AN EVALUATION METHODOLOGY FOR THE LEVEL OF SERVICE AT THE AIRPORT LANDSIDE SYSTEM

by

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✣ *GIVE THANKS AND GLORY TO THE LORD*

SYNOPSIS

A methodology is proposed for evaluating the level of service within an airport landside system from the passenger's point of view using linguistic service criteria. The new concept of level of service for a transport system, particularly within the airports indicates that there must be strong stimulation in order to proceed with the current stereotyped service standards which are being criticised due to their being based on, either physical capacity/volume or temporal/spatial standards that directly incorporates the perception of passengers, the dominant users. Most service evaluation methodologies have been concentrated on the factors of the time spent and the space provided. These quantitative factors are reasonably simple to measure but represent a narrow approach. Qualitative service level attributes are definitely important factors when evaluating the level of service from a user's point of view. This study has adopted three main evaluation factors: temporal or spatial factors as quantitative measurements and comfort factors and reasonable service factors as qualitative measurements. The service level evaluation involves the passenger's subjective judgement as a perception for service provision. To evaluate the level of service in the airport landside system from the user's perception, this research proposes to apply a multi-decision model using fuzzy set theory, in particular fuzzy approximate reasoning. Fuzzy set theory provides a strict mathematical framework for vague conceptual phenomena and a modelling language for real situations. The multi-decision model was applied to a case study at Kimpo International Airport in Seoul, Korea. Results are presented in terms of passenger satisfaction and dissatisfaction with a variety of different values.

➲ **KEY WORDS:**

AIRPORT LANDSIDE SYSTEM; LEVEL OF SERVICE; FUZZY SETS; MULTI-DECISION MODEL

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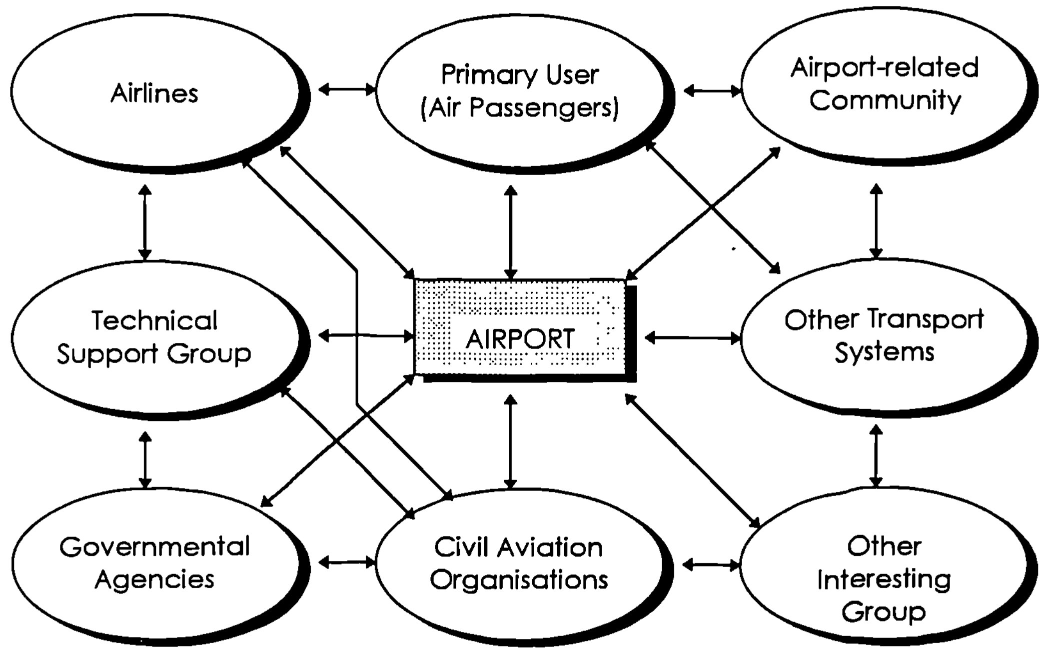
CHAPTER 1

INTRODUCTION

Rapid change has been, and undoubtedly will continue to be a salient feature of air transport. This characteristic is important for airport planning. It is difficult under the best of circumstances to design a system which can respond to the kind of high growth in traffic that has occurred in air transport.[de Neufville 1976:37] Paced by rapidly expanding demand for air transport of all kinds, and an enlarging fleet of heavier, faster, and more powerful aircraft, a nation's (e.g., Far East country's) airport planners and operators have been under relentless pressure to increase the capacity of the national airport system and to do so quickly and economically.[Young *et al.* 1974:933]

Airports can be thought of as servicing stations for their users - passengers, aircraft, airlines, airport related organisations, employees, visitors, and others who all utilise them at the starting and terminal points of flights. They are also the control centres of aviation operations providing a high standard of safety and regulation. Most airports are either voluntarily or compulsorily connected with peripheral systems. Varied environmental factors, elements, and characteristics affect the effective and efficient operation and management of airport systems. Wide-ranging peripheral systems, for example, socio-economic, political, environmental, demographic, consumer behavioural factors and such like, are very significant in airport system planning and operations. So long as transport systems differentially affect different groups with different interests, a universally acceptable normative solution to the overall evaluation problem will appear to be a will-o'-the-wisp [de Neufville *et al.* 1973:63]. A multi-criteria or integrated approach is definitely needed to provide and analyse appropriately the service and its performance to users.



<**FIGURE 1-1**> GROUPS PARTICIPATING IN THE AIRPORT SYSTEM

1-1 RESEARCH MOTIVATION FOR THE LEVEL OF SERVICE AT THE AIRPORT LANDSIDE SYSTEM

The level of service for an airport landside system supposes that its users will arrive at a decision about the service level group through their perception of the provision of service at a service activity area. Factors such as 'service processing time', 'waiting time', 'internal environment', 'convenience', and 'comfort' are aspects of the level of service that could be selected as fundamental factors in an evaluation process for an airport landside system due to the users' expression of subjective opinions. For example, their expression can be measured using linguistic terms such as good, moderate, or bad regarding the degree of personal satisfaction.

There are undoubtedly quantitative as well as qualitative aspects of service which greatly influence users' sensory perceptions. From the passengers' point of view, for instance, they include such factors as; 'complexity of service procedure', 'service delay', 'density of waiting areas', and 'convenience'. This is true for an airport landside system, in particular airport passenger terminal buildings. However, a lack of behavioural vividness of performance indices are inherent in an airport landside system especially in terms of the level of service for its system with objective criteria. Accordingly, evaluation of the entire process is needed to assess the level of service. Recognising this situation, the author decided to conduct this study in which a technical methodology to support the service level evaluation in the airport landside system would be developed.

A primary motivation for the research is the feeling that attention must now be paid to aspects of level of service that influence overall user satisfaction. The sense of fit between the user needs and service activity must be identified and the performance factors for an airport landside system be defined. The necessity for the identification and definition of the determinants of system performance factors consistent with overall user satisfaction depicts the problems of developing a method for the description and measurement of fit between the airport landside system and its users for evaluation of the level of service.

1-2 SCOPE OF THE RESEARCH

The real performance data of an airport system are critical and extensive. They relate to data on traffic, physical facilities, transport-related institutions, transport expenditures, environmental impacts, and available technologies and identification also to the definition of all policies and objectives within the transport sector. All this data can be collected from the various users as they finish using a specific facility or component in the airport system.

The fundamental goal of an airport system should be to focus on primary users as well as upon secondary users. The air passenger is the primary user of an airport. The reason for an airport system is to provide satisfactory services for users. The secondary users can be defined as the supporting groups for the primary user, being the airport employees, airlines, and other airport-related systems. Thus a major goal of the airport system ought to be concerned with providing the maximum satisfaction for air passengers through its various provision services. The term level of service is a significant performance indicator of the level of operation when evaluating the passenger's satisfaction. As the service level is a constitutive performance indicator, it is natural that great interest is focused on it.

Due to the substantial restrictions and difficulties associated with conducting this research and in the collection of information, a methodology for evaluating an airport system based on the concept of level of service has tended towards one of simple structure, allowing for easy implementation, but with optimal effort when selecting information under highly restricted conditions. Therefore, the scope of this research centres on the level of service for the service areas at an airport landside system and on departure passengers for the target investigations.

1-3 INTENTIONS AND FRAMEWORK OF THE THESIS

Having defined the level of service as the major performance indicator of the operations in the airport system as one of obvious importance, the research proposes to seek an integrated and comprehensive analytic model for service level evaluation from the passenger's viewpoint. The intentions of this study are:

Firstly, to provide a quantitative evaluation model which is defined as a multi-decision model(MDM) suitable for service level evaluation by means of a comprehensive approach.

Secondly, to set up the relative weighting values for specific service facilities which are based on the measurable indices for the multi-decision model. Major factors influencing the level of service are defined.

Thirdly, in order to give perspective to the model and greater emphasis it is attempted through the contribution of air passengers to assess from their perceptions the provision of services at each airport landside system.

Finally, to discover the degree of satisfaction with the selected service facilities at the airport landside system in order to supply useful sources of information for actual operations in a case study of the airport.

The thesis presents nine chapters to investigate the air passengers' satisfaction in terms of the level of service using the multi-decision model which represents the procedures and components of the research.

Chapter one describes the overall introduction to the research and *chapter two* presents a review of the literature covering the relevant subject of the level of service at airports.

Chapter three gives a full description of the airport landside systems, their functions and operations. It briefly covers the service facilities of the airports and their service procedures to passengers.

Chapter four deals with the level of service. Definitions of the level of service, applications of the concept to the airport system and service standards are discussed from different aspects.

Chapter five describes factors influencing the level of service for the airport landside system both in general and in particular. These influencing factor groups supply a great input source to a multi-decision model. Service criteria for the model are defined as three linguistic categories. Thus this chapter provides a basic background for a multi-decision model.

Chapter six represents the model development which is one of the most important procedures in this research. The multi-decision model is based on a form of fuzzy set and approximate reasoning. It is an innovative methodology for the evaluation of the level of service at the airport. The first part of the chapter gives a general introduction to fuzzy sets and approximate reasoning and the other part elaborates a heuristic algorithm based on the use of fuzzy mathematics to use the process of the evaluation for the airport landside system in terms of the level of service.

Chapter seven illustrates the different means and methods used to collect useful information at the airports. Many problems and difficulties associated with an airport survey are discussed. Through the identification of problems, a detailed survey method has implemented it called Tracing-Monitoring-Questionnaire(TRAMONIQ) survey.

Chapter eight is a case study applying the proposed methodology and is presented along with results and findings. This application has two main procedures; firstly, it applies the practical aspects as the prime task in using the model; secondly, it compares the results of the methodology and similar research previously conducted.

The final chapter contains the summary, conclusions, and the significance of adopting the proposed methodology. These also denote some limitations of the research and provisional recommendations for the next feasibility study.

CHAPTER 2

OVERALL REVIEW

As a preliminary step, an overall literature review on this topic is needed. In the literature there are only a few limited evaluation methods for the level of service at airports. In the earliest stages using the concept of transport level of service, evaluation had been established by service standards in the area of highway transport. These earlier service standards considered the physical considerations only, for example, the available passenger capacity per unit area at a facility at a given time. The first introduction of the level of service concept in the transport field was in 1950's by the US Bureau of Public Roads[1950]. The earliest forms of service level were defined under three capacity terms; basic, possible, and practical capacity. They were ambiguous and so in practice highway engineers were unable to judge the effects of operating under given capacity definitions.

Fruin[1971] constructed the dimensional design of pedestrian spaces involving the application of traffic engineering principles plus the consideration of human convenience and the design environment. He developed standards for six levels of design based on service volumes and the qualitative evaluation of driver convenience. In this work, service standards considered only the physical conditions in terms of crowding density of pedestrians.

Heathington and Jones[1975] and Brink and Maddison[1975] were mainly concerned with the influencing factors on the level of service at airports from another standpoint, that of air passengers with baggage, visitors, and employees. They also discussed demand and operating factors. These were largely subjective judgements and comprehensive considerations of user attitudes. Brink and Maddison suggested assessing tools and standards when considering demand patterns and operating characteristics of functional components.

In the 1980's, the research tendency for methods of evaluating levels of service focused on the passenger's perception. Mumayiz[1985] developed the perception-response(P-R) model based on the passenger's point of view of the time spent in various terminal processes using a three category level of service structure - Good; Tolerable; Bad. This research was one of the pioneering attempts to provide a practical measure of service standards for airport operations and management especially at the airport terminal building. The attempt proposed a new concept to establish service standards through special surveys which achieved a better interpretation of the capacity of individual facilities by relating the demand levels imposed to relevant service measures. The P-R model helped to enhance existing practices in planning, operation, and management of airport terminals, and has proved to be a practical and convenient tool to airport terminal planners, consultants, and to airport operators and managers. The model requires a sufficient data sample to indicate sensible service standards for any one variable such as processing or waiting time at a service facility in the airport terminal buildings.

The other academic research was done by Müller[1987]. He addressed the quantitative modelling of passenger service quality at the airport terminal and developed a framework to estimate the value passengers give to the quality of service in the terminal, providing a basis to evaluate terminal alternatives considering passenger perceived benefits. This suggested framework is quite appealing because it was based on psychological theories of perceptual scaling and categorical judgement. This analytical framework for measuring the level of service was provided by the passenger check-in function at an airport passenger terminal which allowed survey responses, consisting of qualitative user assessments of their experience in the terminal using a quantitative perception scale.

The Transportation Research Board[1987] presented how landside capacity can be defined and measured at airports together with guidance for applying these definitions. This work included such processes as - description of the behaviour of individual functional components and interactions among components and the demand and operating factors generally influencing that component's service level and capacity; discussion of the demand patterns that the component must typically accommodate, particularly the peaking conditions likely to give rise to service level and capacity problems; description of the operating characteristics typical of the airport landside component; review of analysis tools and assessment standards to assist in assessing the service facility's capacity and the levels of service; an example of the assessment process to demonstrate how data were gathered and used to estimate achievable service volume based on a specific pattern of demand and service-level target. This proposed process for measuring airport landside capacity takes an important first step in supporting an adequate service standard in practical operation and management.

Omer and Khan[1988] proposed the use of a utility approach to evaluate user perceived value of the level of service for the airport landside subsystems. They recognised the need to reduce different service measures such as queue length or crowding to a common scale and proposed an approach that would transform the actual measured value to a [0 - 1] scale using a linear transformation and would use passenger ranking as important when producing a weighted combination. This utility approach, however, transpired to contain some serious flaws, such as a linear transformation problem, a combination of different service measures, and conceptual invalidity.

Ashford[1988] reviewed the various approaches developed by different agencies for the level of service at the airport terminal building. These all define levels of service in terms of specified values of particular service parameters. Such measures have been adopted by organisations such as Transport Canada[1979], the British Airports Authority[1982], Aeroport de Paris, and the International Air Transport Association[1981]. Pushkarev and Zuppan[1975] set out five service levels for standing pedestrians with a required area per person for different activities and/or pedestrian walking speed. These service standards owe their origin to traffic engineering concepts of capacity-volume or time-volume based as the space or time standards respectively.

Since 1990, a variety of methods for the level of service evaluation have been attempted. The methods are still focused on the passenger's perception as the prime target investigation. Two branches of research, which are for airport access and passenger terminal buildings, were of major interest when considering the level of service concept.

Innes and Doucet[1990] examined the importance of airport proximity as well as the effects of the level of service factors on alternative airport choice. Disaggregate modelling techniques were used in the identification of factors affecting the choice of alternate airports in a limited geographical area. This work demonstrated the significance of the level of service variables in the airport-choice decision by passengers.

Bolland[1991] suggested an assessment method for passenger's perception of the level of service provided by the various modes of transport using a quantitative rating for a range of different service factors. This evaluation methodology for airport ground access was applied to a case study of access at London Heathrow Airport. There were eight different types of transport modes considered. The attempt to fit measurable values to the level of service ratings was not totally successful, but it showed that the method used was applicable to the level of service rating for airport access. The results drew on two interesting points which are, the significance of habit and convenience in mode choice and the poor rating by all passengers of the level of information available on airport access. These results would enable one to identify in which areas improvements should be made to the services to passengers.

Lemer[1992] offers a very comprehensive discussion about the principal factors comprising a framework for describing performance focusing primarily on passengers, airlines, and the airport operator, while Odoni and Neufville[1992] presented practical procedures for incorporating such considerations into terminal design, based both on theory and on experience internationally at major airports. This work considered the sequences of flows of the passengers, their likely dwell-time in each facility, and their psychological response to the configuration of the spaces. Both studies suggested that computer-based models in terms of objective-oriented simulation seems to be the most promising modelling technique.

Martel and Seneviratne[1990] discussed performance evaluation in terms of the quality of service at the passenger terminal building using their perceptions for variables influencing its performance. Six significant factors influencing service performance associated with each of the terminal elements were established using a chi-square(χ^2) tests of proportions. These are the six factors such as (1) information; (2) waiting time at processing activities; (3) convenience at processing activities in terms of physical efforts; (4) availability of seats; (5) concessions in terms of variety and accessibility; (6) internal environment such as aesthetics and climate. The findings drew from a survey for departing passengers at Dorval International Airport in Montreal, Quebec.

Other important background issues on the level of service evaluation were proposed by Bandara[1990] who suggested that a way to choose terminal geometry that minimises walking distances is considered to be the major service level factor. Pullen[1993] concentrated on the definition and measurement components of quality management processes for local public transport services based on passengers' waiting times, lost mileage, and expanded seats of measures and indices. This work suggested a method for monitoring the quality of service for local transport services by both performance and psychometric measures. These can be measured on a periodic basis and compared across time.

Literature related to this research topic, reviewed only the well recognised researches relevant to the progress of the research. The methodology implemented by this research has emphasised establishing a practical and quantitative approach drawn after reviewing professional and academic literature. Most previous studies adopted the systems approach and required the mounting of extensive data collection efforts to provide sufficient reliability of the proposed models. In this research, the systems approach has been adopted and applied to a new decision model using fuzzy set theory, particularly fuzzy approximate reasoning as the major executive tool of the methodology.

CHAPTER 3

AIRPORT LANDSIDE SYSTEM

3-1 AIRPORTS AND THEIR SYSTEMS

Modern airports provide a wide range of facilities and services for the air traveller, the airport operator, and various commercial and industrial interests.[Hasan *et al.* 1986:145] Airports are complex industrial enterprises. They act as a forum in which disparate elements and activities are brought together to facilitate, for both passengers and freight, the interchange between air and surface transport.[Doganis 1992:7] Airports are used by various users such as passengers, airlines, visitors, employees, cargo shippers, consignees, a host of companies or agencies providing essential services and supplies to the airports themselves and to carriers and patrons of the airport. "Hence, an airport encompasses a wide range of activities which have different and often conflicting requirements. Yet they are interdependent so that a single activity may limit the capacity of the entire complex."[Horonjeff *et al.* 1994:181]

"Airports are bad neighbours but good business partners. As such, all major urban centres must endure the associated poignant unpleasantries of noise and air pollution to sustain their economic base. This welfare trade-off appropriately gives rise to some optimal rate of airport activity in the region; this desirable level of airport operation must reflect the meteorological and demographic characteristics as well as the socio-economic fabric of the community."[Ferrar 1974:163] The community served by an airport, depends upon the airport for transport, jobs, business opportunities, recreation, and education, but gives rise to environmental problems for the community. Therefore, the airports are a huge and complex system with multi-purpose, technically diverse, sensitive roles, together with environmental responsibility to the related community. "Organisational, managerial, administrative, and operational structures are quite complex, and activities within the system are initiated, motivated, or sustained by factors that are not necessarily aviation or transport-oriented; they may be commercial-financial, institutional, social, political, or environmental."[Mumayiz 1985:22]

De Nuefville[1976:9] tackled the airport issues from a wider view in terms of a system approach: "airports perform a broad spectrum of services, through many different facilities and organisations, to a wide variety of users. The nature and mix of the activities is not stable: daily, weekly, and seasonal peaks for different kinds of traffic aggravate the situation. The flows of traffic through the facilities, and the relationship between them, are affected by many, interdependent factors. Airports, furthermore, exist in a social and economic environment which imposes conflicting objectives and subjects them to continuing competition and even political conflict."

Ashford, Stanton, and Moore[1984:1] pointed the three major components of the air transport system: the *airport*, including the airways control; the *airline*; the *user*. Furthermore, they were concerned with the airport neighbour organisations as the community component of the airports. <TABLE 3-1> displays a more complete listing of the involved organisational sub-system for a large airport.

<TABLE 3-1> ORGANISATIONS AFFECTED BY THE OPERATION OF A LARGE AIRPORT

PRINCIPAL ACTOR	ASSOCIATED ORGANISATIONS
AIRPORT OPERATOR	Local authorities and municipalities Central government Concessionaires Suppliers Utilities Police Fire service Ambulance and medical services Air traffic control Meteorology
AIRLINE	Fuel supplies Engineering Catering/duty free Sanitary services Other airlines and operators
USERS	Visitors(passengers) Meeters and senders
AIRPORT NEIGHBOUR ORGANISATIONS	Local community groups Airport booster organisations Local chambers of commerce

[*Source*: Ashford ***et al.*** 1984:3]

Doganis[1992:7-10] viewed the overall airport umbrella. A wide range of services and facilities are divided into three distinct groups: essential operational services, traffic-handling services, and commercial activities.

Essential Operational Services and Facilities: Such services are primarily concerned with ensuring the safety of aircraft and airport users. They include air traffic control services provided at the airport to facilitate the approach and landing of aircraft, meteorological services, telecommunications, police and security, fire and ambulance services including those for search and rescue, and finally runway and building maintenance. These facilities and services are normally provided by the airports themselves or by local or central government departments. But even when the airport operator is responsible for their provision, that operator may have relatively little discretionary control over them because their provision may be heavily influenced by government policies or national or international regulations.

Traffic-handling Services: A variety of handling activities are associated directly with the aircraft itself and include cleaning, provision of power, and loading or unloading of the baggage/freight hold. This is sometimes referred to as ramp handling. Other handling activities are more directly traffic related and cover the various stages of processing of passengers, baggage or freight through the respective terminals and on to the aircraft. Various parts of the handling process may be the responsibility of different authorities.

Commercial Activities: The airport commercial facilities and services are provided by concessionaires and by the airport authorities. At most of the European airport authorities let commercial facilities to concessionaires, but there are a few airport authorities themselves directly involved in running some or virtually all the commercial outlets. For examples, Aer Rianta, the Irish Airport Authority, and Düsseldorf airport operates the duty-free shops, in Rome the duty-free shop and restaurants, and at Amsterdam all catering outlets.

Generally, airports can be divided into two parts as a functional mechanism. One of these is the airside system. It can be defined as the airfield and its components, the runways, taxiways, apron-gate areas, and air traffic control systems used by the aircraft and pilots. The other is the landside system it includes aircraft parking positions and gates, terminal buildings, car parking areas, access roads, and the services provided for users of these facilities. Mainly, passengers, employees of the airports, cargo, visitors, and aircraft maintenance activities use the landside of airports' facilities and services.

3-2 AIRPORT LANDSIDE SYSTEM

3-2.1 Components of the Airport Landside System

The airport landside is controlled to a great extent by the local community such as airport users, airport neighbours, and governmental agencies. In addition to this airport-related community, the airport operators must also co-operate with airlines. These landside sub-systems may deal directly with any of the others on matters affecting the airport. The landside system at airport, therefore, is a complex collection of individual components such as the following. [TRB 1987:19-22] <Figure 3-1> shows the summary of the individual components.

I. *Environs*
- ✈ Ground access
  - Remote terminals
  - Transit links
  - Highway links -
    - Remote parking and shuttle;
    - Access roads/interchanges
- ✈ Air-related industrial land and buildings

II. *Airport Grounds*
- ✈ Approach roads
- ✈ Remote processing facilities and services
- ✈ Parking areas
  - Taxis; Private vehicles; Rental cars
- ✈ Circulation/distribution roads
- ✈ Cargo docking area

III. *Terminal Building*
- ✈ General configuration
  - Pier; Satellite; Linear; Transporter
- ✈ Terminal Kerb
  - Departures; Arrivals
- ✈ Terminal Transition
  - Entry ways and foyers; Lobby area
- ✈ Airline facilities
  - Office; Ticket counter; Baggage check/claim
- ✈ Circulation
  - Corridors; Stairs; Escalators; Security screening

- Passenger amenities
  Food/beverage; news/tobacco; Drugs; Gifts; Clothing;
  Florists; Barber and shoeshine;
  Car rental and flight insurance;
  Public lockers and telephones;
  Post office; Amusement arcades; Vending machines;
  Restrooms and nurseries; Showers and health club;
  Chapels; VIP waiting areas
- Departure lounges (Passenger waiting areas)
- International facilities/Federal Inspection Services (FIS)
  Immigration and naturalisation; Customs;
  Plant and animal health (Agriculture);
  Public health
- Airline Operations
  Flight operations/crew ready rooms;
  Valuable/outsized baggage storage; Air freight and mail;
  Administrative offices
- Airport Operations and Services
  Offices; Police; Medical and first aids;
  Fire fighting; Building maintenance;
- Building Mechanical Systems
- Communications Facilities
- Electrical Equipment
- Government Offices
  Air traffic control; Weather; FIS and public health
- Conference and press facilities

IV. *Apron-gate System*

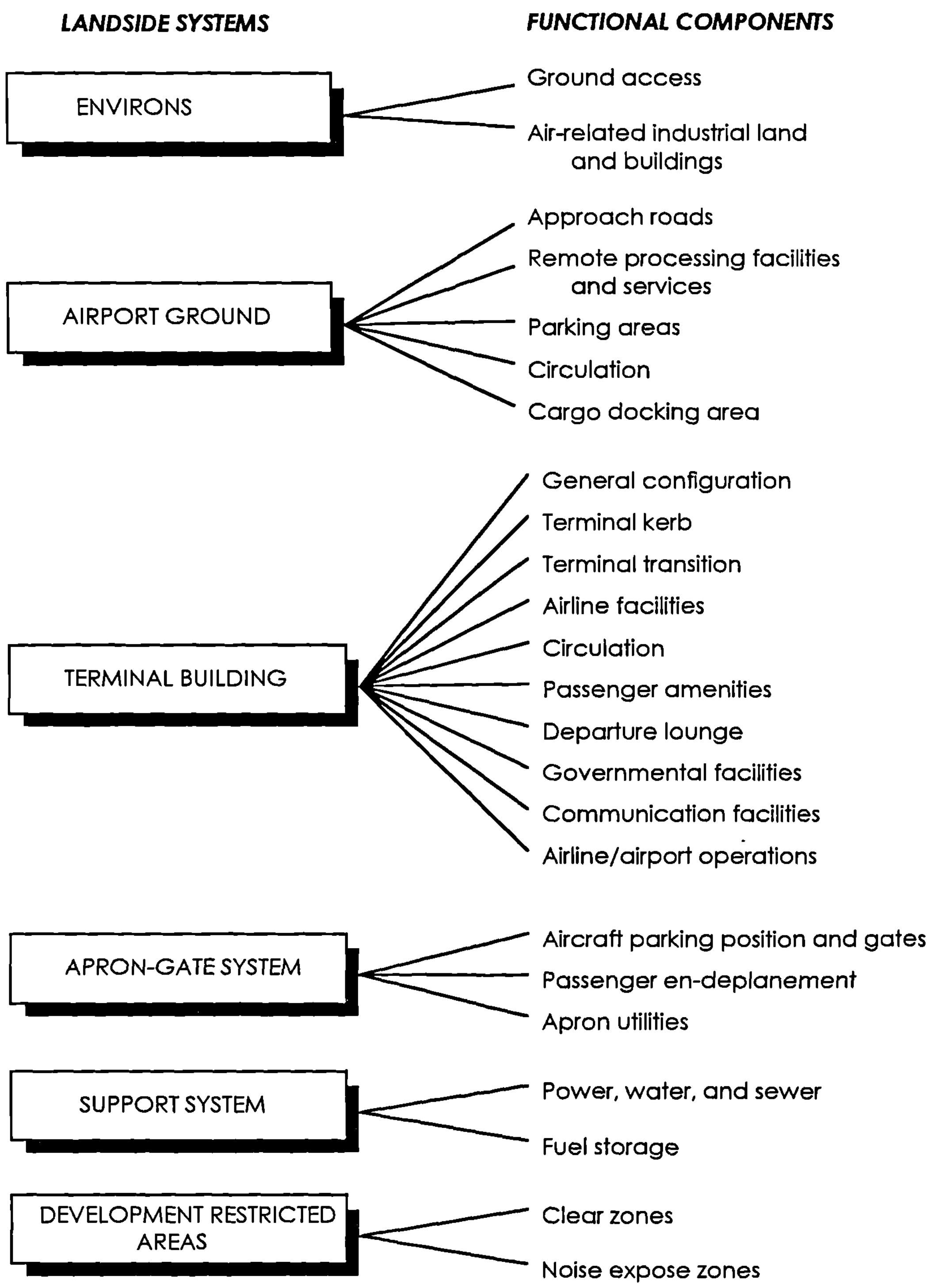
- Aircraft Parking Positions and Gates
- Passenger Enplanement/deplanement
  Waiting areas; Bridge; Stairs; Mobile conveyance
- Apron Utilities
  Fuel; Electric power; Aircraft electrical grounding;
  Apron lighting and marking
- Cabin Services, Aircraft Maintenance
- Aircraft Parking and Circulation

V. *Support Systems*

- Power, Water, and Sewer
- Fuel Storage

VI. *Development Restricted Areas*

- Clear Zones
- Noise Exposure Zones



<FIGURE 3-1> THE INDIVIDUAL FUNCTIONAL COMPONENTS OF AIRPORT LANDSIDE SYSTEMS
[*Source*: Summarised from TRB 1987]

3-2.2 Functions of the Airport Landside System

The airport landside systems provide various services to its users. Users take the services at each functional component such as ground access to the airports, car parking, security search, departing or arriving processing services - ticketing, check-in and baggage drop, central security check, passport control, immigration, customs, holding areas, circulation, concessions, and other miscellaneous activities. These complex ranges of activities and services for passengers can be broadly classified into four sub-systems based on the geographical location. These are the airport parking position and gates, the passenger terminal building, car parking, and ground egress to the airports or to the final destinations such as home, office, or hotel.

3-2.2.1 Airport Parking Position and Gates Sub-system

The apron provides the connection between the terminal buildings and the airside. It comprises aircraft parking positions, aircraft circulation, and taxiing areas for access to the apron gates or to the taxiways. Among these, aircraft parking positions and apron gates are included in the landside sub-system. Normally, aircraft parking positions are designated by scheduled aircraft operations. The designated locations which serve the aircraft unloading and loading passengers and baggage and the gates through which passengers pass to board or leave an aircraft.

