Improving Timetable Planning of Airport Bus Stop to Enhance Seamless Transportation of Off-shore Islands

Suiling Li[a]

[a] *National Penghu University of Science and Technology,300 Liu-ho Rd.,Magong, Taiwan*
suiling@npu.edu.tw

Abstract: The paper propose two optimizing planning models, in order to make the best arrangement of airport arriving/departing time point which is based on the advantageous necessary connection time of flight-bus-relationship and given flight demand for each time point in each hour. This study integrate the merits of a bi-level and fuzzy multi-objectives model to expand optimal performance of the minimum connection time between flight and bus and maximum the coverage of flight served in different level of waiting time Meanwhile, designing regulated schedule parameters of passenger departure/arrival procedure. The outcomes show that the optimal model reschedule is better than the serving efficiency of current bus timetable. The outcome show the available under 35 minutes of rescheduling operational time for each time point of airport bus stop, not only comply with the passengers' acceptable waiting time and connecting time, but also enhance the managing strategies and flight serving level.

Keywords: Bus Timetable, Off-shore Island Airport, Waiting Time, Fuzzy Multi-objectives Programming

1. INTRODUCTION

Passengers rely on the taxis, tourist buses, or cars to access most off-shore island airports, not only because they are unwilling to take a scheduled bus, but because the bus schedule is infrequent and inconvenient shortage. These tourism phenomena result in a waste of transportation resources and a bad image of public transportation. However, public transportation save energy and decreases carbon consumption in the summer tourism season, the bus seamless transportation to be a very significant and important issues for off-shore island airport access without railway modes by geography constraints. Once the bus scheduled time table is not well planned and operated, it will cause the loss of customers and passengers. Therefore, it is important that how to develop precisely timetable. Thus, modifying the schedule of bus arriving/departing airport could enhance bus serving quality and green transportation related approach such as purchasing vehicles, constructing new transit modes to enhance transit service quality. However, these methods either incur huge expenditures or have some impacts on the environment. Furthermore, these changes take a long time to implement. Therefore, for long term improvements first step is to understand how to effectively utilize limited bus frequencies with rescheduled timetable allocation of arriving and departure time points. Meanwhile improving the ability of bus frequency management is first priority and the lower management costs. In order to evaluate the performance of time point planning and reach available minimum connection time between bus and flight. In the short term, first thing is how to make the better planning between an bus's airport timetable existing limited vehicles and passengers' take-off/landing flights timetable to enhance available bus scheduled timetable. Because off-shore islands is short of financial resource and transport environment limits, this paper will be potentially the most effective means of enhancing green public transportation for passenger access convenience of off-shore islands airports. In order to evaluate the performance of bus timetable and determine whether current bus timetable is being utilized effectively, it is necessary to develop a practical model to integrate bus and flight timetables. This study will proposes a rescheduled concept of bus timetable and by rescheduled the present time point of airport bus stop.

In fact, some bus arrival/departing time point may not the optimal utilization of schedule frequency, which worsens inconvenient problems, not seamless. To ensure more seamless bus transportation, two representative measures are used; the schedule parameters of passenger arrival/departure procedure and passenger acceptable waiting time for a bus, as these influence a passenger's decision to take the bus. One is helpfully understanding the suitable schedule relationship and connecting time both flight arrival time to bus departure schedules and flight departure time to bus arrival schedules. The others will clearly understanding how to allocate and reschedule the sequence of bus timetable to meet the passenger demand to arrange and measure a suitable model of timetable planning. Li (2013) proposes bus timetable of bi-level reschedule model can improve connected time between flight and bus transit and waiting time for flight passenger's acceptance. Therefore, this paper will in advance measure and improve the relationship function between the minimum connection time and maximum flights by bus served to generate more strategies of bus timetable planning. In advance, this paper will propose fuzzy model to measure the membership function of both allocation relationship of the connecting time between departing-flight to arriving-bus and arriving-flight to departing-bus, and generate the merits of less waiting time and more served flights. The upper level of the bi-level model is used to design the optimal bus timetable and the lower level determines the maximum number of flights that a bus timetable can serve in an ecological manner. The coverage of an optimal bus timetable is firstly discussed new strategies are then proposed for planning the bus timetable.

The outline of this paper is as follows: firstly the importance of the airport bus schedule issues is assessed. Section 2 provides a brief overview measurements and connection issues for the flight timetable and the bus timetable. This section also develops a measurement strategy for the connection time between the flight timetable and the bus timetable and the important points connecting constraints or factors. In section 3 the upper level of bi-level-fuzzy mathematic framework is constructed, using important variables and parameters for the bus timetable and the flight timetable, and the acceptable waiting time for passengers is used to determine the maximum number of buses required to serve flights and to construct a lower level measurement model. The model constructs the membership function of the connection time between the flight timetable and the bus timetable. Section 4 utilizes an April 2012 flight timetable of Magong airport, bus timetable and a questionnaire concerning the waiting time for bus passengers. This section also compares the optimal bus timetable and the current bus timetable. Section 5 summarizes the results and draws major conclusion.

2. MEASUREMENT SEAMLESS CONNECTION TIME AND WAITING TIME BETWEEN THE FLIGHT AND AIRPORT BUS

2.1 The Concepts and Measurement of Connection Time and Waiting Time Between Flight and Airport Bus

This study reviews the literature for bus timetable planning and operation for bus transportation such as Ceder, Golany, and Tal (2001), Yan , Chi, and Tang.(2006) and Salicru, Fleurent, and Armengol (2011) focus the analytical timetable model and simulation to generate interactions between planning/execution binomial but integrate flight and bus timetable. In general, airport service quality literature will examine accessibility and connectivity to evaluate airport compositeness. Accessibility can be seen as demand-side measure that captures how easily passengers are able to access air transportation. Connectivity can be as a supply-side measure that define how well-integrate an airport into a larger network. Many studies research focus on airport connectivity and airline network connectivity (Wittman ;2013). Redondi, Malighetti, and Paleari (2013) studied European small airport and measured airport accessibility and connectivity with travel time, and decompose travel time into three components : access time to departure airports, flight time including waiting times in intermediate airports, and access time from arrival airports to final destinations. Li (2010; 2013) studies debate the frequency issues between the bus timetable and flight timetable, only mention the small airport access issues and construct bi-level model to integrate flight timetable and bus timetable to measuring suitable bus timetable to meet the arrival/departure acceptable connection time and waiting time. Therefore, this study will expand integrate the connection relationship between the bus timetable and flight timetable to improve and achieve passenger’s good accessibilities.

