PUBLIC TRANSPORTATION MODELLING TO DETERMINE THE PERFORMANCE OF BUS SERVICES: CASE STUDY OF PENANG ISLAND

by

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I have made every effort to identify the original sources of information sated but, if there have been any accidental errors of missions, I apologises to those concerned.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PERMODELAN PENGANGKUTAN AWAM UNTUK MENENTUKAN PRESTASI PERKHIDMATAN BAS AWAM: KAJIAN KES DI PULAU PINANG

ABSTRAK

Tesis ini membincangkan analisis ke atas permodelan pengangkutan awam untuk menentukan prestasi perkhidmatan bas awam di Pulau Pinang dengan menggunakan perisian EMME/3. Sejumlah 14 senario telah dikenalpasti untuk mengkaji kesan ke atas perbezaan masa (i.e. pagi, tengahari dan petang untuk hari-hari bekerja serta hujung minggu) dan perbezaan jarak kepala (yang diperhatikan dan yang dijadualkan) untuk bas-bas Rapid dan juga untuk sistem kombinasi bas (Bas Rapid dan bas-bas lain). Pengumpulan data bagi tujuan kajian ini adalah koordinat stesen-stesen bas, pemilihan zon, matriks asalan-destinasi, tempoh berhenti, tempoh menunggu, tempoh perjalanan, jarak kepala, kelajuan bas dan isipadu penumpang. Hasil akhir kajian ini adalah untuk menilai keadaan semasa pengangkutan awam dan mengkaji kesan jarak kepala yang berbeza (yang sebenar dan dijadualkan) ke atas prestasi bas awam di Pulau Pinang. Kesan permintaan pengguna untuk masa yang berbeza (iaitu pada waktu puncak pagi, tengahari dan petang) ke atas bilangan bas, bilangan penumpang naik, faktor beban dan juga hubungan antara kelangahan jarak kepala dengan factor beban telah di analisa secara empirik. Analisa tentang punca kelengahan jarak kepala pula bertujuan mengenalpasti kawalan operasi yang boleh dilakukan untuk memperbaiki ketetapan perkhidmatan dan secara tidak langsung mengurangkan insiden kekebihan beban serta meramal keperluan untuk perkhidmatan tambahan. Dalam kajin ini, jarak kepala yang baru untuk bas Rapid semasa hujung minggu juga telah dihasikan. Selain itu, perjalanan baru bagi bas telah dicadangkan untuk menaiktarafkan prestasi system bas.

PUBLIC TRANSPORTATION MODELLING TO DETERMINE THE PERFORMANCE OF BUS SERVICES: CASE STUDY OF PENANG ISLAND

ABSTRACT

This thesis discusses on public transportation modelling to determine the performance of bus services in Penang Island. To simulate the public transportation system, EMME/3 software was employed. A total of 14 scenarios were identified in order to assess the effects of different periods of time (i.e. in the morning, afternoon and evening of weekdays and during weekends) and different headways (observed and scheduled headway) for Rapid Penang buses and combined bus system (Rapid Penang buses and non Rapid Penang buses). In this research, field data including the bus station coordinates, zones selection, OD matrix, layover time, waiting time, travel time, headway, speed and the passenger volume were collected. The main aim of this study was to evaluate the existing public transportation and to investigate effects of different headways (observed and scheduled) on the performance of bus services in Penang Island. The effects of passenger demand during the different period of time (i.e. in the morning, afternoon and evening peak hours) on fleet buses, passenger volume and load factor in Penang Island, and also the relationship between headway delay and load factor was empirically analyzed. In turn, analysis on the causes of headway delay served to identify possible operations control actions that would improve the service regularity and consequently, reduce incidences of overloading and forestall the need for additional services. In this research, new headways were proposed for Rapid Penang buses during weekends to improve the

bus services. Beside this, new routes were proposed in order to enhance the performance of the bus system.

CHAPTER 1
INTRODUCTION

1.1 Introduction

Today, many cities in the world are facing serious land transport challenges. Increasing traffic congestion has brought with it environmental, social and economic implications. With the proportion of the world's population residing in urban areas projected to increase to more than two-thirds over the next 20 years or so, and with rising car ownership, more cities will find themselves facing the potentially crippling problems of traffic congestion. Many major cities in Malaysia such as Kuala Lumpur, Penang, Johor Bahru and others are currently facing serious transport problems as other big cities of the world.

