SIZING THE AIRPORT PASSENGER DEPARTURE LOUNGE FOR THE NLA

Alexandre G. Barros
Research Assistant
The University of Calgary
Department of Civil Engineering
2500 University Dr NW
Calgary, AB, T2N 1N4
CANADA
Phone: (403) 220-4813
Fax: (403) 282-7026
E-mail: agdbarro@acs.ucalgary.ca

S. C. Wirasinghe
Professor
The University of Calgary
Department of Civil Engineering
2500 University Dr NW
Calgary, AB, T2N 1N4
CANADA
Phone: (403) 220-5731
Fax: (403) 282-7026
E-mail: wirasing@acs.ucalgary.ca

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Alexandre G. Barros

S. C. Wirasinghe

ABSTRACT

The introduction of new large aircraft (NLA) is expected to cause a significant impact on planning and design of airports. Besides the problems caused by its large dimensions on airport airside design, the increased passenger capacity featured by the NLA will require larger passenger processing facilities. Given the high costs implied both by changes in existing facilities and by the construction of new areas, anticipating the changes with a reasonable precision might help airports save a considerable amount of money.

One of the most affected passenger terminal facilities will be the departure lounge. Current studies carried by major manufacturers indicate that the NLA might be able to carry as much as 800 passengers. This is double the capacity of the largest existing passenger aircraft, the Boeing 747. In order to accommodate all these passengers in the same lounge, many solutions have been proposed. Examples of such solutions are the construction of a second level to allow an increase in passenger storage capacity without the need for horizontal expansion, and the use of the satellite section of a pier-satellite terminal as a single NLA gate.

This paper discusses the implications of high-capacity aircraft on the passenger departure lounge. Using deterministic queuing theory, we present some analytical methods to evaluate possible solutions and to assess both the lounge area and the number of seats which minimize the overall cost of the lounge. The use of a spreadsheet to implement the methods is also explained.

INTRODUCTION

Major aircraft manufacturers are currently undertaking studies to build a new large aircraft (NLA). The expression *new large aircraft* has been agreed to define any future aircraft larger than the Boeing 747-400 (*1*).

The two biggest aircraft manufacturers in the world – namely Boeing and Airbus – are planning the construction of the NLA in two stages. The first stage will be an aircraft with 500-600 seats, which could be flying by the end of the year 2000. Boeing's project for this first stage, which is known as B747-500X/600X, is a stretched version of the 747 (*2, 3)*. In turn, Airbus will need to design a new aircraft, since the European consortium does not currently produce one. The Airbus project for the first stage is known as A3XX-100.

The second stage of the development of the NLA will be a full double-deck aircraft, which will be capable to carry up to 800 passengers. Such an aircraft will need to be completely designed from scratch. Table 1 compares some dimensions of the NLA to some existing heavy aircraft. A comparison between Boeing's NLA and the 747 is shown in Figure 1.

The introduction of the NLA will cause a significant impact on the design of airports, on both the airside and the landside. On the airside, both its wide wingspan and long fuselage, as seen in Table 1, will create the need to increase the size of runways, taxiways, aprons and gate positions (*4*). On the landside, the high passenger capacity of the NLA will imply the need for processing more passengers within the same time period. The inescapable conclusion is that the passenger terminal facilities will have to be expanded.

The impact of the NLA on the airport airside has been the subject of several studies (*3, 4, 5, 6, 7, 8*). In fact, designing a new airport for the NLA is mainly a matter of determining the dimensions of the facilities so that minimum aircraft separation requirements and sufficient passenger processing capacity are available. Although a little more complicated due to land and existing facility constraints, preparation of existing airports to accommodate the NLA is ultimately the same process.

There seems to be, however, a lack of research on the effects of the NLA on the passenger terminal. A need for expansion is recognized in almost all landside facilities; however, how this expansion should be done and by how much still remains unclear. Answering these questions well in advance to the advent of the NLA is important to help airports prepare themselves at the minimum possible cost.

In this paper, we discuss the implications of the NLA in the passenger departure lounge. A methodology based on deterministic queuing theory (*9*) is presented to determine both the optimal area size and the optimal number of seats, such that the overall cost of the lounge is minimized. The methodology also takes into account the effects of adding a second level and a second loading bridge to the existing structure.

For the purpose of this paper, we will break the problem of sizing the departure lounge into two parts: designing a new facility and converting existing facilities to serve the NLA.

PLANNING A NEW TERMINAL

When designing a new passenger terminal, the size of the departure lounge must be set such that it can comfortably accommodate all passengers, at a reasonable cost.

Wirasinghe & Shehata (*9*) presented a method to determine the area necessary for a departure lounge, as well as to choose the number of seats, such that the overall cost of the lounge is minimized. The method is based on deterministic queuing theory, as described below.

Determination of the Number of Passengers

Passengers arrive at the departure lounge following a cumulative arrival distribution $A(t)$, where t is the time remaining to departure. Given the boarding rate b, it is assumed that boarding begins as late as possible, such that by the time of departure, all passengers are on board. Thus the instant at which boarding begins, t_b, is given by:

$$t_b = \frac{N}{b} \tag{1}$$

where N is the number of passengers who will be on the flight. The value of N is set to the passenger capacity of the largest aircraft that will make use of the lounge. Figure 2 shows two examples of arrival curves and a boarding curve with a rate of 28 passengers per minute.

