VEHICLE GENERATION MODEL AT AN AIRPORT

Rusmadi SUYUTI
Research Staff
Directorate of Transportation Technology, BPPT
BPPT 2nd Building, 10th Floor
Jl. MH Thamrin 8, Jakarta 10340
Indonesia
Fax: +62-21-3169345
E-mail: rusmadi@hotmail.com

Abstract: There is a need to have an appropriate model of the vehicle movements generated by the airport, in order to adequately evaluate the primary road network particularly in the airport's surrounding area. This paper describes the methodology developed to model the airport vehicle generations, using a case study at Auckland International Airport, New Zealand. The paper begins with a brief review of vehicle generation models that have been formulated for the planning of international airports. Hence, following a brief potential vehicle generation types, it was decided to develop a technique which use a combination of unitgraph and multiple linear regression techniques based on aircraft passenger data and traffic counts to/from International and Domestic terminals. Calibration of the vehicle generation model to the observed road network flows was also proposed.

1. INTRODUCTION

The ground access component of air travel is an important element of the planning for the surrounding land transport network. The traffic generated by an airport imposes considerable vehicle flows which often lead to recurrent traffic congestion. Thus, appropriate techniques of modelling airport vehicle generation are needed in order to manage these problems. There is also a need to provide a strong base for the future prediction of vehicle generation as development of the airport and the surrounding area proceeds.

For the employee as well as the air travellers and visitors, the time consumed in coming to or going from the airport can make up a great proportion of their total travel time. Hence, the land transport network needs to provide efficient and well managed travel for all users.

The objective of this research was to develop an appropriate model of the vehicle trip generation for the various site activities and passenger movements at the Auckland International Airport, New Zealand.

Auckland International Airport is situated on the northern shore of the Manukau Harbour, approximately 21 kilometres south of the Auckland's Central Business District. On a typical day, data in 1996 mentioned that more than 50,000 visitors and 18,000 travellers passed through the international an domestic terminals. Typically, aircrafts were either landing or taking off every two or three minutes.

2. VEHICLE GENERATION MODELS AT AIRPORTS – A REVIEW

Relatively few methodological approaches have been formulated for the planning of international airports. This appears due to the wide range political and organisasional influences involved in their development.

In the context of this research, four techniques of modelling generated ground traffic were evaluated as potential options for the project, namely:

- Growth rate technique
- Unitgraph technique
- Simulation models
- Linear regression equation

2.1 Growth Rate Technique

The growth rate technique was used for the Auckland Airport by Murray-North Limited (1994) and Manukau Consultants (1993) to estimate daily vehicle trips in the horizon year. This was undertaken by using the growth rate of the number of air passengers and employment multiplied by the vehicle trip rates in each category.

In considering these trips to the airport, trips were analysed in three categories as follows:

- Trips related to employment and other users
- Trips related to international passenger movements
- Trips related to domestic passenger movements

The number of trips related to employment (trips by employee to and from work and trips made to and from the airport in the course of employment) were derived from: estimates of employment levels at the airport, an analysis of the trip rate per employee and an analysis of the ratio of trips per employee to the employment related trips.

Vehicle trips made by international passengers were derived from projections of international passenger numbers and surveyed data on the number of vehicle trips per passenger.

Vehicle trips made by domestic passengers were derived from projections of domestic passenger numbers and surveyed data on the number of vehicle trips per passenger.

The growth rate technique is simplistic and therefore has poor predictive abilities also it is not able to model vehicle generation by time period.

2.2 Unitgraph Technique

The unitgraph technique was used by Davidson *et al* (1969) who developed a model for Brisbane airport which is analogous to those used in hydrological studies.

They assumed that for any aircraft movement there will be a definable pattern of road vehicle flows, the scale of which will be proportional to the number of passengers involved in the aircraft movement.

Least square approximate method was used to obtain unit effect graph ordinates. These graph ordinates give the magnitude of traffic per time interval generated by an aircraft carrying a standard number of air passengers.