The rapid development of Penang Island has increased the cost of living of the citizen. It influences the travel pattern of community from origin to any destination. Transportation system is also affected by the development as shown by the increase in the number of vehicles annually on roads. Referring to Table 1.1, the statistic shows that the number of vehicle with respect the vehicle composition has increased every year in Penang Island. This survey is derived from the statistics provided by Jabatan Pengangkutan Jalan, Malaysia. Figure 1.1 shows the condition of traffic congestion in Penang Island.

Table 1.1: Registered motor vehicles by type, Penang Island, 1995-2008 (http://www.seri.com.my/ap/publication.html)

Year	Motorcycle	Private passenger car	Taxi	Bus	Lorry and Van	Hire Cars	Others	Total
1995	482,885	231,116	1,100	2,544	25,723	1,610	-	744,978
1996	526,036	266,407	2,266	2,734	29,724	422	-	827,589
1997	569,877	305,525	2,301	3,149	33,538	386	-	914,776
1998	602,017	322,598	2,358	3,582	34,151	299	-	965,005
1999	636,503	351,280	2,408	3,723	35,144	315	-	1,029,373
2000	659,975	376,227	2,421	3,845	36,169	340	11,666	1,090,643
2001	707,851	435,744	2,518	3,949	38,588	380	12,757	1,201,787
2002	737,334	481,951	2,601	4,033	40,439	394	13,482	1,280,234
2003	770,662	519,181	2,659	4,136	42,404	367	14,018	1,353,427
2004	822,185	569,356	2,903	4,448	45,666	400	14,777	1,459,735
2005	878,582	632,898	3,077	4,767	49,582	384	15,537	1,584,827
2006	928,280	681,748	3,198	4,885	52,050	369	16,212	1,686,742
2007	979,853	728,493	3,354	5,133	54,552	440	16,866	1,788,691
2008	994,868	741,328	3,377	5,168	55,282	461	17,033	1,817,517

Figure 1.1: Traffic congestion in Penang Island

Maintaining reliable service is important for both transit passengers and transit providers. Surveys have shown that reliability is strongly related to passenger satisfaction and perceptions of service quality (TCRP, 1999), while stated preference experiments have found that passengers implicitly value reliability (Bates et al., 2001) and consider it in their mode choice decisions (Prioni and Hensher, 2000). Unreliable service results in additional waiting time for passengers (Wilson et al., 1992).

Unreliable service also has negative economic consequences for transit providers. Effective service capacity is diminished when vehicles become unevenly spaced, or "bus bunching," occurs. Bus bunching results in more frequent passenger overloads, which necessitates provision of additional service. Such service expansions would not be required if vehicles were more regularly spaced and passenger loads were more evenly distributed. Capital investments in the vehicle fleet are affected because reliability problems are most acute during peak service periods (Strathman et al., 2000).

There has been considerable research on the underlying causes of unreliable service (Turnquist and Bowman, 1980; Strathman and Hopper, 1993). Primary causes of unreliability have been attributed to route characteristics (e.g., length, the number of signalized intersections, the extent of on-street parking, stop spacing), operating conditions (e.g., traffic volume, service frequency, passenger activity), and vehicle operators (e.g., departure delays, operator-specific behaviour differences). Considerable attention has also been devoted to identifying operations control actions to improve reliability (Turnquist and Blume, 1980; Abkowitz and Engelstein, 1984).

This thesis explores an application of archived observed data to analyse the performance of bus services in Penang Island using EMME/3 software as transportation model and its effects on passenger volume. EMME/3 is an interactive graphic of multimodal urban transportation planning system. In offers the planner a complete and comprehensive set of tools for demand modelling, multimodal network modelling and analysis and for implementation of evaluation procedures. EMME/3 is also a decision support system which provides uniform and efficient data handling procedures, including input data validation. Its database is structured to permit the simultaneous description, analysis and comparison of several contemplated scenarios.

1.2 Objectives

The objectives of this research have been set as follows:

- To evaluate of performance of existing bus services.
- To investigate effects of different headway and different period time on passenger volume and load factor.
- To propose new routes for Rapid Penang buses in Penang Island.
- To analyze the relationship between headway delay and load factor.
- To evaluate the existing headway of buses on weekends for Rapid Penang buses in Penang Island.

1.3 Scope of the Research

The scope of this study focuses mainly on the evaluation of existing bus services in Penang Island. In order to develop the transportation model in EMME/3, information such as headway, OD matrixes, layover time, speed of buses, passenger volume and transit network were observed during weekdays and weekends for both Rapid Penang buses and non Rapid Penang buses. In this study, statistical analyses were also conducted based on the observed data using the MINITAB software. Also, the observed passenger volumes were compared to the results obtained from the analysis of EMME/3 and calibration was conducted for the transit assignment parameters such as boarding time, auxiliary time, wait time factor, wait time weight and boarding time weight. In this study, focus was given to the main bus routes in Penang Island only.