If the boarding rate b is high enough to ensure it is always higher than the passenger arrival rate, then the maximum number of passengers simultaneously at the departure lounge, Q, is the cumulative number of passengers who will have arrived at the time of beginning of boarding, i.e.:

$$Q = A(t_b) = A\left(\frac{N}{b}\right) \tag{2}$$

It may happen that the passenger arrival rate is higher than b at some instants. This is particularly true when the lounge is sized for the NLA, due to the high number of passengers being serviced at the same time. In this case, the maximum number of passengers at the departure lounge will be the highest value of the difference between the cumulative number of passengers arrived and the cumulative number of passengers boarded, i.e.:

$$Q = Max[A(t) - B(t)] \tag{3}$$

where *B(t)* is the boarding function, defined as:

$$B(t) = \begin{cases} N - b \cdot t, t \leq t_b \\ 0, otherwise \end{cases} \tag{4}$$

Note that Equation 2 is a special case of Equation 3, in which *b* is always higher than the instant arrival rate.

Evaluation of the Lounge Area

The minimum total area of the departure lounge, *A*, is equal to the sum of the areas occupied by both sitting and standing passengers:

$$A = \alpha\left[m_1 S + m_2 (Q - S)\right] \tag{5}$$

where:

S: number of seats in the lounge

α: multiplier which accounts for passenger circulation and airline activities;

m_1: area per sitting passenger;

m_2: area per standing passenger.

Other areas may be added for service facilities and for architectural reasons.

Minimum level of service

The parameters m_1 and m_2 represent the minimum area per passenger so that a given level of service is provided to the passenger when Q passengers are in the lounge. However, it may happen that the flight is delayed, and the lounge must then accommodate the full aircraft load N. If that happens, it is desirable to set a minimum area per standing passenger, m_3. Hence, a constraint is added to the problem to account for this minimum level of service:

$$A \geq \alpha\left[m_1 S + m_3(N - S)\right] \tag{6}$$

Substituting for A from Equation 5 in Equation 6, it follows that:

$$S \leq \frac{m_2 Q - m_3 N}{m_2 - m_3} \tag{7}$$

i.e., an upper limit is imposed to the number of seats. It can also be shown that the constraint represented by Equation 6 can only be satisfied if $Q/N \geq m_3/m_2$. Therefore, the number of passengers for which the lounge will be sized also has a lower limit that must be taken into account.

Choice of the Number of Seats

Once the number of passengers at the lounge is evaluated, next step is to determine the optimal number of seats.

The lower curve in Figure 3 represents the number of passengers compulsorily standing – i.e., because all available seats are occupied by other passengers – when S seats are available. The shaded area, called area R_1, is the area limited up by the seating curve and down by the boarding curve. It represents the total passenger-standing time per aircraft departure.

The choice of the value of S is made so that the overall cost of the lounge per aircraft departure, C_L, is minimized. This overall cost of the lounge is given by (*9*):

$$C_L = \gamma_C S + \alpha\gamma_L m_2 Q + \gamma_P (\text{area } R_1) \tag{8}$$

with:

$$\gamma_C = \alpha\gamma_L(m_1 - m_2) + \gamma_S \tag{9}$$

where:

γ_L: cost of lounge per unit area per aircraft departure;

γ_S: cost of a seat per aircraft departure;

γ_P: disutility of compulsory standing, per passenger per unit of time;

In Equation 8, the first term represents the cost of adding seats; the second term represents the total cost of building and operating the departure lounge, excluding the cost of seats; and the third term is the total cost of passenger compulsory standing. Since the second term does not depend on the value of *S*, the problem becomes minimizing the sum of the first and third terms of Equation 8, i.e. finding the value of *S* that minimizes C_{Ls} given by:

$$C_{Ls} = \gamma_C S + \gamma_P(\text{area } \mathrm{R}_1) \tag{10}$$

subject to the constraint presented in Equation 7.

The first term in Equation 10 increases with *S*, whereas the second term decreases as the value of *S* increases. Clearly, there must be a tradeoff, i.e. a value of *S* for which the function C_{Ls} is minimized. The solution for this problem with the use of a spreadsheet is explained later in this paper.

CONVERTING EXISTING FACILITIES TO SERVE THE NLA

The conversion of existing gates to serve the NLA is a little more complicated than the design of new ones. Existing terminals are originally designed to serve a given aircraft mix. This original design might represent some difficulty and even a severe constraint when it has to be changed to accommodate a larger aircraft.

Assuming the existing space between gates is not enough to allow unrestricted operation of NLA's, there are two ways to overcome this problem. The first solution is to enlarge the space between gates, relocating them such that the separation between positions provides the minimum wing-tip-to-wing-tip separation. A second solution would be to block positions adjacent to that in use by an NLA. Although the first solution might appear to be harder to implement – due to the need for relocation of the loading bridges – the second one may result in a greater loss of gate positions.

In cases where only a few NLA operations are expected and a pier-satellite terminal exists, it might be interesting to use the satellite section of the terminal as a single NLA gate. This option will also be discussed ahead.