Using the model by Davidson *et al* (1969), Blake and Dunn (1976) developed a car parking model for Auckland Airport, which predicted the magnitude of the accumulation and vehicular flows (entry and exit) through the car parks. The model was developed and calibrated from interview and car parking survey data. It was then used to predict future parking demands at the airport.

Apelbaum and Richardson (1978) undertook the development of a model for Tullamarine Airport in Melbourne which was also similar to the concept developed by Davidson *et al* (1969). Unitgraphs describing the probability of a vehicle trip occuring during a given time interval (five minute intervals were adopted) relative to aircraft arrival/departure times were developed for each surveyed flight. The model was able to specify trip generation characteristics of air passengers for both the domestic and international terminals.

All of three of the unitgraph technique models have the disadvantage that the trip generation of non-air travellers and visitors was not modelled.

2.3 Simulation Models

Simulation models have a wide range of application and have been used for many international airport projects. Low (1974) has outlined several major airport projects that were analysed using simulation models and described some of the potential pitfalls and suggested guidelines. These airport projects included:

- Dallas-Fort Worth Regional Airport
- Greater Pittsburgh Airport
- Maiquetia International Airport at Caracas, Venezuela

McCabe and Carberry (1975) concluded that the most realistic method of quantitatively determining airport landside traffic problems, appears to be computer simulation. Their paper described how simulation can be used to represent or model the airport landside system to determine the flow and holding capacity and the associated delays.

Simulation models can provide a high level of accuracy and detail. However, they are usually time consuming in terms of data collection and have limited application because of their expense. Their main application is for time-based situations of such complexity that simpler mathematical models are not appropriate.

2.4 Linear Regression Technique

Koussious and Homburger (1967) employed step-wise multiple linear regression to develop relationship between the hourly vehicular flows associated with either the carpark facilities or the main route, and the number of air passenger arrivals or departures per hour.

The results of this regression analysis indicated that that a stable relationship did exist between airport generated ground traffic and the number of arriving/departing air passengers. The model represented a useful methodology for predicting vehicular volumes in relation to air passenger volumes. However, disaggregation of domestic and international terminal and also time blocks of less than one hour were not considered in this model.

3. MODEL METHODOLOGY AND RESULT

After reviewing several modelling techniques as potential options for this study, it was decided to develop a model based on the linear regression and unitgraph techniques. Similar to the model by Koussious and Homburger (1967), traffic count data were used as the dependent variable in the linear regression equations. However, for this research, the linear regression equations were developed based on the separate movement of aircraft passengers in the domestic and international terminals. Furthermore, the traffic counts were classified into 15 minutes interval instead of one hour as used by Koussious and Homburger (1967) in order to make the analysis more accurate.

Multiple linear regression equations were then derived relating the vehicle traffic to/from the domestic and international terminals to the arriving and departing passenger flows at those terminals.

To derive the linear regression equations, assumed untigraphs for each aircraft/ground traffic movement type were created. A unitgraph is a graph of passenger movement on each aircraft whose ordinates when summed equal to 100 %. As explained earlier, 15 minutes time interval is implemented for each unitgraph ordinate.

An outline of the proposed vehicle generation model for the Auckland International Airport is presented in Figure 1 below.

For this study, the unitgraphs were based on the study by Blake (1974) which use recorded field data. The unitgraphs were then modified to take account of the current passenger and traffic flow conditions at the Auckland Airport. The assumed unitgraphs used are illustrated in Figure 2.

After the assumed unitgraphs were created, they were then used to construct passenger flow graphs for each aircraft/ground traffic movement type. Four different macros using Visual Basic language were developed in order to make computing process faster. Predicted passenger flows were then classified into 15 minutes interval so as to establish linear regression equations together with traffic count data.