1.4 Thesis Organisation

The layout of the thesis is discussed in this section. This thesis is divided into five chapters. The first chapter gives a brief introduction and discussion on the public transportation modelling. The second chapter reviews the relevant literatures related to the methods of transportation modelling and related theories. Subsequently, chapter 3 discusses the study methodology carried out in this study. Chapter 4 is about data analysis and discussion. Finally, chapter 5 presents the findings of the research, a brief research outlook for future study and conclusions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The relevant literatures are discussed in this chapter. Initially, this chapter begins by giving a brief overview on the travel forecasting modelling. Consequently, the modelling of urban transportation planning process is reviewed. Subsequently, travel forecasting modelling software development and transportation planning models are examined. Finally, the discussions on software package classification and transportation planning software were conducted.

2.2 Historical Development of Public Transportation System in Penang

Penang Island once had an impressive local transport system. There were steam trams, horse trams, electric trams and trolleybuses. There is even an obsolete tram-way track at the Chulia Street-Penang Road junction in inner George Town. The 50m tramline was unearthed about two years ago during works at the junction to facilitate the replacement of old public utility cables and pipes. Realizing the significance of the discovery, the Penang Municipal Council left the tramline intact where they were found, so as not to compromise their authenticity. History records have shown that George Town was one of the first urban centres in Southeast Asia to operate steam trams, horse trams, electric trams and trolleybuses. Figure 2.1 shows the buses waiting to pick up passengers along a busy street in Penang back in 1978.

Figure 2.1: Buses waiting to pick up passengers along a busy street in Penang back in 1978

During those days, the then City Council of George Town had effectively provided and sustained a public transportation system that was said to be the pride of the city. The city also once had the smallest trolleybus in the world with the size of a large private car. According to Francis and Ganley (1963), these small trolleybuses were specifically built in 1934 for shuttle service from the Lower Station of the Hill Railway to Air Itam main road, about 1.6km away. Penang's first recorded tramway and steam tram were run in the 1880s by Mr Gardiner. It was more of a light railway than a tramway, which ran from Weld Quay jetty to Air Itam Road with a branch to the Botanic Gardens. When the authorities considered steam locomotives as being too dangerous to be used in town streets, horse-drawn cars were introduced to ply Magazine Road, Penang Road, Chulia Street and Weld Quay. However, the “horse tram” fast lost its popularity among commuters due to lack of speed and safety. The George Town Municipal electrical trams were subsequently launched in December 1905 and were reaping high profits until World War I. The war had hampered the supply of replacement parts for the vehicles.

In 1925, the first trolleybus, with a maximum of 24 passengers, started its operation from Magazine Road to Weld Quay jetty via Chulia Street. Although the Tramways Workshop increased the number of trams in an effort to improve their service, the company also faced intense competition from private buses. Also known as “mosquito buses”, the private buses operated with much flexibility without regular schedules and moving as fast as a private car. Suffering from tremendous losses over the years, the trams were eventually scrapped and replaced by trolleybuses.

By 1951, George Town was well covered by municipal trolley and motorbus services, which charged a 10-cent fare per passenger from any one point to destination or terminus. The starting point of the routes was Victoria Pier in Weld Quay and from there the visitor can go by trolleybuses to Pulau Tikus, Bagan Jermal, Air Itam, the foot of Penang Hill, Sungai Pinang and Jelutong. The municipal motorbuses provided supplementary services around Jelutong, Gottlieb Road and Pulau Tikus while privately owned motorbuses operated regular services beyond the municipal limits.

In 1956, the new George Town Municipal Transport board purchased five former London Tran-sport double-deckers. However, the novelty wore off quickly and the vehicles soon became uneconomic with relatively low fares and three crewmembers onboard. Being cast-offs from the London Transport, the double-decker buses were also disintegrating rapidly. At the beginning of 1957, the City Council had a fleet of 55 public vehicles, comprising 41 trolleybuses and 14 diesel buses. When the council came under the Socialist Front's control, the Transport

Department under the then chairman councillor Lim Kean Siew made a change to an all diesel fleet despite having many new trolleybuses.

Starting November 1959, the trolleybuses were gradually replaced and by 1961, George Town lost its last electric vehicle when the trolleybuses passed into history. The last runs along Jelutong route were made unceremoniously on July 31, 1961, and were quickly followed by the dismantlement of the electric wiring. By August 1962, the only wiring left was the few pieces of overhead in Jelutong, which are now used for street lighting.