Respacing / Blocking Gates

The main problem that may arise when converting existing gates to NLA gates regards the area available for the departure lounge. Whether respacing gates or blocking gate positions adjacent to NLA positions, whether using one or two loading bridges, the final departure lounge area might or might not be enough to accommodate all passengers. To overcome this problem, one solution is the construction of an upper level. Since the NLA will certainly feature an upper deck, the distribution of the passengers through the departure lounge levels would match the distribution through the aircraft decks.

Figure 4 shows the variation of aircraft capacity with the wingspan. It can be seen that aircraft capacity is roughly proportional to the wingspan. Thus, in a linear terminal configuration, a departure lounge with a fixed width will have an area proportional to aircraft capacity. However, the *needed* area might not be proportional to the aircraft capacity, due to variations both in the time of boarding and in the passenger arrival patterns. Additionally, Figure 4 also shows that the second-stage NLA passenger capacity outlies the trend line, featuring a larger capacity for its wingspan. Therefore, the lounge area needed for the NLA must be evaluated and compared to the existing available area in order to decide whether a second level is necessary.

Let SG_e be the existing space between gates and SG_N be the new space provided for NLA positions. Let also A_e be the area available for the departure lounge of one gate and A_N be the final area available for an NLA gate (see Figure 5). In a linear terminal configuration, the area available for the NLA will be given by:

$$A_N = A_e\left(1+\frac{SG_N - SG_e}{SG_e}\right) \qquad (11)$$

The area calculated in Equation 11 is that available at the existing terminal level. If a second level is to be built, the available area will be doubled.

Second Level and Optimum Number of Seats

The decision of whether to build a second level is tied to both the area necessary to accommodate all passengers and the choice of the number of seats.

Let L be a zero-one decision variable. If L assumes the value 0, then the decision is not to build the second level; otherwise, the second level must be built. The problem, then, is to find the values of S and L that minimize the overall cost of the lounge per aircraft departure, C_L:

$$C_L = \gamma_S S + L\gamma_L^* A_N + \gamma_P (areaR_1) \tag{12}$$

where γ_L^* is the cost of adding a second level per unit area per aircraft departure.

In Equation 12, the first term represents the cost of providing seats; the second term represents the cost of building a second level, excluding the cost of seats; and the third term is the total cost of passenger compulsory standing. It is assumed here that a second level will have exactly the same area as the existing level.

This minimization is constrained by the available area, A_N. The area required A – calculated as in Equation 5 – must be lesser than the available area, whether one or two levels are provided. Therefore, the cost as given in Equation 12 must be minimized subject to:

$$A \leq (L+1)A_N \tag{13}$$

Substituting for A from Equation 5 in Equation 13, the constraint becomes:

$$\alpha\left[m_1 S + m_2 (Q - S)\right] \leq (L+1)A_N \tag{14}$$

To provide a minimum level of service, it must be ensured that the total final area is enough to accommodate the full aircraft load of passengers N and still provides a minimum area per passenger standing, m_3. Thus, the following constraint is also added:

$$(L+1)A_N \geq \alpha\left[m_1 S + m_3(N-S)\right] \tag{15}$$

Because the third term in Equation 12 is an integration, the problem is a nonlinear mixed integer programming problem. The solution can be found with the use of a spreadsheet, as described later.

Use of the Satellite Section of a Pier-Satellite Finger as a Single NLA Gate

The satellite section of a pier-satellite finger terminal usually features a departure lounge that is common to all gates in the satellite. Should one of the bridges be modified for loading an NLA, it might be necessary to reserve this gate for NLA operations only.

From Equation 5, the existing area is given by:

$$A_e = \alpha\left[m_1 S_e + m_2(Q_e - S_e)\right] \tag{16}$$

where A_e is the total existing lounge area, S_e is the existing number of seats and Q_e is the existing lounge capacity. From Equation 16, it follows that:

$$Q_e = \frac{\frac{A_e}{\alpha} - (m_1 - m_2)S_e}{m_2} \tag{17}$$

Using deterministic queuing theory as described earlier, it is possible to determine the needed capacity of the lounge for the NLA, Q. If $Q_e < Q$, the lounge cannot accommodate all the passengers of the NLA with its current configuration. However, it can be shown that if:

$$\frac{m_3}{m_2} \leq Q \leq \frac{A_e}{\alpha m_2} \tag{18}$$

then it is possible to adapt the lounge for the NLA by reducing the number of seats. From Equation 16, the new number of seats will be given by:

$$S_N = \frac{\dfrac{A_e}{\alpha} - m_2 Q}{(m_1 - m_2)} \tag{19}$$

On the other hand, if $Q_e > Q$, then there is room for expansion of the seating capacity. If S' is the number of seats to be added, then the final number of seats is equal to the sum of the existing number of seats and the additional seats, i.e.:

$$S = S_e + S' \tag{20}$$

and the problem becomes to minimize:

$$C_L = \gamma_S S' + \gamma_P (areaR_1) \tag{21}$$

subject to:

$$\alpha\left[m_1 S + m_2 (Q - S)\right] \leq A_e \tag{22}$$

$$A_e \geq \alpha\left[m_1 S + m_3 (N - S)\right] \tag{23}$$

$$S = S_e + S' \tag{24}$$

Note that the area R_1 is still a function of *S*, which in turn is a function of *S'*.