The aims of seamless transportation require two representative objective measurements.

One objective is to design the timing of the optimal bus timetable to ensure a minimum connection time between flight and bus timetables. This objective can measure the membership function of optimal connection time between flight and bus timetables with fuzzy multi-objectives programming. The membership function can analyze the difference between arrival/departure connection time. The other objective is maximum the number of flights covered by the bus timetable, to satisfy green transportation objectives. In order to show the sequential decision-making for these two objectives, with the constraints of connection time for bus and flight timetables and passenger processing at the airport, this study proposes a bi-level programming model to determine the frequency of the bus timetable, and to ensure a greener use of transportation. The upper level of bi-level model determines the minimum connection time between flight and bus timetables, Firstly, the coverage of the optimal bus timetable is discussed and new strategies are proposed for planning the bus timetable.

This study examines how the process for passenger embarkation and bus procedures and the acceptable waiting time for a bus, influences a passenger's decision to take the bus. According to airline regulation, the passengers who take the bus arrive at the airport 30 minutes before flight departure to check in and complete formalities at the airport under normal circumstances, if there are no flight delays or technical delays, so travelers taking a bus or car must arrive at the airport 30 minutes before flight departure. The arriving passengers may be subject to flight delays or technical delays and they may need to negotiate baggage claim and walk from the terminal to the bus station and wait for the bus. This study was to define the relationship between bus schedules and flight schedules for passengers traveling from/to the airport. These constraints or factors for the acceptable connection time between the airport bus timetable and the flight timetable include the acceptable waiting time for a bus, the time required for luggage claim and the minimum arrival time for check in before departure flight and these are used to construct an analysis framework and to determine the schedule parameters of passengers' inbound/outbound procedures.

2.2 Measuring Bus Connection Time And Cover Flight With A Fuzzy Multi-objectives Programming And Bi-level Programming Application

2.2.1 The Concept of Fuzzy Multi-objectives Model

In general, a fuzzy multi-objectives programming problem is defined as follows function (1) to (2). The membership function $DS_s(W_s)$ which indicate the degree of satisfaction for each objective W_s is defined as function (2). Each W_s^* represent the ideal solution to shows the independently optimal performance of its objective W_s. Meanwhile, each $W_s^\#$ represents the anti-ideal solution to show the worst possible performance of its objective while optimizing other objectives. Both W_s^* and $W_s^\#$ are used as the reference points to define the membership function.

$$DS_s(W_s) = \begin{cases} 1 & W_s \le W_s^* \\ \dfrac{\left(W_s^\# - W_s\right)}{\left(W_s^\# - W_s^*\right)} & W_s^* < W_s \le W_s^\#, s = 1,2,3,....n \\ 0 & W_s > W_s^\# \end{cases} \tag{1}$$

A compromise-grade λ is defined to represent the degree of overall satisfaction of the optimization and is expressed as function (2)

$$\lambda = \underset{s}{MIN}\left\{DS_s(W_s) \middle| s = 1,2,3,...,n\right\} \tag{2}$$

Through the maximization of the λ, we may get the compromised solutions, the multi-objective problem is transformed to the following function (3) to (5).

$$Max \quad \lambda \tag{3}$$

s.t.

$$\lambda \le (W_s^\# - W_s)/(W_s^* - W_s^\#), s = 1,2,...,n \tag{4}$$

$$\lambda \in [\ 0\ ,\ 1 \tag{5}$$

We also used Lee and Li(1990) proposed a two-phase fuzzy programming with a fully compensatory operator averaging and restricting by $\lambda_s \ge \lambda, \forall s$. The compromise-grade λ_s as function (6) to (8)

$$Max \quad \frac{1}{\mathrm{n}}\left(\lambda_1 + \lambda_2 + ... + \lambda_n\right) \tag{6}$$

s.t.

$$\lambda \le \lambda_s \le (W_s^\# - W_s)/(W_s^* - W_s^\#), s = 1,2,...,n \tag{7}$$

$$\lambda_s \in [0,1], \quad s = 1,2,...,n \tag{8}$$

2.2.2 The Concept of Fuzzy Multi-objectives Model

This study seeks to determine the minimum connection time and to maximize the number of flights served. In order to improve the current bus timetable, this study proposes a bi-level programming model to modify and evaluate the bus timetable.

In general, a bi-level programming problem is defined following functions (9) to (12).

$U1)$ is defined as an upper level problem and $L1)$ a lower level problem. The planner at the upper level influences the lower level decision maker by setting x, thus restricting the feasible constraints set for the lower level decision maker. The upper level decision maker also interacts with the lower level decision maker via the objective function of the lower level planner. The decision variable for the lower level problem is expressed as a function of the decision variable at the upper level ($y(x)$).

$$U1) \quad \min_{x} \quad F(x,y) \tag{9}$$

$$s.t. \quad G(x) \le 0 \tag{10}$$

Where $y(x)$ is implicitly defined by

$$L1) \quad \min_{x} \quad f(x,y) \tag{11}$$

$$s.t. \quad g(x,y) \le 0 \tag{12}$$

3. THE PLANNING MODEL FOR THE BUS TIMETABLE

This study constructs a bi-level fuzzy programming model to reschedule an existing time point for airport bus stop to allow it to serve the maximum number flights under current constraints for bus operation. This section separates the assumption, notation and model three parts.

3.1 Notation and Descriptions

The notation and description of the parameters and variables is as follows:

X_{ij} : whether scheduled flight i can be served by scheduled bus j

BT_j : the scheduled time for bus j arrival at the airport

BT_j^0 : the current scheduled time for bus j arrival at the airport

FT_i^a :the current scheduled time for flight i arrival

FT_i^d : the current scheduled time for flight i departure

$BFTA$: the time for arriving passengers to claim luggage and walk to the airport bus stop and wait for the bus

$BFTA^0$: the minimum required time at least 15 minutes for arrival passengers to claim luggage and walk to the airport bus stop and wait for the bus

$BFTD$: the time for departing passengers arriving airport check-in counters before departing flights at the airport bus stop 30 minutes before the departure of flight i

$BFTD^0$: the minimum required time according to airline regulation at least 30 minutes before flight take-off in domestic airports for departing passengers arriving airport check-in counters before departing flights at the airport bus stop

BS: the serving arrival/departure flight numbers of bus serving level

$BSOT$: the operational time of bus manpower constraints influence the acceptable time point of bus rescheduled.