2.3 Current Transportation System in Penang Island

The current bus services in Penang Island can be divided into two main categories, namely Rapid Penang buses and non Rapid Penang buses. Non Rapid Penang buses are generally unsystematic and do not have a reputation of reliability. Therefore, the usage of public transport was low and causes traffic jams in the city during rush hours. Therefore, in order to overcome this problem, bus services operated by Rapid Penang Sdn.Bhd. were launch on 31 July 2007.

2.3.1 Non Rapid Penang buses in Penang Island

Penang Island has been putting up with very poor public bus service for many years. State government and local authority of Penang have tried many approaches to address this problem. Finally, the Federal Government has approved the Penang Municipal Council's bus package system which would be effective started on 1st April 2006. This system was aimed at extending public bus services to a wider area, including some housing estates that have been neglected all these years. Under the package system, stage buses will play major roads in the city while mini buses will complement their service by plying social routes in the outskirts. The idea is so that the stage buses do not compete against the mini buses. The non Rapid Penang buses network for Penang Island has been divided into three packages for stage buses and three zones for mini-buses.

Package 1, covering routes between Pengkalan Weld to Tanjung Bungah and Teluk Bahang, will use buses spotting dark blue colour. It will be operated by Syarikat KGNHin Co Sdn Bhd with 29 buses. Package 1 Route 1 is Pengkalan Weld-Tanjung Bungah-Teluk Bahang via Jalan Burmah while Route 2 is Pengkalan Weld-Ladang Lada via Jalan Mount Erskine and Jalan Utama and Route 3 is Pengkalan Weld-Tanjung Bungah via Jalan Kelawei. Of all the routes, only Route 1 is in operation now.

Package 2, covering routes from Pengkalan Weld to Air Itam, will be plied by red colored buses operated by Transit Link Sdn Bhd with 39 buses. Package 2 Route 1 is Pengkalan Weld-Air Hitam, Route 2 is Pengkalan Weld-Jalan Kampung Melayu via Jalan Padang Tembak and Route 3 is Pengkalan Weld-Bandar Baru Air Hitam-Paya Terubong-Pekan Air Hitam. Route 4 is Pengkalan Weld-Jalan Masjid Negeri via Jalan Petani and Jalan P.Ramlee, Route 5 is Pengkalan Weld-Jalan Tan Sri Teh Ewe Lim via Jalan Perak, Route 6 is Pengkalan Weld- Jalan Air Hitam via Jalan Padang Tembak and Route 7 is Pekan Air Hitam-Pekan Balik Pulau. Currently, only Route 2 is in operation.

Package 3, from Pengkalan Weld to Bayan Baru, will use yellow buses operated by Milan Travel Sdn Bhd with 57 buses. Package 3 Route 1 is Pengkalan Weld-Bayan Baru, Route 2 is Pengkalan Weld-Bayan Baru-Batu Maung via Taman Tun Sardon, Jalan Bukit Gambir, Jalan Datuk Ismail Hashim and Permatang Damar Laut. Route 3 is Pengkalan Weld-Bayan Baru via Jalan C.Y. Choy, Jalan Sungai Dua and Relau, Route 4 is Pengkalan Weld-Balik Pulau via Bayan Baru and Route 5 is Komtar-Bayan Baru. Of all the routes, only Route 1, 2 and 3 are in operation. (The Star, 2008). Table 2.1 shows some details of non Rapid Penang buses such as origin and destination and also name of the company for each package.

Table 2.1: Details of non Rapid Penang buses (The Star, 2008)

non Rapid Penang buses	Origin	Destination	Company
Package 1	Pengkalan Weld	Tanjung Bungah	KGNHin
Package 2	Pengkalan Weld	Air Itam	Transit Link
Package 3	Pengkalan Weld	Bayan Baru	Milan Travel

2.3.2 Rapid Penang Buses in Penang Island

In 31 July 2007, Rapid Penang Sdn.Bhd. has started operation with 150 buses. The objective of the transit system was to provide a comfortable, affordable and reliable public transport service for Penang Island. Rapid Penang was incorporated by the Ministry of Finance to assist the public transportation in Penang which was in poor state and to emphasis safety, reliability, trust and finally to encourage the use of public transport in Island. Currently, Rapid Penang provides services to 33 routes which are divided into 8 corridors (illustrated in Figure 2.2) to shuttle for inter corridor links on both the island and mainland including some social routes. The details of current operation corridors are shown in Table 2.2.