Use of the Satellite by Regular Jets

In order to help reduce loss of gate capacity, it may be possible to allow one or more regular jets (RJ's) to make use of the satellite concurrently with an NLA. To do so, it is necessary that wing-tip-to-wing-tip minimum separation requirements are met, and the lounge capacity must be high enough to accommodate all passengers present at the lounge at the same time.

Figure 6 shows an example of the passenger arrival and boarding curves for both an NLA and an RJ departing at the same time. These curves are added in Figure 7. The maximum accumulation of passengers at the lounge, Q_{NR}, can be calculated as in the case of a new terminal. Note that the time of departure of the RJ can be dissociated from the NLA's, and that the value of Q_{NR} will vary according to the difference in departure times. Varying this difference, it is possible to establish the minimum time separation between an NLA departure and a RJ departure so that the lounge is able to accommodate all passengers, i.e. $Q \geq Q_{NR}$.

CALCULATION OF THE AREA R_1 AND NUMERICAL EXAMPLE

The cost minimization problems discussed in the previous sections are non-linear programming problems, due to the presence of area R_1 in the objective function. The area R_1 is a non-linear function of the number of seats. In this section, we will present a solution for the minimization problem that can be easily implemented with the use of a commercially available spreadsheet.

Area R_1 can be analytically calculated through the following integral:

$$areaR_1 = \int_0^{t_d} \left[G(t) - B(t) \right] dt \tag{25}$$

with:

$$G(t) = \begin{cases} A(t) - S, & if \quad A(t) - S \geq B(t); \\ B(t), & otherwise \end{cases} \tag{26}$$

where t_d is the time at which passengers start to arrive at the lounge, and *G(t)* is the cumulative number of passengers at instant *t* who did not find a seat when they arrived at the lounge.

In order to evaluate the value of the area R_1, the *trapezoidal rule* (*10*) is used. Both the passenger arrival function *A(t)* and the boarding function *B(t)* can be made discrete for given time intervals. If we set this time interval to be 1 minute and we assume that *A(t)* equals zero for *t* > 120 minutes, then it can be shown that:

$$\begin{aligned} areaR_1 = \frac{1}{2}\{&\left[G(0) + 2G(1) + 2G(2) + 2G(3) + \ldots + 2G(118) + 2G(119) + G(120)\right] \\ &- \left[B(0) + 2B(1) + 2B(2) + 2B(3) + \ldots + 2B(118) + 2B(119) + B(120)\right]\} \end{aligned} \tag{27}$$

gives us an accurate approximation for the value of area R_1.

An electronic spreadsheet can be easily setup to calculate Equation 27. The costs represented by Equations 10 and 12 can also be automatically evaluated by the spreadsheet. With no constraints, the optimum number of seats can be found just varying the number of seats and comparing the costs of each solution.

In other cases, where constraints exist, the use of a commercial solver is recommended.

Numerical Example

Consider the problem of enlarging the space between gates designed for the B767. The existing separation between gates is 55 m, and the existing lounges each have an area of 410 m^2. The space between gates for the NLA is estimated to be 92 m. These parameters and others necessary to solve this problem are summarized in Table 2. The passenger arrival distribution function is shown in Figure 3.

The first step is to evaluate the lounge area available to the NLA. Substituting for the values of the parameters in Equation 11, it comes out that the area available is approximately 685 m^2.

Next step is to assess the value of Q, the maximum number of passengers simultaneously at the lounge. The spreadsheet described earlier in this section can be set up to perform this assessment automatically, using Equation 3. The value found is 556 passengers.

Finally, the search for the optimum number of seats and for the decision whether to build a second level must be performed. There are two ways to do this search in our spreadsheet: setting up a zero-one variable as described above and making use of a solver; or making the assessment for two values of the area constraint – one with one level and the other with two levels. Table 3 shows the results using the former. It can be seen that the overall cost of the lounge will be higher if a second level is added. Therefore, the decision is to build only one floor.

If there is a second level and the boarding process makes use of two bridges, it is perfectly possible to separate both levels completely (at least for the passengers). Assuming that the number of passengers carried on each deck of the aircraft is the same, the passengers could be directed to the correct lounge level according to their assigned deck in the aircraft. The number of seats could be equally distributed through the two floors.

In this example, the value of γ_P is assumed to be constant. Its determination, however, may not be so simple. Hence, a sensitivity analysis must be done for various value of γ_P. The results of such analysis are shown in Figure 8.

For $\gamma_P < 0.005$, the cost of standing is so low with respect to the other costs that it does not warrant the provision of any seats at all. For $0.005 < \gamma_P < 0.01$, the number of seats increases with γ_P. At $\gamma_P = 0.01$, the area necessary to accommodate all passengers reaches the available area. Any increase in this area must be done through the construction of the second floor. However, for $0.01 < \gamma_P < 0.457$, the reduction in passenger standing cost would not compensate for the cost of adding the second level, so the optimum solution remains the same for any value in this interval. Finally, for $\gamma_P > 0.457$, the optimal solution requires two levels.

CONCLUSIONS

The advent of the NLA will bring out the need for changes in airports. Along with several other airport passenger terminal components, the passenger departure lounge is expected to be highly affected by the increase in aircraft passenger capacity.