"The various activities of arrival and departure combine with facilities' characteristics to determine the number of flights that the gate complex can accommodate in a period of time and the delays to which passengers and aircraft may be exposed. In addition, gate operations influence passenger demand characteristics and thus service levels throughout the airport landside."[TRB 1987:61] The demand for aircraft gates or other aircraft parking positions is determined by the flight schedule for the airport, the number of aircraft gates, the size of the gates, and the aircraft parking layout in the gate area.

3-2.2.2 Terminal Building Sub-system

The airport passenger terminal constitutes one of the principal elements of infrastructure cost at the airport.[Ashford *et al.* 1992:286] The airport terminal, the building itself and the paved areas surrounding it on the airside and the landside, is the zone of transition for passengers, providing the link between surface and air transport. Design and operation of the terminal have an influence on both airside capacity and ground access and the overall rate at which aircraft can be handled.[Wells 1992:141] Hence, airport terminals facilitate a wide and broad range of services and activities for the various passengers as the prime client, such as transfers, multi-lingual travellers on international flights, commuters, and holiday-makers on chartered flights as well as for meeters and senders. Analytically, airport terminals perform several functions simultaneously, that are all put into a specific order and follow a particular procedure according to regulations and practices adopted, which significantly vary between different times and locations[Mumayiz 1985:25].

Ashford and Wright[1992:286-287] viewed the passenger terminal as performing three main functions which are change of mode, processing, and change of movement type.

Change of Mode. Few air trips are made direct from origin to destination. By their nature, "air" trips are mixed-mode trips, with surface access trips linked at either end to the line haul air trips. In changing from one mode to the other, the passenger physically moves through the airport terminal according to a prescribed pattern of movement. These movement patterns are accommodated by passenger circulation areas.

Processing. The terminal is a convenient point to carry out certain processes associated with the air trip. These may include ticketing and checking in the passengers, separating them from and reuniting them with their baggage, and carrying out security checks and governmental controls. This function of the terminal requires passenger processing space.

Change of Movement Type. Although aircraft move passengers in discrete groups in what is termed "batch movements", the same passengers access the airport on an almost continuous basis, arriving and departing in small groups mainly by bus, auto, taxi, and limousine. The terminal, therefore, functions on the departure side as a reservoir that collects passengers continuously and processes them in batches. On the arrivals side, the pattern is reversed. To perform this function, the terminal must provide passenger holding space.

Consequently, the main functions of the passenger terminals comprise change of mode at circulation areas, processing at the terminal required processing areas, and change of movement type at passenger holding areas. In addition, other support functions are also necessary to provide more comfort, convenience, and safer operations for users and to ensure the highest satisfaction for the provision services and activities.

Horonjeff and McKelvey[1994:431-432] discussed another viewpoint for the passenger terminal system, but it is quite close to Ashford's one. According to their view, the passenger terminal system can be divided into three major components. These components and the activities that occur within them are as follows:

Access Interface. The passenger transfers from the access mode of travel to the passenger processing component. Circulation, parking, and kerbside loading and unloading of passengers are the activities that take place within this component.

Processing. The passenger is processed in preparation for starting, ending, or continuation of an air transport trip. The primary activities in this component are ticketing, baggage check-in, baggage claim, seat assignment, federal inspection services, and security.

Flight Interface. The passenger transfers from the processing component to and from the aircraft. The activities that occur here include assembly, conveyance to and from the aircraft, and aircraft loading and unloading.

Thus, the airport terminal system comprises three major parts: the access interface, the processing system, and the flight interface. These facilities are provided to perform the functions of the airport passenger terminal system.

Ashford, Stanton, and Moore[1984:209-232] discussed in some detail the individual terminal activities based on the airport operational standing. They classified the terminal activities into five principal component groups: (1) direct passengers services; (2) airline-related passenger services; (3) governmental activities; (4) non-passenger related airport authority functions; (5) airline-related operational functions. The following lists show examples although they are not exhaustive.

Direct Passenger Services: These services are typically involved in two major activities: commercial and noncommercial.

✈ *Commercial activities*

- Duty-free shops
- Car rental
- Insurance
- Banks
- Hotel reservations
- Advertising
- Amusement machines
- Hairdressers, dry cleaners, valet services
- Other shops - books shops, tourist shops, boutiques, etc.

✈ *Noncommercial activities*

- Portering
- Baggage trolleys
- Left baggage lockers
- Directional signs
- Seating
- Rest rooms
- Toilets, nurseries, and changing rooms
- Flight and general airport information
- Post office and telephone areas

Airline-related Passenger Services: Many operations within the airport terminal system are usually handled entirely by airlines or their agents.

- Airline information services
- Reservations and ticket purchase
- Loading and unloading baggage at aircraft
- Baggage delivery and reclaim, it is often under authority control.
- Airline passenger "club" facilities

Governmental Requirements: At major airports, international passengers are handled according to governmental controls on.

- Customs
- Immigration
- Health
- Agricultural produce

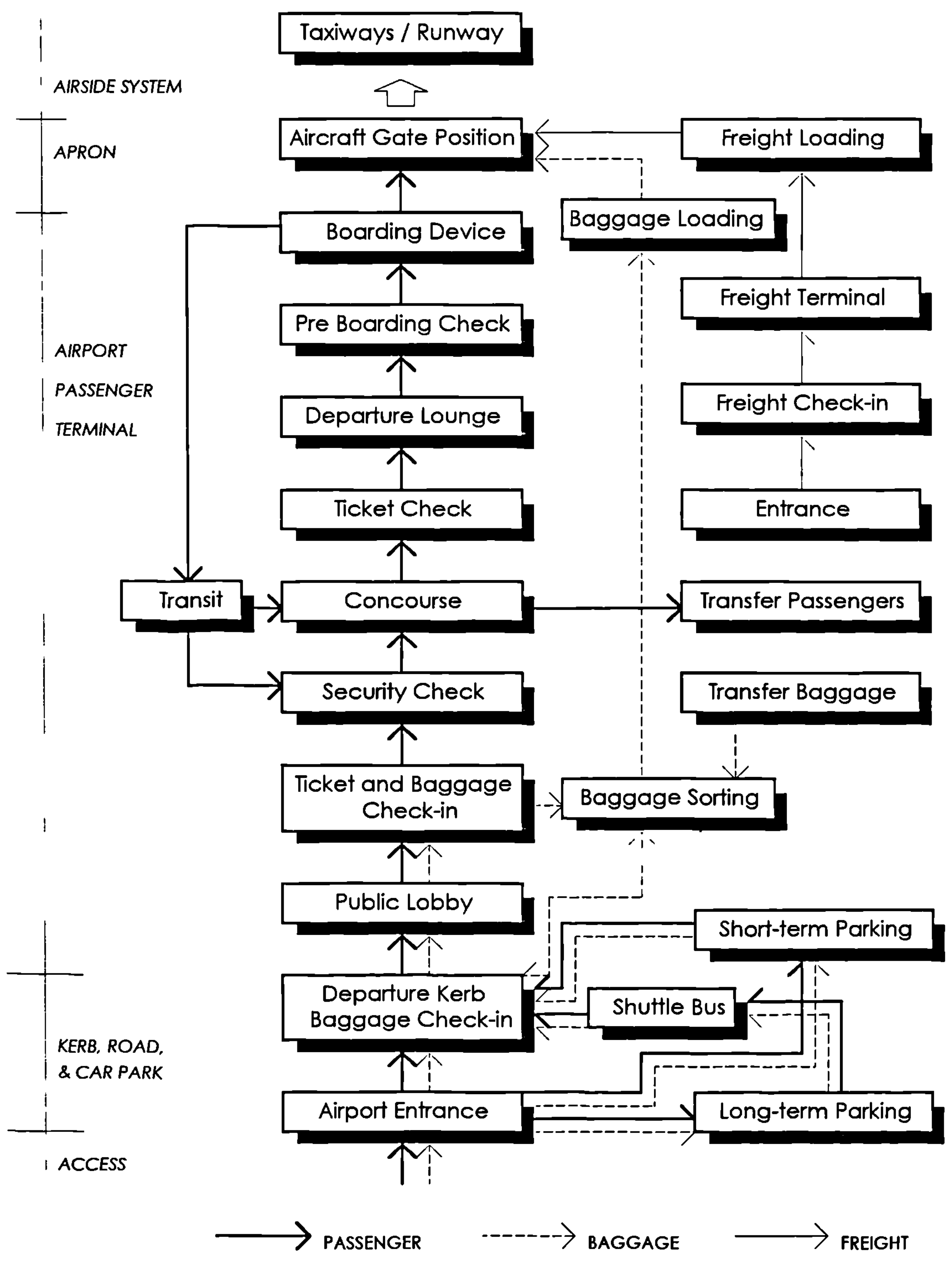
Non-passenger Related Airport Authority Functions: It is often convenient at smaller airports to locate within a terminal building; otherwise, at larger airports, it is customary to separate these authority functions into a distinct building or buildings away from the terminal building.

- Management
- Purchasing
- Finance
- Engineering
- Law
- Personnel
- Public relations
- Aeronautical services
- Aviation public services (e.g. environmental services)
- Plant and structure maintenance

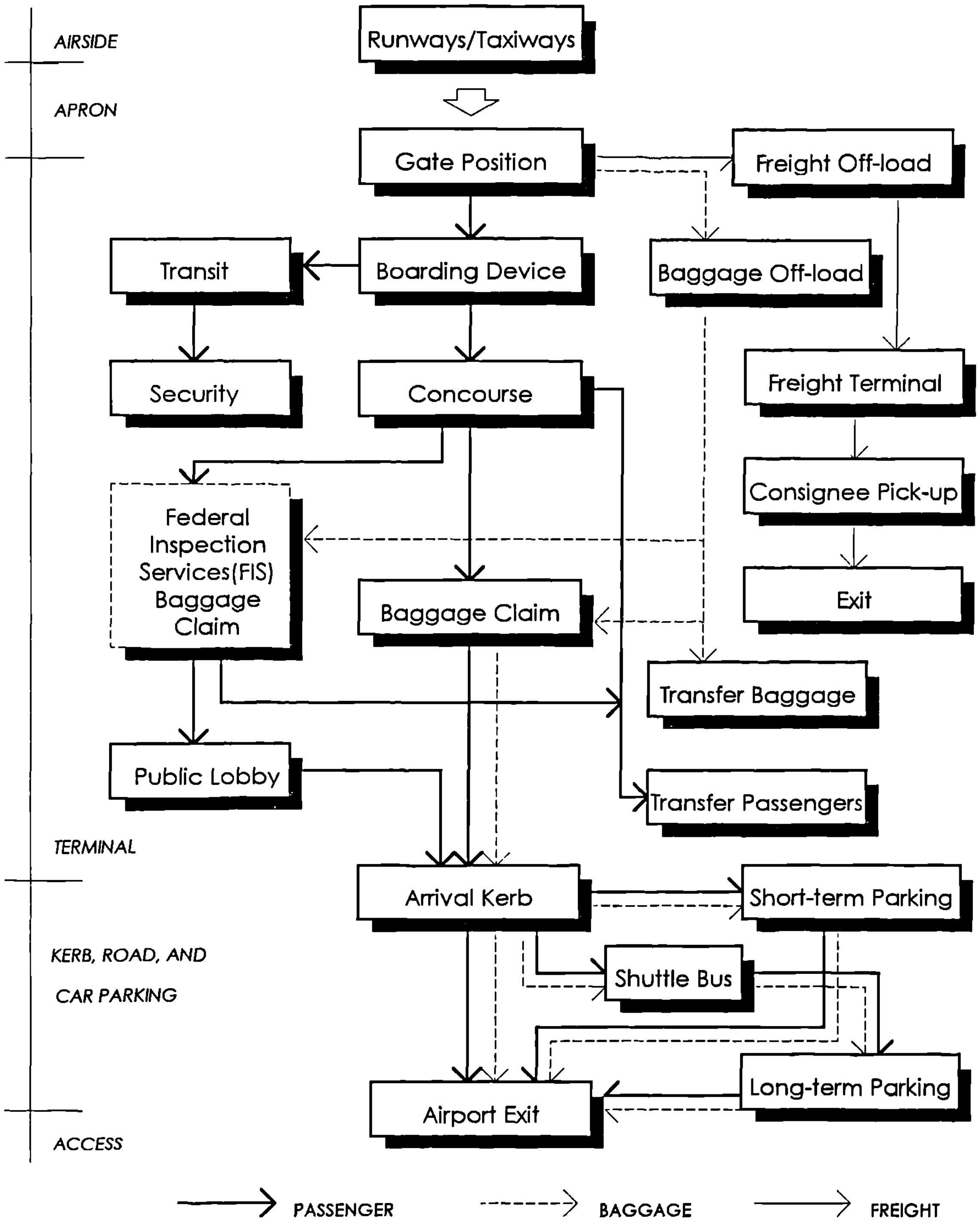
Airline-related Operational Functions: Control of many of the activities associated with operational functions such as refuelling, cleaning aircraft, and the loading of food is necessary to prepare on time departures.

- Flight planning
- Aircraft weight and balance
- Flight crew briefing
- Flight watch

The terminal area is the major sub-system at the landside system. The system provides the connection between the aircraft and the ground access transport modes for users. The passengers and baggage flow at typically large airports are shown in <FIGURE 3-2> and <FIGURE 3-3>.



<FIGURE 3-2> US DOMESTIC AND INTERNATIONAL PASSENGER AND BAGGAGE FLOW - OUTBOUND
[*Source*: Hart 1985:18]



<FIGURE 3-3> US DOMESTIC AND INTERNATIONAL PASSENGER AND BAGGAGE FLOW - INBOUND
[*Source*: Hart 1985:18]

3-2.2.3 Car Parking Sub-system

Parking facilities at an airport are used for the storage of the vehicles in surface lots or multi-level parking buildings. Most major airports provide separate parking and storage areas for the vehicles of air passengers and visitors' vehicles, also for employees vehicles, rental cars, taxis, airport limousines, and buses. These requirements have relatively little impact on capacity or service levels provided by the airport from the passenger's point of view.

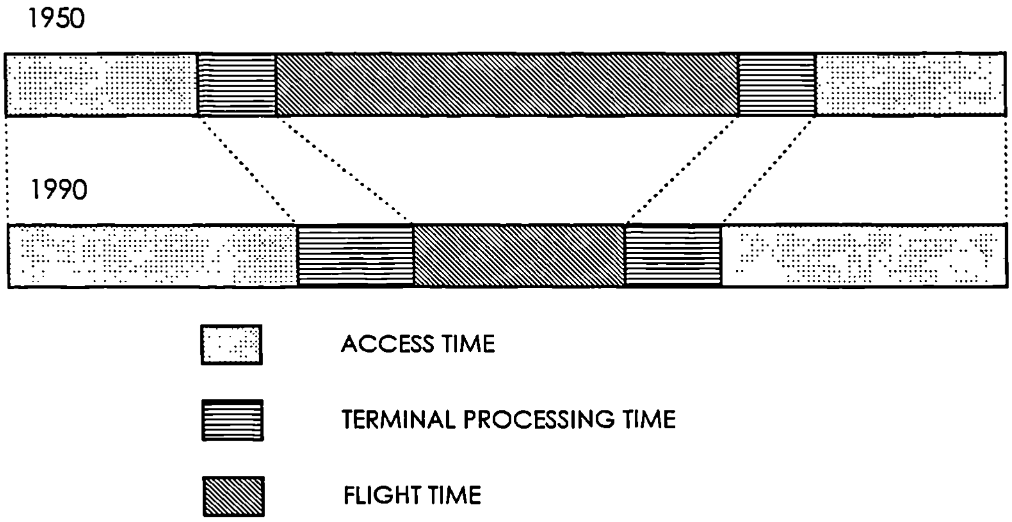
Parking facilities for air passengers and visitors are often segregated into three general categories: short-term, long-term, and remote parking. Usually, a short-term car park is the most convenient to the terminal buildings and serves the people dropping off or picking up air travellers. However, it charges the highest premium rate. In the United States, short-term parkers usually remain at the airport for under three hours. These car parks account for approximately 80 percent of the parking at an airport, however, they account for only 15 to 20 percent of the accumulation of vehicles in the parking facility over the course of a year[FAA 1988]. Long-term parkers usually leave their vehicles in the car park while they travel. It means that the long-term car park has a low turnover rate and a long duration of stay. Remote parking is usually located away from the main terminal complex, and provisions are normally made for courtesy vehicle transport to the terminal. Thus, it charges a more economical rate.

Parking demand is a complex function of the number of persons accessing the airport, the available access modes, the type of air traveller, the parking cost, and the duration of the parking period, which is determined by the type of person making the trip, i.e., traveller, worker, service personnel, or visitor.[Ashford *et al.* 1992:433] Distribution of parking demand is characterised by parking spaces, the purpose of trip, and the cost of parking. Clearly, it is very sensitive to the pricing policy. The parking charge policy is a very effective operational means to divert parkers to less expensive parking areas and can cause them to choose public transport modes in particular the price-sensitive parkers. "The number of parking spaces required to provide adequate service levels is normally greater than total parking demand. This is because at a large parking facility in which many areas can not be seen simultaneously, for example, in a multi-level garage or extensive open lot, it is rather difficult to find the last empty spaces. Thus, a large parking facility may be considered full when 85 to 95 percent of the spaces are occupied, depending on its use by long or short-term parking, size, and configuration."[TRB 1987:114]

3-2.2.4 Airport Access Sub-system

Access to the airports is an integral component of the passenger's and visitor's journey from origin to the airport. Although the access system also serves others for the airport population such as the employees, airport service personnel, and other airport related personnel ground access provides an assortment of private and public transport modes. The access system at the airport comprises the multi-modal transport system that is related to the variety of needs of airport users and is designed to match the various airport situations. The numbers of access modes which must be made available at an airport should be designed for private cars, taxis, buses, express buses, airport special buses and limousines, rail systems, underground vehicles, and hotel service vehicles. In a few cases, the system must cope with vertical take-off and landing(VTOL) aircraft and waterborne modes. Unfortunately, the VTOL service is often rather more expensive than the others, but it can be excellent for business travellers.

Historically, access to airports was not dealt with as a significant issue in the early days of aviation. Air passengers paid the relatively high cost of travel which meant there were only a few travellers. Nowadays it has emerged as a very important system for an airport. For example, "over the last 40 years, short-haul city centre to city centre travel has shown that potential time savings brought about by the introduction of jet aircraft have been partially or wholly negated by increases in surface access and terminal processing time, and this is the essence of the problem. Clearly, the impact of poor access has maximum implications for short-haul trips, where the proportion of access time to the overall trip time is high."[Ashford *et al.* 1992:418] <FIGURE 3-4> indicates the scale of changes from first-origin to final-destination times for a short-haul.



<FIGURE 3-4> COMPARISON OF SHORT-HAUL CITY-CENTRE TO CITY-CENTRE TRAVEL, 1950 VS. 1990 [*Source*: Ashford *et al.* 1992:419]

Access demand is primarily determined by the travel modes selected by passengers and visitors, the number of persons per vehicle, the circulation patterns of these vehicles, and how long before or after a flight a person arrives at or leaves the airport. Demand patterns of courtesy vehicles and scheduled limousines and buses may not be directly related to air passenger activity patterns. Access demand is influenced by the extent of the public transport system available, passenger trip purpose, the availability of parking, type of flight, and the availability of alternative check-in areas. Cost of parking can have a particularly significant impact on access mode choice at large airports.[TRB 1987:122]

According to the increasing numbers of air passengers together with the higher volume of access traffic, the management of efficient access puts more strain on an already difficult situation, as the airport needs to provide sufficient kerbside areas, adequate terminal-to-terminal circulation, plus sufficient car parking spaces at the airport. Additionally, the transport modes of the airport's outside boundary and the congestion of access roads have to be considered together with many other aspects of the planning and management of the airport access system. Ashford and Wright[1992:419] suggested that three major areas in preparing the design of access system are usually considered:

> Firstly, the collection and processing, if necessary, of passengers in the central area of the city and other centres of high demand.
>
> Secondly, the movement of passengers, cargo, and service traffic to the airport by surface or air vehicles.
>
> Finally, the distribution of access traffic and internal circulation traffic to terminals and gate positions.

CHAPTER 4

LEVEL OF SERVICE

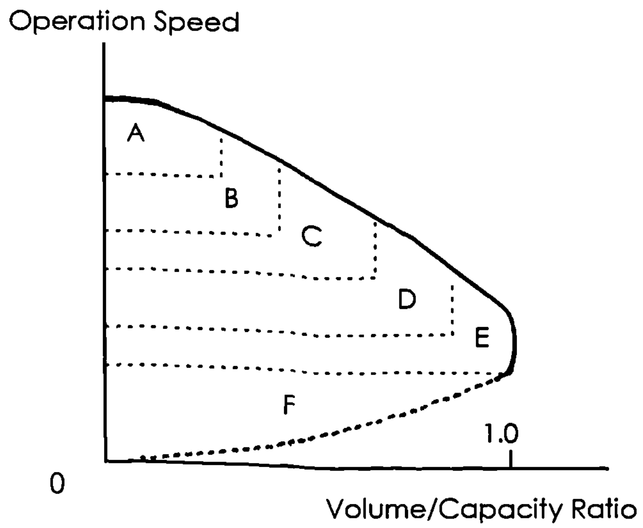
4-1 INTRODUCTION

Systems performance measurement can be an acceptable reflection of level of service in terms of assigned objectives. The level of service measures can depend upon how a system's performance is assessed and upon the impact of specific actions in the system. System performance measures are used to select data to compare the actual state of the system with standards, or among areas, or with previously set targets. Its measures will play a significant role in describing the achievement of the level of service of an airport system. Furthermore, useful performance measures will provide a basis for the development of system planning information. Thus, it is necessary to choose, measure, and analyse the service performance at the airport. This is needed for the airport system evaluation based on the concept of level of service that was the fundamental consideration in this research.

4-2 DEFINITIONS OF THE LEVEL OF SERVICE

Nowadays, the primary objective of many airports needs to shift to the maximising of users' satisfaction with a high standard of service in terms of perception of the provision service rather than supplier's interests.[Park *et al.* 1994:87] The concept of level of service is one of the most important performance indicators regarding airport planning and design, operation, and management. Service standards are essential in calibrating the performance of operation in transport systems, and when expressed as a framework, their level could serve as a yardstick of the system's performance.[Mumayiz 1985:41] The concept of level of service has been developed by planners and designers to provide some degree of sensitivity in the processes of design and capacity analysis[Ashford 1988:5], as well as performance analysis for the service facilities. The earliest stage of using the concept of transport level of service which was simply concerned with the broad range of factors came from the highway capacity analysis. The first introduction of the level of service concept in transport was in the Highway Capacity Manual by US Bureau of Public Roads[1950]. This manual was revised in 1965 to provide better highway design and capacity through the concept of level of service by the Highway Research Board[1965].

The first known definition for the level of service is that "level of service is a term which, broadly interpreted, denotes any one of an infinite number of differing combinations of operating conditions that may occur on a given lane or roadway when it is accommodating various traffic volumes". Level of service is a qualitative measure of the effect of a number of factors, which include speed and travel time, traffic interruptions, freedom to manoeuvre, safety, driving comfort and convenience, and are defined in terms of particular limiting values of certain of these factors.[HRB 1965:7] The road conditions were divided into six levels of designated service [A] to [F], from best to worst. The description of each level of service considers the service volume and capacity ratio, operating speed, and density, as shown in <FIGURE 4-1> and <TABLE 4-1>.



<FIGURE 4-1> THE RELATIONSHIP BETWEEN LEVEL OF SERVICE AND THE OPERATING SPEED, VOLUME/CAPACITY ENVELOPE (NOT TO SCALE) [*Source*: US HRB 1965]

<TABLE 4-1> THE DESCRIPTION OF EACH LEVEL OF SERVICE

LEVEL OF SERVICE	FLOW	VOLUME	SPEED	FREEDOM OF USER
A	free	low	highest	desirable
B	stable	low	high (Beginning restriction)	reasonable
C	stable	high (Suitable for urban)	medium (still satisfactory)	restricted
D	unstable	fluctuate	tolerable	little
E	unstable	high (near capacity)	low	-
F	forced	high (below capacity)	stoppage	-

The original highway capacity manual has been updated by the Transportation Research Board[TRB 1985] to give an update on the most recent experience and information. However, the main concepts and definitions remain essentially unchanged. Nevertheless, the concept of the highway level of service can not be directly used in an airport system, as the given conditions have different characteristics. For example, the basic units of the highway level of service are a highway with vehicles, but units of the airports are the runways with aircraft and terminal buildings with passengers.

The definitions for the level of service at the airport, particularly the landside systems are the following:

Brink and Maddison[1975] defined the level of service for the airport landside system for passengers moving through the airport landside as a "level of service which is a subjective impression of the quality of transfer between the access mode and the aircraft. This subjective impression is dependent on a series of factors including time the necessary to proceed through the landside, reliability or predictability of processing time, reaction to overall landside environment, physical comfort and convenience, reaction to treatment by airline personnel, concessionaires, security officers, and other airport personnel, cost of air fare and airport services, type of passenger and purpose of trip, frequency of air travel, and expectation of service." This definition reveals its numerous intermingled, subjective, and complex constituents, which evidently, will seriously limit its utilisation, and minimise its usefulness[Mumayiz 1985:44].

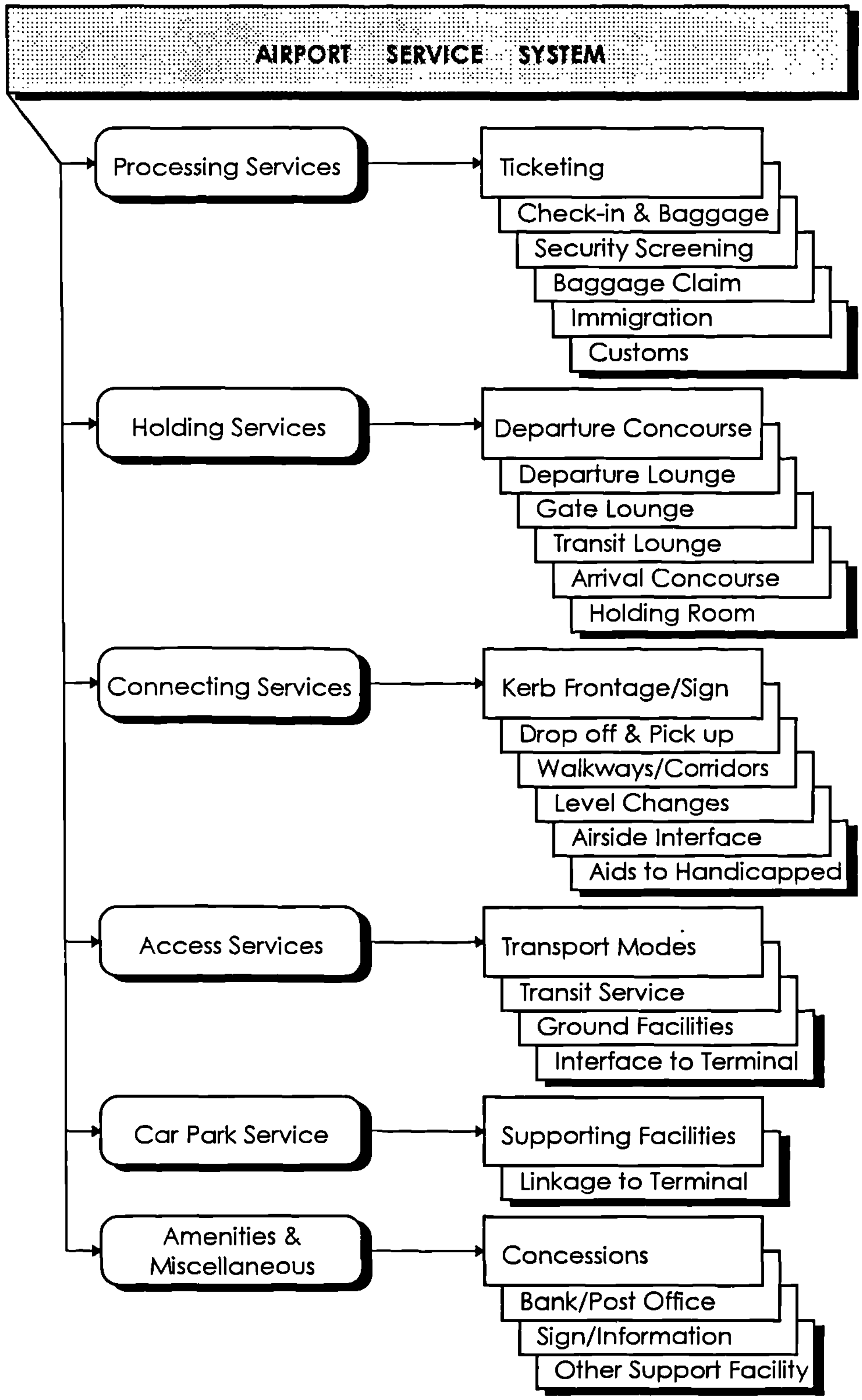
TRB updated the above definition that redefined the level of service as: "the quality and conditions of service of a functional component or group of functional components as experienced by passengers constitute the service level. Factors such as waiting time, processing time, walking time, crowding, and availability of passenger amenities for comfort and convenience are measures of the service level of components." Many of these factors are interrelated, and there may be others of importance at a particular airport. There are a variety of ways in which some of these factors may be measured, whereas other factors may be difficult to quantify.[TRB 1987:25]

Transport Canada[1979] defined it as "a measure or assessment of the conditions and operating characteristics of any subsystem or terminal facility at a particular level of demand or user volume. Since the traffic demand at each airport is dynamic and varies the service measure must reflect these dynamic aspects. Level of service, therefore, can be considered as a range of values or assessment of the ability of supply to meet demand." The level of service framework of Transport Canada is a six-level one similar to the Highway Capacity Manual's, but all its factors are qualitative and subjective.

The current concept of level of service needs to know the passenger's perception as a primary user of the system. Thus, most airports and airport authorities should be able to develop an updated service standard based on the passenger's perception to provide more comprehensive service levels to the user's maximum satisfaction. This service standard connotes multi-dimension applications in terms of physical and psychological approaches.

4-3 SERVICE STANDARDS

The level of service standard is basic information for design, capacity analysis, or operation of an airport system. It is defined at the various service facilities in the airports and their corresponding characteristics influence the service standards. The major kinds of service facilities of an airport landside system can be divided into six different categories; service processing facilities, holding facilities, connecting facilities, access system, car park service, and amenities and other miscellaneous service facilities. It is clear that each of these six airport service sub-systems are likely to require different service standards or criteria for the service provided to users. <FIGURE 4-2> shows the overall service facilities of the airport landside system.



<FIGURE 4-2> AN AIRPORT LANDSIDE SERVICE SYSTEM

Currently service levels are set simply in terms of standards which the authority attempts to meet, either in terms of design (space standards) or in terms of operation (time standards). In a number of facilities, standards are set in both terms of time and space, but the interaction of time and space has never been examined.[Ashford 1988:11] The review for the constructed service level standards is needed to understand the existing design and operation input of the airports traced in literature.