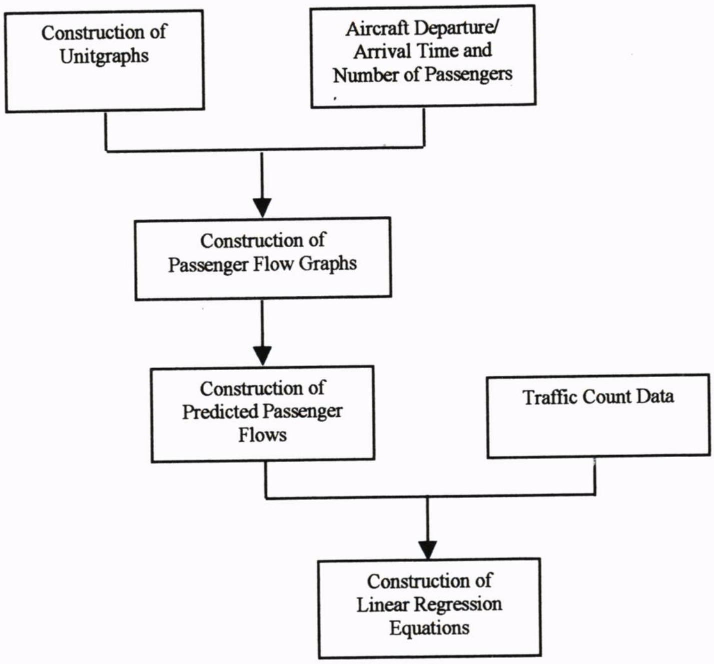

Figure 1. Flow Chart of Vehicle Generation Model

The stepwise linear multiple regression combined the data collected (traffic counts and predicted passenger flows) to derive equations of the form:

$$Y = a + bX_1 + cX_2 \qquad (1)$$

Where,
Y = dependent variable (vehicle traffic counts)
X_1, X_2 = independent variables (predicted passenger flows)
a, b, c = constant

After performing the step as outlined before, the linear regression equations for this research project were obtained as listed in Table 1.

Table 1. The Result of Multiple Linear Regression Equations

Model	**Equation**	**R^2**	**Standard Error**
Domestic Inbound Traffic	$Y_1 = 58.3447 + 0.786*X_{11} + 0.2062*X_{21}$	0.6444	34.1985
Domestic Outbound Traffic	$Y_2 = 52.8685 + 0.4119*X_{21} + 0.6423*X_{22}$	0.4958	39.4059
International Inbound Traffic	$Y_3 = 47.6653 + 0.3091*X_{31} + 0.4966*X_{32}$	0.5581	38.3539
International Outbound Traffic	$Y_4 = 48.217 + 0.138*X_{41} + 0.5452*X_{42}$	0.5581	38.3539