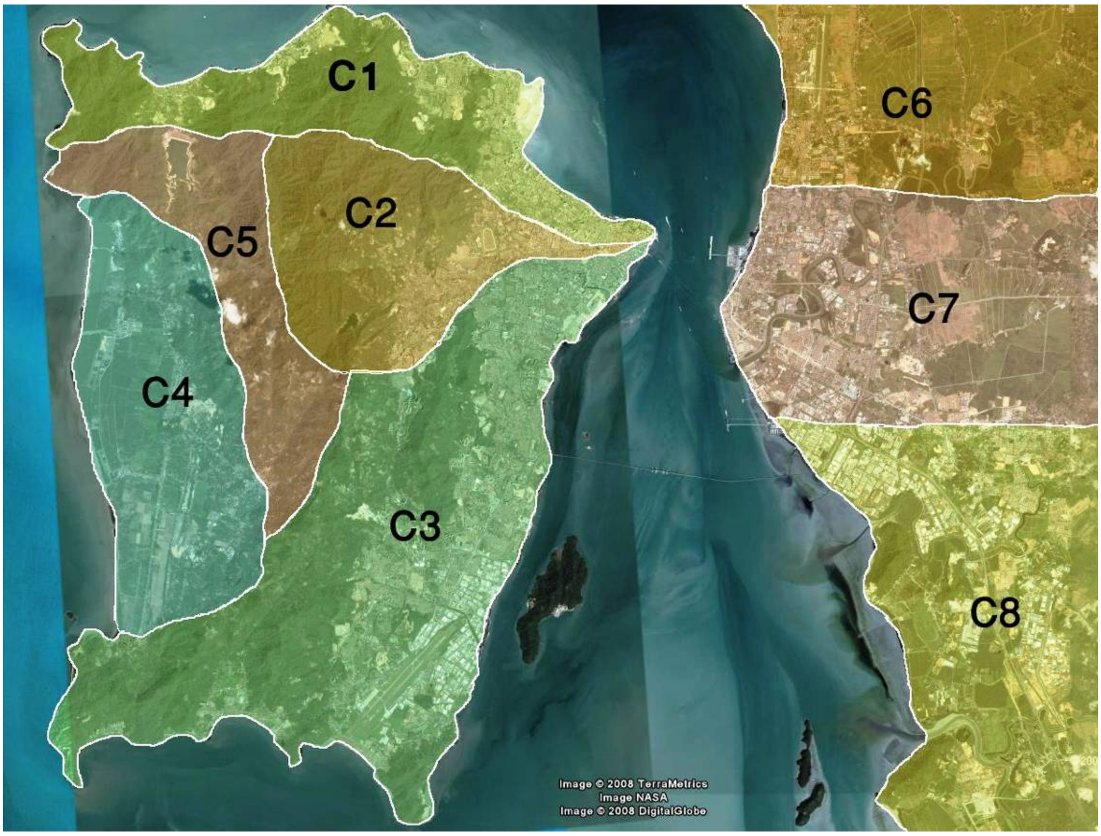

Figure 2.2 Current operation corridors for Rapid Penang buses in Penang Island (Google Earth)

Table 2.2: Details of corridor links for Rapid Penang buses in Penang Island (http://www.rapidpg.com.my/)

Number of corridors	Number of routes	Number of buses
Corridor 1	3 Routes	18 Buses
Corridor 2	5 Routes	27 Buses
Corridor 3	10 Routes	40 Buses
Corridor 4	4 Routes	19 Buses
Corridor 5	2 Routes	6 Buses
Corridor 6	2 Routes	10 Buses
Corridor 7	5 Routes	18 Buses
Corridor 8	2 Routes	12 Buses

Out of 150 buses, 110 buses are deployed on the Island and 40 buses on the mainland. The main terminal on the island is situated at Weld Quay where all buses from all corridors on the island converge (Figure 2.3).

Figure 2.3: Weld Quay is the main terminal in Penang Island

In this research, the transportation modelling was conducted for Penang Island only. The transportation forecasting modelling requires preparation of surveyed data for Rapid Penang buses which includes the 14 main bus routes with U-type's names for 5 corridors and 34 zones and non Rapid Penang buses which includes the 5 bus routes and 23 zones. Table 2.3 shows that origin and destination of bus routes operated by Rapid Penang Sdn.Bhd.

Table 2.3: Rapid Penang buses details (http://www.rapidpg.com.my/)

Bus Route	Origin	Destination	Bus Route	Origin	Destination
U101	Weld Quay	Teluk Bahang	U204	Weld Quay	Bukit Bendera
U102	Weld Quay	Ladang Pepper	U206	Weld Quay	Tesco
U103	Weld Quay	Tanjung Bunga	U301	Weld Quay	Lbh. Relau
U104	Weld Quay	Tanjung Bunga	U302	Weld Quay	Bukit Maung
U201	Weld Quay	Pekan Air Itam	U303	Weld Quay	Bukit Gedung
U202	Weld Quay	Paya Terubong	U307	Weld Quay	Bayan Baru
U203	Weld Quay	Pakan Air Itam	U401	Weld Quay	Bukit Pulau

2.4 Travel Forecasting Modelling

Route design aspect of transit planning and especially bus transit modelling is very important and have impression on human and human life, so several researchers have contributed in this field.