λ_A: the satisfaction degree of the connection time optimization between arrival flight and bus

λ_D: the satisfaction degree of the connection time optimization between departure flight and bus

W_A^*: the ideal solution to shows the independently optimal performance of its the connection time optimization between arrival flight and bus

W_D^*: the ideal solution to shows the independently optimal performance of its the connection time optimization between departure flight and bus

W_A: the membership function of the connection time optimization between arrival flight and bus

W_D: the membership function of the connection time optimization between departure flight and bus

$W_A^\#$: the anti-ideal solution to show the worst possible performance of the connection time optimization between arrival flight and bus while optimizing other objectives.

$W_D^\#$: the anti-ideal solution to show the worst possible performance of the connection time optimization between departure flight and bus while optimizing other objectives.

3.2 Construct Fuzzy Multi-objectives Bi-level Model

This study assumes all scheduled flight operation and scheduled bus operation are normal on time and no delay. The scheduled buses reschedule time points of airport bus stop, are acceptable roster time and capacity in normal operation for bus authorities.This study defines the bus schedules as not being a constraint and that traffic flows freely and assumes no flight or technical delays. The minimum connection time between the bus timetable and the flight timetable is assumed to be the upper level of the model and the maximum number of flights that the bus timetable can serve is the lower level. This section defines the fuzzy membership function of connection time between the bus timetable and the flight timetable is assumed to be the upper level of the model and the maximum number of flights that the bus timetable can serve is the lower level.

3.2.1 Upper level model

This upper level is concerned with the fuzzy membership function of connection time between the bus timetable and the flight timetable, the satisfaction degree of fuzzy membership function of total connection time is this study main objective. This membership function combines both membership function of arrival passenger's connection time and departure passenger's connection time. From the relationship change between both membership function of arrival passenger's connection time and departure passenger's connection time, we can get more physical operation strategies of planning bus timetable. Therefore, the fuzzy number for membership function of total connection time achieve 1 is better. Function 13 combines arrival and departure fuzzy number (compromise-grade), the number is bigger better. Function 14 is the relation of arrival flight membership function between ideal solutions, anti-ideal solution of arrival flight connection time. Both W_A^* and $W_A^\#$ are used as the reference points to define the membership function. Function 15 is the relation of departure flight membership function between ideal solutions, anti-ideal solution of departure flight connection time. Both W_D^* and $W_D^\#$ are used as the reference points to define the membership function. Function 16 is the arrival flight membership function of connection time between bus depart at the airport and flight arrival must take account of passengers' departure procedure at the airport. Function 17 is the departure flight membership function of connection time between bus arrival at the airport and flight take-off must take account of passengers' departure procedure at the airport. Function 18 is the fuzzy number of membership function for arrival flight connection time is larger equal to 0 and less equal 1. Function 19 is the fuzzy number of membership function for departure flight connection time is larger equal to 0 and less equal 1. Function 20 and function 21 indicate whether a passenger for an arrival/departure flight wants to take the bus and consider the constraints of the time for baggage claim and check-in thirty minutes before flight departure. If the buffer time for baggage claim and walking to the bus stop at the airport are not included, the passenger will not catch the bus. For departing passengers taking the bus to airport, the travel time and before flight take-off 30 minute buffer at the airport must be included, to ensure that they can check in and catch the flight. Function 22 indicates the minimum service level for each scheduled bus serving a number of arrivals / departures. Function 23 indicates that every modified time point of bus timetable must not exceed available operation time of bus company capacity and working hours. Function 24 represents the available operation time of manpower capacity and working hours movements must larger than 0. Function 25 represents each time point of the optimal bus schedule must be larger than 0. Function 26 represents each scheduled bus serving each arrival / departure with integer values of zero or one. Function 27 represents the variables of time point in the optimal bus scheduled with the integer variables. Function 28 represents the available operation time of each time point for the bus company capacity and working hours with the integer variables.

$$MAX \quad \frac{1}{2}(\lambda_A + \lambda_D) \tag{13}$$

$$S.T. \quad \lambda_A(W_A^{\#} - W_A^{*}) - W_A^{\#} + W_A \le 0 \tag{14}$$

$$\lambda_D(W_D^{\#} - W_D^{*}) - W_D^{\#} + W_D \le 0 \tag{15}$$

$$W_A = X_{ij}\left|BT_j - FT_i^a - BFTA\right| \tag{16}$$

$$W_D = X_{ij}\left|BT_j - FT_i^d + BFTD\right| \tag{17}$$

$$\lambda_A \in [0,1] \tag{18}$$

$$\lambda_D \in [0,1] \tag{19}$$

$$BFTA \ge BFTA^0 \tag{20}$$

$$BFTD \ge BFTD^0 \tag{21}$$

$$\sum_{j=1}^{m} X_{ij} \ge BS_j \tag{22}$$

$$X_{ij} \cdot \left| BT_j - BT_j^0 \right| \leq BSOT \tag{23}$$

$$BSOT > 0 \tag{24}$$

$$BT_j > 0 \tag{25}$$

$$X_{ij} \in 0-1\ Integer \tag{26}$$

$$BT_j \in Integer \tag{27}$$

$$BSOT \in Integer \tag{28}$$

3.2.2 Lower level model

Function 29 represents the maximum number of flights that the bus timetable can serve, as the objective of a lower level. Function 30 represents the time constraints of arrival flight must comply with BFTA parameter minutes and less equal than the bus departure time. Function 31 represents the time constraints of departing flight must be in keeping with BFTD parameter minutes and more equal than the bus arrival time. Function 32 represents that every modified time point of bus timetable must not exceed available operation time of manpower capacity and forward/backward movement time of working hours must larger than zero. Function 33 represents each scheduled bus serving each flight arrival / departure with integer values of zero or one.

$$MAX \quad \sum_{i=1}^{n} \sum_{j=1}^{m} X_{ij} \tag{29}$$

$$S.T. \quad X_{ij} \cdot (BT_j - FT_i^a - BFTA) >= 0 \tag{30}$$

$$X_{ij} \cdot (BT_j - FT_i^d + BFTD) <= 0 \tag{31}$$

$$X_{ij} \cdot \left| BT_j - BT_j^0 \right| \leq BSOT \tag{32}$$

$$X_{ij} \in 0-1\ Integer \tag{33}$$

4. THE MODEL APPLICATION

4. 1 The study Case

Taiwan Makung airport of off-shore island is more traffic in July 2011 and 2012 with 287,918/303,219 visitors for that month. There are 4,170 flights in July 2012, or approximately 148 flights per day. The peak hours of scheduled flight have three periods such as 8:00-10:00, 13:00-15:00, and 18:00-20:30. Passengers access the airport always using taxis and tour buses, but not public buses. The off-shore island buses are not convenience. There are some tourism routes including the routes of Pengh bus, such as Longmen, Jianshan, Taiwu, Qingluo and Wukan. The Penghu bus routes from the airport stop to the city center are very fast only 15 minutes or 30 minutes routes of good views to see. Many passengers complain of the bus waiting times not bus travel times. According to 300 copies of passenger questionnaire as Table 1, the maximum acceptable waiting time for a bus is 15 minutes.