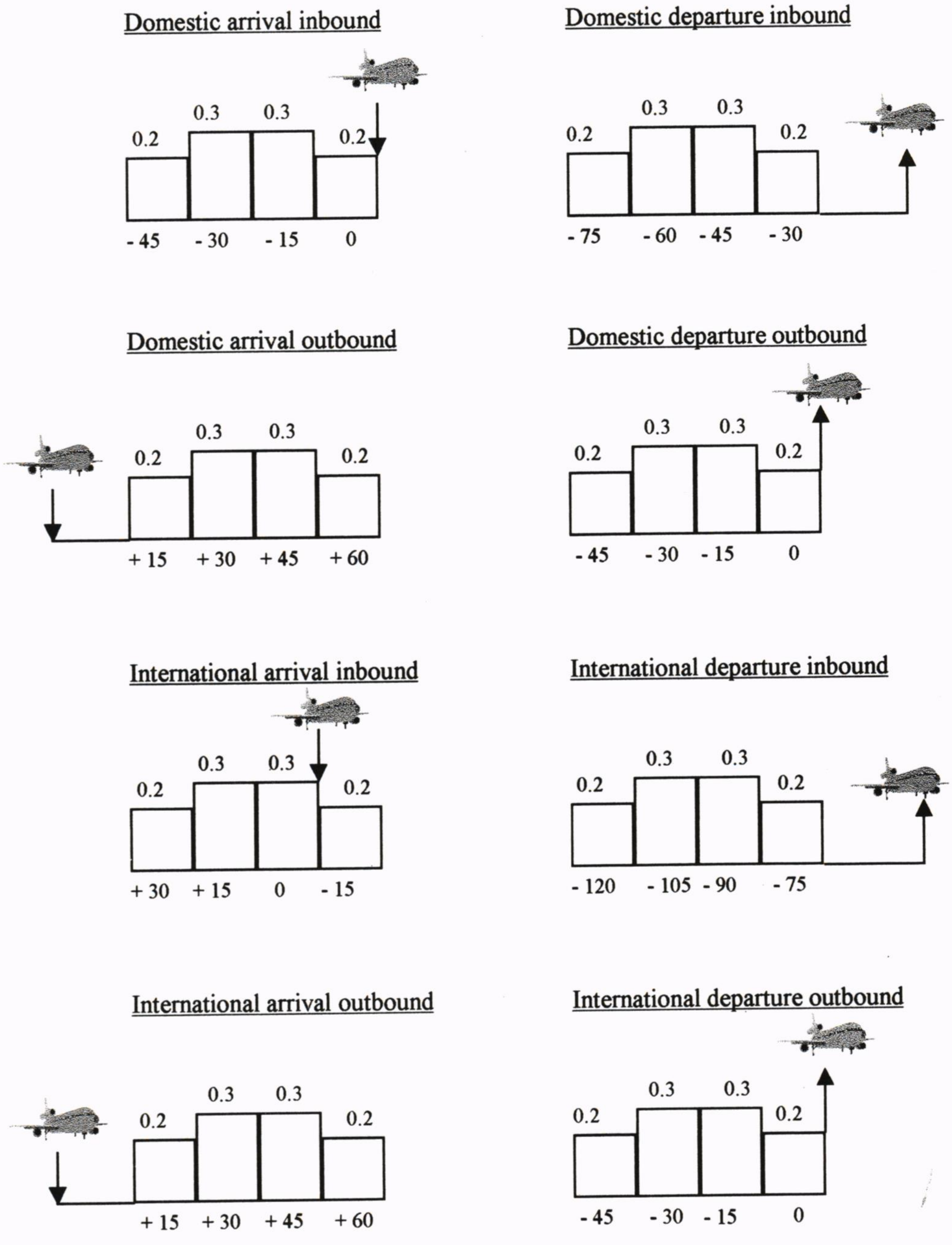

Figure 2. Assumed Unitgraphs for Each Aircraft/Ground Traffic Movement Type

Where,
Y_1, Y_2 = number of domestic inbound, outbound vehicles per 15 minutes
Y_3, Y_4 = number of international inbound, outbound vehicles per 15 minutes
X_{11} = predicted inbound domestic departure passenger flows per 15 minutes
X_{12} = predicted inbound domestic arrival departure passenger flows per15 minutes
X_{21} = predicted outbound domestic departure passenger floes per 15 minutes
X_{22} = predicted outbound domestic arrival passenger flows per 15 minutes
X_{31} = predicted inbound international departure passenger flows per 15 minutes
X_{32} = predicted inbound international arrival passenger flows pe r15 minutes
X_{41} = predicted outbound international departure passenger flows per 15 minutes
X_{42} = predicted outbound international arrival passenger flows per 15 minutes

As shown in the Table 1, the multiple linear regression analysis produced a stable relationship between domestic/international terminal generated vehicle flows and the number of arriving/departing passengers. The equation also produced reasonable R^2 values (coefficient of multiple regression) and standard error of estimates.

4. MODEL CALIBRATION

Proposed calibration of the vehicle generation model was undertaken by adjusting the linear regression equations and the ordinate of assumed unitgraph. Outline detail of the proposed method to calibrate the vehicle generation model are shown in Figure 3.

The general steps of the process undertaken are as follows:

- The linear regression equations obtained were used to calculate the modelled/predicted vehicle flows using the predicted passenger flow information
- The modelled vehicle flows were then compared to the actual vehicle count data
- As a result of this comparison, calibration factors were obtained, namely:

$$\text{calibration factor} = \frac{\text{actual vehicle counts}}{\text{modelled vehicle flows}} \tag{2}$$

- The calibration factor for each aircraft/ground traffic movement type was then used to construct new unitgraphs
- The modelling process was repeated again by using modified unitgraph for each aircraft/vehicle movement type
- The calibration process continued until the calibration criteria (number of iterations) are met.

