Methodology for Level of Service Analysis for Airport Curbside and Roadway Operations

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ABSTRACT : The paper evaluates existing level of service (LOS) of the airport curbside and roadway operations at the Bandaranaike International Airport (BIA) and how user characteristics can be incorporated to LOS improvements. Curbside performance has been proved to be a significant component in the overall LOS of an airport. Sensitivity of the variables was considered to identify the critical parameters. Multivariate regression is used to obtain mathematical relationships of user characteristics which correspond to the dwell time. The study used an analytical approach instead of the traditional simplified method given in International Air Transport Association (IATA) manual as a design guideline. Measures were identified to improve the operational efficiency of these facilities and to propose improvements to ensure better operational efficiency for the forecast future demand.

1 INTRODUCTION

Bandaranaike International Airport (BIA) is one of two international airports serving Sri Lanka. It is operated by Airport and Aviation Services (Sri Lanka) Limited (AASL). BIA is currently experiencing more than 8 million annual peak passenger movements which surpass the capacity of existing terminal. AASL's peak forecast of annual traffic is 14.542 million in 2020 (Ministry of Civil Aviation, 2012).

2 OBJECTIVES

The objectives are to study the importance of vehicles and user characteristics on the performance of curbside and roadway area of the BIA. Also to incorporate them in the evaluation of Level of Service (LOS) using an analytical approach as an alternative for traditional methods. This is used to analyze the existing infrastructure will perform with expected growth in demand as well as planned new development such as a new terminal.

3 LITERATURE REVIEW

3.1 *Importance of the curbside*

Global index for the evaluation of the LOS of the operational components at an airport is useful in evaluating the overall LOS on a single scale and according to user perceptions (Andersen et al. ,2008). It is assumed that the overall LOS is a function of the LOS of individual components, such as check-in, departure lounges, etc., as well as socio-economic variables.

3.2 *Performance evaluation*

Two guidelines were available to analyze and evaluate the performance of the curbside and roadway operations. Traditional simplified method given in International Air Transport Association (IATA). This gives standard figures which can be used in designs (IATA, 2004). Airport Cooperative Research Program (ACRP) provides more calculations and detailed evaluation models than IATA manual in their study report ACRP Report 40-Airport Curbside and Roadway Operations (ACRP 40) (Transport Research Board, 2010).

3.3 *User characteristics*

Parameters which are sensitive to the user characteristics are; vehicle dwell time, passenger occupancy level, passenger baggage handling rate, passenger groups, passenger lag time and lead time, passenger category, trip purpose of the air passenger, mode choice peak-hour factors, travel speeds, queue length etc.

3.4 *Airport roadways*

Roadway operations cannot be solely represented as a function of air passenger volumes.

Curbside roadways are one-way roadways located immediately in front of the terminal buildings where vehicles stop to pick up and drop off airline/non-airline passengers and their bags. Generally, curbside roadways consist of following road categories. (1) Inner lanes where vehicles stop or stand in a nose-to-tail manner while passengers

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load and unload.. (2) Adjacent maneuvering lane which is used to approach the inner lane. (3) Through or bypass lanes; which are used to move the vehicles through the facility without stopping or trying to stop there (Transport Research Board, 2010).

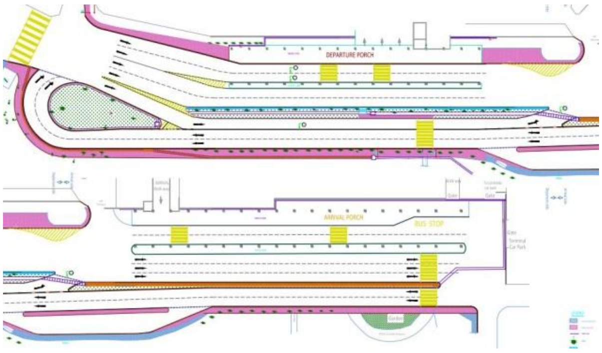

Fig. 1 Existing curbfront configuration

4 RESEARCH METHODOLOGY

An extensive literature survey identified the importance of the LOS improvements by incorporating user characteristics. IATA manual (International Air Transport Association) provides a more general approach. ACRP 40 proposes a methodology that incorporates an analytical approach compared to the IATA manual. Therefore this research considers the ACRP guideline to propose recommendations.