Lampkin and Saalmans (1967) used regularity determination algorithms and separate route because of computational difficulty. The trip-focusing process proposed in this paper introduces a service-frequency element into the route-design process.

Rea (1972) applied a level-of-service (LOS) approach to route design. It is based on the minimum viable demand and maximum possible capacity of the modes available on the link. In subsequent iterations, the service level is adjusted to reflect trip assignment results. This modification of service level amounts to focusing process similar to the one proposed in this paper. Rea (1972) seems to have been the first to employ this technique.

Ceder and Wilson (1986) developed a technique that seeks to minimize the difference between the minimum possible travel time and the actual travel time.

Elgar and Kfir (1992) used the EMME/3 model to perform a “free” assignment of transit trips onto the “loaded” network by first assigning automobile traffic and then using the link travel times as the basis for the transit assignment as an automobile mode. They only looked at road network elements and used an approach that resulted in increasing user cost with increasing transit demand, which is different to reality and may be expected to distort results. Their research is nevertheless an extension of their proposal of free assignment of transit demand incorporating concurrent assignment of private and transit trips, temporal demand pattern influences, the inclusion of all modes and diverse vehicle fleets, and the implementation of a focusing process with an incrementally decreasing generalized cost function to realistically model transit.

Dhingra and Shrivastava (1998) proposed a multi objective planning approach to route and frequency determination using genetic algorithms, fuzzy logic, and artificial intelligence techniques.

Palma and Lindsey (2001) consider the optimal time table under fixed demand, and a fixed number of departures over a period of fixed length. Users have linear, possibly heterogeneous, scheduling cost.

Yin et al. (2004) developed a generic simulation-based approach to assess transit service reliability, taking into account the interaction between the network performance and passengers' route choice behaviour. Three types of the reliability, system wide travel time reliability, schedule reliability, and direct boarding waiting-time reliability, were defined from perspectives of the community or transit administration, the operator, and passengers.

Desaulniers and Hickman (2007) focused mainly on mathematical methods for each individual steps of the planning process. Fan and Machemehl (2004) present reviews of the transit network design problem as an introduction to their applied research.

Lu and Ismutulla (2006) set up a model that contained the transferring via three public transport routes with different running time reliabilities. The model was applied to simulate the impacts of the departure time reliability of public transport services on the arrival lateness.

Zhao and Dessouky (2008) looked at service characteristics of and the relationship between demand-responsive transit services and fixed-route service. Furth and Rahbee (2004) address a similar problem using modern modelling techniques and geographic information systems (GIS).

And also Samimi and Aashtiani (2009) investigated short term management strategies to help the operators maintain service quality without confusing the users by abrupt changes in the system.

2.5 Modelling the Urban Transportation Planning Process

Generally, it is believed that the Urban Transportation Planning Process (UTPP) originated with the Chicago Area Transportation Study (CATS), in which traffic demands were forecasted based on the assumption that they were related to human travel behaviour, land use, and travel patterns (Chang and Meyers, 1999). The UTPP has been the most popular tool for travel demand forecast in urban areas. UTPP defined as "to perform a conditional prediction of travel demand in order to estimate the likely transportation consequences of several transportation alternatives that are being considered for implementation". This process is an iterative, sequential procedure for evaluation and selection of transportation projects to serve present and future land uses. It is also recognized as a long-term planning process to forecast the future demand by mode and evaluate alternative networks based on certain scenarios. Throughout the years this sequential process has been refined with various techniques and methodologies. Models are continually adapting, changing and improving with new research advances, as well as demands placed upon them. The traditional and sequential "four-step process" is still used in the majority of planning purposes. The steps that are generally considered as part of the four-step sequential process include trip generation, trip distribution, mode choice and traffic assignment (MCG,2008), as shown in Figure 2.4.