This study also surveys baggage claim time to nearly about 10-12 minutes at the Magong airport and the passengers walking time from terminal to bus stop only 2-3 minutes. According airline regulation all passengers before departure flight take-off 30 minutes must arrival airport to check in for domestic schedule flights. Therefore, this study take these parameters for and thirty minutes before departure for check-in, as a connection time between the bus and the flight timetable. Therefore, this study uses the $BFTA$ parameter to assign at least 15 minutes for arriving passengers' baggage claim and walking to the airport bus stop and waiting for a bus. $BFTD$ is assigned at least 30 minutes for departing passengers to arrive at the airport and board the departing flight. This study follows above mention two models and uses Lingo software for calculations. Therefore, this model also designs the passenger's different acceptable waiting times to discuss the impact of timetable acceptable.

Table 1 The waiting time of taking departing bus and departing flight schedule for survey

Waiting bus time of arrival flight passenger (minutes)	Number of passenger	Percent	Waiting flight time of ahead departing flight schedule(minutes)	Number of passenger	Percent
5-10	114	38.00%	35-40	120	40.00%
11-15	129	43.00%	41-45	118	39.33%
16-20	52	17.33%	46-50	57	19.00%
21-	5	1.67%	51-	5	1.67%
Total	300	100.00%	Total	300	100.00%

In order to easily execute and show the issues of current bus timetable, this paper not only compares Li(2013) bi-level model and designs bi-level-fuzzy model. The difference of

Li(2013) bi-level model only replace objective function (13) for bi-level fuzzy model of upper level and cancel functions (14)-(19). Minimum objective Function (34) in upper level of bi-level model as follows.

$$\sum_{i=1}^{n}\sum_{j=1}^{m} X_{ij} \cdot \left|BT_j - FT_i^a - BFTA\right| + \sum_{i=1}^{n}\sum_{j=1}^{m} X_{ij} \left|BT_j - FT_i^d + BFTD\right| \quad (34)$$

4. 2 The Results and Discussion

4.2.1 The performance of the optimal/fuzzy optimal time point for the airport bus stop

The bi-level-fuzzy 1 of this paper used Li (2013) bi-level model the same as serving flight number for each time point serving distribution of current airport bus timetable. The bi-level-fuzzy 1, which there is at least 84 flights can be served by bus for 148 flights. The value of BSOT, which is operational time constraints of between time point and time point, if the value is larger than more hours will cause the manpower loading cost of the bus company, and extend another cost issues not this paper focus issue. Thus Li (2013) finds the BSOT decision variable of optimal solution for bi-level model is 35 minutes, this value is well acceptable to bus company rescheduling work and easily compare the performance among current timetable and models. This paper also employs and design all approaches of time point are beyond 35 minutes of operational capabilities constraints. In order to show the performance bi-level-fuzzy model, this paper designs another bi-level-fuzzy 2 model, which the time point distribution of flight demand are relaxing and not the same as flight demand of airport bus timetable, there are at least 117 arriving/departing flights can served except 19:00-21:00 over bus serving time. Table 2 show the value of BSOT four models are less than 35 minutes.

Table 2 The time point planning of current airport bus stop and four models

Current schedule (1)	Bi-level 1 model (Li) (2)	Bi-level -fuzzy 1 (3)	Bi-level 2 model (Li) (4)	Bi-level -fuzzy 2 (5)	Current schedule (1)	Bi-level 1 model (Li) (2)	Bi-level -fuzzy 1 (3)	Bi-level 2 model (Li) (4)	Bi-level -fuzzy 2 (5)
07:10	06:35	06:35	07:39	06:39	12:35	12:33	12:10	12:50	12:50
07:20	06:45	06:45	07:50	06:55	12:50	13:15	13:00	13:25	13:25
07:25	06:50	07:40	08:00	07:40	14:25	14:30	13:55	13:50	13:50
08:20	07:45	08:20	08:30	08:00	15:05	15:05	14:55	15:00	15:00
08:30	08:25	09:00	08:50	08:30	16:45	16:20	16:20	16:10	16:10
09:25	09:00	10:00	09:30	09:00	16:50	16:51	17:25	16:20	16:30
09:30	09:30	09:30	09:50	09:30	17:10	17:30	16:35	16:35	17:25
10:30	10:05	09:55	10:50	09:55	17:35	18:00	17:00	17:00	18:00
11:00	10:45	10:25	10:25	11:20	18:10	18:45	18:45	17:35	18:45
11:10	11:00	10:50	11:25	10:50	18:10	18:30	17:46	18:45	18:30
11:50	11:25	11:25	12:00	11:25	18:55	19:14	18:30	19:30	19:30
12:25	12:10	12:00	12:10	12:10					

According to the maximum acceptable waiting time for a bus from the passenger questionnaire, this paper considers design the passenger's different acceptable waiting times not only can show the timetable design questions but also can discuss the passenger acceptability to time point of bus timetable. This study uses 0,1-5, 6-10,11-15,16-20,21-25 and 26-30 minutes as 7 scale size of waiting time, this design methods let small waiting time only generate one flight can be one bus served, if the waiting time expansion and did not exceed the length of between time points, the situation of the one flight can be one more buses served happen. Therefore, these scale size of waiting time can many solutions routes for serving passenger between airport and downtown.