4.1 *Data collection*

A supplementary field survey was carried out at the BIA in the month of January which is one of the peak passenger movements according to historic data in addition to the data available from a previous study by Galagedara et al. (2014). Operational regulations and other recorded data were gathered from the relevant divisions of the AASL. Addition to that several field visits were done to observe the practical operation conditions in BIA.

Historic passenger movements' data were considered in order selecting most critical and suitable time for the field survey.

Weaving section is a segment where most complex vehicle movements occur. Vehicles from departure curbside to arrival bypass roadway, vehicles from departure bypass roadway to arrival curbside roadway are the main vehicle streams that could be observed.

4.2 *Critical parameters*

Identify the significant components to evaluate existing and forecasted LOS while considering lowest as the governing LOS of the system (curbside and roadway). Variables of the each component have to be considered in the analysis to identify the most significant user characteristic. Mathematical models provide in the ACRP 40 Methodology has to be checked with respect to the sensitivity over other variables.

4.3 *Demand Forecasting*

Future peak passenger movements of the BIA were forecasted by JICA (Japan International cooperation Agency) with the purpose of using it in the future planning process. With proposed infrastructure developments, there are some variations in the passenger movements. Since responsible authorities have not taken any policy decision about how to manage new facility with existing facility; it is required to make reasonable assumption. It can be assumed as 25% and 50% movements will be transferred to the new terminal.

5 ANALYSIS

BIA falls to the small hub airport category under the ACRP performance level criteria and is used those guidelines to analyse the BIA roadway performances (Transport Research Board, 2010).

5.1 *Departure and arrival curbside*

The average waiting time in the queue is used as a performance measure to evaluate the LOS of the arrival/departure curbside area.

$$AWTQ = \frac{AR \times 3600}{\frac{60 \times NoS}{DT} \times \left\{\frac{60 \times NoS}{DT} - AR\right\}} \dots\dots\dots\dots (1)$$

Where *AWTQ* is Average Waiting Time in the Queue, *AR* is Arrival Rate, *Nos* is Number of Slots and *DT* is Dwelling Time.

Average departure passenger occupancy level is 3.82 according to the most recent field survey carried out. Average dwell time was 2.69 minutes. Peak hour vehicle volume were recorded as 340veh/hour. This correspondence to a LOS of C as per the criteria set out in ACRP 40 methodology.

Alternatively, curbside utilization can be used as a performance measure for Departure and arrival roadways. Curbside utilization is the ratio between Design Length (given in equation 2) and the available length.

$$DL = \left\{\frac{AR \times DT}{60}\right\} \times F \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Where; AR - Arrival Rate, *DT* - Dwelling Time, *F* - Average vehicle stall length and *DL* - Design Length.

The analysis found the factor of curb side utilization is 1.03 for departure curb side roadway which corresponds to a LOS "C" (for 2.5 minutes Dwell Time).

5.2 *Access roadways*

Access Roadways LOS analysis is proposed based on the Highway Capacity Manual 2000 (HCM 2000) Methodology for Multi-lane roads. The LOS is determined from a table based on the average speed, design speed limit (free flow speed) and the vehicular flow. Under recorded data, mean of the speed at the access road is 31.64 km/h. Current LOS is "B" for the peak hour flow of 340vehicle/hour and considering a speed limit of less than 40 km/h for internal roadways.

5.3 *Weaving segment*

Density is used to evaluate the performance of the Weaving segments for LOS analysis. Density is defined as the adjusted flow (v-passenger cars /hr lane)/ average speed. User characteristics that influence on lane change rate were identified as; 1.speed of the vehicle, 2.driver familiarity, 3.driver response time and irregular and apparently random fluctuations in speed (Transport Research Board , 2010).