4-3.1 Processing Service Facilities

The airport facilities for processing services are the most important and vital parts of the system. They are significant factors in the complexity of the system. The complexity of these service facilities is caused by the needs of organisations in order to perform certain regulatory and operational activities. They involve the passenger and baggage handling systems so as to provide the safe transfer of passengers and baggage with confidence through the landside system. These service processing facilities have different characteristics and operations according to the nature of the process, the passenger's arriving time, required processing time, and the procedures of operation. Thus, it is not easy to set service standards for each service facility in the system. Furthermore, the involved organisations such as airlines, governmental agencies, and airport authorities have their own policies, interests, operation rules, and objectives which also cause difficulty when setting a service standard.

Normally, the level of service for processing facilities is determined by the time spent at each service facility. This time spent can be defined by waiting time in the queue and actual service time. The acceptability of a queue is in reality also related to the space provided, that means that the interaction effect between the time spent and the space provided must be dealt seriously. There are service standards suggested by the British Airports Authority [BAA 1982] which examined the BAA service standards in comparison with those of the International Air Transport Association(IATA). The BAA suggested that additional space was required for primary throughways and circulation. In broad terms the BAA set 25% for concourses and departure lounges and 20% for gaterooms. The BAA standards were defined such that under these design conditions, 95% of the passengers would receive the desired level of service. The design service standards of the Schiphol Airport Authority and Aeroports de Paris are also good input data. These are shown in <TABLE 4-3> and <TABLE 4-4> respectively.

<TABLE 4-2> SELECTED BAA AND IATA DESIGN AND SERVICE STANDARDS

FACILITY	BAA STANDARDS		IATA STANDARDS	
	Space Standard	Queueing Time	Space Standard	Queueing Time
DEPARTURES				
CHECK-IN & BAGGAGE DROP	0.8m^2/Pax. with hold Bag. 0.6m^2/Pax. with cabin Bag.	95% of Pax. less than 3 min.	0.8m^2/Pax. with Bag. on a trolley. 0.6 m^2 for visitors	95% of Pax. less than 3 min. 80% of Pax. less than 5 min. (Peak time)
PASSPORT CONTROL	0.8m^2/Pax. with hold Bag. 0.6m^2/Pax. without hold Bag.	95% of Pax. less than 1 min.	0.8m^2/Pax. with hold Bag. 0.6m^2/Pax. without hold Bag.	95% Pax. less than 1 min.
CENTRAL SECURITY	N/A	N/A	N/A	95% Pax. less than 3 min. 80% < 8 min. for high security flights
ARRIVALS				
IMMIGRATION	0.6m^2/Pax.	95% < 4 min. for EEC 95% < 12 min. for others	0.6m^2/Pax.	95% < 12 min. for all Pax. 80% < 5 min. for nationals
BAGGAGE RECLAIM UNITS	1.25m^2/domestic Pax. 2.0m^2/short-haul int'l Pax. 3.25m^2/long-haul Pax.	Max. of 25 min. between first Pax. arrival in hall and reclaim of last bag. from unit	0.8m^2/domestic and shot-haul int'l Pax. 1.6m^2 for long-haul Pax.	Max. 25 min. between first Pax. arrival and availability of last bag on the unit 90% < 20 min. in hall for all Bag.
CUSTOMS	N/A	N/A	2.0m^2 for interviewed Pax.	N/A

[*Source*: BAA 1982]

<TABLE 4-3> AEROPORTS DE PARIS DESIGN STANDARDS

FACILITY	SPACE STANDARD	TIME STANDARD
DEPARTURE		
CHECK-IN & BAGGAGE DROP	30m²/check-in unit 10 metre minimum dimension in front of check-in desk	80% of Passengers queue less than 15 min.
PASSPORT CONTROL	3.0m²/Pax. with luggage	80% of passengers queue less than 15 min.
CENTRAL SECURITY	N/A	80% of passengers queue less than 15 min.
ARRIVAL		
IMMIGRATION	0.6m²/Pax.	95% of passengers queue less than 12 min.
BAGGAGE RECLAIM UNITS	Reclaim frontage of 1.0 metre for every five Pax. Length of 60 metre for B747 sized aircraft Length of 45 metre for A300 sized aircraft Length of 30 metre for B727 sized aircraft	Maximum of 25 min. between arrival of first Pax. in hall and reclaim of last baggage from unit
BAGGAGE RECLAIM	Space set by dimension of reclaim units as above, with 8 metre minimum between units and 4 metre minimum between unit and wall	N/A
CUSTOMS	1 metre per passenger along searching bench	N/A

[*Source*: Adapted from Ashford 1988]

<TABLE 4-4> HANDLING TIME STANDARDS AT SCHIPHOL AIRPORT

SERVICE	TIME STANDARD
Overall Handling Time	Less than 30 minutes
Check-in & Baggage Drop	Less than 5 minutes
Passport Control (Departure)	Less than 5 minutes
Baggage Claim Waiting (Narrow Body)	Less than 15 minutes
Baggage Claim Waiting (Wide Body)	Less than 20 minutes
Embarking and Disembarking Passengers from Aircraft	Less than 15 minutes

[*Source*: Adapted from Ashford 1988]

The above mentioned service criteria were set by the airport designers or planners based on the traffic engineering concepts of space and time criteria. That means that these are not corresponded to the level of service as perceived by the airport users, particularly the air passengers. A trial was carried out by Mumayiz[1985] at the case study airports to build the service level standards using the air passenger's perception. Three linguistic standards were proposed - Good; Tolerable; Bad. As passengers proceeded through the airport terminal building they were asked to grade the provision service according to three perception criteria. <TABLE 4-5> summarises the results of a Birmingham International Airport survey. A detailed discussion of this work is in chapter 8.

<TABLE 4-5> LEVEL OF SERVICE STANDARDS FOR PROCESSING TIME FOR BIRMINGHAM INTERNATIONAL AIRPORT, ENGLAND

PROCESSING SERVICE	SERVICE LEVEL GOOD	SERVICE LEVEL TOLERABLE	SERVICE LEVEL BAD
CHECK-IN			
Charter	< 11 minutes	11 - 12 minutes	21 minutes <
Scheduled Long-haul	< 15	15 - 25	25 <
Scheduled Short-haul	< 7.5	7.5 - 14	14 <
SECURITY CHECK	< 6.5	6.5 - 10.5	10.5 <
PASSPORT CONTROL	< 6.5	6.5 - 10.5	10.5 <
IMMIGRATION	< 6.5	6.5 - 14.5	14.5 <
BAGGAGE CLAIM	< 12.5	12.5 - 22.5	22.5 <
CUSTOM CONTROL	< 6.5	6.5 - 11.5	11.5 <

[*Source*: Mumayiz 1985]

4-3.2 Holding Service Facilities

The holding facilities are at various waiting areas in the terminal building where passengers spend varying amounts of time awaiting the next service. Service standards for these facilities are normally set, providing a space per passenger in terms of the design functional concept. "In principle, those standards are norms derived from ergonomics or human factor engineering so as to fulfil the requirements of individuals to function and perform designated activities naturally and comfortably. Basically, those functions and activities are directly attached to specific dimensions of the human body, and the space these dimensions describe in motion or in different stationary positions."[Mumayiz 1985:56] Thus, the service standards of a holding facility depend upon the terminal physical factors such as the number of aircraft served at any given time or period, seats provided, time length between commencement of boarding of flight and its departure, and facilities for family or friends accompanying the passenger.

Some airport organisations suggested the service standards for holding areas at the terminal buildings considering planning, design, and operation. These standards were expressed by the space dimension in terms of areas reasonably adequate to accommodate users of that facility. However, these considered only design and operation aspects, and are not linked to users' satisfaction in terms of their perceptions.

Fruin[1971] developed queueing level of service standards based on the human body dimensions and personal space preferences, and the synthesis of pedestrian mobility. These design standards do not only apply to queueing areas for pedestrian waiting, such as lobbies, lift, or escalator, but in other areas in which queueing is likely to result from service stoppages or inadequate capacity of pedestrian service facilities. Therefore, these standards are quite a useful input for holding service standards at an airport terminal building. The level of service descriptions for queueing is shown in <TABLE 4-6>.

Service standards for the holding areas at airport passenger terminals have been suggested by Turner[1977], the BAA[1982], and other airport authorities. Turner presented terminal planning criteria at the Western European Airports Association conference. The range of space provision is shown in <TABLE 4-7>. The BAA and IATA joint standards, Schiphol Airport Authority and Aeroports de Paris of the design service standards are shown in <TABLE 4-8> through <TABLE 4-10> respectively.

<TABLE 4-6> LEVEL OF SERVICE DESCRIPTIONS FOR QUEUEING

LEVEL OF SERVICE	AVERAGE PEDESTRIAN AREA OCCUPANCY (ft^2/person)	AVERAGE INTER-PERSON SPACING (ft)	DESCRIPTIONS
A	13 or more	4 or more	Free Circulation Zone
B	10 - 13	3.5 - 4	Restricted Circulation Zone
C	7 - 10	3 - 3.5	Personal Comfort Zone
D	3 - 7	2 - 3	No-touch Zone
E	2 - 3	2 or less	Touch Zone
F	2 or less	close contact with surrounding persons	Body Ellipse

[*Source*: Fruin 1971]

<FIGURE 4-7> SPACE PROVISIONS IN WAITING AREAS *

HOLDING AREAS	SPACE STANDARD
✈ Area per Seated Passenger	1.0 - 1.5 m^2
✈ Area per Standing Passenger	1.0 m^2
✈ Average Seating Provided as a Percent of Occupation at Capacity:	
Landside Concourse	
Departures	30 - 50%
Arrivals	20% **
Airside	
Departure Lounge	40 - 80% ***
Gate Holding areas	50 - 80%

[*] Higher end of range applies where there is high transfer traffic, e.g. Kastrup and Frankfurt.

[**] In predominantly domestic traffic airports, e.g. Hamburg, short dwell times require only 5% seating.

[***] Reported ranges from survey of 20 West European airports.

[*Source*: Turner 1977]

<TABLE 4-8> SELECTED BAA AND IATA DESIGN AND SERVICE STANDARDS FOR HOLDING FACILITY

FACILITY	BAA SPACE STANDARDS	IATA SPACE STANDARDS
DEPARTURES		
DEPARTURE CONCOURSE	1.0m²/seated person (normal density seating) 0.8m²/seated person (high density seating) 1.0m²/standing person Provision of seating for 10% of people present.	N/A
DEPARTURE LOUNGE	1.0m²/seated Pax. (normal density seating) 0.8m²/seated Pax. (high density seating) 1.0m²/standing Pax. Provision of seating for 60% of Pax. present.	1.5m²/seated Pax. (normal density) 1.0m²/seated Pax. (high density) 1.2m²/standing Pax. with hold Bag. on trolley 1.0m²/standing Pax. Provision of seating for 50% of normal density throughput.
DEPARTURE COACH-GATE	1.0m²/seated Pax. (normal density) 0.8m²/seated Pax. (high density) 1.0m²/standing Pax. Provision of seating for 70% of Pax. present.	Standard of non-pier service 20-25% of Pax. per day will be coached. 1.5m²/seated Pax. 1.0m²/standing Pax. 50% of Pax. seated
GATE LOUNGE	1.0m²/seated Pax. (normal density) 0.8m²/seated Pax. (high density) 1.0m²/standing Pax. Provision of seating for 70% of Pax. present.	Queueing Space: 0.6m²/Pax. without hold Bag. 0.8m²/Pax. with hold Bag. (includes all standby Pax.) Space Allowance in Lounge 1.0m²/Pax. Loading bridge access to aircraft on 95% of pier served operations.
ARRIVALS		
BAGGAGE RECLAIM HALL	1.25m²/domestic Pax. 2.0m²/short-haul international Pax. 3.25m²/long-haul Pax. (excludes space occupied by reclaim units)	0.8m²/domestic and short-haul international Pax. 1.6m²/long-haul Pax.
ARRIVAL CONCOURSE	1.0m²/standing person 0.8m²/seated person (assumes high density seating) Provision of seating for 10% of people present.	0.6m²/standing meeter 1.0m²/seated meeter 0.8m²/short-haul Pax. 1.6m²/long-haul Pax.

[*Source*: BAA 1982]

<TABLE 4-9> SCHIPHOL AIRPORT DESIGN STANDARDS FOR HOLDING AREAS

SERVICE FACILITY	SPACE STANDARD
WAITING LOUNGES	1 m^2/Pax. for the expected number of departing passengers taken over the average of the 20 highest peak hours. Provision of seating for 30% of these passengers.
GATE LOUNGES	1 m^2/Pax. based on the capacity of the largest aircraft to be handled at that gate. Provision of seating for 50% of these passengers.

[*Source*: Adapted from Ashford 1988]

<TABLE 4-10> AEROPORTS DE PARIS DESIGN STANDARDS FOR HOLDING AREAS

SERVICE FACILITY	SPACE STANDARD
DEPARTURE CONCOURSE	3.0m^2/Pax. with luggage 1.5m^2/Pax. without luggage 1.0m^2/greeter No seat provision
TERMINAL DEPARTURE LOUNGE	1.5m^2/seated Pax. 1.0m^2/standing Pax. Seating for between 50 and 75% of people present. 20% of area for circulation.
DEPARTURE COACH-GATE	1.5m^2/seated Pax. 1.0m^2/standing Pax. 50% of Pax. seated.
GATE LOUNGE	0.6m^2/queueing Pax. (80% of Pax. queue less than 5 min.)
ARRIVALS CONCOURSE	3.0m^2/Pax. with luggage 1.5m^2/Pax. without luggage 1.0m^2/greeter No seat provision

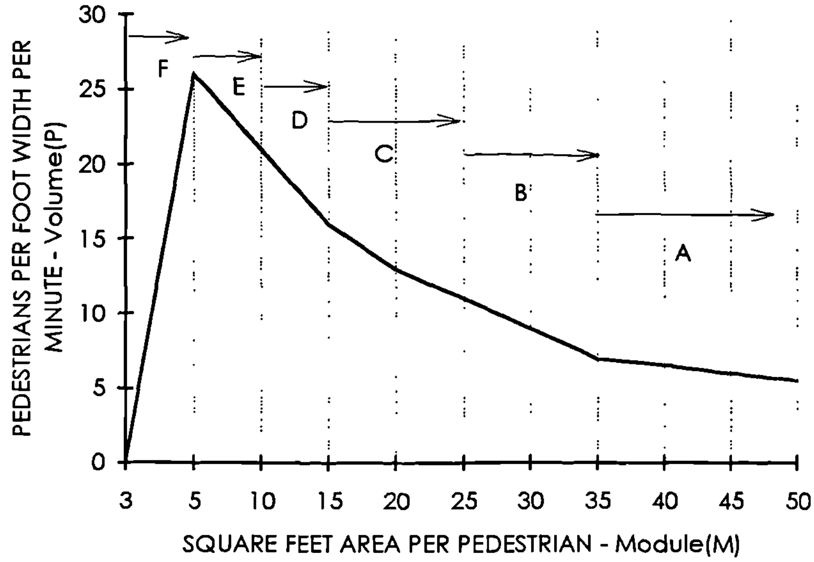
[*Source*: Adapted from Ashford 1988]

4-3.3 Connecting Service Facilities

These facilities provide linkage between various service procedures in the terminal as well as between car park and terminal or terminal kerb frontage and main entrance through corridors, concourses, stairways, conveyors, or walkways. Passengers move physically through the airport system, particularly between terminals using the connecting system, which should be simple to find and easy to follow. These facilities are necessary for the user's self-service activities using the given equipment for self-movement between different parts, inside or outside the terminal building. Thus, the connecting service standards are influenced by terminal configuration, passenger characteristics, flight schedule, walking speed, and the density of pedestrians.

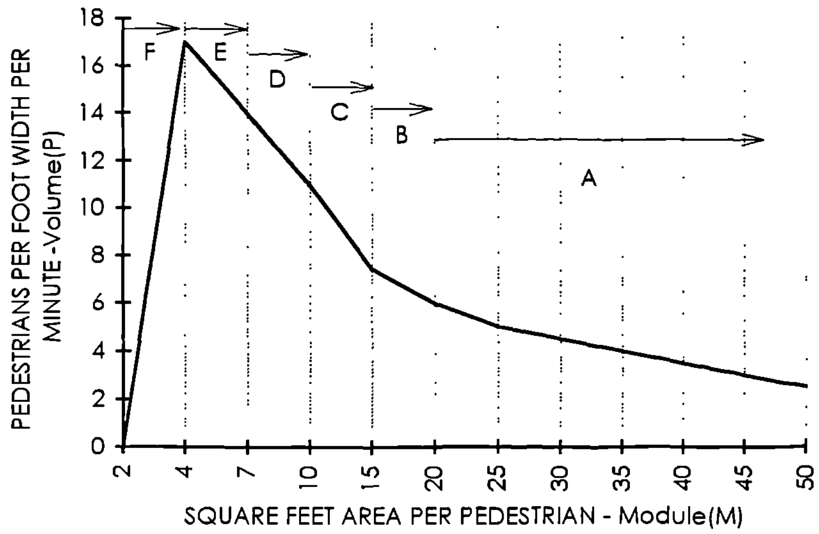
The service standards of connecting facilities in Fruin's work[1971] can be considered, mainly because this work was originally done in a passenger terminal. However, the work was not done specifically in airport terminals but a bus terminal in New York. These two types of terminals are functionally similar, but the characteristics of the passengers and operations are quite different. Therefore, the validity of applying Fruin's service standards directly to the airport terminals is questionable because depth considerations and a clear understanding of the nature of traffic are needed. Fruin developed level of service design standards considering the dimensional design of pedestrian spaces which involve the application of traffic engineering principles plus the consideration of human convenience and the design environment. The work proposed a six level structure for walkway and stairway which was based on the relationship between pedestrian flow and the area provided per pedestrian. The standards provided the means of determining the design quality of corridors, sidewalks, entrance ways, and stairways. The service standards for walkway and stairway are shown in <FIGURE 4-3> and <FIGURE 4-4>.

For terminal kerb frontage, preliminary design guidelines have been reported by Reynolds and Hills[1981] which indicated at least 0.5 ft (0.15 m) per peak-hour enplaning passenger and 0.8 ft (1.24 m) per peak-hour deplaning passengers in terms of kerb frontage length. This work was carried out at Geneva Intercontinental Airport.



Service Level A:	Free selection of walking speed; Free bypassing of slower pedestrians; Avoiding cross conflicts.
Service Level B:	Available to select normal speeds; Available to bypass other pedestrians in primarily one-directional flows; Minor crossing conflicts will occur.
Service Level C:	Restrict freedom to select individual walking speeds; Restrict freedom to bypass other pedestrians; Existence of pedestrians cross movements and reverse flows (high probability of conflicts).
Service Level D:	Normal walking speed would be restricted and reduced; Difficult to bypass slower moving pedestrians; Reverse and cross flow would be severely restricted.
Service Level E:	Walking speeds would be virtually restricted; Forward progress would only be made by shuffling; Reverse and cross flow would be extremely difficult.
Service Level F:	Walking speeds are extremely restricted; Forward progress can only be made by shuffling; Reverse or crossing movements would be virtually impossible.

<FIGURE 4-3> LEVEL OF SERVICE STANDARDS FOR WALKWAYS [*Source*: Fruin 1971]



Service Level A:	Freely select locomotion speed; Freely bypass other slower moving pedestrians; No difficulties to reverse traffic flows.
Service Level B:	May freely select locomotion speed; Some difficulties in passing slower moving pedestrians; Reverse flow would cause minor traffic conflicts.
Service Level C:	Locomotion speeds would be restricted slightly; Unable to pass slower moving pedestrians; Minor reverse flow would encountèr some difficulties.
Service Level D:	Locomotion speeds are restricted for the majority of persons; Limited open thread space and an inability to bypass pedestrians; Reverse flows would encounter significant difficulties and traffic conflicts.
Service Level E:	Locomotion speeds are reduced for all persons; Minimum tread space and inability to bypass others; Reverse-traffic flows would experience serious conflicts.
Service Level F:	Traffic flows are at complete breakdown with many stoppages; Forward progress would depend on the movement of those in front.

<FIGURE 4-4> LEVEL OF SERVICE STANDARDS FOR STAIRWAYS [*Source*: Fruin 1971]

4-3.4 Other Service Standards

The service standards for airport access, car park facilities and other amenities at the airport landside system are in a relatively rudimentary state of development. It is quite difficult to set service standards, because these depend almost entirely upon passenger perceptions in terms of subjective judgements. Recently, the standards of efficiency operational spaces for service facilities or configurations at the airport terminal building have been carried out. However, the service guideline or standard is unfortunately still not accessible. One stereotype of the work has been done by the US Federal Aviation Administration(FAA). The FAA used the most widely relied-on design parameter which was the typical peak hour passenger(TPHP). The FAA terminal space design standards for passenger amenities are indicated in <TABLE 4-11>.

<TABLE 4-11> FAA TERMINAL SPACE DESIGN STANDARDS

US DOMESTIC TERMINAL FACILITY	SPACE REQUIRED PER 100 TPHP
Eating Facilities	1600 ft^2
Kitchen and Storage	1600 ft^2
Other Concessions	500 ft^2
Toilets	300 ft^2

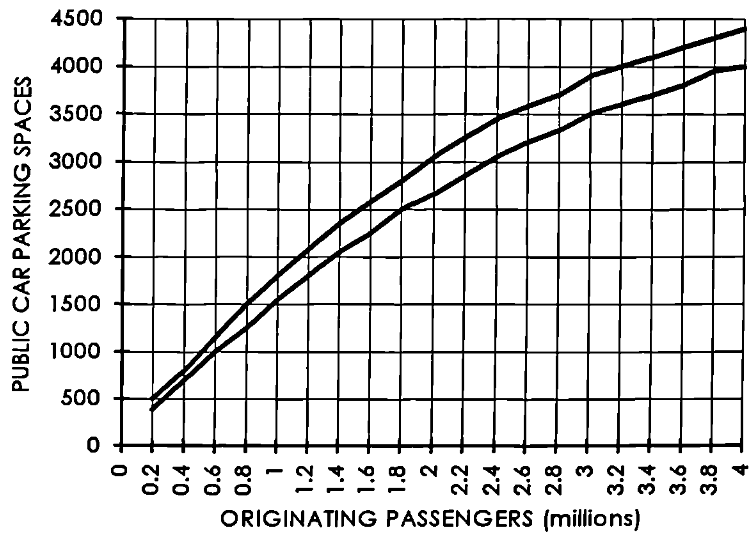
[*Source*: Adapted from FAA 1969]

The FAA[1980] and Roads and Transport Association of Canada[RTAC 1980] have been developed to estimate parking space requirements at an airport, particularly non-hub and smaller airports using a variety of rules of thumb and computational procedures. These guidelines are set by the annual or average monthly originating passengers, because transfer passengers do not create parking demand and arriving passengers create a relatively small portion of the demand. Both car parking space requirements at the airports are shown in <TABLE 4-12>. A report[FAA 1975] provided preliminary planning estimates of the number of parking spaces required at an airport represented in <FIGURE 4-5>. In planning for the Geneva Airport, preliminary design criteria required two parking spaces per peak-hour passenger on the design day. More refined estimates of the total amount of parking required and of the breakdown of short and long-term space are obtained from analyses performed in the schematic design phase of the terminal planning process.[Horonjeff *et al.* 1994: 451]

<TABLE 4-12> INDICES OF CAR PARKING SPACE REQUIREMENT

SOURCE	INDEX
RTAC (Small Airports)	1.5 spaces per peak-hour passenger; 900 - 1200 spaces per million annual enplaned passengers
US FAA (Non-hub Airports)	Approximately I space per 500 to 700 annual enplaned passengers

[*Source*: RTAC 1980; FAA 1980]



<FIGURE 4-5> ESTIMATED REQUIREMENTS FOR PUBLIC PARKING AT US AIRPORTS
[*Source*: FAA 1975]

4-4 RELATIONSHIP LEVEL OF SERVICE AND SERVICE VOLUME

Service volume, the principal measure of capacity, is the number of passengers that can be accommodated by a functional component or group of components at a given service level given the demand placed on that component. For components where passenger processing takes place, such as the ticket counter or security screening, service volume may be measured as a rate: passengers per unit of time. For components where passengers wait or stand in queues, service volume may be measured as the number of passengers accommodated at any given time. For components that involve both passenger waiting and processing, both measures may be appropriate.[TRB 1987:28] Thus, the service level determines service volume and delay. Capacity and service delay at an airport landside component become a problem when service volume is quite high, even though it is generally less than maximum throughput. Usually, this situation occurs at peak-hours or busy-hours in terms of the concentrated demand.

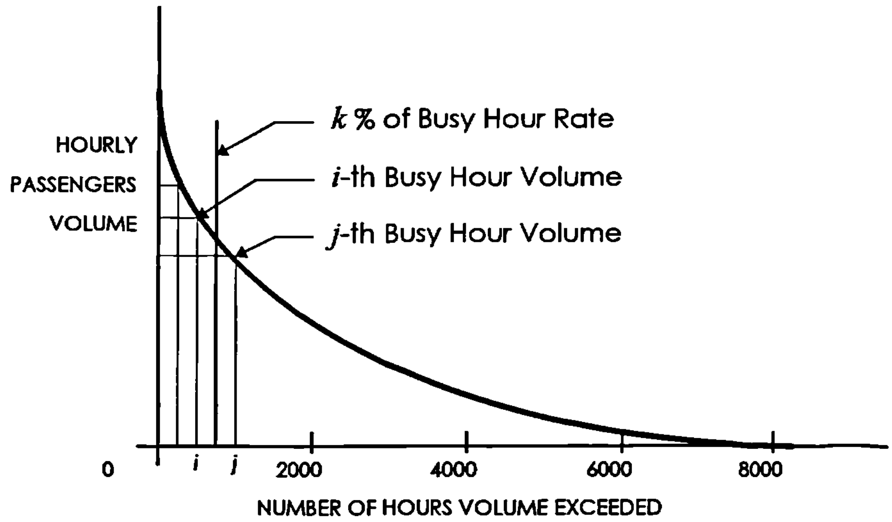
Transportation Research Board[1987] suggested a useful definition of the airport landside capacity. It has considered *flow rates* and *crowding*. Both of them are reflected by a variety of passenger capacity indicators. First, flow-rates capacity indicators, passengers per unit of time, vary between the maximum throughput and a lower service volume. Maximum throughput means that the maximum rate at which passengers can be processed by a functional component or group of functional components. In practice this rate is actually observed only when demand equals or exceeds the component's processing capability, and is typically sustained for only a brief period of time. Second, crowding capacity indicators, the number of passengers within a specific area during a given time period, at maximum throughput may cause crush conditions or reflect a lower service volume that maintains service levels consistent with passenger safety, health, comfort, and convenience. Therefore, service volume for both flow rates and crowding is the principal capacity indicator used throughout.

Using the technical terms, capacity can give rise to confusion with demand. Capacity refers to the physical capability of an airport landside facility it is a measure of supply and independent of both the magnitude and fluctuation of demand and the amount of service delay. Delay, however, is dependent on capacity and demand, for example, the service delay at an airport landside facility can be reduced by increasing that service facility capacity and by redistributing the demand pattern. The terms; volume, demand, and capacity are described as: [Wohl *et al.* 1967]

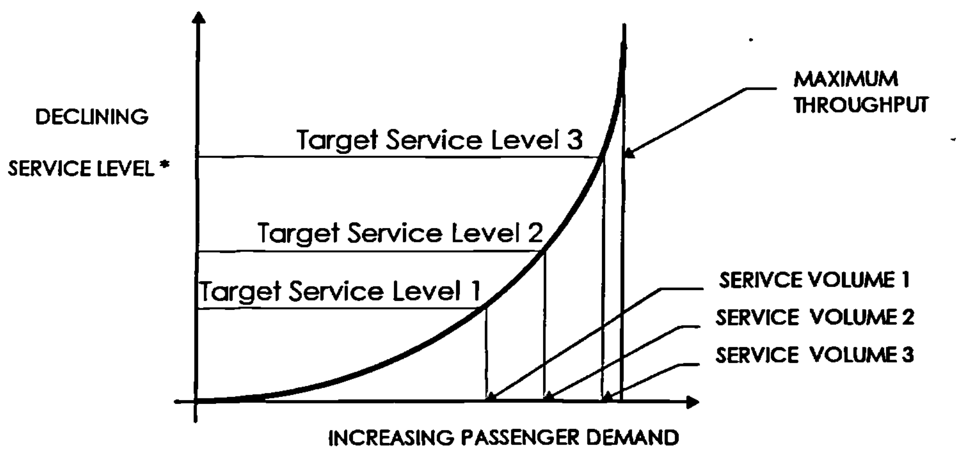
> *Volume* is the measurement term referring to the quantity of movement per unit time.
>
> *Demand* is the term that quantitatively describes the incidence of travel under given conditions.
>
> *Capacity* is the volume-carrying capability that a particular facility can accommodate at the limit.

Practically, some European countries have defined the Standard Busy Rate(SBR) based on the anticipated level of demand during a busy-hour. Different European airport authorities favour different standards, for example, Schiphol International Airport in Amsterdam uses the 20th busiest hour and in France, Aeroports de Paris, demand levels during the 40th busiest hour are used. In the 1970's, the British Airports Authority(BAA) adopted the 30th highest hour as its design standard. Subsequent experience led them to utilise the 5% Busy Hour Rate(BHR) which although no longer used meant that 5% of the total annual passenger traffic operated at volumes in excess of the total design level.

Transport Canada conducted capacity evaluations by using the 90th percentile hour[Transport Canada 1986], defined similarly to the British BHR, but considered the variations in demand within this peak period. The FAA guidance material[FAA 1976] used the peak hour of an average day of the peak month as a basis for planning and design. The definitions of the Busy Hour Rate demand are represented in <FIGURE 4-6>.



<FIGURE 4-6> ALTERNATIVE DEFINITION OF BUSY HOURS [*Source*: Adapted from IATA 1978]



[*] Determined by service-level indicators (waiting time, service time, crowding)

<FIGURE 4-7> SCHEMATIC RELATIONSHIP AMONG SERVICE LEVEL, SERVICE VOLUME, AND MAXIMUM THROUGHPUT [*Source*: TRB 1987:30]

The characteristics of the airport landside demand are seldom exactly matched to a component's service rate, over longer periods of time achievable service volume is generally less than maximum throughput. (see FIGURE 4-7) Airlines adjust to the patterns of demand by assigning additional personnel and by allowing service levels to decline during busy periods. The fixed physical facilities of the airport are often designed to allow for some variation in demand and growth in traffic. [TRB 1987:28] The relationship between service level and service volume is defined as a *reversed interaction*. (see FIGURE 4-7) If service volume is low over non-peak period then the service level is too high, however when service volume is close to the maximum throughput at peak period then service level declines to very low. Thus, the target service level at a service facility can be set by the service volume. A target service level is set in particular during busy hours, the airport authorities or airlines might maintain this level using the possible alternatives such as adjustment of the pattern of demand through re-scheduling of aircraft operations and assigning additional personnel in order to reduce the queueing time. These should be considered under the fixed capacity of the airports. If the physical capacity can be expanded, current service times and delays must determine the additional capacity. The schematic relationship among service level, service volume, and capacity is shown in <FIGURE 4-7>.