1) The connecting time, waiting time and number of served flight

This study use four optimal outcomes to emphasize the model are reasonable acceptability for physical operation, the outcome figures are one flight one bus served, the other ( ) is one flight one more 1-2 buses served. 0-5 small waiting time is only general one flight can be one bus served. 6-10, 11-15, 16-20, 21-25 and26-30 waiting time did not exceed the length of time point, the one flight can be one more buses served happen. The Table 3 show the serving flight number of optimal bus timetable for four models are always better than current bus timetable for serving 84 flight or 117 flight, no matter in number of arriving flights served, number of departing flights served, and total number of flights served. Table 3 and Figure 1 also show the percentage of 6-10 waiting time in the bi-level-fuzzy 2 are better than current timetable and other models. It shows if 10 waiting time is acceptable for flight passengers, at least 39 arrival flights and 32 departure flights can be served. Figure 1 also shows the performance of the bi-level-fuzzy2 is better than the performance of current timetable and other models.

Table 3 The number of arrival/departure flight by bus serving with five approaches

Waiting time	0(minute)		1-5		6-10		11-15		16-20		21-25		26-30		Total(0-30)	
Approaches	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D
Current bus timetable	6	10	4	8	8	3	4	8	6	10	6	3	4	4	38	46
Bi-level 1 model (Li)	16	17	5	9	8	4	8	9(15)	3	5(6)	7(10)	6(7)	2(3)	6	49(57)	56(70)
Bi-level-fussy1 model	16	17	5	9	8	4	8	8(11)	3	5(6)	7(10)	6(7)	2(7)	7(6)	50(61)	53(69)
Bi-level 2 model (Li)	23	15	5	10	9(10)	7(10)	4(6)	6	4(5)	7(9)	6(8)	3(10)	7(11)	9(16)	57(68)	60(76)
Bi-level-fuzzy 2 model	19	19	5	11	15	2	2	9(12)	3	6(10)	8(11)	3	6(9)	9(18)	58(64)	59(75)

() :Represents one flight at least one more buses serving ; A: arrival flights D: departure flights

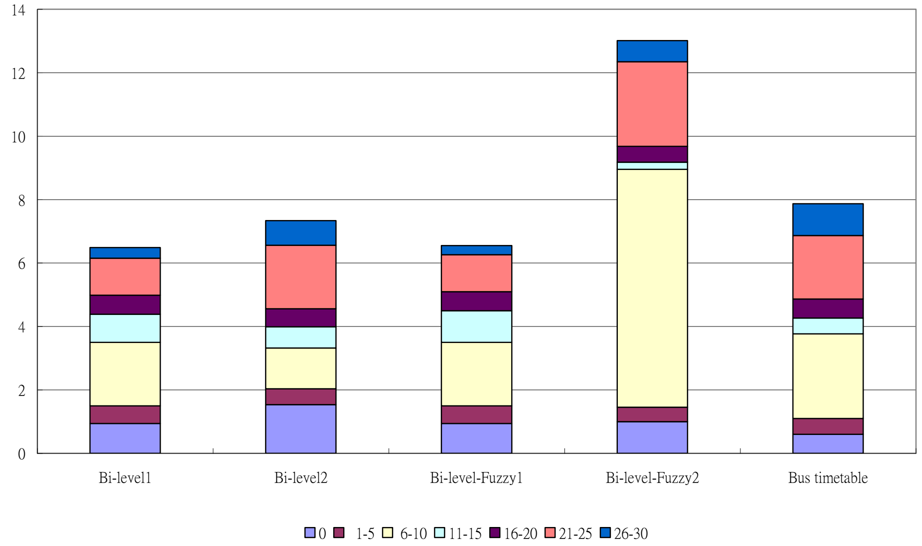

Figure 1 The arrival/departure rate of different waiting time for five approaches

This study compares the performance of Table 4 to show the time points of two optimal models is better than current bus timetable for total passenger connection bus time, Total flight serving number, and average connection time between bus and flight. With the 300 copies of passenger questionnaire, the passenger acceptable waiting time for a bus of 10-15 minutes, it is seen that some departing passengers will not take the bus if their *BFTD* connection time exceeds 30-45 minutes. Some arriving passengers will not take the bus if their *BFTA* connection time exceeds 15-30 minutes. Meanwhile, the optimal bus timetabled can supply 76-78 flights served and better than 51 flights served of current timetable.

Table 4 The performance of flight served with five approaches

Waiting time	Total number of flight served							Average minimum connecting time between bus and flight						
Approaches	0	0-5	0-10	0-15	0-20	0-25	0-30	0	0-5	0-10	0-15	0-20	0-25	0-30
Current bus timetable	16	28	39	51	67	76	84	0	2.14	4.36	6.86	10.00	11.78	13.51
Bi-level 1 model (Li)	33 (33)	47 (47)	59 (59)	76 (78)	84 (87)	97 (104)	105 (127)	0	1.23 (1.23)	2.98 (2.98)	5.62 (5.82)	6.89 (7.23)	9.28 (10.08)	10.83 (13.65)
Bi-level-fussy1 model	33 (33)	48 (49)	66 (70)	74 (82)	84 (93)	93 (109)	103 (130)	0	1.88 (1.94)	4.11 (4.30)	5.69 (5.87)	8.11 (7.54)	10.23 (10.06)	13.55 (13.28)
Bi-level 2 model (Li)	38 (38)	53 (53)	69 (73)	79 (85)	91 (99)	102 (117)	117 (144)	0	1.34 (1.34)	3.29 (3.66)	5.28 (5.26)	7.33 (7.34)	9.82 (9.99)	13.84 (13.74)
Bi-level-fuzzy 2 model	38 (38)	54 (54)	71 (71)	83 (85)	92 (98)	103 (112)	117 (139)	0	1.48 (1.48)	3.52 (3.52)	5.00 (5.41)	6.93 (7.35)	9.66 (9.55)	12.99 (13.53)

( ): Represents one flight at least one more buses serving

Table 4 also show the connection times of smaller scale waiting time are better than the connection times of larger scale waiting time. This means the bus serving quality must be in keeping with passenger waiting time of smaller scale to improving the connection time between bus and flight. If passenger waiting time is very short in ten minutes, we can find the passenger can choose the nearly time-point of bus schedule to arrival/departure airport. If the waiting time over 10 minutes of waiting time, they can take one more buss of the chance. However, passengers don't choose too long waiting of above thirty minutes, they will change another access mode to arrival/ departure airport.

2) The arrival/departure flight coverage at peak hour/non-peak hour

The coverage rate of bus service is very important key index of measuring the level of bus serving flight during different waiting time, the more percent (number) of bus serving flight different waiting time, the better level of bus serving flight different waiting time. The Table 5 shows that the time point of airport bus stop some bus frequency and connection time problems between scheduled bus and scheduled flight.

