. The situation is acceptable as long as it is short lived. Figure 12 displays a wait time distribution for the processing of visitors at a primary inspection line (PIL). The figure indicates wait times of 10 minutes of less for 80% of the passengers. This would not be desirable if the level of service wait time threshold is 10 minutes. However, with a LOS wait time threshold of 20 minutes, the results would be satisfactory with 94% of the passengers processed in due time.
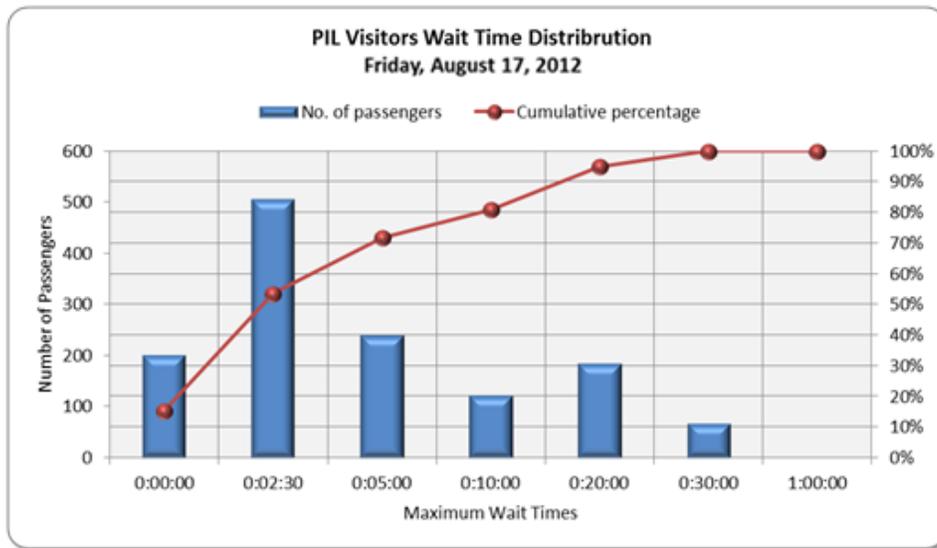
Figure 12: Typical Wait Time Distribution Graph

10   SUMMARY

Airport simulation models, although quite complex and time-consuming to build, provide invaluable insight in the planning and operating of terminals. When building new terminals or expanding existing ones, simulation models can determine capacity requirements and provide guidance in scoping a project.

In situations where increased capacity is required, simulation models can be used to re-engineer processes in order to make them more efficient. In such cases, the refining of airport processes can lead to millions of dollars in savings as a result of deferred capital costs. One such example at Vancouver Airport has been the introduction of kiosks for the customs declaration of returning residents. The need for more capacity in the customs hall was driving a project to expand the terminal and create a ripple effect such as the relocation of aircraft gates. The use of kiosks provided the added capacity, reduced strain on the facility, and saved possibly close to $100 million.

Finally, simulation models are also invaluable in the day to day operations of the airport. They are useful in assessing the required amount of staffing to run smooth operations with wait times that are contained within established levels of service.

AUTHOR BIOGRAPHY

MIKE LAZZARONI is Senior Planning Analyst for the Vancouver Airport Authority. He has been a licensed architect for the past 23 years, first in Quebec and then in British Columbia, Canada. He transitioned to airport design over 10 years ago and has specialized in demand/capacity analyses through simulation modeling. His email is Mike_Lazzaroni@yvr.ca. Additional airport information can be found at www.yvr.ca.