4-5 CONCLUSION

Most service standards for the airports, especially the passenger terminal buildings were defined by the traffic engineering concepts of capacity-volume which are criticised for being either spatial standards or temporal standards. That means these standards give rise to some limitations. Hence, a more comprehensive service standard should preferably be based on the user's perception of operational service rather than on arbitrary standards set from the aspects of operators, transport traffic engineers, designers, and carriers. It would be extremely important if an airport authority constructs a new service standard to provide a better quality of service for its users.

CHAPTER 5

FACTORS INFLUENCING THE LEVEL OF SERVICE

5-1 INTRODUCTION

Most of the research on the level of service(LOS) in an airport has concentrated on the factors of time and space. For example, service processing time, waiting time in queues and at waiting areas, and the density of crowding in the service areas. To evaluate the level of service accurately in the airport systems, the influencing factors are more complicated. A single factor approach will cause limitation of assessment even if it is a priority factor in the evaluation of the level of service for the airport systems.

This research, therefore, adopts a more comprehensive approach method for assessing the level of service in the airport service areas in order to present a more reliable evaluation. This research deals not only with the temporal or spatial factors but also two more factors, those of comfort and a reasonable service factor. They are based on the perceptions of the passengers over the provision of service at each service activity area in the airport system.

5-2 FACTORS INFLUENCING THE LEVEL OF SERVICE IN THE AIRPORT LANDSIDE SYSTEM

The selection of factors for evaluation is considered to be a major task for appraisers in a specific area. Depending upon the selection of the influencing factor, an evaluation can be made as to whether or not useful information is being presented to accommodate its purpose. What the evaluation factors are and how to select them are very important criteria within the evaluation process.

5-2.1 General Factors

A comprehensive set of evaluation factors for the level of service in the airport landside system can be constructed by using a literature review and also by actual investigation. The influencing factors, which are considered as terms of broad category, in an airport include the following:

- type of airport,
- airport location,
- type of air transport service,
- functional component of system, and
- operation and management characteristics.

5-2.1.1 Type of Airport

The type of airport is a key factor as it influences the passenger's experience. According to the airport types, different service standards are needed in order to meet the requirements of their purpose. An example occurs in the classification of airport types by the number of enplaned passengers. A physically small airport takes less time to transfer passengers between the aircraft parking gates and the airport terminal gates. This means that correlation may be found between airport types and the service level standards, for example, baggage claim and the total time required for passengers to travel through landside.

Consideration of airport types is necessary when determining the facilities for the highest level of the peak traffic. The size of facilities in an airport system can be represented by its physical capacity to be able to serve a maximum throughput. Physical capacity relates directly to service time and delay. Furthermore, they are also elements for the level of service measurement at the service areas. Therefore, a target service level can be determined by the relationship between the service level, the service volume, and the maximum throughput in terms of capacity.

5-2.1.2 Airport Location

In almost every airport development situation, the owner or operator of the airport, be he the government, an authority or a private company, rarely knows with any clarity just what is required in a particular situation. The need can arise from one of four events: [Latter 1989]

- Firstly, the city or region does not have an airport and believes that air services are vital to its future.
- Secondly, the existing airport is reaching its capacity. It will need to be expanded to meet future demand, and it may be more advantageous to find an entirely new site.
- Next, the existing airport is reaching its capacity and a second airport is needed.

- Finally, the existing airport creates so much noise and other environmental problems than an alternative site is required.

In developing new airports serious consideration must be made regarding economic restraint, constraints on capital expenditure and the growing community resistance to them. These mainly concern land use, physical characteristics, and accessibility. It is now recognised that the construction of new airports or the expansion of existing ones is almost impossible to accomplish over a short term as the lead time needed for planning, design, approving, and building is rather long, typically 5 to 10 years[Hamzawi 1992:49].

Site selection of an airport has become more difficult because of the dramatic increase in air travel, accompanied and engendered by larger and more powerful aircraft over the last two decades, airports have come to be identified as land users that cause severe environmental deterioration to their neighbours, generate high volumes of surface traffic, and bring economic and community development that may not accord with the desires of surrounding land users[Ashford *et al.* 1984a:88]. In selecting the location of an airport, the ground journey to the airport should be dealt with as a key factor influencing the level of service, as air trips are not complete trips from one airport terminal to the other.

Location decisions should favour sites with a good proximity to freeways, as this means the level of service for the ground traveller at a high standard. Where this can be achieved by high speed transport systems to the airport with the favourable conditions of comfort, convenience, and no delay.

5-2.1.3 Type of Air Transport Service

Whether or not an airline hub-and-spoke operation is to be centred at a particular airport is an important factor. The daily patterns of passenger peak loads change substantially when an airline hub begins operation, particularly with respect to the number of peaks. An airline hub typically increases the number of peaks and raises average daily utilisation of gates and holdrooms.[TRB 1987:163]

Under the hub-and-spoke operating strategies, carriers seek to dominate the key markets by concentrating their feeder traffic into a particular locale, thereby offering convenient(frequent) flight connections. Co-ordinating feeder traffic to concentrate flight arrivals and departures over a relatively short time span results in sharp peaking of traffic both inside the terminal building and on the apron. Furthermore, the increased use of smaller aircraft in commuter/feeder operations increases the number of flights needed to carry the same volume of passengers, thus creating greater demand for apron/gate capacity.[Hamzawi 1992:47]

Hubbing may have a beneficial influence on operating costs per passenger km decreasing as aircraft size, load factor and route density rise, but its effect on stage lengths and utilisation may well have adverse cost implications. The total traffic will tend to grow so that, if there are economies of scale, unit costs will fall. Network density, in terms of the average traffic per station, will tend to increase but the distribution of the density through the system will be very skewed towards the hub.[Caves 1991] In the current deregulated air transport system, operating practices of the airlines are further compounded. Carriers tend to move toward more hub-and-spoke operations in response to business opportunities and in competition with other airlines. These current circumstances have led to further traffic peaking problems and have contributed to increase congestion and delays at the busy hub airports. Therefore, the type of air transport service can determine the consideration of the level of service which will provide a high standard for users.

5-2.1.4 Functional Component of System

The components in an airport terminal building are linked together, and it is here that the passengers transfer to and from the aircraft. In each individual component short queues and delays can occur, even though individually each component is well within the acceptable range for its passengers. There is no single service level or capacity for the whole system in the same sense as there is for a single component unless demand on all components is perfectly matched to each component's maximum throughput or there is an accepted set of comparable service level targets for all components and all components are operating at these target service levels[TRB 1987:148] there will be difficulties, such as congestion resulting in delays.

When all of the individual components of the airport terminal system are serving within their maximum throughput, total throughput of the terminal as a whole can be determined by the maximum level throughput of a component. On the other hand, when an individual component is operating to the maximum capacity, the whole system throughput can definitely be determined by this constrained component. Despite the latter situation, the whole system will still be able to continue processing passengers along with long queues and delays in its related service areas. Practically, long queues, serious crowding, and long-time delays in which a particular component often influences demand in connection components, means that the level of service declines overall.

In general terms, adequate linkages of all of the components of the terminal system within acceptable or at high standard, affect the level of service and the capacity of individual components and this influences the landside system as a whole.

5-2.1.5 Operation and Management Characteristics

In an airport landside system, operation and management characteristics influence the level of service. For example, the processing time which is an important factor in terms of level of service, at any particular airport will depend upon the airlines staff experience, flight market, passenger characteristics, and upon airline operation and management polices.

Typically, airlines lease gates even if they have their own passenger loading bridges and aircraft serving equipment. Lease agreements between the airport operator and the airlines is usually decided by the airlines because of differences in schedules. In this case, the level of service at the gate area is depended upon by the airline strategies for aircraft parking position and gates. Therefore, the airports provide different types of gate operation under the exclusive-use arrangement, preferential and joint-use gate strategies, and common-use basis. A common-use basic type is normal at the small commercial service airports.

The financing of delays or restrictions can be dealt with from a management viewpoint. When an existing airport reaches the saturation situation in terms of physical capacity, the airport owner or operator, planner, and manager should make a decision regarding options to solve the capacity problems. To provide new facilities means increasing the capacity and providing a better service level in regard to crowding, waiting time and so on. Unfortunately, if the airport is faced with a financial restriction when needing additional capacity, this will place a burden on the passengers because of a lower service level. Other factors which may influence the level of service in the airport landside system include configuration of airport facilities and the type of terminal building design.

5-2.2 Factors in the Service Areas

Factors contributing to the level of service in an airport landside system are usually interrelated and overlap. There are a variety of ways in which some of these factors can be quantified. Other factors can be difficult to measure in order to evaluate the level of service at an airport.

Mumayiz[1985:46-47] described the factors contributing to service standards in airport terminals as being divided into two general types: qualitative and quantitative factors.

Qualitative factors are basically subjective, descriptive, difficult to quantify, and are highly susceptible to personal influence and individualistic behaviour.

- *Environmental factors* are exposure weather, terminal internal environment, cleanliness, and the sense of safety.

- *Psychological factors* include reaction to treatment by airport personnel, expectation of service, reaction to overall terminal environment, attitudes towards airport conditions, comfort, safety, and privacy.

- *Aesthetic factors* cover the lighting arrangements, signing, identification of the system facilities, seating provisions, and catering for the disabled and infants.

- *System-related factors* are amenities, complexity of procedures, security measures imposed, and information system - understandability, legibility, consistency, and visibility.

- *Personal factors* are types of passengers and visitors, purpose and origin/destination of trip, convenience, and personality or personal behaviour.

Quantitative factors are those that lend themselves to enumeration and statistical analysis because they are tangible and easily identifiable in the terminal environment.

- *Temporal factors* are time-related factors that include processing time, delay time in waiting for service, total time spent in a facility, reporting time prior to start of service, and delays in flight departures and arrivals.

- *Spatial factors* are distance and area-related factors which cover walking distance, pedestrian density or crowdins, size and dimensions of functional areas, with the relative location of facilities, and level changes.

- *Econometric factors* are airline ticket costs, fares of access trips, concession pricing structure, and airline and airport pricing/charging polices.

- *Statistical factors* include the frequency of air travel, frequency of flights per route, and the number of airlines using the airport.

Heathington *et al.*[1975] have summarised a detailed list of factors that reflect the points of view of all airport users- passengers with baggage, visitors, employees, and so on- at each terminal service activity area.(TABLE 5-1 and 5-2) The susceptibility of these factors to quantification is highly variable from one to another[Mumayiz 1985:48]. To identify the most useful set of factors from his suggestions, a great deal of subjective judgement and a comprehensive understanding of user attitudes is needed.

Brink *et al.*[1975] have suggested the degree of quantifiability of the level of service factors for the airport landside facilities.(TABLE 5-3) TRB[1987] has discussed the demand and operating factors which generally influence the service level and the capacity of each service component in the airport landside system.(TABLE 5-4) He has also discussed the demand patterns during the peak periods and described the operating characteristics that influence component utilisation and effectiveness. Furthermore, TRB has reviewed the analysis and assessment tools for measuring capacity and levels of service. These lists of demand and operating factors will be used subsequently to evaluate the level of service in a particular airport landside system.

Martel *et al.*[1990] have analysed the significant factors influencing the quality of service in the passenger terminal buildings from the passengers' point of view. These factors include (1) circulation elements such as the walking distance, visual information, availability of space and level changes, (2) waiting elements are the availability of seats, seating comfort, ease of access to the waiting area, and the layout of seats, and (3) processing elements are those of the waiting time, convenience, and availability of space.

Lemer[1992] has discussed the factors of performance at airport passenger terminals focusing primarily on passengers, airlines, and airport operators. These factors of performance are substantially useful information, although he neglected one point of view which is the necessity to meet a variety of basic needs unrelated to transport characteristics. Factors of performance from the passengers', operators', and airlines' points of view are shown in <TABLE 5-5>.

<TABLE 5-1> LEVEL OF SERVICE CHARACTERISTICS OF TERMINAL BUILDING SYSTEM: PASSENGERS
[*Source*: Heathington *et al.* 1975]

TYPE OF MEASURE	ORIGINATING	TERMINATING	CONNECTING	THROUGH	STANDBY
1. EXTERNAL WALKWAY					
Quantitative	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped	Working distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped	N/A	N/A	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped
Qualitative	Exposure to weather Safety Information systems and signs Pedestrian density Cleanliness Security Environmental	Exposure to weather Safety Information systems and signs Pedestrian density Cleanliness Security Environmental	N/A	N/A	Exposure to weather Safety Information systems and signs Pedestrian density Cleanliness Security Environmental
2. BAGGAGE CHECK					
Quantitative	Processing time Service variability range	N/A	N/A	N/A	N/A
Qualitative	Convenience Complexity of procedure Courtesy of personnel Environment	N/A	N/A	N/A	N/A
3. TICKETING					
Quantitative	Processing time Service variability range	N/A	N/A	N/A	N/A
Qualitative	Convenience Complexity of procedure Courtesy of personnel Environment	N/A	N/A	N/A	N/A
4. SECURITY					
Quantitative	Processing time Service variability range Location reconcessions	N/A	Processing time Service variability range Location reconcessions	N/A	Processing time Service variability range Location reconcessions
Qualitative	Convenience Complexity of procedure Courtesy of personnel Environment	N/A	Convenience Complexity of procedure Courtesy of personnel Environment	N/A	Convenience Complexity of procedure Courtesy of personnel Environment

(CONTINUED)

<TABLE 5-1> CONTINUED

TYPE OF MEASURE	ORIGINATING	TERMINATING	CONNECTING	THROUGH	STANDBY
5. INTERNAL CIRCULATION					
Quantitative	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped Cost to passenger	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped Cost to passenger	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped Cost to passenger	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped Cost to passenger	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped Cost to passenger
Qualitative	Exposure to weather Safety Information systems & signs Pedestrian density Cleanliness Security Environmental	Exposure to weather Safety Information systems & signs Pedestrian density Cleanliness Security Environmental	Exposure to weather Safety Information systems & signs Pedestrian density Cleanliness Security Environmental	Exposure to weather Safety Information systems & signs Pedestrian density Cleanliness Security Environmental	Exposure to weather Safety Information systems & signs Pedestrian density Cleanliness Security Environmental
6. PUBLIC WAITING					
Quantitative	Number of seats Size of area Lighting	Number of seats Size of area Lighting	Number of seats Size of area Lighting	N/A	Number of seats Size of area Lighting
Qualitative	Seating arrangements Comfort Privacy Amenities	Seating arrangements Comfort Privacy Amenities	Seating arrangements Comfort Privacy Amenities	N/A	Seating arrangements Comfort Privacy Amenities
7. DEPARTURE LOUNGE					
Quantitative	Processing time Service variability range Number of seats Size of area Lighting Location reconcessions	N/A	Processing time Service variability range Number of seats Size of area Lighting Location reconcessions	Processing time Service variability range Number of seats Size of area Lighting Location reconcessions	Processing time Service variability range Number of seats Size of area Lighting Location reconcessions
Qualitative	Convenience Complexity of procedure Courtesy of personnel Environment	N/A	Convenience Complexity of procedure Courtesy of personnel Environment	Convenience Complexity of procedure Courtesy of personnel Environment	Convenience Complexity of procedure Courtesy of personnel Environment
8. BOARDING MEANS					
Quantitative	Walking distance Level Changes Aids for handicapped	Walking distance Level Changes Aids for handicapped	Walking distance Level Changes Aids for handicapped	Walking distance Level Changes Aids for handicapped	Walking distance Level Changes Aids for handicapped
Qualitative	Exposure to weather Safety Convenience	Exposure to weather Safety Convenience	Exposure to weather Safety Convenience	Exposure to weather Safety Convenience	Exposure to weather Safety Convenience

(CONTINUED)

<TABLE 5-1> CONTINUED

TYPE OF MEASURE	ORIGINATING	TERMINATING	CONNECTING	THROUGH	STANDBY
9. BAGGAGE CLAIM					
Quantitative	N/A	Processing time Service variability range Size of area Pedestrian density Claim frontage Care of handling Aids to handicapped Proximity to kerb	N/A	N/A	Processing time Service variability range Size of area Pedestrian density Claim frontage Care of handling Aids to handicapped Proximity to kerb
Qualitative	N/A	Convenience Complexity of procedure Courtesy of personnel Environment Security Availability of sky cap Location reconcessions Seating	N/A	N/A	Convenience Complexity of procedure Courtesy of personnel Environment Security Availability of sky cap Location reconcessions Seating
10. INFORMATION SERVICES					
Quantitative	Consistency Redundancy Legibility Aids to handicapped	Consistency Redundancy Legibility Aids to handicapped	Consistency Redundancy Legibility Aids to handicapped	Consistency Redundancy Legibility Aids to handicapped	Consistency Redundancy Legibility Aids to handicapped
Qualitative	Understandability	Understandability	Understandability	Understandability	Understandability
11. CONCESSIONS AND MISCELLANEOUS SERVICE					
Quantitative	Number and type Location and size Aids to handicapped Conformance with codes	Number and type Location and size Aids to handicapped Conformance with codes	Number and type Location and size Aids to handicapped Conformance with codes	Number and type Location and size Aids to handicapped Conformance with codes	Number and type Location and size Aids to handicapped Conformance with codes
Qualitative	Service provided Courtesy of personnel Environment Amenities	Service provided Courtesy of personnel Environment Amenities	Service provided Courtesy of personnel Environment Amenities	Service provided Courtesy of personnel Environment Amenities	Service provided Courtesy of personnel Environment Amenities
12. INTERNATIONAL CLEARANCE					
Quantitative	Processing time Service variability range	Processing time Service variability range	Processing time Service variability range	Processing time Service variability range	Processing time Service variability range
Qualitative	Convenience Complexity of procedure Courtesy of personnel Environment	Convenience Complexity of procedure Courtesy of personnel Environment	Convenience Complexity of procedure Courtesy of personnel Environment	N/A	N/A

<TABLE 5-2> LEVEL OF SERVICE CHARACTERISTICS OF TERMINAL BUILDING SYSTEM: VISITORS AND BAGGAGE [*Source*: Heathington *et al.* 1975]

TYPE OF MEASURE	VISITORS		BAGGAGE		
	Well-wisher and greeter	Other	Check-In	Carry-on	Transfer
1. EXTERNAL WALKWAY					
Quantitative	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped	Working distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped	N/A
Qualitative	Exposure to weather Safety Information systems and signs Pedestrian density Cleanliness Security Environmental	Exposure to weather Safety Information systems and signs Pedestrian density Cleanliness Security Environmental	Exposure to weather Safety Information systems and signs Pedestrian density Cleanliness Security Environmental	Exposure to weather Safety Information systems and signs Pedestrian density Cleanliness Security Environmental	N/A
2. BAGGAGE CHECK					
Quantitative	N/A	N/A	Processing time Service variability range	N/A	N/A
Qualitative	N/A	N/A	Convenience Complexity of procedure Courtesy of personnel Environment	N/A	N/A
3. INTERNAL CIRCULATION					
Quantitative	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped Cost to passenger	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped Cost to passenger	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped Cost to passenger	Walking distance Pedestrian assists Pedestrian density Direct flow Lighting Aids for handicapped Cost to passenger	N/A
Qualitative	Exposure to weather Safety Information systems and signs Pedestrian density Cleanliness Security Environmental	Exposure to weather Safety Information systems and signs Pedestrian density Cleanliness Security Environmental	Exposure to weather Safety Information systems and signs Pedestrian density Cleanliness Security Environmental	Exposure to weather Safety Information systems and signs Pedestrian density Cleanliness Security Environmental	N/A

(CONTINUED)

<TABLE 5-2> CONTINUED

TYPE OF MEASURE	VISITORS		BAGGAGE		
	Well-wisher and greeter	Other	Check-in	Carry-on	Transfer
4. PUBLIC WAITING					
Quantitative	Number of seats Size of area Lighting	Number of seats Size of area Lighting	Make-up and storage area	N/A	Make-up and storage area
Qualitative	Seating arrangements Comfort Privacy Amenities	Seating arrangements Comfort Privacy Amenities	Make-up and storage area	N/A	Make-up and storage area
5. SECURITY					
Quantitative	Processing time Service variability range Location reconcessions	N/A	N/A	Processing time Service variability range Location reconcessions	N/A
Qualitative	Convenience Complexity of procedure Courtesy of personnel Environment	N/A	N/A	Convenience Complexity of procedure Courtesy of personnel Environment	N/A
6. DEPARTURE LOUNGE					
Quantitative	Processing time Service variability range Number of seats Size of area Lighting Location reconcessions	N/A	N/A	Processing time Service variability range Number of seats Size of area Lighting Location reconcessions	N/A
Qualitative	Convenience Complexity of procedure Courtesy of personnel Environment	N/A	N/A	Convenience Complexity of procedure Courtesy of personnel Environment	N/A
7. BOARDING MEANS					
Quantitative	N/A	N/A	N/A	Walking distance Level Changes Aids for handicapped	N/A
Qualitative	N/A	N/A	N/A	Exposure to weather Safety Convenience	N/A

(CONTINUED)

<TABLE 5-2> CONTINUED

TYPE OF MEASURE	VISITORS		BAGGAGE		
	Well-wisher and greeter	Other	Check-in	Carry-on	Transfer
8. BAGGAGE CLAIM					
Quantitative	N/A	N/A	Processing time Service variability range Size of area Pedestrian density Claim frontage Care of handling Aids to handicapped Proximity to kerb	N/A	N/A
Qualitative	N/A	N/A	Convenience Complexity of procedure Courtesy of personnel Environment Security Availability of sky cap Location reconcession Seating	N/A	N/A
9. CONCESSIONS AND MISCELLANEOUS SERVICE					
Quantitative	Number and type Location and size Aids to handicapped Conformance with codes	Number and type Location and size Aids to handicapped Conformance with codes	N/A	Number and type Location and size Aids to handicapped Conformance with codes	N/A
Qualitative	Service provided Courtesy of personnel Environment Amenities	Service provided Courtesy of personnel Environment Amenities	N/A	Service provided Courtesy of personnel Environment Amenities	N/A
10. INFORMATION SERVICES					
Quantitative	Consistency Redundancy Legibility Aids to handicapped	Consistency Redundancy Legibility Aids to handicapped	Consistency Redundancy Legibility Aids to handicapped	Consistency Redundancy Legibility Aids to handicapped	Consistency Redundancy Legibility Aids to handicapped
Qualitative	Understandability	Understandability	Understandability	Understandability	Understandability
11. INTERNATIONAL CLEARANCE					
Quantitative	N/A	N/A	Processing time Service variability range	N/A	N/A
Qualitative	N/A	N/A	Convenience Complexity of procedure Courtesy of personnel Environment	Convenience Complexity of procedure Courtesy of personnel Environment	N/A

<TABLE 5-3> SERVICE MEASURES OF LANDSIDE FACILITIES [*Source*: Brink *et al.* 1975]

LANDSIDE FACILITIES	FACTORS FOR LEVEL OF SERVICE	
	Easy to Quantify	Difficult to Quantify
Access facility (roads, transit)	Travel time Delay Transit frequency Cost to passenger	Adequacy of signing Level of congestion
Terminal kerb	Availability of space Delay	Level of congestion Kerbside check-in
Parking facilities (Garage, Remote lot)	Availability of space Distance to check-in	Shuttle bus service to/from remote lot
Ticket counter and check-in	Processing time	Complexity of procedure Courtesy of airline personnel Overall environment
Security	Processing time	Actual procedure Location in relation to concessions Courtesy of security officers
Customs and immigration	Processing time	Complexity of procedure Courtesy of clearance officers Overall environment
Hold rooms	Seat availability	Overall environment Location in relation to concessions Level of congestion
Baggage claim	Waiting time for bags	Hardware involved Level of congestion Availability of sky caps Availability of concessions Availability of seating
Circulation elements (corridors, moving sidewalks)	Walking distance Width of corridors Height of ceiling Travel time Frequency of service Cost to passenger	Overall environment Hardware used Signing Public address systems Level of congestion
Waiting areas	Availability	Seating arrangement Comfort of seating
Passenger services (restrooms, telephones)	Availability Cost to passenger	Service provided Level of congestion Cleanliness
Concessions	Availability Cost to passenger	Service provided Courtesy of operator Overall environment Level of congestion
Information service	Availability	Service provided Clarity, legibility, placement

<TABLE 5-4> DEMAND AND OPERATING FACTORS INFLUENCING SERVICE LEVEL AND CAPACITY [*Source*: TRB 1987]

FACTORS	DESCRIPTION
1. AIRCRAFT PARKING POSITIONS AND GATE	
✈ Number of parking positions and physical layout	Controls the total number of aircraft at gate at one time, should include hardstands and apron parking
✈ Utilisation	Ratio of time gate is effectively occupied(service, layover, and recovery) to total service time available(hours of operation), depends on flight turnaround time, including time for recycling between successive flight operations(a function of aircraft type and airline scheduling practices)
✈ Hours of operation(especially noise restrictions)	Limits number of operations that can be handled per gate in a given day
✈ Flight schedule and aircraft mix	Determines whether gates are likely to be available when needed, taking into account uncertainty in actual operation times compared with schedule; gates must be physically compatible with type of aircraft scheduled (see Utilisation)
✈ Airline leases and operating practices, airport management practice	Gate use strategy controls gate availability and utilisation
2. PASSENGER WAITING AREA	
✈ Waiting and circulation area(lounge and accessible corridor)	Space available for people to move around and wait for departing flights; depends on terminal configuration, e.g., waiting areas may be shared by passengers on several departing flights or restricted to single gate
✈ Seating and waiting area geometry	Seated people may occupy more space but are accommodated at higher service levels
✈ Flight schedule, aircraft type, passenger load, and gate utilisation	Larger aircraft typically mean higher passenger loads; areas used jointly to serve simultaneous departures
✈ Boarding method	Availability and type of jetways, stairs, and doors from terminal to aircraft affect rates at which passengers board as well as airline passenger handling procedures
✈ Passenger behavioural characteristics and airline service characteristics	How soon before scheduled departure people arrive at gate areas, amount of carry on baggage, knowledge of system, and percentage of special needs passengers(families with small children, elderly, handicapped, first class and business travellers); airline passenger service policy, seat assignment and boarding pass practices
3. PASSENGER SECURITY SCREENING AREAS	
✈ Number of channels, space, and personnel	Influences number of passengers processed per unit time(magnetometer and X-ray considered separately)
✈ Type, equipment sensitivity, and airport/airline/agent policy and practice	Determines average service time per passenger and likelihood of close inspection
✈ Passenger characteristics	Amount of hand luggage, mobility, and patterns of arrival influence average service time as well as number of passengers
✈ Building layout and passenger circulation patterns	Interference among pedestrian flows can influence flow rates and create congestion
✈ Flight schedule and load	Basic determinant of number and direction of people on concourse

(CONTINUED)

<TABLE 5-4> CONTINUED

FACTORS	DESCRIPTION
4. TERMINAL CIRCULATION	
✈ Terminal configuration	Space available for people to move freely without conflict of flows; availability of alternative paths; placement of seating, commercial activity, stairs, escalators
✈ Passenger characteristics	Amount of hand luggage, mobility, and rate of arrival before scheduled departure influence demand loads and service time
✈ Flight schedule and load	Basic determinant of number and direction of people on concourse
5. TICKET COUNTER AND BAGGAGE CHECK	
✈ Number and type of position	Processing rates are function of position type(baggage check only, ticket purchase, frequent or first class traveller, etc.)
✈ Airline procedures and staffing	Number of positions manned and processing times
✈ Passenger characteristics	Number pre ticketed or with boarding pass, amount of luggage, and distribution of arrival before scheduled departure influence demand loads, fraction of passengers by-passing check-in
✈ Space and configuration	Available waiting area for queues approaching agent positions; banked or separate queues; conflict with circulation patterns
✈ Flight type, schedule, and load	Basic determinant of number of people arriving at ticket area
✈ Airline lease agreement and airport management practices	Counter use policy, as formalised in lease agreements, similar to gate issues and options
6. TERMINAL KERB	
✈ Available frontage	Length of kerb frontage modified by presence of obstructions and assigned uses(e.g., airport limousines only, taxi only), separation of departures and arrivals
✈ Frontage roads and pedestrian paths	Number of traffic lanes feeding to and from frontage area; pedestrians crossing vehicle traffic lanes
✈ Management policy	Stopping and dwell regulations, enforcement practices, comical access control, public transport dispatching
✈ Passenger characteristics and motor vehicle fleet mix	Passenger choice of ground transport mode, average occupancy of vehicles, dwell times at kerb, passenger patterns of arrival before scheduled departure, baggage loads
✈ Flight schedule	Basic determinant of number of people arriving and departing at given time in given area
7. GROUND ACCESS	
✈ Available modes and prices	Connections from various parts of the metropolitan area served, considering prices, comfort, and convenience, particularly with respect to baggage and required vehicle changes
✈ Access times	Total, including wait for vehicles or access and travel from representative locations
✈ Passenger characteristics	Fraction choosing each mode, vehicle occupancy, number of people accompanying passenger, other visitors, baggage loads, origination/destination share
✈ Vehicle operator behaviour	Fraction going directly to kerb or to parking, weaving, kerb dwell time, knowledge of traffic patterns
✈ Flight schedule and load	Basic determinant of number of people using ground facilities
✈ Facilities and background traffic conditions	Highway and transit routes, interchanges; levels of traffic on facility for other than airport purposes; availability of remote check-in facilities

(CONTINUED)

<TABLE 5-4> CONTINUED

FACTORS	DESCRIPTION
8. CONNECTING PASSENGER TRANSFER	
✈ Terminal configuration	Distance between gates, information for connecting passengers, intervening security screening
✈ Ground transport	Connecting passenger assistance systems, baggage transfer systems
✈ Passenger characteristics	Fraction needing assistance for ground transport, intergate travel speeds, baggage loads
✈ Fright schedule and load factors	Basic determinant of number of people making peak-period connections
9. PARKING AREA	
ACCESS(enplaning)	
✈ Available space	As a function of distance from terminal area, systems for reaching terminal, prices for parking, and availability of weather-protected waiting and waking areas
✈ Access times	Total, including search for space, wait and travel from remote locations
✈ Passenger characteristics	Percentage of people driving, automobile occupancy, visitor ratios, length of stay
✈ Pricing	Higher fees may suppress demand or divert some to lower-cost lots
✈ Flight schedule	Basic determinant of number of people arriving at parking areas
EGRESS(deplaning)	
✈ Access time	Total, including wait and travel to remote locations, with consideration for availability of weather-protected wait and walk areas
✈ Exit position and employee efficiency	Number and direction to exits, service times to exit lots
✈ Passenger characteristics	Fraction driving, automobile occupancy, length of stay
✈ Flight schedule and load	Basic determinant of number of people arriving at parking areas
10. BAGGAGE CLAIM	
✈ Equipment configuration and claim area	Type, layout, feed mechanism, and rate of baggage display; space available for waiting passengers; relation of wait area to display frontage; access to and amount of feed belt available
✈ Staffing practices	Availability of porters(sometimes called "sky caps") and inspection of baggage at exit; rate of baggage loading/unloading from cart to feed belt
✈ Baggage load	Numbers of bags per passenger, fraction of passengers with baggage, time of baggage arrival from aircraft
✈ Passenger characteristics	Rate of arrival from gate, ability to handle luggage, use of carts, number of visitors
11. CUSTOMS AND IMMIGRATION	
✈ Number of channels, space, and personnel	Inspector channels, US citizen pass-through positions in immigration, "red-green" channel use in customs
✈ Inspector	Average processing time per passenger, efficiency rate of selection for close inspection policy
✈ Passenger characteristics	Fraction US citizens, flight origin, citizenship of foreign nationals, baggqge loads
✈ Space and configuration	Available queue space, access to and configuration of baggage display devices, use of carts
✈ Flight schedule load	Basic determinant of number of people arriving at FIS areas

<TABLE 5-5> FACTORS OF PERFORMANCE FROM PASSENGERS', OPERATORS', AND AIRLINES' POINTS OF VIEW [*Source*: Lemer 1992]

POINT OF VIEW	FACTORS	DESCRIPTION
Passengers	Comfort and Diversion	Crowding Sound levels, clarity, and noise Visual character Choice of things to do Influence on sociability
	Compactness	Kerb-to-gate distance Kerb-to-gate time Difficulty of level changes Difficulty of choice points
	Cost	Food and drinks Departure fees Connection fees(interline, inter terminal)
	Delay	Service times: check-in, baggage claim Waiting times Variability of wait
	Service Reasonableness	Signing or sightliness Spatial logic Service justice (first in first service)
	Service Reliability	Service levels variation Required time before departure Connection time Flight alternatives: airline, flights
Operators	Effectiveness	People accommodated per unit time Passenger service levels over time Baggage service reliability over time Flight ground delays
	Efficiency	Gate utilisation Space utilisation Labour utilisation Power, fuel consumption
	Finances	Revenue yield Operators, maintenance expenses Debit coverage
	Flexibility	Architectural (new passenger demands) Optional (new aircraft, airlines services)
	Functionality	Reliability Maintainability
	Operational	Passenger served per unit time
	Risk	Security effectiveness Life safety, public health Crime (theft, smuggling)
Airlines	Corporate Image	Control of space, design Maintenance of service levels Market share
	Effectiveness	Baggage transfer reliability Passenger service times
	Flexibility	Operational (new service and aircraft) Architectural (image and passenger accommodation)
	Operational	Aircraft turnaround, flight service time
	Station Cost	Terminal fees Labour costs Equipment costs Inventory costs

5-3 METHOD FOR SELECTION OF EVALUATION FACTORS

In general, the performance of the airport landside system is concerned with the transference of passengers and their baggage between the ground access and the aircraft parking positions. Passengers, airport operators, airlines, and airport-related systems and users have a range of concerns about perceived factors which have been discussed in the previous section.