Table 5 The coverage rate distribution of current bus service for passenger waiting time

		0 minutes		0-5 minutes		0-10 minutes		0-15 minutes		0-20 minutes		0-25 minutes		0-30 minutes	
Time period	A:D	A	D	A	D	A	D	A	D	A	D	A	D	A	D
7:00-7:59	4:0	0.0%	-	0.0%	-	25.0%	-	50.0%	-	75.0%	-	75.0%	-	100.0%	-
8:00-8:59	8:7	12.5%	14.3%	25.0%	28.6%	25.0%	28.6%	25.0%	42.9%	37.5%	57.1%	50.0%	57.1%	50.0%	57.1%
9:00-9:59	5:7	20.0%	42.9%	40.0%	42.9%	40.0%	42.9%	40.0%	71.4%	40.0%	71.4%	60.0%	71.4%	60.0%	85.7%
10:00-10:59	4:4	25.0%	50.0%	50.0%	50.0%	100.0%	50.0%	100.0%	75.0%	100.0%	75.0%	100.0%	75.0%	100.0%	100.0%
11:00-11:59	4:5	0.0%	40.0%	0.0%	60.0%	0.0%	60.0%	25.0%	100.0%	25.0%	100.0%	75.0%	100.0%	100.0%	100.0%
12:00-12:59	2:4	50.0%	0.0%	100.0%	0.0%	100.0%	25.0%	100.0%	25.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
13:00-13:59	9:4	0.0%	0.0%	0.0%	25.0%	0.0%	50.0%	0.0%	50.0%	0.0%	50.0%	0.0%	75.0%	11.1%	100.0%
14:00-14:59	4:6	25.0%	0.0%	25.0%	0.0%	25.0%	0.0%	50.0%	0.0%	75.0%	0.0%	75.0%	0.0%	75.0%	0.0%
15:00-15:59	4:4	0.0%	20.0%	0.0%	60.0%	0.0%	60.0%	0.0%	60.0%	0.0%	60.0%	0.0%	60.0%	0.0%	80.0%
16:00-16:59	5:5	20.0%	0.0%	20.0%	0.0%	40.0%	0.0%	60.0%	0.0%	60.0%	0.0%	100.0%	40.0%	100.0%	40.0%
17:00-17:59	5:4	0.0%	25.0%	0.0%	25.0%	40.0%	50.0%	40.0%	75.0%	80.0%	75.0%	80.0%	75.0%	100.0%	75.0%
18:00-18:59	7:4	0.0%	0.0%	0.0%	50.0%	28.6%	50.0%	28.6%	50.0%	42.9%	100.0%	42.9%	100.0%	42.9%	100.0%
19:00-19:59	8:9	0.0%	0.0%	0.0%	11.1%	0.0%	11.1%	0.0%	22.2%	0.0%	66.7%	0.0%	66.7%	0.0%	66.7%
20:00-20:59	5:8	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21:00-21:59	0:2	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Total	74:74	8.1%	13.5%	13.5%	24.3%	24.3%	28.4%	29.7%	39.2%	37.8%	52.7%	45.9%	56.8%	51.4%	62.2%

A: arrival flights. D: departure flights.

The bus service coverage rate for departure flights is better than the bus service coverage rate for departure flights in many hours except 12:00-12:59 occupy the 100% bus service coverage for two arrival flights. There are scheduled buses of three time points (such as 12:25, 12:35, and 12:50) will arrive and depart the airport bus stop during the non-peak hour. The peak hours such as 13:00-13:59, and 19:00-19:59 time periods, there are no scheduled bus arrangement. Another peak hour of 8:00-8:59 yet arranged two time point of 8:20, and 8:30 to be very concentrated and closed, not equilibrium distribution. The bus service coverage rate for arrival flights are always lower than bus service coverage rate for departure flights in different passenger waiting scale, reflect not to meet the passenger traffic demand and friendly for first time to visiting tourists. These shortages of allocating time points between peak hours and non-peak hours pay to improve.

Therefore, this study proposed the bi-level fuzzy multi-objectives model to improve the current bus timetable of airport bus stop show as Table 6 and Table 7. Both models not only mainly enhance the bus service coverage rate but and improve the bus service coverage rate for arrival flights. Both models will reach 51.4%-55.4% bus service coverage rate for arrival flights and departure flights before 0-15 minutes of passenger waiting time, but current bus timetable only reach 29.7%-39.2% bus service coverage rate for arrival flights and departure flights before 0-15 minutes of passenger waiting time. The enhance efficiency of bus service coverage rate of fuzzy multi-objectives model is more significant and better than the efficiency of bus service coverage rate of bi-level model. Thus, the bus service coverage rate of peak hours (8, 9, 13, 18, 19, and 20 pm) for bi-level2 and bi-level-fuzzy 2 models fuzzy are better than current bus timetable. The performance of bi-level-fuzzy 2 is improving more than the performance of bi-level 2 in peak period.