In this paper, analytical methods to evaluate the impact of the NLA on the passenger departure lounge using deterministic queuing theory have been presented. It has been shown that it is possible to size the departure lounge and to choose the best option to accommodate the NLA such that the overall cost of the lounge is minimized. For large airports that expect to serve several aircraft of that type, these methods can help saving a significant amount of money through the life of the passenger terminal.

The disutility of passenger standing, γ_P, is critical for the evaluation of the optimal solution. It is therefore recommended that its determination be done with care.

REFERENCES

1. Chevallier, J-M & Gamper, D. Counting the Costs of the NLA, *Airport World*, September 1996, pp. 36-42.
2. Boeing Commercial Airplane Group (1994). *Large Airplane Development and Airports*. Boeing Commercial Airplane Group, Seattle, 1994.
3. Gervais, E. L. *New-Generation Aircraft – Airport Compatibility*. 23rd International Air Transportation Conference of the ASCE, Arlington, 1994.
4. Barros, A. G. & Wirasinghe, S. C. *New Aircraft Characteristics related to Airport Planning*. I Air Transport Research Group Conference, Vancouver, Canada, 1997.
5. Fife, W. A. *Introduction of New Aircraft – Airport Operators Perspective*. 23rd International Air Transportation Conference of the ASCE, Arlington, 1994.
6. David, C. The impact of new aircraft developments on the design and construction of civil airports. *Proceedings of the Institution of Civil Engineers – Transportation*, no. 111, 1995, pp. 59-69.
7. Rines, S. Larger Aircraft do not scare Airport Planners. *Jane's Airport Review*, Vol.7, No.2, 1995, pp. 36-38.
8. Storms, J. R. Designing For New Large Aircraft at CLK. *Airport Technology International*, 1996, pp. 69-72.
9. Wirasinghe, S. C. & Shehata, M. Departure Lounge Sizing and Optimal Seating Capacity for a given Aircraft/Flight Mix. In *Airport Terminal Planning*, Hong Kong Polytechnic, Hong Kong, 1993.
10. Leithold, L. *The Calculus with Analytic Geometry*. 3rd Edition, Harper & Row Publishers, New York, 1976.
11. Ashford, N. & Wright, P. H. *Airport Engineering*. 3rd Edition, John Wiley & Sons Inc., New York, 1992.
12. Boeing Commercial Airplane Group. *777 Program Review*. Boeing Commercial Airplane Group, Seattle, 1996.

13. Burns & McDonnels, *Aircraft Characteristics*. Burns & McDonnell Inc., 1995.

14. Horonjeff, R. & McKelvey, F. X. *Planning & Design of Airports*. 4th Edition, McGraw-Hill Inc., New York, 1994.

15. Transport Canada. *Departure Assembly Areas (Hold Rooms)*. Report AK-62-01-800, Airports and Construction Services Directorate, Transport Canada, Ottawa, Canada, 1977.

List of tables

TABLE 1: Existing and Proposed Subsonic Aircraft Dimensions

	Aircraft parameters						
Aircraft	Wingspan (m)	Length (m)	Wheel base (m)	Wheel track (m)	Runway length (m)[a]	Passengers	Maximum takeoff weight (kg)
B767-200	47.5	48.5	19.7	9.3	1828	216-255	142880
B767-300	47.5	54.9	22.8	9.3	2438	261-290	156488
A340-200	60.3	59.4	23.2	10.7	2316	262-375	253511
A340-300	60.3	63.7	25.6	10.7	N/A	295-335	253500
B777-200	60.9	63.7	25.9	11.0	2651	305-375	242670
B777-300	60.9	73.8	25.9	11.0	2651	368	299370
MD-11	51.8	61.3	24.6	10.7	2986	323-410	273287
B747-400	64.9	70.4	25.6	11.0	2681	400	362871
A3XX-100	76.0	80.0	N/A	N/A	N/A	500-600	N/A
B747-500X	64.4	77.8	29.2	11.0	N/A	500-600	N/A
A3XX-200	80.0	80.0	N/A	N/A	N/A	600-800	N/A
Boeing NLA	88.0	85.0	N/A	17.0	N/A	600-800	771101

Sources: References 2, 11, 12, 13, 14.

N/A: Not Available

[a] At sea level, standard day, no wind, level runway

TABLE 2: Parameter Values for the Numerical Example

Parameter	Value
SG_e (m)	55
SG_N (m)	92
A_e (m^2)	410
b (passengers / minute)[a]	28
m_1 (m^2/passenger)[a]	1.5
m_2 (m^2/passenger)[a]	1
m_3 (m^2/passenger)	0.5
α[a]	1.1
γ_L^* (\$/m^2/aircraft departure)[b]	0.15
γ_P (\$/hour/passenger)[b]	0.25
γ_S (\$/seat/aircraft departure)[b]	0.01

Sources: [a] Reference 15; [b] Reference 9

TABLE 3: Lounge Capacity and Optimal Number of Seats for the NLA Gates

No. of floors	Area (m^2)	Lounge Capacity	No. of seats	Overall cost ($/departure)
1	685	556	133	59.7218
2	1370	972	545	108.25