Practically, when evaluating a real situation or system, simplicity of application, ease of data acquisition, and representative coverage should be considered in terms of selecting evaluation variables or factors. With this in mind, this research centred on the level of service evaluation in an airport landside system approached from the view of the departing passenger's perception of a given service activity in each service component or facility.

Generally, the alternative methods for selecting the influencing factors in the evaluation of the level of service in an airport landside system can be built up through the expert panel survey and passenger survey. For example, research that concentrates on the passengers' point of view, obtains the required information directly from the passengers as the main users of the airport system. Alternatively, research which needs more experience and knowledge based information, can be obtained this requirement from the experts' views for they include different points of view drawn from airport authorities, airlines, airport handling agencies, governmental institutes, planning and design agencies, and related research groups other than the passengers'.

In order to determine the factors that are selected as being influential for level of service evaluation of the airport landside system, this research has adopted the expert panel method, because this method represents the object of the survey together with the experts' knowledge. This method is particularly suitable for establishing service standards for the airports or determining factors influencing the selection of service concepts. Whereas replies of individual passengers are not likely to be useful to the related groups; planners, operators, managers, designers and others, because if the selection of influential factors is applied to individual passengers, a passenger's survey as the next step must match them as the respondents. In this situation, the results of the survey can represent the real phenomena. This method, however, can only be considered if the sample size is sufficiently large. In practice, this is not likely to be possible due to the difficulties faced when taking a survey with a large target sample in an airport.

5-3.1 Method of the Expert Panel Survey

This is the most convenient point at which to discuss the panel method, in which the aim is to collect data from the same sample on more than one occasion.[Moser *et al.* 1986:137] The panel begins as a randomly selected sample of the surveyed group. Data is then sought from this sample by personal interview. This means the chief problem of the panel is maintaining sample representativeness. It is, therefore, pursued by forming a panel randomly selected, but from each of the representing service factors associated with the airport system or facilities.

The panel will then be selected from the major influencing factors according to prespecified factor categories in each system facility. The replies of these experts produce a collective opinion from the questionnaire. This opinion can be used as subjective information. The ideal number of participants on a panel is quite difficult to specify, but 20 and 25 participants seems reasonable[Mumayiz 1985:133].

5-3.1.1 Panel of Experts

The first task was to organise an expert panel. A small scale panel of experts was selected to decide the factors which influence the airport service level, especially focused on the landside service facilities. The panel was focused in Korea and consisted of 28 Korean participants in charge of factor selection and determination of degree of service facility importance.

<TABLE 5-6> THE DETAILS OF THE EXPERT PANEL

EXPERTS	EXPERIENCE(YEARS)					
	UNDER 3	3-6	7-10	11-14	OVER 15	TOTAL
AIRPORT PLANNER		1	3	3		7(25%)
AIRPORT OPERATOR/MANAGER			2	7		9(32%)
AIRPORT DESIGNER	1		1	1		3(11%)
RESEARCHER	2				2	4(14%)
AIRLINE OPERATOR/MANAGER		2	1			3(11%)
OTHERS		1	1			2(7%)
TOTAL	3(11%)	4(14%)	8(29%)	11(39%)	2(7%)	**28**

There were 7(25%) airport planners, 9(32%) airport operators or managers, 3(11%) airport designers, 4(14%) researchers, 3(11%) airline operators or managers, and 2(7%) others. They had different experience in airport or airport-related fields. The longest length of experience was over 15 years, and the shortest was just under 3 years. The lengths of experience were 3(11%) experts of under 3 years' experience, 4(14%) of 3-6 years, 8(29%) of 7-10 years, 11(39%) of 11-14 years, and 2(7%) experts of over 15 years' experience.

5-3.1.2 Questionnaire

This study only considered departure passengers, therefore a service facility refers to the five different areas which are service processing, holding, circulation, ground access, concessions, and car park facilities. To meet the objectives of the research, efforts were made to construct the questionnaire so as to be relevant. The questionnaire for the panel of experts comprised three parts.(See APPENDIX 1)

The objective of the first part was to refer to the professional identity and the length of experience of the participants in their specific field as the general background. The detail of it has already been discussed previously in section (5-3.1.1).

The purpose of the second part was to establish the subjective ratings for airport landside facilities regarding the degree of importance in affecting the service level. These service facilities were set up as service processing facilities, holding facilities, circulation facilities, ground access, and concessions. The importance ratings for these facilities will use the component weighting value to the multi-decision model as an input parameter.

The third part attempted to determine the subjective selection by experts of the evaluation factors based upon the degree of importance for affecting the airport service level. The questionnaire gave lists of influencing factors for the level of service in each service facility. The lists of overall evaluation factors of the questionnaire were extracted through the wide literature review.

The lists of overall evaluation factors are given as;

- *Service processing facilities*
  - Service procession time
  - Complexity of service procedure
  - Courtesy of personnel
  - Number of service facility
  - Overall environment
  - Service variability

- *Holding facility*
  - Crowding
  - Information system
  - Internal environment

- Seat availability
- Accessibility to concession

- *Circulation*
  - Walking distance
  - Sign system
  - Level changes
  - Level of congestion
  - Aids to handicapped
  - Assistant facility to passengers
  - Number of the pedestrian crossings at terminal kerb

- *Ground access to airport*
  - Journey time
  - Availability of transport modes
  - Costs to passengers
  - Travel comfort

- *Concessions*
  - Access distance
  - Variety of choice of things
  - Retail costs to user
  - Courtesy of personnel
  - Visibility
  - Display or arrangement of the goods and location of concessions

- *Car parking*
  - Space availability
  - Simplicity of the access to car parking
  - Car parking fare
  - Sign system
  - Linkage between car park and passenger terminal

It is difficult to prove that these factors perfectly cover the reliability and representativeness of the evaluation factor groups. These, however, are likely to be reasonable because they have been found to be the major influencing factors for the airport service level evaluation through some well recognised studies [Heathington and Jones 1975; Brink and Maddison 1975; Mumayiz 1985; Müller 1987; Martel and Seneviratne 1990; Lemer 1992] and are still considered as the important factors or variables for the level of service concept. Hence, the sets of evaluation or influence factors were carefully considered and selected.

5-3.2 Results of the Expert Panel Survey

The expert panel survey provided a large amount of information. In this survey, six levels of numeric ranking(1 to 6) were used for the service facility with regard to the degree of importance. For instance, ranking 1 is the most important facility to influence the service level evaluation, and ranking 6 is the least important. The numeric ranking levels were also used for the degree of importance for affecting the landside service level. The numeric ranking of each facility depended upon the given considered factors' group. If, for example, the provision factors at a service facility were five, numeric ranking gave five levels; 1 to 5 where ranking 1 is a rather important factor and ranking 5 is less important even though it has a possible influence on the service level. To determine and select from the most important facility and factor to the least, the weighting values were given according to a numeric ranking. For instance, a facility that receives the highest ranking, then takes as well the highest weighting. The decision criteria, therefore, to determine the degree of importance considers both weighting and ranking. The decision criteria can be defined as;

$$dC_i = \sum_{ij} r_{ij} \times w_{ij}, \qquad i = 1, 2, \ldots, I, \; j = 1, 2, \ldots, J,$$

where, dC_i is a decision criterion at service facility or factor i,

r_{ij} is a frequency of ranking jth at service facility or factor i, and

w_{ij} is a weighting value of jth at service facility or factor i.

This research has considered departure passengers. Thus the service facility set can be defined by

$$G = \{G_m\}, \quad m = 1, 2, ..., M, \ M = 6,$$

where, G_1 is service processing facility,
G_2 is holding facility,
G_3 is circulation facility,
G_4 is ground access to airport,
G_5 is concessions' facility, and
G_6 is car parking facility.

Each service facility includes the detailed services which are

$$G = \{G_m\} = \{g_{mn}\}, \quad m = 1, 2, 3, .., 6, \qquad n = 1, 2, 3,$$

where, g_{11} is check-in and baggage drop,
g_{12} is security screening, and
g_{13} is passport control service,
g_{21} is waiting areas,
g_{31} is terminal intra circulation, and
g_{32} is terminal kerb circulation,
g_{41} is ground access to airport,
g_{51} is concessions' service, and
g_{61} is car park facility.

According to the selected service facilities and given considered factors, numeric rankings and weighting values are determined. Each ranking and weighting value is as follows:

- *Ranking and weighting for the service facilities*

$r(G_m)$	1	2	3	4	5	6
$w(G_m)$	0.6	0.5	0.4	0.3	0.2	0.1

- *Ranking and weighting value for the considering factors*

  - *Service processing*

$r(g_{1j})$	1	2	3	4	5	6
$w(g_{1j})$	0.6	0.5	0.4	0.3	0.2	0.1

  - *Holding areas*

$r(g_{21})$	1	2	3	4	5
$w(g_{21})$	0.5	0.4	0.3	0.2	0.1

  - *Terminal intra circulation*

$r(g_{31})$	1	2	3	4	5	6
$w(g_{31})$	0.6	0.5	0.4	0.3	0.2	0.1

  - *Terminal kerb circulation*

$r(g_{32})$	1	2	3	4
$w(g_{32})$	0.4	0.3	0.2	0.1

  - *Ground access*

$r(g_{41})$	1	2	3	4
$w(g_{41})$	0.4	0.3	0.2	0.1

- *Concessions*

$r(g_{51})$	1	2	3	4	5	6
$w(g_{51})$	0.6	0.5	0.4	0.3	0.2	0.1

- *Car parking*

$r(g_{61})$	1	2	3	4	5
$w(g_{61})$	0.5	0.4	0.3	0.2	0.1

Discussions with experts revealed that interpretations of the ranking for service facilities and influencing factors were not always the same from expert to expert, indicating the need for establishing criteria to ensure that the selection of major influencing factors will be used later as an input into the multi-decision model. The results of the expert panel survey are shown in <TABLE 5-7> and <TABLE 5-8>.

<TABLE 5-7> THE FREQUENCY OF EACH RANKING AND DECISION CRITERIA FOR SERVICE FACILITIES

	RANKING						CRITERION
SERVICE FACILITY	**1**	**2**	**3**	**4**	**5**	**6**	$dC = \sum r \times w$
SERVICE PROCESSING	21	2	2	1	2	0	15.1
HOLDING AREA	1	7	2	8	4	6	8.7
CIRCULATION	0	8	10	5	4	1	10.4
GROUND ACCESS	4	5	7	7	1	4	10.4
CAR PARK	0	3	1	4	11	9	6.2
CONCESSIONS	2	3	6	3	6	8	8.0

<TABLE 5-8> THE FREQUENCY OF EACH RANKING AND DECISION CRITERIA FOR SERVICE FACTORS AT EACH FACILITY

FACTOR	RANKING						CRITERION
	1	2	3	4	5	6	dC =Σfxw
1. SERVICE PROCESSING FACILITY							
PROCESSING TIME	16	9	3	0	0	0	15.3
COMPLEXITY OF PROCEDURE	7	14	4	2	1	0	13.6
COURTESY OF PERSONNEL	1	4	4	10	8	1	8.9
NO. OF SERVICE FACILITY	1	0	11	6	5	5	8.3
OVERALL ENVIRONMENT	3	0	5	7	8	5	8.0
SERVICE VARIABILITY	0	1	1	3	6	17	4.7
2. HOLDING AREAS							
CROWDING	7	10	4	4	3		9.8
INFORMATION SYSTEM	14	6	4	4	0		11.4
SEAT AVAILABILITY	2	2	5	6	13		5.8
INTERNAL ENVIRONMENT	3	7	7	7	4		8.2
ACCESSIBILITY TO CONCESSIONS	2	3	8	7	8		6.8
3. INTRA TERMINAL CIRCULATION							
WALKING DISTANCE	15	5	4	2	1	1	14.0
SIGN SYSTEM	10	11	3	4	0	0	13.9
LEVEL CHANGES	1	6	6	9	3	3	9.6
CROWDING	1	3	8	6	7	3	8.8
AIDS TO HANDICAPPED	0	2	0	4	8	14	5.2
ASSISTANT FACILITY TO PAX.	1	1	7	3	9	7	7.3
4. TERMINAL KERB CIRCULATION							
WALKING DISTANCE TO ENTRANCE	15	9	1	3			9.2
LEVEL OF CONGESTION	3	8	16	1			6.9
SIGN SYSTEM	10	11	7	0			8.7
NO. OF PEDESTRIAN CROSSING	0	0	4	24			3.2
5. GROUND ACCESS TO AIRPORT							
JOURNEY TIME TO AIRPORT	9	10	6	3			8.1
AVAILABILITY OF TRANSPORT	18	8	2	0			10.0
COSTS TO PASSENGERS	1	5	4	18			4.5
TRAVEL COMFORT	0	5	16	7			5.4
6. CONCESSIONS							
ACCESS DISTANCE	8	8	3	4	2	3	11.9
VARIETY OF CHOICE	11	5	5	1	4	2	12.4
COST TO USER	0	6	5	4	5	8	8.0
COURTESY OF PERSONNEL	2	4	7	8	6	1	9.7
VISIBILITY	2	1	3	5	6	11	6.7
DISPLAY AND LOCATION	5	4	5	6	5	3	10.1
7. CAR PARK FACILITY							
SPACE AVAILABILITY	17	4	1	3	3		11.3
SIMPLICITY OF THE ACCESS	3	7	11	5	2		8.8
PARKING FARE	1	1	3	3	20		4.4
SIGN SYSTEM	3	1	11	11	2		7.6
LINKAGE TO TERMINAL	4	15	2	6	1		9.9

5-3.3 Determining the Number of Evaluation Factors

Research into the diversity of factors affecting the level of service and the difficulty of measuring the evaluation methods for an airport service level have largely been focused on the quantitative factors such as temporal and spatial. This is because the qualitative factors were relatively difficult to transfer to a quantitative measurement.

Although there is as yet no universally accepted way to measure level of service[Müller *et al.* 1991:46] for airports, different approaches have been attempted by some studies. For example; Mumayiz[1985] used the Perception-Response model that predicted the percentage of passengers that rate a particular service facility as; "good", "tolerable", or "bad" on the basis of service processing time and crowding; Müller and Gosling[1991] proposed an analytical framework to measure the level of service based on psychological theories of perceptual scaling and categorical judgement; Fruin[1971] looked at other transport facilities. Pushkarev and Zappan[1975] also focused on requirements of area per person for different activities and/or pedestrian walking speed.

The reliability of their evaluation is questionable, even though the major factors have been dealt with in their studies because they are only quantitative. An airport is a complex system that involves many factors affecting the level of service such as the service performance parameters. However, the airport service level is even broader and more complicated than other transport services. Therefore, the highest hurdle in evaluation of the service level is how much can be represented or described of the real phenomena of the provision of services at the airports and whether they are affected by quantitative or qualitative factors. This study has tried to assess the airport service levels by a more comprehensive and overall approach which means that the evaluation factors are constructed from various aspects in the airport landside system. Many of these factors can be considered to help to understand the real service performance. However, in practice it is rather difficult to take all the affecting factors as the evaluation parameters. How many factors are obtained and how they are chosen are the key to the questions.

The number of evaluation factors has been determined by the results of the expert panel survey. <TABLE 5-8> shows the decision criteria which indicate the degree of importance for each evaluation factor of the level of service in the airport landside system. The possible number of evaluation factors is based upon the groups of overall factors in the questionnaire for the panel of experts, because the proposed methodology to assess the level of service needs a matrix structure for the input data. That means the number of evaluation factors in each group must be equal. If there are different numbers in the factor groups, the minimum number will represent the maximum number of evaluation factors. For instance, the number of evaluation factors in the service processing facilities, intra terminal circulation, and concessions are six, in the holding area and car parking facility are five, and terminal kerb circulation and ground access are four. In this case, therefore, four evaluation factors are taken as the input data size for the multi-decision model in the later discussions.

The next step is to prove the validity for determining the number of evaluation factors. The decision criteria and their cumulative percentages can be used as basic measurements. They are defined by the fourth ranking factor at each service facility as shown in <TABLE 5-9>. To increase the representative range for the evaluation factor selection, the cumulative percentages are set at over 50% for each service facility. Thus, from the second to the fourth the ranked factors are considered to be the possible number of evaluation factors. The average cumulative percentages of each criterion ranking are:

Second ranked factors: 60.22 % ,
Third ranked factors: 82.07 % , and
Fourth ranked factors: 100.00 % .

<TABLE 5-9> RANKING OF CRITERIA AND CUMULATIVE PERCENTAGES AT EACH SERVICE FACILITY

SERVICE FACILITY	RANKING OF CRITERIA			
	1st	2nd	3rd	4th
SERVICE PROCESSING FACILITY	15.3	13.6	8.9	8.3
CUMULATIVE PER CENT (%)	(39.19)	62.69	82.00	100
HOLDING AREAS	11.4	9.8	8.2	6.8
CUMULATIVE PER CENT (%)	(31.49)	58.56	81.22	100
INTRA TERMINAL CIRCULATION	14.0	13.9	9.6	8.8
CUMULATIVE PER CENT (%)	(30.24)	60.26	80.99	100
TERMINAL KERB CIRCULATION	9.2	8.7	6.9	3.2
CUMULATIVE PER CENT (%)	(32.86)	63.93	88.57	100
GROUND ACCESS TO AIRPORT	10.0	8.1	5.4	4.5
CUMULATIVE PER CENT (%)	(35.71)	64.64	83.93	100
CONCESSIONS	12.4	11.9	10.1	9.7
CUMULATIVE PER CENT (%)	(28.12)	55.10	78.00	100
CAR PARKING	11.3	9.9	8.8	7.6
CUMULATIVE PER CENT (%)	(30.05)	56.38	79.79	100

This cumulative percentages approach to the decision criteria explains the taking of four evaluation factors. However, we must not overlook an important fact which is that the minimum number of factor groups in terminal kerb circulation and ground access to airport, have connotations of incompleteness for adopting evaluation factors even though they are provided with reasonable and comprehensive factor lists from the overall literature review. To get rid of this potential risk to the assessment of the level of service, a conservative risk hedge is needed. In this research, this can be done by cutting off the lowest ranked factor. After the risk hedge, the average cumulative percentage of the decision criteria still remains too high (82.07%). Consequently, the number of factors to be considered for the service level evaluation is set at *three main factors*. The list of selected major effective factors is represented in <TABLE 5-10>.

<TABLE 5-10> FACTORS FOR LEVEL OF SERVICE FROM THE EXPERTS' POINT OF VIEW

FACILITY	TEMPORAL & SPATIAL	COMFORT	REASONABLE SERVICE
1. SERVICE PROCESSING			
CHECK-IN AND BAGGAGE DROP	PROCESSING TIME	COMPLEXITY OF PROCEDURE	COURTESY OF PERSONNEL
SECURITY SCREENING	PROCESSING TIME	COMPLEXITY OF PROCEDURE	COURTESY OF PERSONNEL
PASSPORT CONTROL	PROCESSING TIME	COMPLEXITY OF PROCEDURE	COURTESY OF PERSONNEL
2. HOLDING			
WAITING AREAS	CROWDING	INFORMATION SYSTEM	INTERNAL ENVIRONMENT
3. CIRCULATION			
TERMINAL CIRCULATION	WALKING DISTANCE	SIGN SYSTEM	LEVEL CHANGES
KERB CIRCULATION	WALKING DISTANCE TO ENTRANCE DOOR	SIGN SYSTEM	LEVEL OF CONGESTION
4. ACCESS			
GROUND ACCESS	ACCESS TIME	TRAVEL COMFORT	AVAILABILITY OF TRANSPORT MODE
5. OTHER			
CONCESSIONS	ACCESS DISTANCE	VARIETY OF CHOICE OF THINGS	FUNCTIONAL DISPLAY OR LOCATION
6. PARKING SERVICE			
CAR PARKING FACILITY	AVAILABILITY OF SPACE	SIMPLICITY OF ACCESS	LINKAGE TO TERMINAL

This research, therefore, draws that three evaluation factors are the most suitable to carry out the service level evaluation, and takes the three top ranking factors from the expert panel survey. Each evaluation factor will be used in assessing the provision of service to passengers at each service facility. The factors are divided into three categories; temporal or spatial, comfort, and reasonable service factor.

5-3.4 Selected Evaluation Factors

The evaluation factors are selected through the experts panel survey. These factors are the principal information for assessing the service level. Each selected factor belongs to one of three factoral categories; temporal or spatial, comfort, and reasonable service factors.

5-3.4.1 Temporal or Spatial Factors

This can be defined as "the passengers' subjective perception and judgement of the degree of rapidity, density, and physical distance for the service given to them in an airport landside system component or facility". The temporal and spatial factors include the elements:

- *Service processing time*: This is the time taken by a passenger to be served at a particular processing facility such as the ticket counter and the check-in and baggage drop, passengers' security screening, and passport control. This service processing time can be represented by both waiting time in the queue and provision service time at each related facility. It is a facility-specific factor that is relatively insensitive to demand variations, because it represents the supply side of the processing activity at that facility. It seems likely to be the prime determination factor to affect the service level evaluation. Many attempts to assess the service level have dealt with temporal factors as a service performance indicator.

- *Crowding*: This has physical characteristics, and is a direct outcome factor caused by supply and demand interaction. This could be measured at the waiting areas, holdrooms, and concessions in the landside system. The distribution of crowdedness shows the differences between peak time and non-peak time. It stems also from a lack of system or the spatial capacity of the facility. Here, the spatial capacity can be defined by the maximum number of passengers handled within a specific service area during a given time period. The maximum number means that demand equals the acceptable capability of a service facility as opposed to crush conditions or a lower service level.

- *Physical walking distance*: This could be used as an effective service measurement for the circulation or linking facilities such as the inter terminal and kerb circulation. Originating passengers are those passengers arriving at the terminal by ground transport mode and then walking from the ground transport facility service areas at the terminal such as bus stop, taxi stand, and car park to the departure gate through the necessary service activities. The terminal configurations and geometry determine the passenger walking distance. The optimal arrangement of the service facilities would be in accordance with the terminal characteristics, for instance, the centralised and semi-centralised pier configurations and the satellite and pier-satellite configurations that produce minimum passenger walking distance and therefore a higher level of service. The passenger walking distance, therefore, is an important level of service measure.

- *Ground access time*: This is an essential and continual factor for the service level evaluation. It includes wait time for vehicles and journey time from representative locations. The access road system, availability mode, and roadway congestion influence ground access time. High roadway congestion, the complexity of the road system, and the long interval operations of public transport reflect a lower service level and add the burden of more journey time for passengers.

- *Availability of parking spaces*: This is also a physical characteristic. The facilities consist of surface lots or multi-level buildings used to park the vehicles of air passengers and visitors. Airport employee vehicles, rental cars, taxis, and buses also need parking areas, but these service facilities have relatively little influence on the airport service level as viewed by a passenger. Parking spaces are primarily determined by the rate of long-term parking as well as occupied time length, because it generates the most space-hours. The availability of parking spaces is one of the most important factors to evaluate the level of service at a car parking facility. To provide high standard service levels, the numbers of parking spaces need to be greater than the total parking demand, because many parking spaces can not be seen simultaneously and it is therefore difficult to find the last available spaces.

5-3.4.2 Comfort Factors

These can be defined as "a degree of satisfaction in terms of comfort for the given service to passengers at a particular service facility or component in an airport landside system, which will depend upon the subjective perception of passengers". The comfort factors cover the elements as follows:

- *Complexity of service procedures*: This is a measure of service at a service processing facility in the airport terminal buildings. It is a performance measure of the supply side so it can depend upon the operating characteristics, for instance, service providers' skill and experience as well as on the operating disciplines at each service activity. A simpler procedure is helpful to shorten the service processing time as well as reaching a higher service level.

- *Information and sign system*: This is an audio visual factor, it is a major service performance in terms of the supply side of its activity. Information generally includes aircraft-related information such as aircraft, arrivals, departures, origins/destinations, gates, airlines, flight numbers, and baggage delivery, together with special services covering security, customs, hotels, public transport, car rental, and matters of a general nature(tourism and conventions). A sign system provides the direction, orientation, and the identification of locations that include all the facilities in an airport landside system. This factor can be measured by a subjective passenger's perception.

- *Travel comfort*: That is measured by passengers' subjective judgement of the access roadway congestion, traffic and direction sign system, public vehicle occupancy, seat comfort, baggage loads, and vehicle internal environment. Its performance measurements consider the passenger demand characteristics. The passenger demand patterns may be directly related to the extent of the public transport system available, passenger trip purpose, and the availability of parking courtesy vehicles and scheduled limousines and buses.

- *Variety of choice*: This is considered as a measure of the concession service. The perceived level of the service to passengers is a subjective decision and defines particular preference for a given service. A variety of choice provides satisfaction to passengers' needs and also a high level of service.

- *Simplicity of access to car parking*: This is effectively used in the evaluation of level of service for a car park facility. It concerns the signing system from the airport entrance to the car park entrance and the number of car park gates. The physical design of the parking entries and an effective sign information system can affect the overall perceived service levels as viewed by users.

5-3.4.3 Reasonable Service Factors

This can be defined by "the reasonableness and suitability of the provided service to passengers at a service facility in the airport landside systems". It should consider a passenger's subjective perception and judgement. The reasonable service factors include the following elements:

- *Courtesy of personnel*: This is a difficult area to quantify as it is a direct relation between the service provider and the passenger, and can be measured only through a passenger's subjective judgement and preference.

- *Internal environment*: This is an important factor in measuring service performance in airport terminal buildings. It represents the passengers' perception of the services that are provided. This factor refers to aesthetics, climate characteristics, lighting systems, air conditioning, noise and visual levels, the furniture, and so on.

- *Level changes*: These are a physical element in a circulating service facility. Level changes include the vertical movements that require passengers to use stairways, escalators, or elevators.

- *Level of congestion*: This includes factors such as delay and the direct interrelation of both supply and demand. The primary determinant is the amount of kerb frontage space required at a terminal. The lengths of time that vehicles- bus, airport limousines, taxis, and others- stop for loading and unloading depend upon these operating rules and terminal kerb spaces. The level of congestion in a kerb area can be relieved through the enforcement of regulations on access and by the use of signs and traffic management to separate the users with different demand characteristics.

- *Availability of transport mode*: This is a measure of the airport access services, signifying the relative importance for its users, and defining the passengers' preference for the service. The demand for ground access to the airport is primarily determined by the transport modes selected by the users. Its users- passengers, visitors, and others- characteristics can be affected by the connection from various parts of the metropolis, the required vehicle changes, the baggage considerations, and convenience. Costs to users for riding and parking can also have particularly significant impact on the choice of access mode at large airports.

- *Functional display of goods and location of concessions*: This is the performance measure that is intended for certain passengers. The arrangement of concessions should be designed to attract user's attention, in other words, where the displays can be seen easily. It gives more convenience to the user. Attractive functional display must be provided for the users' satisfaction. Functional display of concessions, therefore, has a significant impact on the service level.

- *Linkage between car park and passenger terminal*: This is characterised by the environment between parked vehicles and the terminal. These environmental characteristics include such aspects as weather-protected walkways, escalators, moving sidewalks, buses, people movers, or other mechanical assistance to reduce passenger discomfort.