Thus after each iteration the calibration process was stopped and the modified unitgraphs and linear regression equations were obtained. The modelled vehicle flows obtained from the new linear regression equations were then compared again to the actual vehicle count data. Due to time and data limitations, further analysis to improve the calibration method were not undertaken.

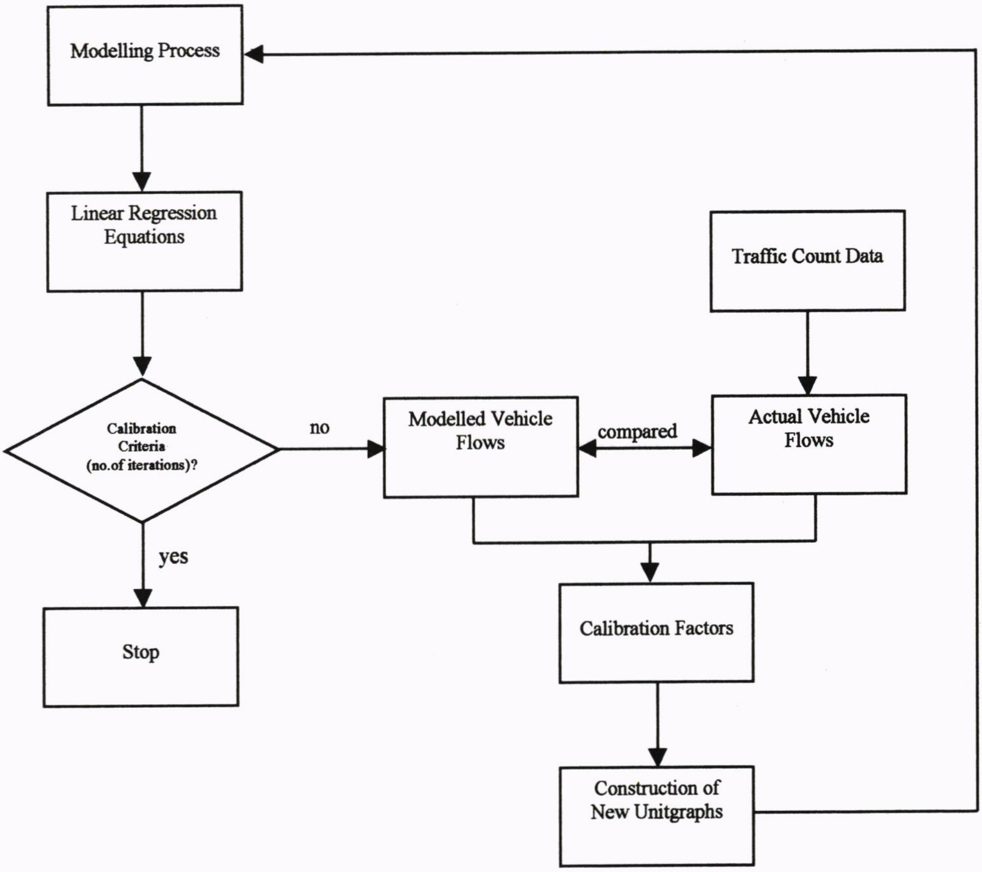

Figure 3. Calibration Process of the Vehicle Generation Model

5. SUMMARY AND CONCLUSSIONS

The methodology developed to predict the ground traffic flows to and from the airport during the a.m. peak period has been proven to be successful. In brief the vehicle generation model was based on a combination of unitgraphs and multiple linear regression techniques. Assumed unitgraphs for each aircraft/vehicle movement type were used to produce the predicted passenger flows. The linear regression equations were then developed using the relationships between vehicle flows obtained from traffic counts and the predicted passenger flows in 15 minutes intervals. Four sets of equations were developed, namely: inbound and outbound vehicle flows, to and from the domestic and international terminals.

Further researchs need to be undertaken to improve the proposed calibration method for the vehicle generation model.

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