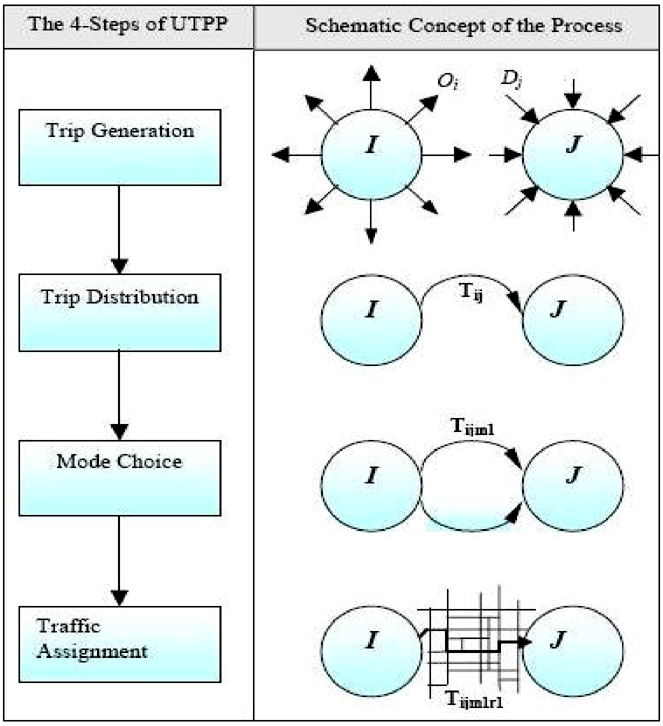

Figure 2.4: Schematic of the four-steps in UTPP (Chang and Meyers, 1999)

2.5.1 Trip Generation

The main occupation of the trip generation is to process and estimate the total number of trips generated and attracted by each zone and sub zone in conjunction with the land use and the socio-economic characteristics of each zone. There are three approaches commonly used in the trip generation analysis which are regression analysis, trip rate analysis, and cross-classification analysis. However, other novel approaches to approximate data with more complex mathematical models such as the use of neural networks and genetic algorithms might prove to be successful in the future.

2.5.2 Trip Distribution

In trip distribution, each zone is taken one at a time and a determination is made of the zones to which its produced trips will be attracted (Travel Demand

Forecasting, 2008). The trip pattern within a study area is usually represented by means of a trip table. The distribution of trips is assumed to be dependent upon factors such as the availability of jobs, transportation facilities and travel times. Many mathematical models have been used in trip distribution analysis such as linear programming formulations, regression models, growth factor model, intervening opportunity model and gravity-type models.

2.5.3 Modal Choice

The modal choice attempts the assignment of person-trips to the various alternative modes available in the study area.

2.5.4 Traffic Assignment

This step involves the assignment of the distributed volumes of trips, by mode, to individual network links. Some types of assignment techniques used are such as all-or-nothing, iterative, incremental, user-equilibrium, and system optimal traffic assignments.

2.6 Bus Modelling

Due to the development and increase demand of bus services in cities, it is essential to identify a suitable system that is able to meet the demand during peak hours.

Lampkin and Saalmans (1967) used a random search algorithm for the fleet assignment problem, which starts with an initial frequency for each bus route and then iterates and randomly tries the new frequencies from a predetermined set.

Though the frequency setting procedure is not theoretically rich, this algorithm could be implemented on a prefixed set of bus routes. In some studies, frequency setting algorithm is not dissociable and could not be used for a predefined set of routes.

Spiess and Florian (1989) formulated the transit assignment problem in a linear optimization framework. The optimization problem was called Optimal Strategy and a 2-step solving algorithm was proposed for that. The algorithm finds the optimal strategy at the first step and then assigns the demand to that strategy.

DeCea and Fernandez (1993) introduced a transit assignment algorithm for congested bus networks by controlling the capacity of transit lines and stations. In this model, the passengers who are not able to take their desired bus reroute their trip to less crowded lines in order for the model to capture the capacity restrain.

Tom and Mohan (2003) suggested a genetic algorithm that minimizes the total cost, in order to solve the bus route choice and fleet assignment problems. In their proposed solving algorithm, the frequency of each route alters between a lower and upper bound and the transit lines with a zero frequency are automatically omitted. The remaining lines with the associated frequency build the final network.

Babazadeh and Aashtiani (2005) formulated the transit assignment problem in a series of complementary equations and replicated the congestion effect in the bus transit network perfectly. Because of the size and also nonlinearity of the complementary model, it was almost impossible to find the equilibrium solution for an extensive network.

A parametric approach for the estimation of transit route OD matrices was first incorporated by Li and Cassidy (2007), where all the stops of a bus route were classified into two categories, major and minor stops. Then the conditional probability that a passenger alights at a major (or minor) stop given that the passenger boarded at a major (or minor) stop was modelled and estimated using on–off counts of passengers. The entries of an OD matrix were calculated on the basis of these conditional probabilities. This approach was shown to have many computational advantages over the balancing method.