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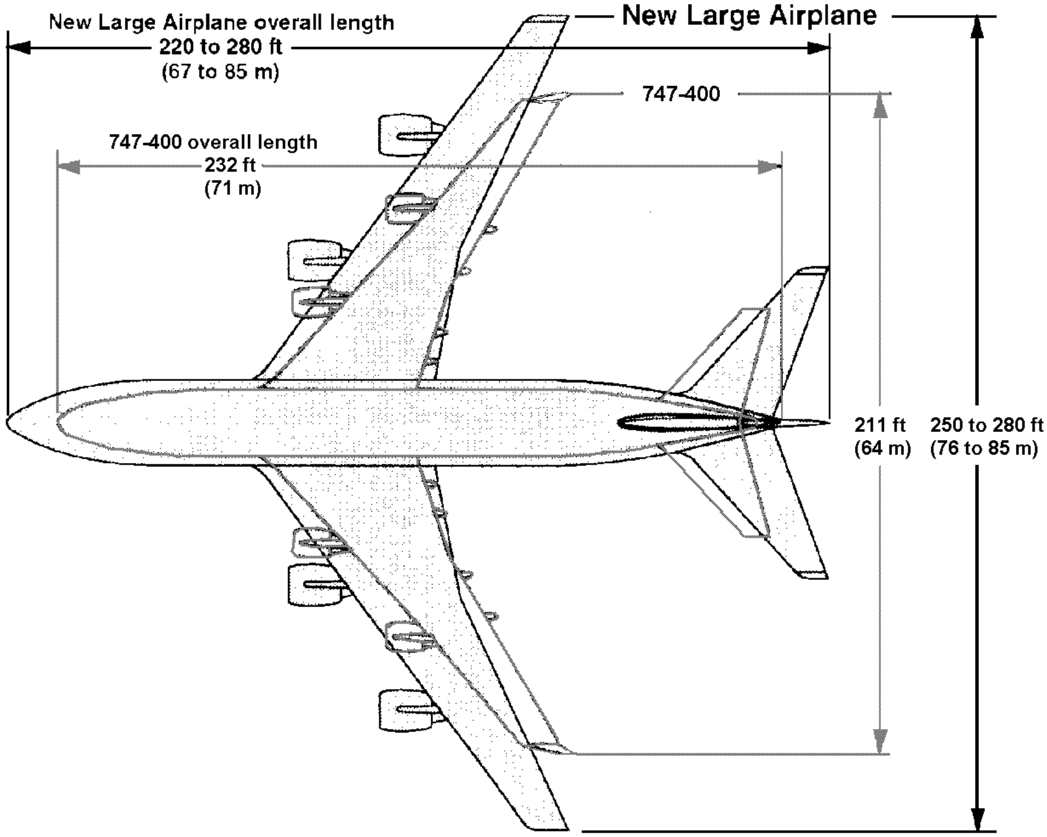

FIGURE 1: Size Comparison: NLA versus 747-400 (*2*)