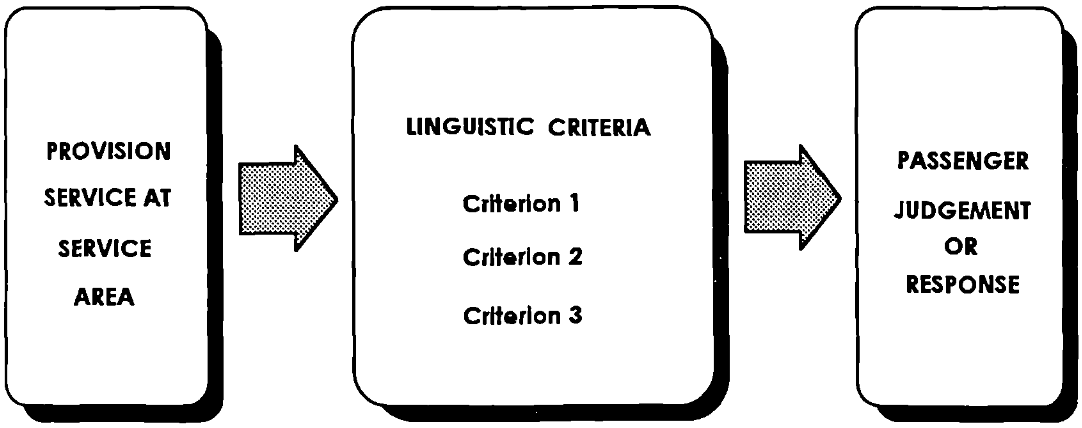
This research has centred on the level of service evaluation regarding these chosen factors. We should recognise that any method for selecting evaluation factors can not perfectly achieve a risk free stage even though the sets of evaluation factors are fairly comprehensive and extensive. Only a trial can investigate the best method necessary to produce a high standard of accuracy, validity, and representativeness.

5-3.5 Service Level Criteria

The factors for the level of service evaluation in an airport landside system were selected according to the qualitative and quantitative factors from the experts' point of view concerning passengers. In order to evaluate this level of service regarding these factors, the evaluation criteria will be only those that are considered to be basically needed.

When considering the characteristics of the necessary evaluation factors, there is a linguistic criterion, which can be defined as natural language. This is a possible methodology. It can be dealt with according to quantitative and qualitative variables because it depends upon the passengers' judgement as to the outcome. This methodology might be suspect because of the substantially different passenger characteristics. To reduce the variation and to increase the reliability of the outcome, the linguistic service criteria should be generalised and simplified in order to provide as precise a judgement level to passengers as possible.

This research divided the service criteria into three categories, 1, 2, and 3. Criterion 1 represents positive and satisfactory passenger's perception for a provided service at an airport landside facility. Criterion 3 expresses negative and unsatisfactory passenger perception in terms of a linguistic variable. Criterion category 2 presents a neutral position between criterion 1 and 3, it means tolerably satisfactory passenger perception.



<FIGURE 5-1> THE PROCESS OF PASSENGER RESPONSE

5-4 CONCLUSION

Factors influencing the level of service for the airport landside system in general and in particular were discussed, so as to consider the evaluation factors at each service facility. Also, service level criteria were defined by linguistic variables such as the natural language. These should be based on the passengers' perception for a given service rather than the arbitrary standards which were built in by airport operators, planners. The reasonable evaluation factors were selected and will be used as a basic input into a multi-decision model in order to evaluate the level of service for an airport landside system from the passengers' point of view.

CHAPTER 6

MULTI-DECISION MODEL

6-1 INTRODUCTION

The need for an analytical framework to evaluate the level of service provided by the airport landside system has been increasingly recognised to be a critical issue in airport system planning and management. Applying an up-to-date and innovative methodology to the evaluation of airport landside level of service is an urgent task that needs to be studied attentively. Therefore, how to use an up-to-date method and which tool can innovate the level of service in this field are the central problems.

This research has used fuzzy mathematics as an evaluation model for the process of the airport level of service. An approach to evaluating the airport level of service using fuzzy sets and approximate reasoning is now presented.

6-2 FUZZY SET APPROACH

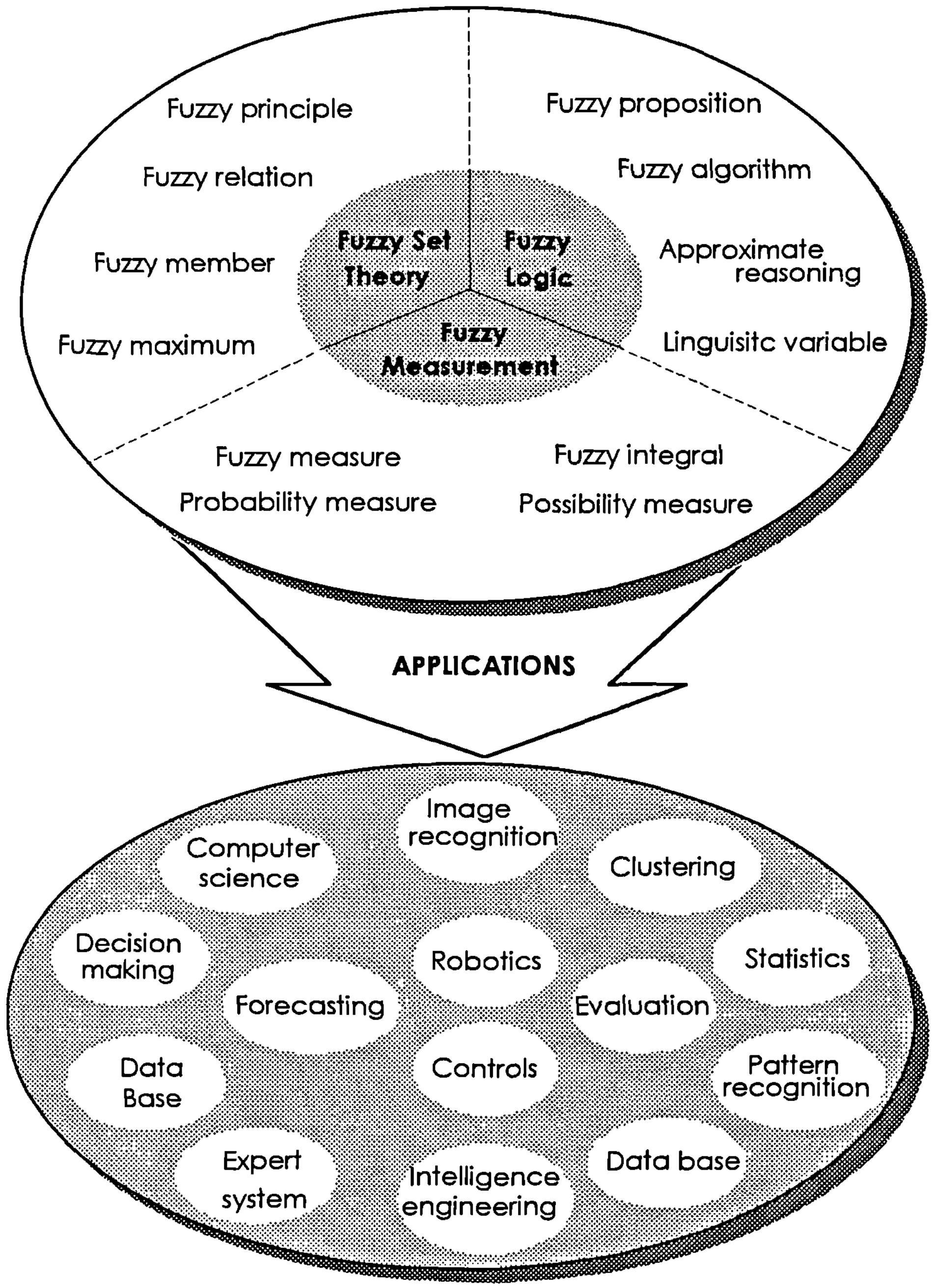
6-2.1 Introduction

Fuzzy set theory was developed by Zadeh[1965] as an area of research in mathematical system theory. Since the early 1960's, it has been used as a suitable mathematical tool for dealing with systems of organised complexity. The application of fuzzy set theory can be found in a wide variety of fields, such as in artificial intelligence, computer science, decision making, human factors engineering, interpersonal communication, medicine, meteorology, pattern recognition, robotics, and transport. It has also applied to an evaluation methodology.

According to the first publication of fuzzy set theory by Zadeh[1965:339], "the notion of a fuzzy set provides a convenient point of departure for the construction of a conceptual framework which parallels in many respects the framework used in the case of ordinary sets, but is more general than the latter and potentially, may prove to have a much wider scope of applicability, particularly in the fields of pattern classification and information processing. Essentially, such a framework provides a natural way of dealing with problems in which the source of 'imprecision' is the absence of sharply defined criteria of class membership rather than the presence of random variables."

In other words, 'imprecision' means here a sense of vagueness rather than the lack of knowledge about the value of a parameter as in tolerance analysis[Zimmermann 1991:6]. Imprecision can arise from a variety of sources[Dutta 1985]; incomplete knowledge, inexact language, ambiguous definitions, inherent stochastic characteristics, measurement problems and so on.

Fuzzy set theory in the last two decades has developed along two lines[Zimmermann 1991:6]:



<FIGURE 6-1> A CONCEPTUAL DIAGRAM FOR FUZZY SET AND ITS APPLICATION FIELDS
[*Source*: Lee *et al*. 1991:1-14]

- First, as a formal theory which, when maturing, became more sophisticated and specified and was enlarged by original ideas and concepts as well as by "embarking" on classical mathematical areas such as algebra, graph theory, topology, and so on by generalising(fuzzifying) them.

- Second, as a very powerful modelling language, that can cope with a large fraction of the uncertainties of real-life situations. Because of its generality it can be well adapted to different circumstances and contexts. In many cases this will mean, however, the context-dependent modification and specification of the original concepts of the formal fuzzy set theory. Regrettably this adaptation has not yet progressed to a satisfactory level, leaving an abundance of challenges for the ambitious researcher and practitioner.

6-2.2 Applications of Fuzzy Set Theory in the Transport Field

While the diversity of successful applications has been expanding rapidly, the theory of fuzzy sets in particular and the mathematics of uncertainty and information in general have been achieving a secure identity as valid and useful extension of classical mathematics.[Klir *et al.* 1988:4] Fuzzy set theory is a methodology providing some useful and possible tool for particular systems and phenomena in the real situations which are very often uncertain or vague through the mathematical definitions. Therefore, fuzzy set theory provides not only a strict mathematical framework in which vague conceptual phenomena exist but also a modelling language for situations in which fuzzy relations and criteria occur.

Fuzzy set theory has attempted to deal with the decision processing that involves subjective judgement. Subjective judgement of an evaluation has typically faced the problem of building a mathematical framework, because it can not deal effectively with the decision maker's feeling of ambiguity, uncertainty and vagueness. Fuzzy sets make it possible to analyse these problems by the manner of multi-valued logic.

Because of the huge advantages of fuzzy set theory, the transport field has adopted it to analyse existing problems, in particular decision processes needing subjective judgement. A few researchers have attempted to apply a fuzzy logic controller on traffic junctions [Mamdani and Pappis 1977], aircraft flight control [Larkin 1985], and an automobile speed control system [Murakami and Maeda 1985] as well as predictive fuzzy control applied to automatic train operation [Yasunobu and Miyamoto 1985].

Recently, a special issue of Transportation Planning and Technology [vol.17(2), 1993] dealt with the application of fuzzy set theory to transport problems. It was a pioneering effort to compile literature on fuzzy set theory applications to transport. This issue proposed such specific methods as the application of fuzzy set theory to transport investment planning[Tzeng and Teng], a modelling framework for route choice in the presence of information based on concepts from fuzzy set theory, approximate reasoning and fuzzy control [Lotan and Koutsopoulos], estimating an origin-destination (O/D) matrix with fuzzy weights [Xu and Chan], minimisation of the total cost caused by aircraft delay at an airport using the fuzzy inference technique [Teodorovic and Babic], incremental benefit-cost analysis and dynamic programming for traffic safety planning on an urban expressway using fuzzy budget constraints [Akiyama and Shao], traffic signal installation by the fuzzy expert system [Chang and Shyu], and a method to solve transport problems using the three different models- classical, interval, and fuzzy [Chanas *et al.*].

They will stimulate the motivation of study in transport, especially in the field of airports for evaluation or decision process problems approaching fuzzy set theory as a new methodology.

6-2.3 Fuzzy Mathematics

This section deals with the basic fuzzy mathematics that will serve for further considerations, and aid understanding of the application model for the airport landside system.

6-2.3.1 Basic Definitions

A crisp(classical) set is normally defined as a collection of individual object x which can be finite, countable, or over countable. To indicate that an individual object x is either an element of a set A or not an element, we write

$x \in A$, x is an element of a set A,
$x \notin A$, x is not an element of a set A.

A crisp set can be described in different ways: (1) describe the elements of a set by stating conditions for membership, i.e., $A = \{ x | \ x \leq 7 \}$, (2) describe the member elements by using the characteristic function which assigns a value of either 1 or 0 to each individual in the universe set.

This characteristic function can be generalised so that the values assigned to the elements of the universal set fall within a specified range and indicate the membership grade of these elements in the set in question[Klir *et al.* 1988:10]. Larger(smaller) values connote higher(lower) degrees of set membership. This function, which allows the various membership grades for the elements of a given set, is called a *membership function* and the set defined by it as a *fuzzy set*.

Given a universal set X. Then a fuzzy subset A of X is usually defined as having the form

$$A = \{ (x, \mu_A(x)) \mid x \in X \}, \quad \mu_A : X \to [0, 1]$$

so that [0,1] denotes the interval of real membership of x in A, i.e., the degree of compatibility or degree of truth of x with the concept represented by the fuzzy set A. Clearly $\mu_A(x) = 0$ means that x is definitely not a member of A, and $\mu_A(x) = 1$ means that x definitely is a member of A.

6-2.3.2 Operations on Fuzzy Sets

A calculus of fuzzy sets was formulated by Zadeh[1965,1973a] and other authors who built up a consistent framework in terms of the following specific operators of set union, intersection, and complement.

If A and B are two fuzzy subsets of X the union, $C = A \cup B$, is also a fuzzy subset of X in which for any $x \in A$,

$$C(x) = \mu_{A \cup B}(x) = \max [\ \mu_A(x), \mu_B(x)\ ] .$$

The intersection, $D = A \cap B$, is defined as a fuzzy subset of X in which for any $x \in A$,

$$D(x) = \mu_{A \cap B}(x) = \min [\ \mu_A(x), \mu_B(x)\ ] .$$

The complement of a fuzzy subset A denoted $\overline{A}$ is defined by

$$\mu_{\overline{A}}(x) = 1 - \mu_A(x) \qquad \text{for any } x \in A .$$

6-2.3.3 Fuzzy Relations

This section provides an overview of fuzzy relation and fuzzy relation equations. Rather than concentrating on specific cases, general methodological aspects are centred.

A crisp relation represents the presence or absence of association, interaction, or interconnectedness between the elements of two or more sets[Klir *et al.* 1988:65]. A crisp relation can be represented by the Cartesian product. It can be generalised for a family of crisp sets $\{X_i | i \in \mathbf{N}_n\}$ and denoted by $\bigtimes_{i \in \mathbf{N}_n} X_i$. Element of the Cartesian product of n crisp sets are n-tuples $(x_1, x_1, \dots, x_n)$ such that $x_i \in X_i$ for all $i \in \mathbf{N}_n$. Thus,

$$\bigtimes_{i \in \mathbf{N}_n} X_i = \{\ (x_1, x_1, \dots, x_n) \mid x_i \in X_i\ \},\ \text{ for all } i \in \mathbf{N}_n .$$

A relation among crisp sets $X_1, X_1, \ldots, X_n$ is a subset of the Cartesian product $\times_{i \in \mathbf{N}_n} X_i$. It is denoted by the abbreviated form $R(X_i \mid i \in \mathbf{N}_n)$. Thus,

$$R(X_1, X_1, \ldots, X_n) \subset X_1 \times X_1 \times \ldots \times X_n \,,$$

so that for relations among sets $X_1, X_1, \ldots, X_n$, the Cartesian product $X_1 \times X_1 \times \ldots \times X_n$ represents the universal set. This concept can be generalised to allow for various degrees or strengths of relation or interaction between elements. Degree of association can be represented by membership grades in a fuzzy set.

A fuzzy relation is a fuzzy set defined on the Cartesian product of crisp sets $X_1, X_1, \ldots, X_n$, where tuples $(x_1, x_1, \ldots, x_n)$ may have varying degrees of membership within the relation. The membership grade is usually represented by a real number in the closed interval [0,1] and indicates the strength of the relation present between the elements of the tuple. [Klir *et al.* 1988:68] Hence, fuzzy relations are fuzzy subsets of $X \times Y$, that is, mapping from $X \rightarrow Y$ [Zimmermann 1991:69].

Definition 1

Let $X, Y \subseteq \Re$ be universal sets, then a fuzzy relation on $X \times Y$ is defined as

$$R = \{ [(x, y), \mu_R(x, y)] \mid (x, y) \subseteq X \times Y \} \,,$$

where, μ_R is the membership function of the given relation R.

Definition 2

Fuzzy relations are obviously fuzzy sets in product spaces. Let R and Z be two fuzzy relations in the same product space. The union and intersection of R with Z is then defined by

$$\mu_{R\cup Z}(x,y) = \max\{\,\mu_R(x,y),\, \mu_Z(x,y)\,\}, \qquad (x,y) \in X\times Y,$$
$$\mu_{R\cap Z}(x,y) = \min\{\,\mu_R(x,y),\, \mu_Z(x,y)\,\}, \qquad (x,y) \in X\times Y.$$

6-2.3.3.1 Binary Relation

Any relation between two sets X and Y is known as a binary relation. It is usually denoted by $R(X, Y)$.[Klir *et al.* 1988:71] The domain of a crisp binary relation is defined as the crisp subset X:

$$\text{dom } R(X,Y) = \{\, x \mid x\in X,\ (x,y)\in R, \qquad \text{for all } y\in Y \,\}.$$

If $R(X, Y)$ is a fuzzy relation, its membership function is defined by

$$\mu_{\text{dom}R}(x) = \max_{y\in Y} \mu_R(x,y), \quad \text{for each } x\in X.$$

The range of crisp binary relation is defined as the crisp subset Y:

$$\text{ran } R(X,Y) = \{\, y \mid y\in Y,\ (x,y)\in R, \quad \text{for all } x\in X \,\}.$$

If $R(X, Y)$ is a fuzzy relation, its membership function is defined by

$$\mu_{\text{ran}R}(y) = \max_{x\in X} \mu_R(x,y), \quad \text{for each } y\in Y.$$

When each member of the domain of a binary relation R appears exactly once in R, the relation is called a *mapping* or a *function*. If $R(X, Y)$ is a mapping, it is denoted by $R(X \to Y)$ and its membership function $\mu_{R(X \to Y)}(x, y) > 0$ then y is called the image of x in R.

Fuzzy relation in different product spaces can be combined with each other by the operation "composition". The max-min composition has become the best known and the most frequently used one. [Zimmermann 1991:74]

Definition 3

Let $R_1(x, y)$, $(x, y) \in X \times Y$ and $R_2(y, z)$, $(y, z) \in Y \times Z$ be two fuzzy relations. The max-min composition [R_1 max min R_2] is the fuzzy set

$$R_1 \circ R_2 = [(x, z), \max_{y \in Y} [\min(\mu_{R_1}(x, y), \mu_{R_2}(y, z))]], \text{ for all } x \in X, y \in Y, z \in Z.$$

$\mu_{R_1 \circ R_2}$ is the membership function of a fuzzy relation on fuzzy sets.

6-2.3.3.2 Fuzzy Relation Equations

The notion of fuzzy set relation equations is associated with the concept of composition of binary relations. The composition of two fuzzy binary relations $R_1(x,y)$, $(x, y) \in X \times Y$ and $R_2(y, z)$, $(y, z) \in Y \times Z$ can be defined in terms of an operation on the membership matrices of R_1 and R_2:

$$R_1 = [\, \mu_{R_1}(x, y) \,],$$
$$R_2 = [\, \mu_{R_2}(y, z) \,].$$

Suppose that two relations are constrained as

$$R(x, z) = R_1(x, y) \circ R_2(y, z) ,$$

where, the operator "∘" denotes the max-min composition. Hence, the matrix equation of two relations is defined by

$$\mu_R(x, z) = \max_{y \in Y} [\min (\mu_{R_1}(x, y), \mu_{R_2}(y, z))] , \text{ for all } x \in X, y \in Y, z \in Z .$$

This matrix equation is referred to as a *fuzzy relation equation.*

6-2.3.4 Approximate Reasoning

The theory of approximate reasoning often referred to as fuzzy reasoning, whose basic principles have been formulated by Zadeh[1979], can be formulated as a *compositional rule of inference* which subsumes the standard inference rule *modus ponens* as a special case[Zadeh 1975]. It is essentially a methodology for representing vague and incomplete knowledge in terms of linguistic variables.

6-2.3.4.1 Linguistic Variables

A linguistic variable is defined as a variable, the values of which are words, phrases, or sentences in a given language where such a language can either be natural or artificial.[Schmucker 1983] Zadeh[1973b:3] presented in a nutshell the motivation for fuzzy logic and approximate reasoning as "in retreating from precision in the face of overpowering complexity, it is natural to explore the use of what might be called *linguistic variables*, that is, variables whose values are not numbers but words or sentences in a natural or artificial language and the motivation for the use of words or sentences rather than numbers is that linguistic characterisations are, in general, less specific than numerical ones".

For example, linguistic terms such as *<high, more or less high, moderate, more or less moderate, low>*, *<strong, average, weak>*, *<many, several, few>*, *<likely, more or less likely, unlikely, more or less unlikely, not likely>*, *<close to 1, close to middle, close to 0>*, *<satisfactory, more or less satisfactory>*, *<good, tolerable, bad>*, and so on can be considered. These words form a term-set or general terms useful in defining situations or problems through knowledge and experience. The general terms are still imprecise and can be further modified using a *linguistic hedge* or a *modifier*. Which is an operation that modifies the meaning of a term or, more generally, of a fuzzy set[Zimmermann 1991:137].

The concept of linguistic hedges or modifiers is very important and useful for using linguistic variables in fuzzy logic. A hedge acts as modifier in order to determine the meaning of an arbitrary term of the term set using natural language statements such as "*very*", "*fairly*", "*highly*".

For example, if A is a fuzzy set then the hedge h generates the composite term $B=h(A)$. Let "Age" be a linguistic variable with the term set[Zadeh 1973b:83]

$$T\,(age) = \{\ old,\ very\ old,\ very\ very\ old,\ \cdots\cdots\}\ .$$

The term set can now be generated recursively by using the following rule:

$$T^{i+1} = \{old\} \cup \{very\ T^{i}\}$$

that is,

$$T^{0} = \varnothing$$
$$T^{1} = \{old\}$$
$$T^{2} = \{old,\ very\ old\}$$
$$T^{3} = \{old,\ very\ old,\ very\ very\ old\}$$

6-2.3.4.2 Fuzzy Logic

This section is intended to provide a brief overview of basic concepts of classical logic and fuzzy logic.

Classical logic, in particular two-valued logic, deals with propositions that are required to be either *true* or *false*, that is, have the true value 1 or 0. Therefore an arbitrary proposition can be in either of the two truth values which are required to assume opposite truth values. For example, sex; man and woman as well as living and dead are clearly classified into two truth values.

Propositions are sentences represented in some language. Each sentence consists of a subject and a *predicate*. For example, a simple proposition can be expressed in the canonical form

x is A

where x is a symbol of a subject and A is a predicate, which characterises a property.

Generally, we hardly define a property of characteristics for many things in real situation such as "young", "clever", "sick", "beautiful", and so on. These characteristics can not be dealt with as classic logic because they have various ranges of properties or characteristics. In order to get rid of this limitation, the classical two-valued logic can be extended into three-valued logic in various ways. It is common to denote the truth, falsity, and indeterminacy by 1, 0, and $\frac{1}{2}$, respectively. It is also common to define the negation $\bar{a}$ of a proposition a as 1- a; that is, $\bar{1} = 0$, $\bar{0} = 1$, and $\overline{\frac{1}{2}} = \frac{1}{2}$ [Klir *et al.* 1988:27].

Fuzzy logic is an extension of set theoretic multi-valued logic. Its ultimate goal is to provide foundation for approximate reasoning with imprecise propositions using fuzzy set theory as the principle tool[Klir *et al.* 1988:30]. In fuzzy logic, the truth values are linguistic variables or terms of the linguistic variable truth.

Differently from classical logic, fuzzy logic is centred on natural linguistic statements, where approximate reasoning with imprecise proposition is rather typical. Hence, such an imprecise proposition in linguistic terms that can not be dealt with by the classical predicate logic. In order to use the linguistic variables: likely, fairly, very, extremely, and so forth as *fuzzy modifiers* or *hedges*, young, old, dangerous, beautiful, clever, rare, and so on as *fuzzy predicates*, many, few, almost all, usually, and such like as *fuzzy quantifiers*, quite true, very true, more or less true, mostly false, and so on as *fuzzy truth values*.

For example, let consider a simple proposition

PARK IS YOUNG

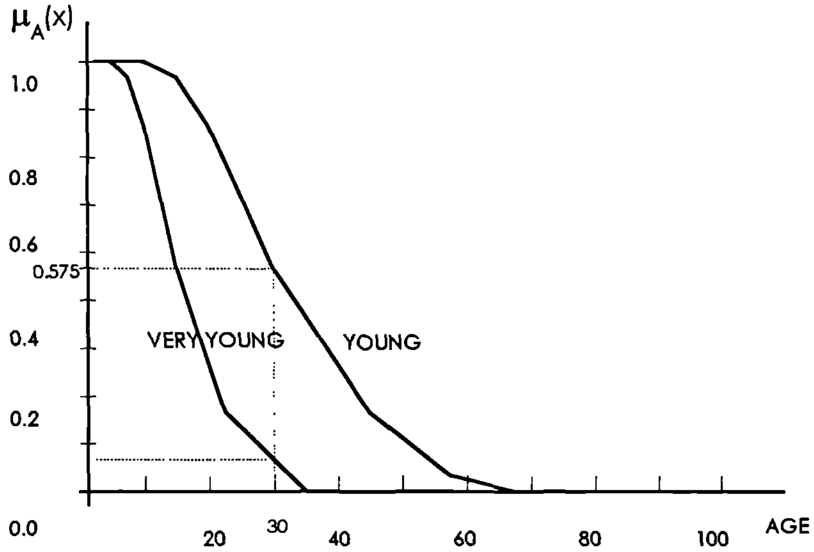
which connotes the name of a person and the meaning of the word young.

Assuming that the expected life of a human is up to 100 years, then the integers of universal set is from 0 to 100. Suppose membership function and the truth value of this proposition are given in <FIGURE 6-2> and <FIGURE 6-3> respectively. Examples of some possible truth claims are:

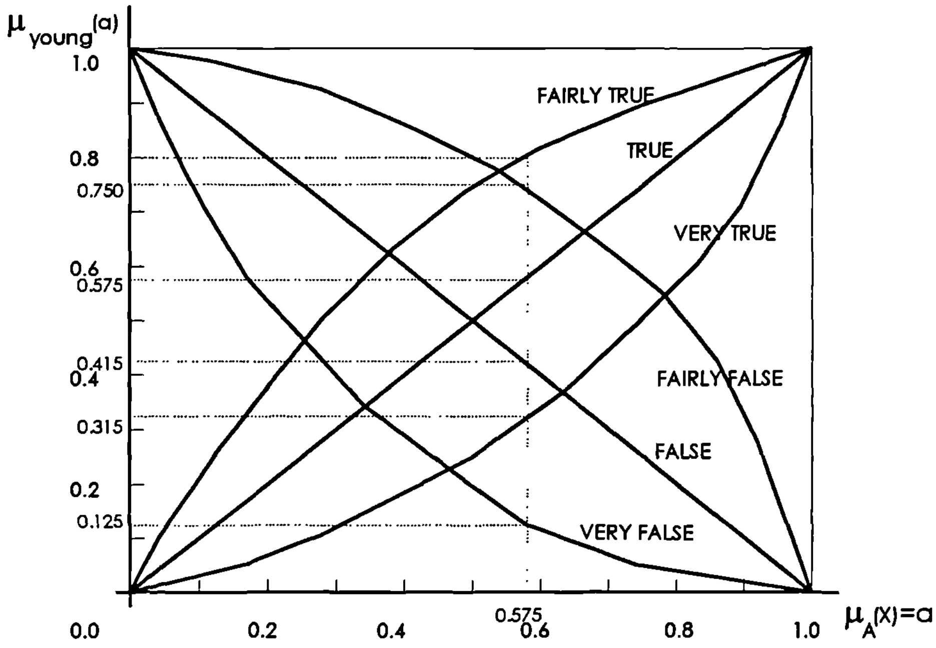
	very true (VT)
	true (T)
Park is young is	fairly true (FT)
	fairly false (FF)
	false (F)
	very false (VF)

Each of the possible truth claims can be presented by a fuzzy set, that is defined on the interval [0,1].

If PARK is 30 years old, $a = \mu_A(30)$, we obtain $\mu_A(30) = 0.575$ and the truth values $\mu_{young}(0.575)$ are; 0.800(FT), 0.575(T), 0.315(VT), 0.750(FF), 0.415(F), and 0.125(VF) respectively.



<FIGURE 6-2> THE MEMBERSHIP GRADE OF THE LINGUISTIC VARIABLE



<FIGURE 6-3> TRUTH VALUES OF A FUZZY PROPOSITION

6-2.3.4.3 Approximate Reasoning

Approximate reasoning is based on fuzzy logic and its idea is to extend the classical logic in order to relax the restriction that everything that can be contained about anything is either absolutely true, 1, or absolutely false, 0.

The original fuzzy inference mechanism extended the traditional modus ponens rule that is $(A \wedge (A \Rightarrow B)) \Rightarrow B$ or

Premise *Implication*	*A* is true If *A* then *B*
Conclusion	*B* is true

A and *B* are statements or propositions and the *B* in the conditional statement is identical to the *B* of the conclusion.[Zimmermann 1991:146]

In order to define the generalised modus ponens, the traditional modus ponens needs to allow statements or propositions that are characterised by fuzzy sets and to relax the identity of the statements "*B*" in the implication and the conclusion. For example, let *A*, *a*, *B*, *b* be fuzzy statements, then the generalised modus ponens reads

Premise *Implication*	*x* is *A* If *x* is *a* then *y* is *b*
Conclusion	*y* is *B*

For instance[Mizumoto *et al.* 1982:254]

Premise *Implication*	This tomato is *very red* If a tomato is *red* then the tomato is *ripe*
Conclusion	This tomato is *very ripe*

The above form of inference may be viewed as a generalised modus ponens which reduces to modus ponens when a is A and b is B.

Moreover, the following form of inference which also contains a fuzzy conditional proposition is possible[Mizumoto *et al.* 1982:254]

Premise *Implication*	y is b If x is A then y is B
Conclusion	x is a

This inference can be considered as a *generalised modus tollens* which leads to the *modus tollens* when b is not B and a is not A.

In the meantime some authors ([Baldwin 1979]; [Tsukamoto 1979]; [Baldwin *et al.* 1980]; [Mizumoto *et al.* 1982]; [Nafarieh *et al.* 1991]) have approached different methods and investigated also the modus ponens, modus tollens, as well as syllogism.

6-3 CONSTRUCTION OF THE MULTI-DECISION MODEL

6-3.1 Decision Functions

This section illustrates the basic knowledge and rules of the decision functions for the multi-decision model. It consists of the three main functions: appropriate rule, translation rule, and decision-making process.