A common approach for the estimation of an OD matrix is to calculate its entries using traffic counts obtained on pre-selected links of a transport network, without imposing any specific model on the entries (Li, 2005).

Hadas and Ceder (2008) utilized agent-based modelling in their work on bus service configuration, looking closely at transfers within the system. Teodorovic (2008) and Yang et al. (2007) worked on public transport network design and operations scheduling.

In most of the bus network studies, a transit assignment procedure has been utilized in order to have a good representation of passengers' decision making process in a transit system. Any transit trip may be broken into four different movement types which are walking, boarding, riding and alighting movements. (Samimi and Aashtiani, 2009).

2.7 Development of Travel Forecasting Modelling Software

Fragmented development of travel forecasting computer codes in the US in the early 1970s has led to a more coordinated effort within the US Department of Transportation. The Urban Transportation Planning System (UTPS), designed and led by Dial, introduced a more widespread practice of several advanced models such as the multinomial model function for forecasting mode choice, a user-equilibrium algorithm for assigning auto trips to congested road networks and improvements in the coding of transit networks and the assignment of transit trips. Changes in US policy in 1981 has led to a decision to terminate the development of UTPS, which encouraged the development of codes for the IBM Personal Computer (PC) by Comsis, a consultant involved in UTPS code development, resulting in MinUTP. A somewhat similar product called TranPlan had been under development for several years, supported initially by the Control Data Corporation, an earlier competitor to IBM. These two software systems, either directly or indirectly encompassing the model and code development efforts of US DOT, were the initial versions of PC-based travel forecasting models and software. Recently, these systems were merged into CUBE (Citilabs, 2008). Other software systems from that period have not survived.

In parallel with these developments, Florian and colleagues from the University of Montreal have developed EMME/3, building on their equilibrium-based multi-mode travel forecasting model. Their commercial software system was released in the late 1980s for linking and solving the models of the four-step procedure. In addition to a rigorous implementation of a user-equilibrium road assignment algorithm and a stochastic transit route choice algorithm, EMME/3 includes tools for solving the doubly constrained trip distribution model, stochastic mode choice models, and network coding and related utilities (INRO, 1998). Several leading metropolitan planning organizations in the US were early adopters of the system.

Building on the capabilities of the emerging field of Geographical Information Systems, Slavin and his collaborators developed TransCAD based on PC technology (Caliper Corporation, 2005). Another US-developed, research-based software system, which has been found a market in smaller regions, is QRS II developed by AJH Associates (2005). Recently, the German software developer PTV (2005) introduced its Vision system into US and Canadian practice. From its strong base in Germany, PTV expanded into other European countries, as well as the US and Canada.

EMME/3 and TransCAD enjoyed considerable success in the US during the 1990s. EMME/3 also developed an international success in the UK, Sweden, Canada, Australia, New Zealand, South Africa and Asia.

By the middle of the 1970s, the era of the large urban transport studies in the UK was ending and few cities had the resources or inclination to maintain large models. With few exceptions, most notably in London, model systems constructed a decade or more earlier, and the databases that supported them, were allowed to atrophy. Much local expertise dispersed, and the under-resourced and lonely task of local authority modellers fell on fewer and fewer shoulders. Throughout the 1990s, there was also an increasing interest in demand restraint; several metropolitan areas conducted modelling exercises involving public transport, traffic restraint and, in some cases, limited highway investment.

For such purposes, several software packages are available in the private sector. In fact, a key feature of the 1980s and early 1990s was one of fragmentation of travel forecasting software. In turn, large consultancies found it in their interest to join forces with smaller specialist companies, particularly in the context of implementation of land use models, micro econometric studies of discrete choice (typically multimodal studies), and stated preference exercises.

A prominent example, and one of the most widely used in the UK, was TRIPS of Martin, Voorhees and Associates, which is now a component of CUBE (Citilabs, 2008). The various models of the four-stage approach were enhanced and offered in both synthetic and incremental (pivot point) forms (Bates et al. 1987). In the former, travel behaviour is modelled at the cross-section and elasticity parameters estimated prior to forecasting, while in the latter, changes from a given state (e.g., the base state) are estimated utilizing given elasticity parameters. Both are available for application at the micro (individual data) or aggregate (grouped data) level.

Since the mid-1980s, Dirck Van Vliet of the University of Leeds undertook the development of SATURN (Van Vliet, 1982), which was extensively applied in the UK. A matrix updating module was widely applied to breathe new life into dated trip matrices. Initially promoted as a “modern” assignment program, it was the first to offer a rigorous approach to user-equilibrium assignment in UK travel forecasting. SATURN had the capability of working at different levels of network resolutions,