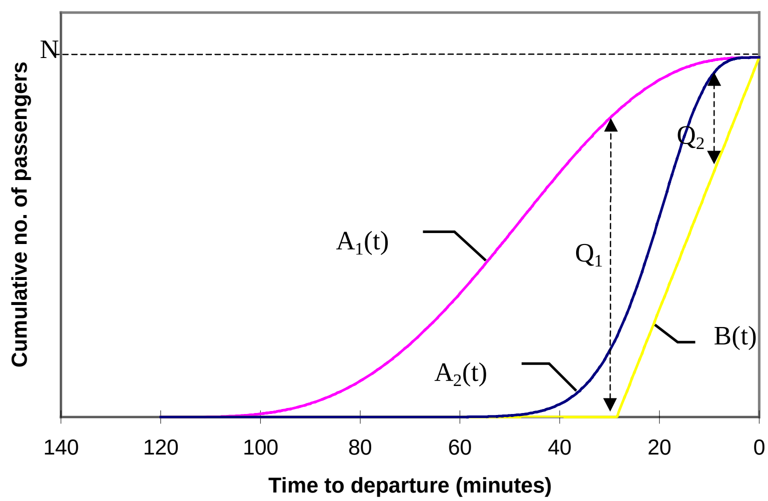

FIGURE 2: Arrival and Loading Curves at the Departure Lounge

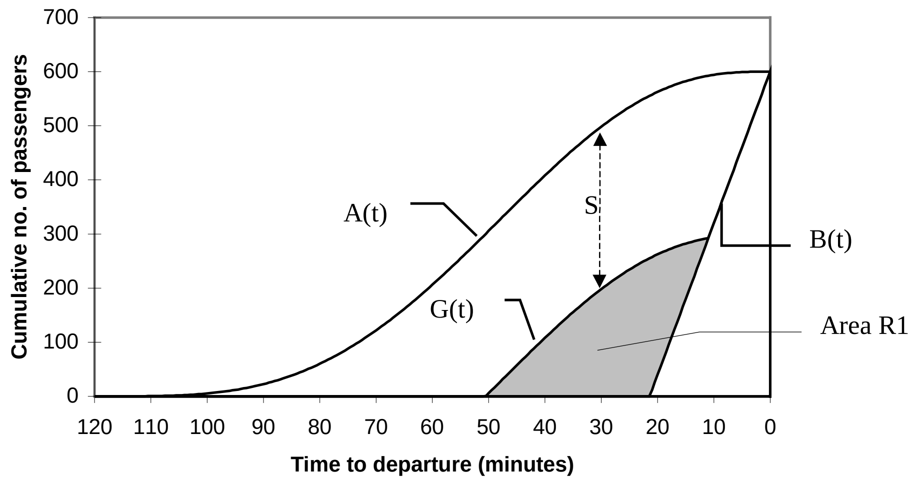

FIGURE 3: Determination of the Number of Seats

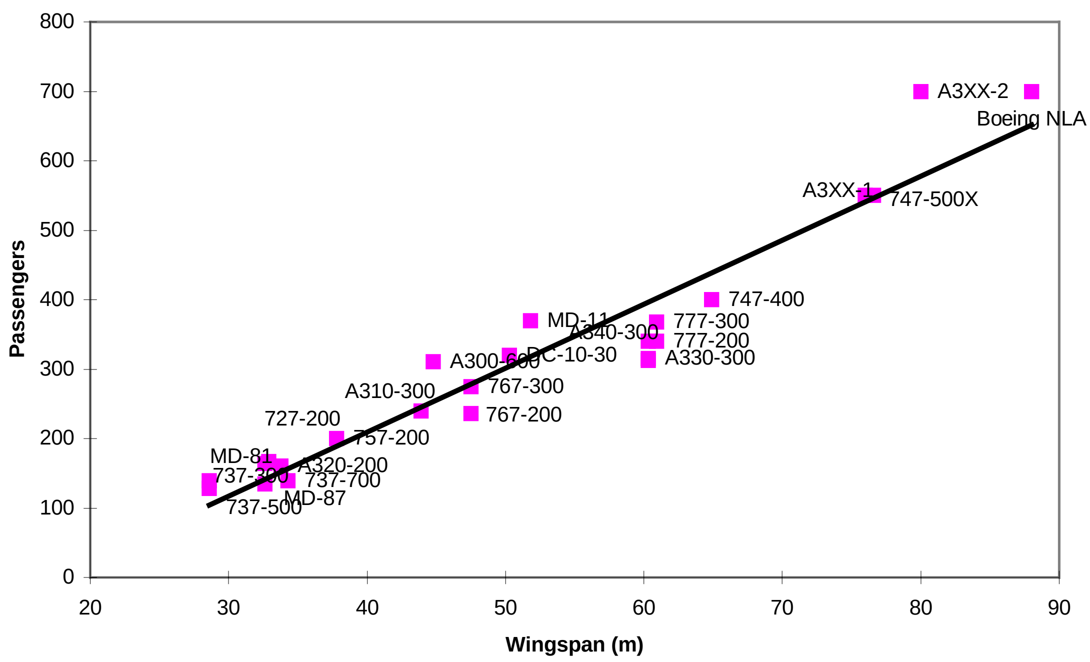

FIGURE 4: Aircraft Passenger Capacity x Wingspan

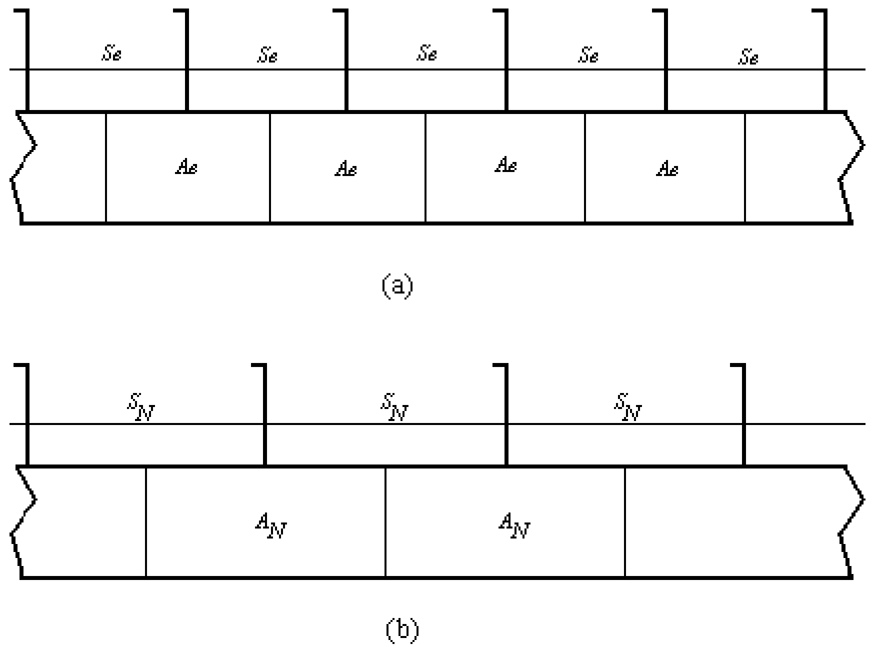

FIGURE 5: Respacing Gates to Accommodate the NLA