Table 6 The coverage rate distribution of bus service with bi-level 2 model

		0 minutes		0-5 minutes		0-10 minutes		0-15 minutes		0-20 minutes		0-25 minutes		0-30 minutes	
Time period	A:D	A	D	A	D	A	D	A	D	A	D	A	D	A	D
7:00-7:59	4:0	50.0%	-	50.0%	-	50.0%	-	50.0%	-	75.0%	-	100.0%	-	100.0%	-
8:00-8:59	8:7	25.0%	28.6%	37.5%	42.9%	50.0%	57.1%	75.0%	71.4%	75.0%	71.4%	87.5%	71.4%	100.0%	71.4%
9:00-9:59	5:7	60.0%	42.9%	60.0%	42.9%	80.0%	57.1%	80.0%	85.7%	100.0%	85.7%	100.0%	100.0%	100.0%	100.0%
10:00-10:59	4:4	25.0%	50.0%	50.0%	50.0%	50.0%	75.0%	50.0%	100.0%	50.0%	100.0%	75.0%	100.0%	100.0%	100.0%
11:00-11:59	4:5	75.0%	0.0%	100.0%	20.0%	100.0%	20.0%	100.0%	20.0%	100.0%	80.0%	100.0%	100.0%	100.0%	100.0%
12:00-12:59	2:4	50.0%	50.0%	50.0%	100.0%	50.0%	100.0%	50.0%	100.0%	50.0%	100.0%	50.0%	100.0%	100.0%	100.0%
13:00-13:59	9:4	44.4%	0.0%	55.6%	0.0%	77.8%	25.0%	88.9%	25.0%	88.9%	50.0%	88.9%	75.0%	88.9%	100.0%
14:00-14:59	4:6	0.0%	0.0%	0.0%	33.3%	25.0%	50.0%	50.0%	50.0%	50.0%	100.0%	50.0%	100.0%	75.0%	100.0%
15:00-15:59	4:4	0.0%	20.0%	0.0%	40.0%	0.0%	40.0%	0.0%	40.0%	25.0%	40.0%	50.0%	40.0%	50.0%	40.0%
16:00-16:59	5:5	60.0%	0.0%	80.0%	20.0%	100.0%	20.0%	100.0%	20.0%	100.0%	20.0%	100.0%	20.0%	100.0%	60.0%
17:00-17:59	5:4	0.0%	25.0%	0.0%	25.0%	20.0%	75.0%	20.0%	75.0%	40.0%	75.0%	40.0%	100.0%	40.0%	100.0%
18:00-18:59	7:4	28.6%	0.0%	28.6%	25.0%	42.9%	25.0%	42.9%	25.0%	42.9%	25.0%	71.4%	25.0%	100.0%	75.0%
19:00-19:59	8:9	25.0%	22.2%	25.0%	33.3%	37.5%	33.3%	37.5%	44.4%	37.5%	44.4%	37.5%	55.6%	37.5%	77.8%
20:00-20:59	5:8	0.0%	25.0%	0.0%	25.0%	0.0%	25.0%	0.0%	37.5%	0.0%	37.5%	0.0%	37.5%	0.0%	62.5%
21:00-21:59	0:2	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Total	74:74	31.1%	20.3%	37.8%	33.8%	50.0%	43.2%	55.4%	51.4%	60.8%	60.8%	68.9%	67.6%	77.0%	79.7%

A: arrival flights. D: departure flights.

Table 7 The coverage rate distribution of bus service with bi-level-fuzzy2 model

		0 minutes		0-5 minutes		0-10 minutes		0-15 minutes		0-20 minutes		0-25 minutes		0-30 minutes	
Time period	A:D	A	D	A	D	A	D	A	D	A	D	A	D	A	D
7:00-7:59	4:0	25.0%	-	25.0%	-	50.0%	-	50.0%	-	75.0%	-	100.0%	-	100.0%	-
8:00-8:59	8:7	12.5%	42.9%	25.0%	57.1%	62.5%	57.1%	62.5%	71.4%	62.5%	85.7%	100.0%	85.7%	100.0%	85.7%
9:00-9:59	5:7	20.0%	57.1%	60.0%	57.1%	80.0%	57.1%	80.0%	100.0%	80.0%	100.0%	80.0%	100.0%	80.0%	100.0%
10:00-10:59	4:4	25.0%	50.0%	25.0%	75.0%	25.0%	75.0%	25.0%	100.0%	25.0%	100.0%	50.0%	100.0%	100.0%	100.0%
11:00-11:59	4:5	75.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	20.0%	100.0%	40.0%	100.0%	40.0%
12:00-12:59	2:4	50.0%	25.0%	50.0%	75.0%	50.0%	75.0%	50.0%	75.0%	50.0%	75.0%	50.0%	75.0%	100.0%	75.0%
13:00-13:59	9:4	44.4%	0.0%	55.6%	0.0%	77.8%	25.0%	88.9%	25.0%	88.9%	50.0%	88.9%	75.0%	88.9%	100.0%
14:00-14:59	4:6	0.0%	0.0%	0.0%	33.3%	25.0%	50.0%	50.0%	50.0%	50.0%	100.0%	50.0%	100.0%	75.0%	100.0%
15:00-15:59	4:4	0.0%	20.0%	0.0%	40.0%	0.0%	40.0%	0.0%	40.0%	25.0%	40.0%	50.0%	40.0%	50.0%	40.0%
16:00-16:59	5:5	20.0%	0.0%	20.0%	20.0%	60.0%	20.0%	60.0%	20.0%	60.0%	20.0%	80.0%	20.0%	80.0%	60.0%
17:00-17:59	5:4	40.0%	50.0%	40.0%	50.0%	80.0%	50.0%	80.0%	75.0%	100.0%	75.0%	100.0%	75.0%	100.0%	100.0%
18:00-18:59	7:4	28.6%	0.0%	28.6%	50.0%	57.1%	50.0%	57.1%	100.0%	57.1%	100.0%	71.4%	100.0%	100.0%	100.0%
19:00-19:59	8:9	25.0%	44.4%	25.0%	55.6%	37.5%	55.6%	37.5%	55.6%	37.5%	55.6%	37.5%	66.7%	37.5%	100.0%
20:00-20:59	5:8	0.0%	25.0%	0.0%	25.0%	0.0%	25.0%	0.0%	37.5%	0.0%	37.5%	0.0%	37.5%	0.0%	62.5%
21:00-21:59	0:2	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Total	74:74	25.7%	25.7%	32.4%	40.5%	52.7%	43.2%	55.4%	55.4%	59.5%	63.5%	70.3%	67.6%	78.4%	79.7%

A: arrival flights. D: departure flights.

3) The relationship between number of bus serving flight, bus coverage rate, passenger waiting time and peak hours

This study used 105 samples for each current bus timetable, bi-level model and fuzzy bi-level model to analyze the relationship between coverage rate of flight arrival/departure, waiting time, flight traffic type (arrival or departure), and peak hours to improve the operation for current bus timetable. The Dummy variables of waiting time less 30 minutes, such as waiting time of 0 minutes(W0), 1-5 minutes(W5), 6-10 minutes(W10), 14-15 minutes(W15), 16-20 minutes(W20), 21-25 minutes(W25), and 26-30minutes(W30). Number of arrival flight type(FA), number of departure flight type(FD), the ratio of arrival/departure flights (FA/FD), coverage rate of flight arrival/departure (CRA,CRD), number of bus serving arrival/departure flights(BSFA,BSFD), and the Dummy variables of peak hours(PH) such as 8,9,13, 18,19 and 20 are employed. Table 8 show that the relationship between connection time and peak hour are not significant in two model. Meanwhile the relationship between connection time and waiting time, flight arrival/departure type are significant in two models.