6-3.1.1 Appropriate Rule

Assume $X = \{ X_1, X_2, ..., X_t \}$ is a set of the evaluation factor and this set is measured over the base set $U = \{U_1, U_2, ..., U_t\}$. Suppose the decision-making for the evaluation is taken from the decision criteria which are to evaluate the level of satisfaction to a valuation of the factors. These decisions are to be based on the linguistic evaluation.

Let d_i(i=1, 2, ..., I) be the a decision criteria which can include the possible linguistic variables in decision.

The selection of superstore, for example, can be based on major variables such as price, location, and variety of goods. Let X_1, X_2, and X_3 indicate the variable price, superstore location, and variety of goods respectively. Let customer satisfaction denote the variable Y which can measured on the interval V = [0,1]. Using the theory of approximate reasoning, we can represent the satisfaction for the selection of superstore as:

d_1: if price is low and location is good and variety of goods is high then customer satisfaction is very high,

d_2: if price is acceptable and location is tolerable and variety of goods is middle then the customer's satisfaction is moderate, and so on.

In general principles, each decision criteria ($d_1, d_2, ..., d_i$) can be put in the form

d_i: if $X_1 = A_{i1}$ and $X_2 = A_{i2}$,..., and $X_t = A_{it}$ and then $Y = B_i$.

where, A_{it} is a fuzzy subset of U_t the basic set of X_t (t = 1, 2, 3, .., T) and B_i is a fuzzy subset of the unit interval V = [0,1].

The construction of a decision function as an appropriate rule is based upon the above general principle. Assume that each of the linguistic variables or factors, X_1, X_2,..., X_t is measured over the base sets, U_1, U_2,..., U_t. The evaluation linguistic variable, A_{it}, is a fuzzy subset of the base set U_t (t = 1, 2, 3, .., T). Let $X = (X_1, X_2, ..., X_t)$ denote the evaluation factors or linguistic variables and $U = U_1 \times U_2 \times ... \times U_t$ the decision criteria

d_i: if $X = A_t$ then $Y = B_i$,

where, A_{it} is a fuzzy subset of U such that for each $u = (u_1, u_2, ..., u_t) \in U$,

$A_{it}(u) = \min [A_{i1}(u_1), A_{i2}(u_2), ..., A_{it}(u_t)]$

and $B_i(v)$ is a fuzzy subset of the unit interval $v = (v_1, v_2, ..., v_i) \in V = [0,1]$.

If d_i is defined as

"d_i: if $X_1 = A_{i1}$ and $X_2 = A_{i2}$ or $X_3 = A_{i3}$ and $X_t = A_{it}$ and then $Y = B_i$"

where, A_{it} is a fuzzy subset of U_t such that for each $u = (u_1, u_2, ..., u_t) \in U$.

The membership function of the fuzzy interference d_i can be defined as

if $A_{it}(u) = \min [A_{i1}(u_1),\ \max [A_{i2}(u_2), A_{i3}(u_3)], A_{it}(u_t)]$ then $Y = B_i(v)$,

where, $B_i(v)$ is a fuzzy subset of the unit interval $V = [0,1]$.

6-3.1.2 Translation Rule

The "if ... then ..." rule with fuzzy predicates is a popular type of fuzzy statement and its modelling is often based on the use of multi-valued implications. Namely an elementary rule of the form "If X is A ($x \in A$) then Y is B ($y \in Y$)" corresponds to a possibility distribution of the form

$$\pi_{x,y}(u, v) = \mu_{A \to B}(u, v) = R [\mu_A(u), \mu_B(v)]$$

where, I is an implication in a multiple-valued logic[Zadeh 1973a]. $\mu_A(u)$ and $\mu_B(v)$ are the membership of u in A and v in B, respectively. A and B are fuzzy subsets of U and V, and u and v are typical elements of the respective universes of discourse.

Many researches have performed theoretical investigation into the characteristics of various implication operators. One of the update studies has been done by Dubois and Prade[1991]. They classified the most usually found implication operations that belong to the three basic classes; S, R, and QL-implication. These are based on the classical view of implication; $p \to q$ is defined as $\neg p \vee q$. From an axiomatic point of view, ten properties of implication, that have been almost universally adopted, have been requested for a 2-place operation[Dubois *et al.* 1991:156].

According to this investigation, Lukasiewicz's implication has clearly shown the most numerous properties among the selected implications. That means it is the strongest fuzzy multi-valued implication. <TABLE 6-1> shows the different implication operators in fuzzy logic.

Nafarieh and Keller's investigation[1991] also provides significant information for the fuzzy implication operators. They introduced a novel approach to inference in approximate reasoning based upon truth value restriction and compared the output of fuzzy inference based on the ten existing implication operators listed in <TABLE 6-2> under several intuitive criteria both theoretically and through simulation experiments. Three simulations were run under a variety of conditions.

According to the results of the simulations, operators 6 and 7 in <TABLE 6-2> are comparatively satisfactory all the concerned relations. This means these operators have performed fairly well with lower error rates among the ten fuzzy implication operators. Operators 6 and 7 were proposed by Mizumoto, Fukami, and Tanaka[1979].

Mizumoto and Zimmermann[1982] dealt with the properties of 15 fuzzy relations in case of *'generalised modus tollens'* and investigated the existing as well as new fuzzy reasoning methods obtained by introducing the implication rules of many valued logic systems. From the results of investigation, they concluded that some fuzzy relations were suitable methods as shown in <TABLE 6-3>. The operators 6 and 7 in <TABLE 6-2> belong to the suitable methods group as fuzzy reasoning.

From these significant investigations, Lukasiewicz and Muzimoto's operator can be considered for the fuzzy implications. Both are superior to the existing methods in terms of the fuzzy interference. However, Lukasiewicz's operator is rather more specified property than the other even though it allows slightly higher error rates for implication. In this research, therefore, Lukasiewicz's operator has adopted as a translation rule for implication of a fuzzy proposition. This is not perfectly elucidated for the real situations but it is an up-to-date rule.

<TABLE 6-1> MULTIPLE-VALUED IMPLICATIONS $R\,[\,\mu_A(u),\ \mu_B(v)\,]$

NAME	FORMULA FOR $R\,[\,\mu_A(u),\ \mu_B(v)\,]$ IN THE INTERPRETATION OF "$X = A_t$ then $Y = B_i$"
Gaines-Rescher	$\begin{cases} 1 & \text{if } \mu_A(u) \le \mu_B(v) \\ 0 & \text{if } \mu_A(u) > \mu_B(v) \end{cases}$
Goguen	$\begin{cases} 1 & \text{if } \mu_A(u) = 0 \\ \max[1,\ \mu_B(v)/\mu_A(u)] & \text{if } \mu_A(u) \ne 0 \end{cases}$
Gödel	$\begin{cases} 1 & \text{if } \mu_A(u) \le \mu_B(v) \\ \mu_B(v) & \text{if } \mu_A(u) > \mu_B(v) \end{cases}$
Kleene-Dienes	$\max\,[1\text{-}\mu_A(u),\ \mu_B(v)]$
Lukasiewicz	$\min\,[1\text{-}\mu_A(u) + \mu_B(v)]$
Reichenbach	$1\text{-}\mu_A(u) + \mu_A(u)\mu_B(v)]$
Willmott	$\min\,[\,\max\,(1 - \mu_A(u),\ \mu_B(v)\,),$ $\max\,[\,\mu_A(u),\ 1 - \mu_B(v),\ \min(\mu_B(v),\ 1 - \mu_A(u))\,]\,]$
Yager	$\mu_B(v)^{\mu_A(u)}$
Zadeh	$\max\,[1\text{-}\mu_A(u),\ \min(\mu_A(u),\ \mu_B(v))\,]$

<TABLE 6-2> CROSS-REFERENCE TO INFERENCE OPERATORS

OPERATOR	FORMULA FOR $R[\mu_A(u), \mu_B(v)]$ IN THE INTERPRETATION OF "$X=A_t$ then $Y=B_i$"
CLASS 1	
1	$[\mu_A(u) \wedge \mu_B(v)]\,[1-\mu_A(u)]$
2	$[1-\mu_A(u)] \vee \mu_B(v)]$
3	$[\mu_A(u) \wedge \mu_B(v)]\,([1-\mu_A(u)] \wedge [1-\mu_B(v)])\,([1-\mu_A(u)] \wedge \mu_B(v))$
4	$\mu_A(u) \wedge \mu_B(v)$
CLASS 2	
5	$1 \wedge ([1-\mu_A(u)] \wedge \mu_B(v))$
CLASS 3	
6	$\begin{cases} 1 & \text{if } \mu_A(u) \le \mu_B(v) \\ \mu_B(v) & \text{if } \mu_A(u) > \mu_B(v) \end{cases}$
7	$\begin{cases} 1 & \text{if } \mu_A(u) \le \mu_B(v) \\ 0 & \text{if } \mu_A(u) > \mu_B(v) \end{cases}$
8	$\begin{cases} 1 & \text{if } \mu_A(u) < 1 \text{ or } \mu_B(v) = 1 \\ 0 & \text{if } \mu_A(u) = 1 \text{ and } \mu_B(v) < \end{cases}$
CLASS 4	
9	$\begin{cases} 1 & \text{if } \mu_A(u) \le \mu_B(v) \\ 1-\mu_A(u)+\mu_B(v) & \text{if } \mu_A(u) > \mu_B(v) \end{cases}$
CLASS 5	
10	$[1-\mu_A(u)] + \mu_A(u)\mu_B(v)$

<TABLE 6-3> FUZZY RELATION IMPLICATIONS $R\,[\,\mu_A(u),\, \mu_B(v)\,]$

FUZZY RELATIONS	FORMULA FOR $R[\mu_A(u), \mu_B(v)]$ IN THE INTERPRETATION OF "X=A_t then Y=B_j"
Rs	$\mu_A(u) \xrightarrow[s]{} \mu_B(v) = \begin{cases} 1 & \text{if } \mu_A(u) \le \mu_B(v) \\ 0 & \text{if } \mu_A(u) > \mu_B(v) \end{cases}$
Rg	$\mu_A(u) \xrightarrow[g]{} \mu_B(v) = \begin{cases} 1 & \text{if } \mu_A(u) \le \mu_B(v) \\ \mu_B(v) & \text{if } \mu_A(u) > \mu_B(v) \end{cases}$
Rsg	$\mu_A(u) \xrightarrow[s]{} \mu_B(v)] \wedge [1-\mu_A(u) \xrightarrow[g]{} 1-\mu_B(v)]$
Rgg	$\mu_A(u) \xrightarrow[g]{} \mu_B(v)] \wedge [1-\mu_A(u) \xrightarrow[g]{} 1-\mu_B(v)]$
Rgs	$\mu_A(u) \xrightarrow[g]{} \mu_B(v)] \wedge [1-\mu_A(u) \xrightarrow[s]{} 1-\mu_B(v)]$
Rss	$\mu_A(u) \xrightarrow[s]{} \mu_B(v)] \wedge [1-\mu_A(u) \xrightarrow[s]{} 1-\mu_B(v)]$

Assume that each of the linguistic variables X_i (i = 1, 2, ..., t) is measured over the base set U_t (t = 1, 2, ...T). Let a fuzzy set $U = U_1 \times U_2 \times ... \times U_t$ for each $u = (u_1, u_2, ..., u_t) \in U$ then give a fuzzy implicational proposition

d_i: if $X = A_{it}$ then $Y = B_i$,

where, A_{it} is a fuzzy subset of U and B_i is a fuzzy subset of the unit interval V = [0,1]. This implicational proposition can be translated into a fuzzy subset R of $U \times V$:

$$R\,[\,\mu_A(u), \mu_B(v)\,] = 1 \wedge [\,1-\mu_A(u) + \mu_B(v)\,]$$
$$= \min [\,1, 1-\mu_A(u) + \mu_B(v)\,] \cdots\cdots \textit{(Lukasiewicz's operator)}$$

6-3.1.3 Rule of Decision-making Process

In this section we consider the aspect of decision-making from the point of view of fuzzy relation equation.

Let a fuzzy set $U = U_1 \times U_2 \times \ldots \times U_t$ for each $u = (u_1, u_2, \ldots, u_t) \in U$ and V is the unit interval [0,1]. Denoting the overall decision is 'optimal' in a certain sense, if it simultaneously satisfies all of the constraints as much as possible.

In the simplest case, if all of the implications $R_1, R_2, .., R_s$ are defined in the space $U \times V$, the decision D results as 'intersection' of all of the implications:

$$D = (R_1 \cap R_2 \cap \ldots \cap R_s).$$

The conjunction(or anding) of fuzzy subsets is equivalent to the intersection of the conjunct components. In the pioneering work of Bellmann and Zadeh[1970], the intersection is modelled by the minimised operator "$\wedge$". Hence, the membership function D reads as follows:

$$D(u,v) = \bigwedge_{i=1}^{t} R_i(u,v), \qquad \text{for each } (u,v) \in U \times V.$$

A decision function D is a fuzzy relationship which connects the satisfaction of the decision maker.

6-3.1.4 Evaluation for Options' Satisfaction

In order to evaluate the satisfaction associated with a particular option or choice, the rule of fuzzy compositional inference is considered. Suppose $X = \{ X_1, X_2, \ldots, X_t \}$ is a set of the linguistic variable and this set is measured over the base set $U = \{ U_1, U_2, \ldots, U_t \}$ respectively. Let $H = \{ H_1, H_2, \ldots, H_t \}$ is a fuzzy subset of the base set U which indicates the value of the option for each linguistic variable. Let G denote as follows:

$$G = (X_1 = H_1 \text{ and } X_2 = H_2 \ldots X_t = H_t)$$

where, G is a fuzzy subset of U for each $u = (u_1, u_2, ..., u_t) \in U$.

According to the appropriate rule, the membership function $G(u)$ can be calculated as

$$G(u) = \min [\, H_1(u_1), H_2(u_2), ..., H_t(u_t) \,], \quad \text{where } u_t \in U_t,\ t = 1, 2, ..., T.$$

The satisfaction S is associated with a fuzzy subset G and a decision D. The satisfaction S can be described by "fuzzy relation equations" as the rule of compositional inference. Depending upon fuzzy relation equations, the satisfaction S can be defined as

$$S = G \circ D$$

where, the operator "∘" denotes the max-min composition. Therefore, the membership function $S(v)$ can be defined as

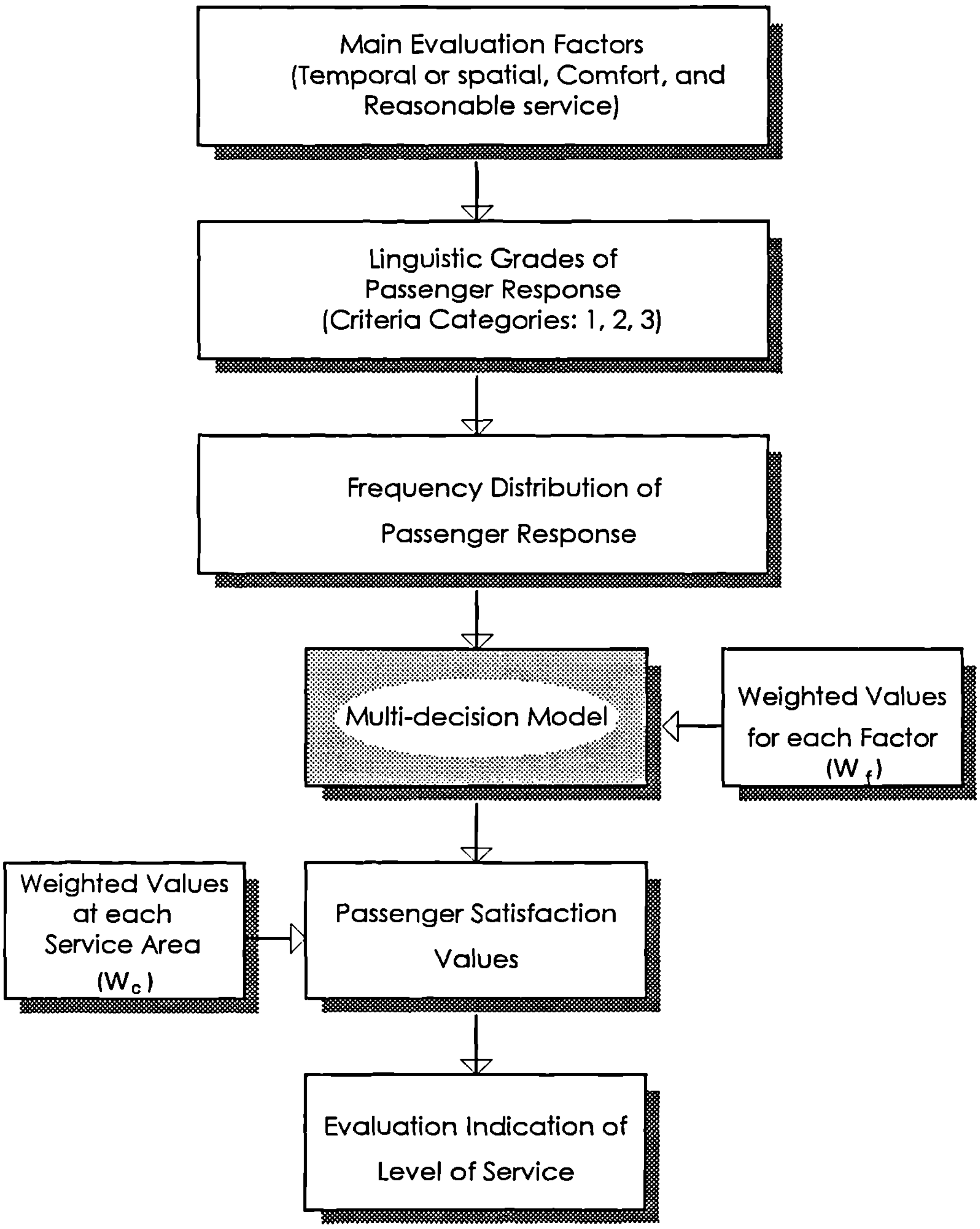
$$S(v) = \max_{u \in U} [\, \min (G(u), D(u, v)) \,] \qquad \text{for each } v \in V.$$

S is a fuzzy subset of the unit interval $V = [0,1]$.

6-3.2 The Heuristic Algorithm for Evaluation of the Level of Service in the Airport Landside System

A heuristic algorithm is presented here based on the use of fuzzy mathematics to use the process of the evaluation for the airport landside system in terms of level of service.

Overall evaluation procedure for level of service in the airport landside system follows the steps of: selection of the main evaluation factors, linguistic grades of passenger satisfaction, the weighted value of each airport service area and service factor, construction of multi-decision function, and selection of best service area in terms of passenger satisfaction values.(FIGURE 6-4)



<FIGURE 6-4> DIAGRAM OF THE EVALUATION PROCEDURE FOR LEVEL OF SERVICE IN THE AIRPORT LANDSIDE SYSTEM

6-3.2.1 Step One: Factors, Service Criteria, and Service Facility

In applying a fuzzy algorithm approach to the evaluation of level of service for an airport landside system, three main factors have been selected in section 5-3, these are temporal or spatial, comfort, and reasonable service factors. The factors are represented by

$$F_e = \{ f_k \}, \quad k = 1, ..., K, \quad K = 3,$$

where,

f_1 is the temporal or spatial factor,
f_2 is the comfort factor, and
f_3 is the reasonable service factor.

Passengers' judgements, which mean the passengers' perceptions of the provision of service through an airport landside facility, were considered as the service level criteria in section 5-3.5. These were classified into three linguistic grades: criterion category 1 - positive or satisfactory in the passengers' judgement, criterion category 3 - negative or unsatisfactory in the passengers' response, and criterion category 2 - neutral or tolerably satisfactory in the passengers' perception.

The set of level of the service criteria is defined by

$$C_s = \{ c_l \}, \quad l = 1,...., L, \quad L = 3,$$

where,

- c_1 is the criterion *category 1*:positive or satisfactory; such linguistic variables as short, simple, kind, uncrowded, good, or low congestion,

- c_2 is the criterion *category 2*:neutral or tolerably satisfactory; such as bearable, acceptable, tolerable, or moderate, and

- c_3 is the criterion *category 3*:negative or unsatisfactory; such as long, complicated, unkind, crowded, bad, or high congestion.

This proposed research has been considered in regard to the service activity to departing passengers. A service activity area (component or facility) refers to the six different classes of passenger activity which are, (1) service processing, (2) holding area, (3) circulation, (4) airport access, (5) parking, and (6) other. Thus, the service area set is defined by

$$G_s = \{ G_m \}, \quad m = 1, \ldots, M, \quad M = 6,$$

where,

$G_1 = \{$ service processing areas $\}$,
$G_2 = \{$ holding areas $\}$,
$G_3 = \{$ circulation areas $\}$,
$G_4 = \{$ airport access $\}$,
$G_5 = \{$ car park area $\}$, and
$G_6 = \{$ other area$\}$.

Each service component belongs to different services which are such as

$$G_m = \{ g_n \}, \quad m = 1, 2, \ldots, M, M = 6, \qquad n = 1, 2, \ldots, N, N = 9.$$

Thus, the detailed service components are represented as follows:

- $G_1 = \{ g_n \}$, $n = 1, 2, 3$;
  g_1 is check-in and baggage drop,
  g_2 is security screening, and
  g_3 is passport control,

- $G_2 = \{ g_n \}$, $n = 4$;
  g_4 is waiting area,

- $G_3 = \{ g_n \}$, $n = 5, 6$;
  g_5 is intra terminal circulation, and
  g_6 is kerb circulation,

- $G_4 = \{ g_n \}$, $n = 7$;
  g_7 is ground access to airport,

- $G_5 = \{ g_n \}$, $n = 8$;
  g_8 is car parking, and

- $G_6 = \{ g_n \}$, $n = 9$;
  g_9 is concession.

Each service component, g_n, is a fuzzy mapping from F_e to C_s, $f: F_e \to C_s$, and the fuzzy mapping f implies a fuzzy relation which can be represented by a fuzzy decision matrix

$$Z_n \in \mathbf{M}_{K \times L}, \quad n = 1, 2, \ldots, N, N = 9, K = 1, 2, 3, \quad L = 1, 2, 3.$$

According to the above considerations, the basic statistic data from a direct questionnaire survey at an airport can be seen in <TABLE 6-4>.

<TABLE 6-4> THE STATISTICS FOR THE LEVEL OF SERVICE IN AN AIRPORT LANDSIDE SYSTEM

SERVICE AREA G_m={g_n}		FACTORS(F_e) f_1			f_2			f_3		
		SERVICE CRITERIA c1	c2	c3	c1	c2	c3	c1	c2	c3
G_1	g_1	p_{111}	p_{112}	p_{113}	p_{121}	p_{122}	p_{123}	p_{131}	p_{132}	p_{133}
	g_2	p_{211}	p_{212}	p_{213}	p_{221}	p_{222}	p_{223}	p_{231}	p_{232}	p_{233}
	g_3	p_{311}	p_{312}	p_{313}	p_{321}	p_{322}	p_{323}	p_{331}	p_{332}	p_{333}
G_2	g_4	p_{411}	p_{412}	p_{413}	p_{421}	p_{422}	p_{423}	p_{431}	p_{432}	p_{433}
G_3	g_5	p_{511}	p_{512}	p_{513}	p_{521}	p_{522}	p_{523}	p_{531}	p_{532}	p_{533}
	g_6	p_{611}	p_{612}	p_{613}	p_{621}	p_{622}	p_{623}	p_{631}	p_{632}	p_{633}
G_4	g_7	p_{711}	p_{712}	p_{713}	p_{721}	p_{722}	p_{723}	p_{731}	p_{732}	p_{733}
G_5	g_8	p_{811}	p_{812}	p_{813}	p_{821}	p_{822}	p_{823}	p_{831}	p_{832}	p_{833}
G_6	g_9	p_{911}	p_{912}	p_{913}	p_{921}	p_{922}	p_{923}	p_{931}	p_{932}	p_{933}

6-3.2.2 Step Two: Weighting Values

Using Z_n as an input of the multi-decision model, a weighting value will be considered as an input parameter. Because the reliability and objectivity of evaluation can be enhanced by using the weighting values of each evaluation input parameter such as factors, variables, and components. The weighting values for this multi-decision model classify into two classes: component weighting value(W_c) for an airport landside system and factor weighting value(W_f) for evaluating factors for level of service at an airport.

Both of these weighting values can be taken by a direct questionnaire and interview of airport experts. These cover airport planners, operators, designers, managers, and airport consultants as well as a survey from the passengers' point of view. Depending upon the view points, the weighting values can be given in different ways.

The factor weighting values, W_f, are given by

$$W_f = w_{nk}^f \in \mathbf{M}_{N\times K}\ , \qquad n = 1, 2, ..., N,\ N = 9, \qquad k = 1, .., K,\ K = 3\ .$$

Also the component weight values, W_c, are given by

$$W_c = w_n^c \in \mathbf{M}_{N\times 1}\ , \qquad n = 1, 2, ..., N,\ N = 9\ .$$

Where W_f and W_c are a fuzzy subset in the factor set F_e and a fuzzy set in the service area set G_s respectively. These subsets can be represented by a fuzzy vector w_{nk}^f and w_n^c .

Now, we can get a fuzzy decision matrix $\widetilde{Z}_n$ which is considered by the factor weighting values(W_f). That can be represented by

$$\widetilde{Z}_n = W_f \cdot Z_n \in \mathbf{M}_{K\times L}\ ,$$

where, $n = 1, 2, ..., N,\ N = 9,\ K = 3,$ and $L = 3$.

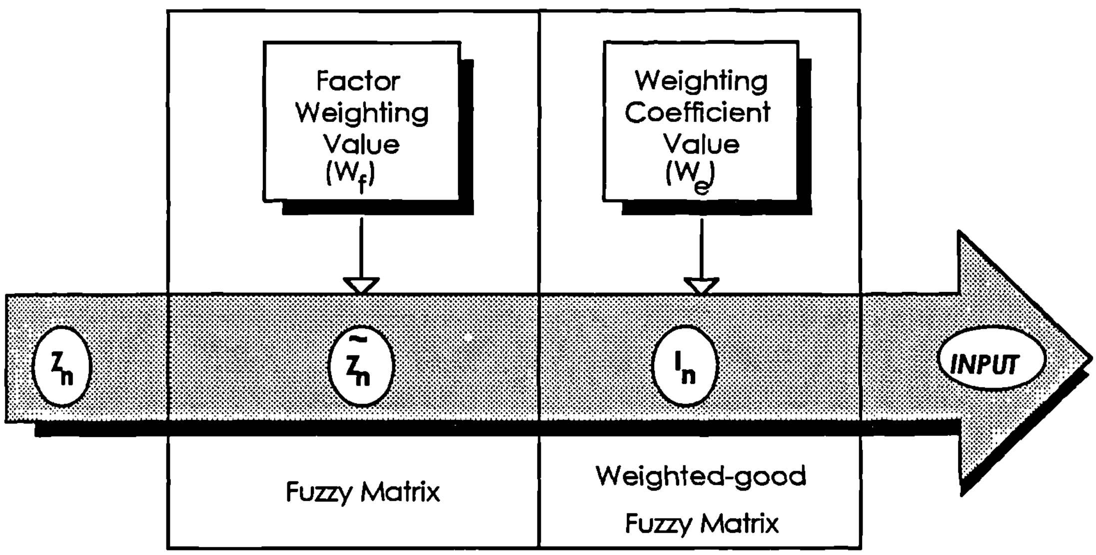
To use $\widetilde{Z}_n$ as an input of the multi-decision model, the weighting coefficient of the evaluation is needed to translate to "good" level consideration. Because the multi-decision model will be defined by 'good' and 'bad' linguistic criteria. Thus, the weighting coefficients of the evaluation criteria are assumed to be:

$$W_e = (\ w^e_{\text{criterion 1}},\ w^e_{\text{criterion 2}},\ w^e_{\text{criterion 3}}) \in \mathbf{M}_{1\times L}\ , \quad L = 1, 2, 3\ .$$

Finally, an input for the multi-decision model, which is called the *weighted-good* matrix can be defined as

$$I_n = W_e \cdot \widetilde{Z}_n \in \mathbf{M}_{N \times K},$$

where, I_n is the weighted-good fuzzy matrix, n = 1, 2, ..., N, N = 9, and K = 3. The calculation process of input is shown in <FIGURE 6-5>.



<FIGURE 6-5> THE PRODUCTION PROCESS OF INPUT FOR MULTI-DECISION MODEL

The membership function of I_n is defined by

$$\mu_{I_n}(F_e) = \left(\sum_{f_i \in F_e} [\mu_{\tilde{Z}_n}(f_i, G_s) \cdot \mu_{W_e}(C_s)] \right),$$

where, $\mu_{\tilde{Z}_n}(f_i, G_s)$ is the membership function of $W_f \cdot Z_n$, and
$\mu_{W_e}(C_s)$ is the membership function of W_e.

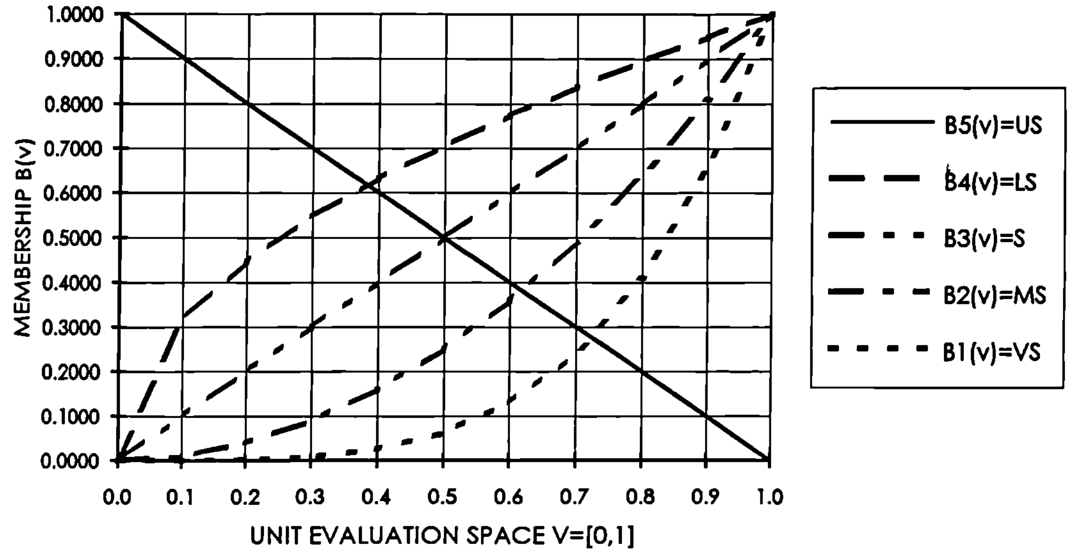
6-3.2.3 Step Three: Decision Criteria

The decision criteria set B can be built up based on the three given evaluating factors which are temporal & spatial factor(f_1), comfort factor(f_2), and reasonable service factor(f_3). In the above section, an input for the multi-decision has been translated to the weighed-good values, so the input can be represented by two linguistic evaluation categories, good(A) and bad($\overline{A} = 1 - A$).