(a) Existing Gate Spacing

(b) New Gate Spacing for the NLA

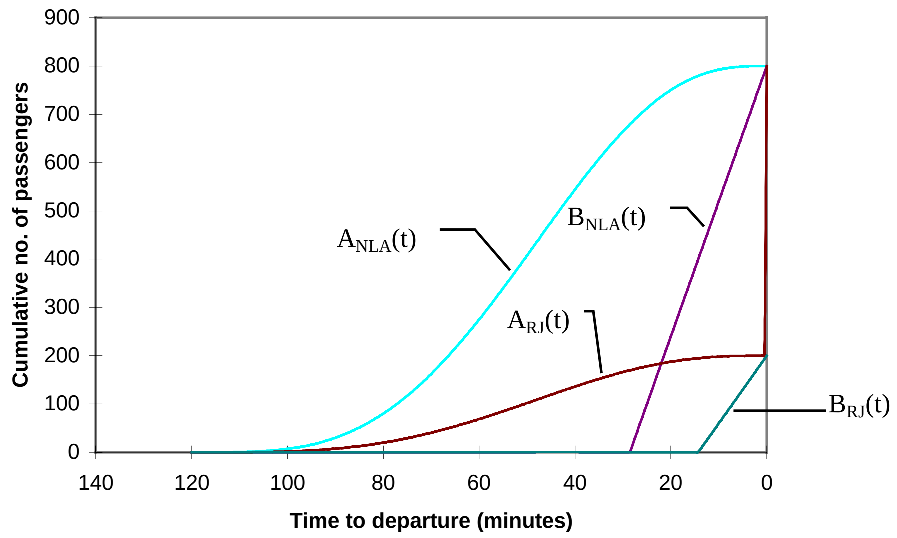

FIGURE 6: Arrival and Boarding Curves for the NLA and a Regular Jet (RJ) Sharing the Same Lounge

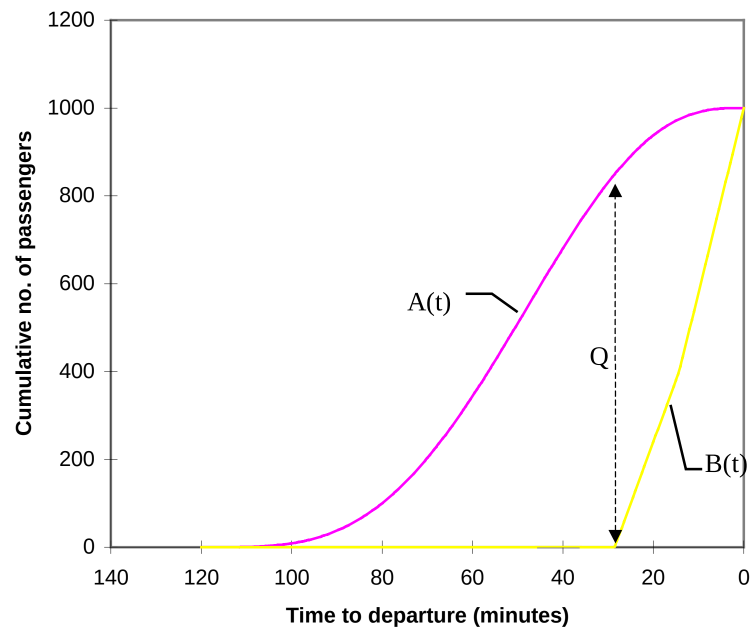

FIGURE 7: Cumulative Arrival and Boarding Curves for the NLA and a RJ

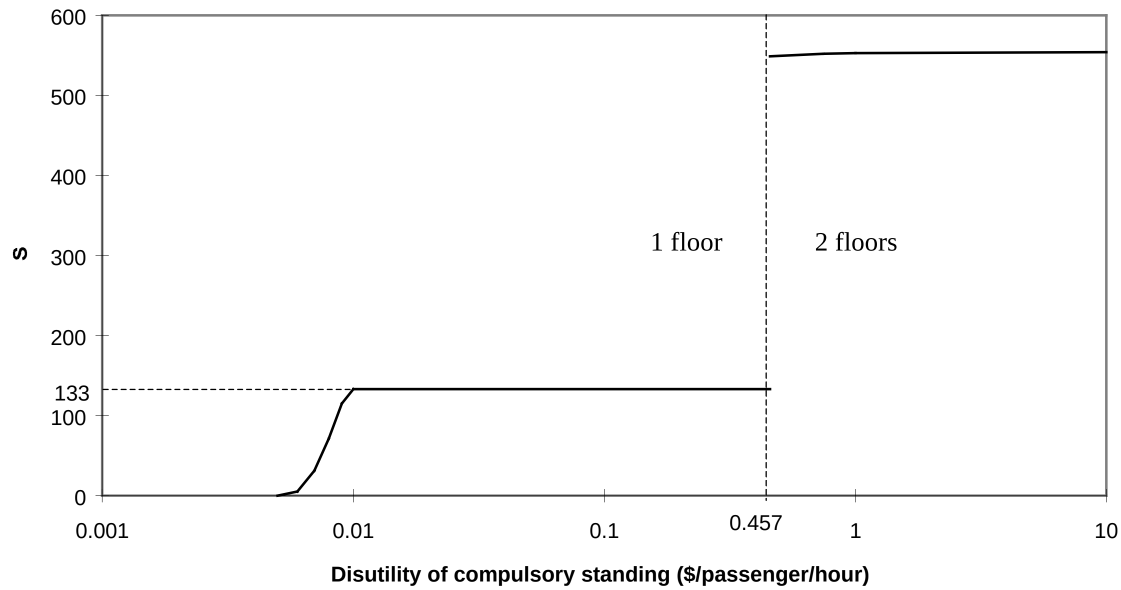

FIGURE 8: Sensitivity Analysis for γ_P