Table 8 shows the correlation coefficient of current bus timetable is not significant with peak hours and the ratio of arrival/departure flights. These figures of bi-level 2 and bi-level-fuzzy 2 indicate that the arrangement bus serving arrival/departure flights are significant with peak hours and the ratio of arrival/departure flights. The bi-level-fuzzy 2 indicate the arrangement bus serving arrival/departure flights are significant with waiting time of 0 minutes, 6-10minutes, and 11-15minutes. Therefore bi-level-fuzzy 2 can suggest some strategies to reschedule current timetable shortages.

Table 8 The comparison correlation coefficient between three approaches

Coefficient		FA	FD	FA/FD	CRA	CRD	W0	W5	W10	W15	W20	W25	W30	PH
Current bus timetable	BSFA	.025	-.114	.104	.930(**)	.073	.026	-.066	.119	-.066	.026	.026	-.066	-.139
	BSFD	.170	.153	.124	-.033	.945(**)	.118	.049	-.123	.049	.118	-.123	-.088	.137
Bi-level 2	BSFA	.304(**)	.009	.332(**)	.898(**)	.055	.488(**)	-.103	.028	-.136	-.136	-.070	-.070	.192(*)
	BSFD	.170	.307(**)	.035	.024	.945(**)	.219(*)	.052	-.048	-.081	-.048	-.114	.019	.176
Bi-level-Fuzzy 2	BSFA	.296(**)	-.016	.342(**)	.894(**)	-.101	.343(**)	-.105	.215(*)	-.201(*)	-.169	-.009	-.073	.155
	BSFD	.225(*)	.314(**)	.066	-.140	.937(**)	.308(**)	.075	-.187	.017	-.071	-.158	.017	.237(*)

** Significant at 1% level * Significant at 5% level

4.2.2 The strategy improvement current time point for the airport bus stop

According to above finding, this study considers the bus authorities can think two approaches to improve the shortage of time connection between flight and bus. The short term approach only reschedules time point for the airport bus to apply the bi-level rescheduling time point at normal days (such as Monday to Thursday) and the fuzzy-bi-level optimal rescheduling time point at holiday and weekend days (such Friday to Sunday). These two ways only reschedule time point and roster bus schedule forward /backward time in working hours, not only pay lower cost, but also the rescheduling times better meet the time distribution of passenger demand and arrival/departure flights. The long term approach still arranges the buses to more suitable time point and add the bus service frequencies to enhance the efficiency of green transportation and seamless transportation between airport and bus.

5. CONCLUSION

The preliminary results and recommendations of this study are summarized as follows:

The optimal model shows that the current 23 scheduled buses serving 148 scheduled flights must be improved. The optimal bus timetable is better than the current bus timetable, in terms of minimizing the total connection time and maximizing the coverage of flights. If the passenger waiting time is less than 15 minutes, the optimal bus timetable serves 76 more schedule flights than the current timetable. The number of arriving flights served is different than the number of departing flights served in 15 minutes of waiting time.

The outcomes show only change the bus arrival airport timetable can improve the service level shortage in peak hours, and the bus company don’t add driver wage, hours of service and budget. This study also in the upper level find the optimal available operation time of bus company capacity and working hours are 35 minutes. This model can use this figure to check the time point of bus arrival/departure time are suitable or not. This model also finds the 9:30 and 15:05 two time point of bus arrival/departure time is the same the time-point design of optimal bus timetable, The smaller the connection time between the bus and the flight timetable, the smaller the number of schedule flights are served, but passengers’ waiting need must be satisfied with the smaller connected time to improve the bus service performance. With the constraint of a maximum acceptable waiting time for a bus of 15 minutes, some departing passengers do not take the bus if their connection time exceeds 45 minutes and some arriving passengers do not take the bus if their connection time exceeds 30 minutes.

This study integrate the fuzzy multi-objectives model and bi-level model to measure the performance of the arriving/departing flight coverage at peak hours/non-peak hours and the relationship between connecting time, and waiting time. The bus authorities can think our suggestions to improve the shortage of current time points of bus timetable. The short term approach only reschedules time point for the airport bus to apply the optimal-bi-level rescheduling time point at normal days (such as Monday to Thursday) and the fuzzy-bi-level optimal rescheduling time point at holiday and weekend days (such Friday to Sunday). These ways only reschedule time point and roster bus schedule forward /backward time in working hours, not only pay lower cost, but also the rescheduling times better meet the time distribution of passenger demand and arrival/departure flights. The long term approach still arranges the buses to more suitable time point and add the bus service frequencies to enhance the efficiency of green transportation and seamless transportation between airport and bus.

Finally, this paper suggests that the transportation administration of should modify the bus timetable to improve its service to passengers and make greener use of its resources. This is an easy way to increase bus serving effects. This study only focuses on the airport bus stop schedules and the needs of passengers. Services passing Makung airport from Tai Wu, Eagle's Nest, Wu Kan, Lung Mun and Tsing Lo and other bus routes, the demands of community services, the overall capacity of the bus fleet, and staff scheduling were not considered. It is recommended that any future research expand the scope of this study to the management of public transportation.

REFERENCES

A.Ceder, B.Golany, O.Tal.(2001). Creating bus timetable with maximal synchronization. *Transportation Research Part A*,35, 913-928

Michael D. Wittman, William S. Swelbar.(2013).Modeling Changes in Connectivity at U.S. Airports: A small Community Perspective, *MIT Small Community Air Service White Paper No.2*.

M. Salicru, C. Fleurent, J.M. Armengol (2011). Timetable-based operation in urban transport: Run-time optimization and improvements in the operating process. *Transportation Research Part A*, 45, 721-740

Renato Redondi,Paolo Malighetti, Stefano Paleari.(2013). European connectivity:the role played by small airports, *Journal of Transport Geography*,29,86-94.

Shangyao Yan , Chin-Jen Chi, Ching-Hui Tang.(2006).Inter-city bus routing and timetable setting under stochastic demands, *Transportation Research Part A*, 40, 572-586

Sui-Ling, Li.(2010). The Timetable Planning of Review and Analysis for Bus Transit of Makung Airport. *Proceedings of 2010 Aviation and Maritime Conference*,*168-180*,Taiwan, Dept. Aviation and Maritime Management, Chang Jung Christian University

Sui-Ling, Li.(2013). Integrate Bus Timetable and Flight Timetable for Green Transportation –Enhance Tourism Transportation. Paper presented at the 13th *World Conference of Transportation Research*, Transport Modes: General, Data and Network Analysis, in Rio de Janeiro, Brazil. July