Equation 3 was used to calculate the heavy vehicle adjustment factor (f_{HV}). Weaving Intensity factor (W) and Average speed of weaving vehicles within the weaving segment (S_w) was calculated from the equation 4 and 5 respectively. Equation 6 and 7 provide the Average speed of non-weaving vehicles in weaving segment (S_{NW}) and Average vehicle speed in the weaving segment(S). Density was calculated using equation 8.

$$f_{HV} = \frac{1}{\{1 + P_T(E_T - 1) + [P_R(E_R - 1)]\}} \quad \ldots\ldots\ldots (3)$$

$$W = 0.226 \times \left[\frac{L_{all}}{L_s}\right]^{0.789} \quad \ldots\ldots\ldots (4)$$

$$S_w = S_{min} + [S_{max} - S_{min}]/[1 + w] \quad \ldots\ldots\ldots (5)$$

$$SN_w = FFS - [0.0072 - LC_{min}] - [0.0048 - \left(\frac{v}{N}\right)] \quad \ldots\ldots\ldots (6)$$

$$S = (V_w + V_{nw}) / [\left(\frac{V_w}{S_n}\right) + \left(\frac{V_{nw}}{S_{nw}}\right) \quad \ldots\ldots\ldots (7)$$

$$D = \frac{\left[\frac{v}{N}\right]}{S} \quad \ldots\ldots\ldots (8)$$

$$V = \frac{V_i}{PHF \times f_{HV} \times F_p} \quad \ldots\ldots\ldots (9)$$

Where, Percentage of Heavy vehicles (P_T), Equivalence of Heavy vehicles (E_T), Percentage of recreational vehicles (E_R), Percentage of recreational vehicles (P_R),Weaving segment length (L_s), Total lane change rate (L_{All}), Non weaving demand flow rate in the weaving segment (V_w), Weaving demand flow rate in the weaving segment (V_{NW}) Free flow speed (*FFS*) Equivalent passenger car units (v), No of lanes within the weaving segment (N), Maximum average speed expected in the weaving segment (S_{max}) and Minimum average speed expected in the weaving segment (S_{min}).

Vehicle volume should be converted to the equivalent passenger car units by using the methodology proposed in the Highway Capacity Manual 2000 for weaving segments (*see* Equation 9). Existing LOS was calculated as "C" using above set of equations and LOS criteria provided in the ACRP 40 Methodology.

5.4 *Circulation Roadway*

Circulation Roadway LOS analysis follows a similar method to calculating the LOS of the Access roadways and the HCM 2000 methodology is adopted. The circulation roadway is a two lane road segment, having a capacity of 1600 vehicles/hr. The current vehicle flow rate is in a lower level of 120 vehicles per hour therefore, the current LOS is "A".

5.5 *LOS Analysis for Future Demand*

Based on the current demand levels the most critical component in the curbside and roadway system is the curbside roadway and the weaving segment which gives the lowest LOS. Similar analysis was conducted for future demand scenarios to evaluate the level of service of the system. Table 2 gives the resulting system LOS for different demand scenarios.

For example, at the arrival curb side, if these existing facilities maintain as it is the situation is will worsen by the year 2020 and the level of service will be "F" which is the worst service level. For the departure curbside for the forecasted demand rates in 2020 LOS is "E" (for 2.5 minutes Dwell Time, and no change in operational conditions).

Table 2. LOS variation with demand

Scenario Considered	LOS
Current LOS	C
Forecasted demand in 2020	
Without any improvements	F
With utilized outer porch	D
25% shifted to new terminal	D
50% shifted to new terminal	B

6 CONCLUSION

The study shows how different user characteristics can affect the performance of different segments related to airport curb side and roadway using an analytical approach. This is an improvement from the simplified approaches where the impact on operations from relevant factors cannot be quantified.

The findings of the study are useful for future planning of the facilities as well as evaluating the impact of operational improvement measures.

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