Classification of the multi-decision criteria divides into five linguistic variables which are based on the satisfactory terminology. They are: {*very satisfactory, more satisfactory, satisfactory, less satisfactory, unsatisfactory*}. They have also been considered by the linguistic hedge. Let $B(v)$ be the multi-decision criteria function, it can be defined by the satisfaction variable B on the set $V = \{v | 0 \leq v \leq 1\} = \{0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0\}$, where V is the unit evaluation space. Each satisfactory variable can be defined as follows:

- Very satisfactory $B_1(v) = v^4$,
- More satisfactory $B_2(v) = v^2$,
- Satisfactory $B_3(v) = v$,
- Less satisfactory $B_4(v) = v^{0.5}$, and
- Unsatisfactory $B_5(v)=1-v$.

<FIGURE 6-6> shows the multi-decision criteria functions for six linguistic variables.



<FIGURE 6-6> THE MULTI-DECISION CRITERIA FUNCTIONS

6-3.2.4 Step Four: Multi-decision Criteria

The multi-decision set D can be defined by the appropriate rule (SECTION 6-3.1.1) in order to evaluate level of service for an airport landside system. According to this rule, the multi-decision for level of service evaluation is defined by five decisions. Thus, D can be represented by

$$D = \{ d_i \}, \quad i = 1, 2, ..., I, \ I = 5 ,$$

where,

- d_1: If all factors are good then it is considered *very satisfactory*.

- d_2: If temporal (or spatial) factor and comfort or reasonable service factor is good then it is considered *more satisfactory*.

- d_3: If comfort and reasonable service factor are good then it is considered *satisfactory*.

- d_4: If temporal (or spatial) factor is good and reasonable service factor is bad then it is considered *less satisfactory*.

- d_5: If temporal (or spatial) factor is bad and comfort or reasonable factor is bad then it is considered *unsatisfactory*.

The evaluation factors- X_1 is temporal or spatial factor, X_2 is comfort factor, and X_3 is reasonable service factor- are measured over the base sets, U_1, U_2, and U_3. The evaluation linguistic variable, A_{it}, is a weighted good variable at a multi-decision i (i = 1, 2, ..., I, I = 5) and for an evaluation factor t (t = 1, 2, 3). Hence, a weighted bad variable at a multi-decision i and for an evaluation factor t can be defined as $\bar{A}_{it} = 1 - A_{it}$. A_{it} is a fuzzy subset of the base sets U_1, U_2, and U_3. Finally, the multi-decision d_i can be represented by

If	$d_1 = f_1 \cap f_2 \cap f_3$	then	$Y = B_1(v)$: *Very Satisfactory*(VS)
If	$d_2 = f_1 \cap \{f_2 \cup f_3\}$	then	$Y = B_2(v)$: *More Satisfactory*(MS)
If	$d_3 = f_2 \cap f_3$	then	$Y = B_3(v)$: *Satisfactory*(S)
If	$d_4 = f_1 \cap \bar{f}_3$	then	$Y = B_4(v)$: *Less satisfactory*(LS)
If	$d_5 = \bar{f}_1 \cap \{\bar{f}_2 \cup \bar{f}_3\}$	then	$Y = B_5(v)$: *Unsatisfactory*(US)

According to the above decision criteria, we can get a fuzzy mapping $f: D \to G$, which can be described by a fuzzy matrix

$$R = (\tilde{d}_1 \;\; \tilde{d}_2 \;\; \tilde{d}_3 \; ..... \; \tilde{d}_I)^{\mathrm{I}} \in \mathbf{M}_{N \times I}, \qquad N = 9,\; I = 5.$$

Then we can use the following fuzzy reasoning of likelihood

- d_1: if $X = \tilde{d}_1$ then $Y =$ VS,
- d_2: if $X = \tilde{d}_2$ then $Y =$ MS,
- d_3: if $X = \tilde{d}_3$ then $Y =$ S,
- d_4: if $X = \tilde{d}_4$ then $Y =$ LS, and
- d_5: if $X = \tilde{d}_5$ then $Y =$ US.

These above implicational propositions can be translated into a fuzzy subset $d_i(u,v)$ which can be represented by the translation rule:

$$\begin{aligned} d_i(u,v) &= 1 \wedge [\, 1 - A_t(u) + B_i(v) \,] \\ &= \text{Min}\, [\, 1,\, 1 - A_t(u) + B_i(v) \,], \qquad t = 1, 2, 3, \qquad i = 1, 2,..., 5, \end{aligned}$$

where, $d_i(u,v)$ is the membership function of $(u,v) \in U \times V$ in the fuzzy subset D and symbol "$\wedge$" is the minimised operator.

6-3.2.5 Step Five: Decision-making

According to rule of decision-making process(SECTION 6-3.1.3), the fuzzy multi-decision matrix can be determined. From a fuzzy mapping from G to V, $f: G \rightarrow V$, where G is the airport service area or facility and V is the unit evaluation space [0,1], which can be represented by a fuzzy matrix;

$$D(u,v) = \bigwedge_{i=1}^{5} d_i(u,v) \in \mathbf{M}_{N \times V}, \qquad N = 9,\; V = 11,$$

where,

$$\begin{aligned} d_i(u,v) &= 1 \wedge [\, 1 - \mu_A(u) + \mu_B(v) \,] \\ &= \text{Min}\, [\, 1,\, 1 - \mu_A(u) + \mu_B(v) \,], \end{aligned}$$

To evaluate the satisfaction associated with each airport component, we apply the rule of fuzzy compositional inference

$$S = G \circ D,$$

where, S is satisfaction associated with the airport component, G is a fuzzy set of the description of the airport component, and D is the multi-decision function. Hence, the membership function of $S_n(v)$ can be defined by the rule of fuzzy compositional inference:

$$S_n(v) = \max_{u \in U} [\, G_n(u) \wedge D_n(u,v) \,], \qquad \text{for each } v \in V.$$

In this case $U = G\{ g_1, g_2, ..., g_n\}$, $n = 1, 2, ..., N$, $N = 9$ the set of the airport service facilities. When describing the characteristics of the airport service facilities over G then the fact that we are interested in evaluating the satisfaction to an arbitrary facility $g_n \in U$. We can represent G as a fuzzy subset of U as follows:

$$G_n(u) = 0 \qquad u \neq g_n,$$
$$G_n(u) = 1 \qquad u = g_n.$$

In this research, the fuzzy multi-criteria decision matrix concerned the case of $G_n(u)$=1. This way will avoid losing too much information and the model of fuzzy multi-criteria decision comes nearer to the perfect.[Feng 1990] The membership function $S(v) = D(u_n,v)$ can be determined by a fuzzy multi-criteria decision matrix

$$S_n(v) = D(u_n,v) \cong \bigcap_{i=1}^{5} d_i(u_n,v) = \begin{pmatrix} \widetilde{E}_1 \\ \widetilde{E}_2 \\ \cdot \\ \widetilde{E}_n \end{pmatrix}^I \in \mathbf{M}_{N \times V}, \; N = 9, \; V = 11.$$

Each $S_1, S_2, ..., S_9$ is a fuzzy subset of unit interval V=[0,1]. $\widetilde{E}_n$ is a fuzzy subset of the unit evaluation space V, which represents the extent of the satisfaction for the airport service facility $g_n \in G$. The fuzzy multi-criteria decision matrix indicates the satisfaction associated with each airport component. In this case, the satisfaction value for level of service at each airport landside component can calculate through "*the point value*"[Yager 1982].

Assume $E_{n\alpha}$ is the α level set of $\widetilde{E}_n$, $\alpha \in V = [0,1]$. It should be noted that the sets $E_{n\alpha}$ are ordinary subsets of the unit interval $V = [0,1]$. If the α level set $E_{n\alpha}$ is

$$E_{n\alpha} = \{\alpha | \alpha_{v-1} \le \alpha \le \alpha_v\} \in \{\alpha | \alpha_0 \le \alpha_1 \le \alpha_2 \le ... \le \alpha_{v-1} \le \alpha_v\}, \quad \alpha_0 = 0, \ \alpha_v = 1,$$

where, the mean value of it, $M(E_{n\alpha})$, can be calculated as

$$M(E_{n\alpha}) = \sum_{v=1}^{V} \frac{\frac{\alpha_v - \alpha_{v-1}}{N_\alpha} \cdot (\alpha_v - \alpha_{v-1})}{\sum_{v=1}^{V} (\alpha_v - \alpha_{v-1})}.$$

The point value for each $E_{n\alpha}$ can be defined as

$$P(E_n) = \frac{1}{\alpha_{\max}} \int_{v=1}^{V} M(E_{n\alpha}) d\alpha,$$

where, α_{max} is the maximum membership grade E_n.

This point value, $P(E_n)$, for each fuzzy subset E_n is the ***satisfaction value*** for each airport service facility $g_n \in G$. Therefore, the bigger $P(E_n)$ means the higher the level of service at an airport service facility or component.

Let $P_{max}(E)$ be an ideal maximum satisfaction value. It can be determined by a unique input condition when passenger's responses are all the highest grade of the questions. This ideal condition represents the passenger's perfect satisfaction for the provision service. The differences between $P_{max}(E)$ and $P(E_n)$ can be defined as *unsatisfied distance*(U_d):

$$U_d(n) = P_{max}(E) - P(E_n) .$$

That is a useful indicator of service evaluation for the practical airport operation and management in order to improve the level of service based on each facility. If a U_d is relatively high, it means the level of performed service is low. On the other hand, if it is low then the level of provided service is relatively high. Therefore, airport operators and managers' interest must be concentrated on the lower level of service if they want to provide better service and rise to the user's maximum satisfaction through the required services.

6-3.2.6 Step Six: Indication of Evaluation

The satisfaction values for an airport service facility represent the measure of the provision of service to the passengers. These have implicated the weighting values of the evaluation factors as input parameters to elevate the reliability of the evaluation. Different degrees of importance from various view points for the chosen factors should exist in evaluating the level of service. Hence, the factor weighted values provide a good input parameter to bring a more accurate output for the real situation.

Furthermore, an area of service activity possesses a different degree of importance for the service performance. This can be defined by the characteristics of each service area as they affect the level of service. In this research, this has been drawn from the expert's point of view. The *weighted-unsatisfactory distance*(WU_d) can be defined as:

$$WU_d(n) = [\, P_{\max}(E) - P(E_n) \,] \times Wc(n)\,,$$

where,

$P_{\max}(E)$ is the ideal maximum satisfaction value(IMSV),
$P(E_n)$ is an evaluated satisfaction value(ESV) of service facility n, and
$Wc(n)$ is a facility or component(n) weighting value.

The weighted-satisfactory values or weighted-unsatisfactory distances have considered a weighting of each service facility regarding degree of importance as well as the level of service. From the view point of airport operation and management, it should deal with a useful information to elevate and enhance the services at an airport. Practically, the weighted-unsatisfactory distances can be used as a performance indicator for the service level evaluation.

6-4 CONCLUSION

A fuzzy set theory approach to evaluate a method for the level of service when considering the provision of a service to its users, e.g. passengers, in an airport landside system has been outlined. This approach helps us to comprehend better the concepts of the linguistic variables. A multi-decision model is more flexible and is more adaptable to the level of service in an airport service component or facility. Hence, it makes us better equipped for dealing with an airport service component especially in the landside system. So to evaluate level of service from the passenger's point of view that is centred on the passenger's perceptions of the provision of service at each service facility. The application of the fuzzy theory especially the fuzzy multi-decision model on the level of service is more in accordance with the decision-making process of airport managers, operators, and planners.

CHAPTER 7

INFORMATION REQUIREMENTS

7-1 INTRODUCTION

The collection of the information brings us up against difficulties, the intention being to implement a methodology corresponding to the objectives of a specific study. The required information for the specified objectives or goals is widely diverse in nature and therefore varies in methods of collection. The multiformity of information derives from the uniqueness and sensitivity of the airport system characteristics. The airport subsystems are involved in different ways, performing various activities of the system's operation. All those activities must be synchronised and performed in conformity with each other in order to reach a high standard level of service for the passengers. The prime role of an airport system is to provide high service level standards for the satisfaction of the majority of passengers.

7-2 INFORMATION IN THE AIRPORTS

Information in an airport and its related systems can be generated from their own operational and technical characteristics as well as traffic flow and demand pattern characteristics. These information resources are very varied and include such sources as government agencies, airlines, airport authorities, and others. The primary sources of data for the airports are the statistics supplied to the government agencies. In general, however, the supply to the government is voluntary. There are some agreements or regulations between the government and airport-related agencies which are necessarily required to make the information more useful and available to access by the various users.

7-2.1 General Types of Information

The Federal Aviation Administration(FAA) has taken significant steps toward building internal computer information management systems to provide readily available data for the activities of the associate administrators.[Carey 1990:12] This system represents the general types of airport information. The types of air transport information categories and these data systems are as follows[FAA 1985]:

- o *Airport Information*: Airport pavement analysis; Airport program management; Bird hazards system; Airport capacity modelling; National plan for integrated airports; Development and analysis statistical specifications; Runway friction measurements program; Airport improvements program; Regional grants management system; Airports information inquiry and reporting system; Airport capacity enhancement reports; and Domestic and terminal area traffic forecasts.

- o *Air Traffic Control(ATC) and Airspace*: Aeronautical information system; Air traffic problem analysis system; Air traffic planning requirements analysis; Air traffic density analysis system; Obstruction, evaluation, and airport airspace analysis; Air traffic publication and research system; ATC information retrieval system; Air traffic count system; and Air traffic field facility summary.

- *Aviation Activity*: Aircraft statistical system; General aviation activity and avionics survey; Certifications catalogues; Air carrier activity information; Air traffic activity; and Aircraft document index.

- *Aviation Safety Analysis*: ATC health information system; Enforcement inspection system; General aviation accident reporting; Comprehensive airman information; Service difficulty reporting; Accident incident data system; Airman medical certification data; and Facility performance reports.

- *National Airspace System Facilities*: Obligation planning system; National airspace performance reporting; National energy management statistics; and National Airspace System(NAS) facilities information.

- *Other FAA Information*: Operator error/deviation reports; Air quality program information; Equipment criteria system; Policy/analytical studies; Aircraft engine emissions information; Environmental noise data; Air carrier delay reporting; International aviation information; Energy policy analysis; Activity forecast; Advisory circular data; Airport noise modelling; Aircraft registration statistics; and Consumer complaint system.

7-2.2 Passenger-related Information

There are different methods of collection of information in airports. The passenger-related information in airports is largely classified by two streams. One of these is that a huge amount of information is essentially related to the passengers' demands. The other information should assemble specific data to describe the related operating characteristics for each serviceable facility at an airport system.

The information about passenger demand in airports is typically related as follows:

o Pedestrian traffic flow characteristics of passengers moving inside various service facilities of the airport terminal; number and fraction of passengers using each service facility or component under review by hourly, daily, weekly, monthly, and seasonal variations.

o Indicators of overall demand load, such as numbers of checked and carry-on baggage per passenger, and number of visitors accompanying each passenger.

o Aspect of passengers' characteristics, for instances, fraction of passengers originating or terminating their trips at an airport, distribution of passengers among airlines, typical times of arrival at an airport versus scheduled flight departure time, and fraction of passengers choosing alternative transport modes for ground access to airport.

The following types of information are usually related to the airport operational characteristics:

o Operational characteristics of service facilities; physical layout, size, arrangement of service facilities, detailed regulatory procedures, and other supporting operational data.

o Flight operational characteristics; origins and destinations, daily flight schedule, aircraft and likely load factors, gate occupancy times, and other related information.

- Employee and agent efficiency at each service facility can be measured in terms of service times per passenger or number of passengers per employee.

Not all information is required about a specific situation. The selection of the proper method should consider the purpose for using the information. Generally, it should determine the required level of detail, extent of aggregation or disaggregation, time-dependency, particular situation and operational conditions at the airport, parties associated with the information collection effort, and the resources available[Mumayiz 1985:110].

7-3 GENERAL METHOD FOR DATA COLLECTION IN THE AIRPORTS

Information collection which is associated with passengers is often conducted by means of airport passenger surveys. Numerous surveys of various types have been carried out in the airports around the world. Each survey has used a particular survey method to satisfy its purposes. Choosing a survey method depends upon factors such as objectives, content, the required personnel and periods, available techniques, and target sample size. Generally, the airport survey methods or techniques are as follows:

7-3.1 Direct Methods

These refer to the methods for collecting data that can be directly obtained at the airports. The start and end of these survey techniques are completed in the airports.

7-3.1.1 Direct Observation

Observation can fairly be called the classic method of scientific enquiry. The accumulated knowledge of biologists, physicists, astronomers and other natural scientists is built upon centuries of systematic observation, much of it of phenomena in their natural surroundings rather than in the laboratory.[Moser *et al.* 1986:244] In the airport field, direct observation as a method of collecting data is often used in a wider sense such as incorporating head counts and time readings either manually or by mechanical devices.

The direct observation method can have a number of advantages over asking for information from respondents. When they are unable to provide the information or can give only very inexact answers, direct observation of a phenomenon can be selected as a proceeding method to collect information. It can also include tape-recorded data-logging where a continuous record is kept by recording into a tape recorder or a specially designed field portable and programmable calculätor[Mumayiz 1985:111] as well as notebook or handbook computers which can provide more benefits to the data collection.

7-3.1.2 Photographic Techniques

The photographic technique is essentially a deferred observation technique.[Braaksma 1976:28]. The direct observation method is not applicable at certain components in the airport system so that it is sometimes necessary to use an alternative to observe operations. Information is sequentially recorded and readily extracted from the tapes or films. This technique can be used with a camcorder, video camera, and time-lapse photography. Photographic equipment is a fixed service facility and subsequently records phenomena which can be used to obtain information, for instance, waiting time in the service queues or service processing time at specific activity. The prime merit of this method is the small number of personnel needed.

7-3.1.3 Monitorial Method

A monitorial method is similar to the photographic technique, but it is used with an internal searching monitor at an airport. The sets of information are continuously recorded by internal monitor recorder. This can be helpful in collecting data about various activities when time is restricted. The monitorial method can also be applied to very sensitive areas in the airports, because it does not disturb the original operations. This method, however, is needed for co-operation between the surveyors and the airport authorities or governmental agencies.

7-3.1.4 Tailing

The tailing technique involves following the small passenger movements through the terminal. The sample can be selected by using a random number table[Braaksma 1976:29]. The surveyor fills in on a survey sheet the traveller's sex, number of carried baggage, physical handicaps, or queueing behaviour. The advantage of it is that it can obtain circumstantial information for the specific characteristics or phenomena at the terminal. Otherwise, it has some limitations such as co-operation with the airport authorities and governmental agencies, costliness, and intrusiveness.

7-3.1.5 Time-stamping Method

The time-stamping method involves the tracing of passenger movements between the main entrances of the airport terminal and departure gates by means of identifiable passengers' tags. Hence, it is also called the "tagging technique". Surveyors request the passengers to enter the various checkpoints through out the terminal on the time-stamping card. They give the card to them either at the terminal entrance gates for departing passengers or at the arrival lounges for arriving passengers. Passengers carry it and then the time is entered on it at each service facility. The time-stamping card is collected when passengers leave the terminal building. It brings a maximum of quantitative data, but the survey can be expensive because of the large number of surveyors and equipment such as time stamps.

7-3.1.6 Collected Questionnaires

This method is used for the situation in which the respondents themselves fill in the answers. It is one of the easiest techniques for getting information from passengers at the airports. Usually, this technique has benefit in a time restricted situation. Air passengers are obviously squeezed for time at an airport so that this self-administered questionnaire method is most suitable for them because it will take only a little time to answer the questions. At some facilities inside the passenger terminal surveyors distribute the questionnaires to passengers and they are self-completed. The completed questionnaires are collected by surveyors or returned to a collection box at a specific area inside the terminal.

For this technique to be applied successfully, the respondents must be captive and not be pressed for time. The questionnaire should be simple, in the sense that questions can be easily understood by respondents. It is also important that the respondent knows the answers to questions rather than to have to guess or estimate.[Braaksma 1976:28] If these constraints are satisfied, the response rate of the questionnaires will be expected to be high.

7-3.1.7 Interviewing

In the personal interviewing method, interviewers ask the questions directly of respondents and record the answers themselves on the specially prepared forms. Although observation and questionnaires could probably be employed more frequently than at present, interviewing is without doubt generally the most appropriate procedure, even though it introduces various sources of error and bias[Moser *et al.* 1986:270]. In the airport terminals, the survey interview is a conversation between surveyor as interviewer and passenger as respondent in order to elicit certain information from the airport passengers. This appears to be a straightforward matter, with the respondents just giving straight answers to the questions asked of them.

A personal interviewing technique is adopted to determine the specific characteristics of demand and terminal population[Mumayiz 1985:111]. It is also suitable when certain aspects of the questionnaire might not be fully understood by respondents or when the line of questioning is dependent on the response to specific questions[Braaksma 1976:28], as well as when the type of information sought could not be obtained by any of the preceding techniques such as direct observation, questionnaires, or tailing. The interviewing method is generally employed only when activities to be surveyed are concentrated at a small number of points, activity levels are low, and the desired sample size is small[Barton 1973].

7-3.2 Indirect Methods

These methods can apply when the required data can not be directly obtained from passengers at the airport. They include such methods as the mail-back questionnaire, telephone collection, and statistical records and documented data.

7-3.2.1 Mail-back Questionnaires

This is a self-administered method to collect data from the respondents. The success of it is highly dependent upon the respondent's attitudes as well as the questionnaire's characteristics- simplicity and comprehensibility. Questionnaires are distributed by surveyors at some points whether inside or outside the airport terminal with a pre-paid envelope to return them. The respondent would later mail the completed questionnaire to the surveyor.

It is suitable for the circumstance when respondents have time constraints or will not be able to answer certain questions until they have left the airport. The mail-back questionnaire technique has some advantages such as cheapness, widely scattered sample, and the requirement of small number of personnel. On the other hand, it can be considered only when the questions are sufficiently simple and straightforward to understand with the help of the given guidance and definitions in the questionnaire.

The surveyor must also realise that the response rate will be remarkably low. In addition, the answers to a mail questionnaire have to be accepted as final, the surveyor can not be sure that the right person completes the questionnaire, and there is no opportunity to supplement the respondent's answers by observational data.

7-3.2.2 Telephone Collection

This method is similar to the mail-back questionnaires. Means of data collection are different from each other. The respondents to mail-back questionnaires would mail the completed questionnaire to the surveyors, but in the case of telephone collection, the surveyors distribute questionnaires and after some reasonable time period can collect the responses by telephone. The distribution of questionnaires can be carried out by surveyors at certain points at the airports. When distributing the questionnaire to the passengers, they ask and note name and correspondence telephone number of the respondents.

The merits of this technique are the rather higher response rates than those of the mail-back questionnaires, surveyors can contact the right person, and it is possible to check the answers. The biggest difficulty is that passengers ordinarily hesitate to provide their names and telephone numbers because these are treated as part of a person's privacy or even security. Furthermore, telephone surveys seem to be relatively unaffected by their length so that once people start an interview on the phone they are very unlikely to hang up [de Vaus 1991:109].

7-3.2.3 Statistical Records and Documented Data

An airport is a huge information generating system. Many of the organisations and agencies of the airport collect data through the files of documents, worksheets, and statistical data-base systems for their own administrative purposes. These are unquestionably useful sources for users such as planners, operators, airport managers, airlines, and governmental institutes. All information related to the airport system is not always published, because it deals with high security data from some sensitive organisations. With co-ordinated organisation, efficient statistical handling, accompanied by computerised compilation, storage, and handling systems, a substantial airport operations data base can be made available, directly extracted from files that are usually shelved and forgotten[Mumayiz 1985:112].

A method of information collection in the airports depends upon the following influencing factors for implementation such as; the objectives and goals of the survey, survey conducting areas, co-operation of the related agencies, financial and personnel constraints, behaviour of respondents, sample size, and level of detail of survey. According to these considerations, the airport surveys can use a combination of the aforementioned techniques. The appropriate combinations, therefore, are determined through the careful preview and discussions with all associated and involved agencies. For example, a survey can be introduced by such methods as tailing passenger movements, interviewing passengers, and direct observation of operations at each service facility in the passenger terminal building.

7-4 DIFFICULTIES ASSOCIATED WITH THE AIRPORT SURVEYS

Many of the problems and difficulties associated with an airport survey are sometimes inherent in the survey itself. The causes of these problems and difficulties can be classified into four types: (1) those due to the complex nature of the organisation, (2) the high security system, (3) participant attitudes, and (4) those due to the poor execution of surveys.

7-4.1 Complex Nature of the Organisation

An airport is a complex system. Many airport-related organisations such as airport authority, airlines, government agencies, and other agencies are involved. Due to the large number of agencies and organisations involved in the operation of the airport, an integrated data base mechanism is needed in order to establish an effective information system, because negotiating with and co-ordinating all of them is an essential task even if it is a complicated job.

To conduct the airport survey with a specific purpose in mind, the approval or authorisation from the airport authority is necessary. In the case of restriction of the survey to only certain parts of the airport owing to the difficulties of arranging for the approval and collaboration of another organisation, the survey could be of limited value. For example, the airlines using the airport might agree to provide some amount of information from their own data base such as load factor and peak time throughputs on the highly competitive flights' route, but the airlines abhor publishing them, being mindful of their public image and concerned about the leakage of information to competitive airlines. This kind of attitude in airlines can prevent an opportunity for doing a survey.

7-4.2 High Security System

The airport involves a large number of supporting agencies carrying out their own operations. The airport, as the point of origin and destination of air travel, must provide a high standard of security for passengers. This leads to the involvement of safety-related organisations such as security screening. They, therefore, are the most sensitive agencies in the airport concerned about passengers and surveys as well. Generally, they include security screening, passport control, immigration, and customs. Their apprehension regarding participation in surveys or approving of the conducting of observations, stems from the sensitivity of transactions performed between governmental organisations and passengers, and confidentiality of the control measures adopted by them. Hence, information associated with governmental agencies' operations is often practically unobtainable.[Mumayiz 1985:115-116]

The information associated with the environment such as noise and air pollution in adjacent airport areas is also very sensitive. In this circumstance, the airport authority would seem reluctant to help in providing information because they think that it should not be revealed for political reasons. Normally, this case occurs more easily in the politically unstable countries such as in the developing countries and the third world nations.

7-4.3 Participant Attitudes

A basic difficulty with surveys is that participants often do not have attitudes on topics that the surveyor considers important, so the responses that are given to particular questions are not very meaningful. Indeed, almost every measurement of participants' attitudes includes some measurement of non attitudes. The surveyor generally wishes to minimise the amount of missing data. Air passengers who are often pressed for time can not afford to waste it if they participate and answer questions. Passengers also miss out some questions in the questionnaire when they find the questions too difficult to answer or hesitate to answer questions invading personal privacy such as income level and age group.

7-4.4 Poor Execution of Surveys

The restrictions of financial availability and special equipment give rise to another problem in carrying out an actual survey. A high quality surveyor is essentially needed to conduct a survey successfully. Every surveyor requires a good understanding of the content of the survey. All these difficulties can lead to the poor execution of surveys.

7-5 PROPOSED METHOD FOR COLLECTING OF INFORMATION

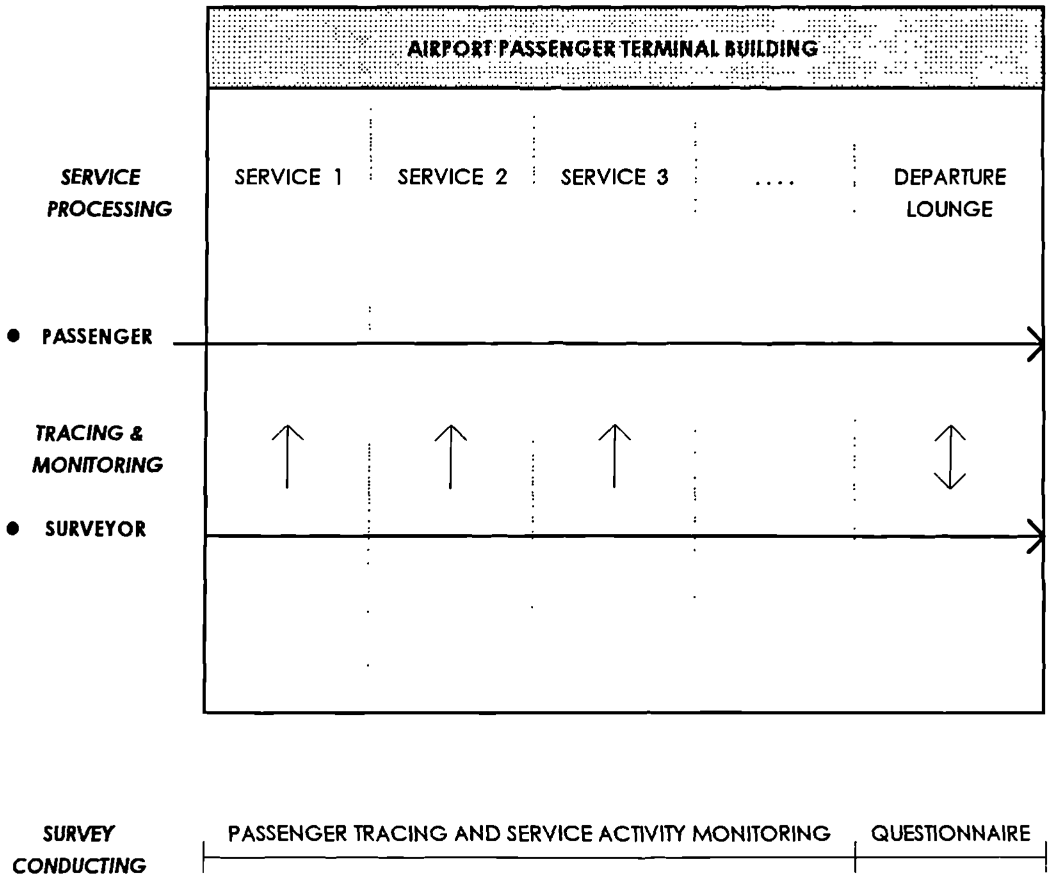
To collect the information associated with passengers in the airports, various methods are considered. The selection of a suitable method to conduct a passenger survey should contemplate the survey goals, contents, quality of surveyor, time dependency, techniques adopted, co-operation of airport organisations, and passengers' characteristics. Different methods for some surveys for passengers have been used in airports.[Meta 1973; Ashford *et al.* 1976; Braaksma 1976; Mumayiz 1985; Müller *et al.* 1991; Seneviratne *et al.* 1991]

7-5.1 Tracing-Monitoring-Questionnaire(TRAMONIQ) Survey Method

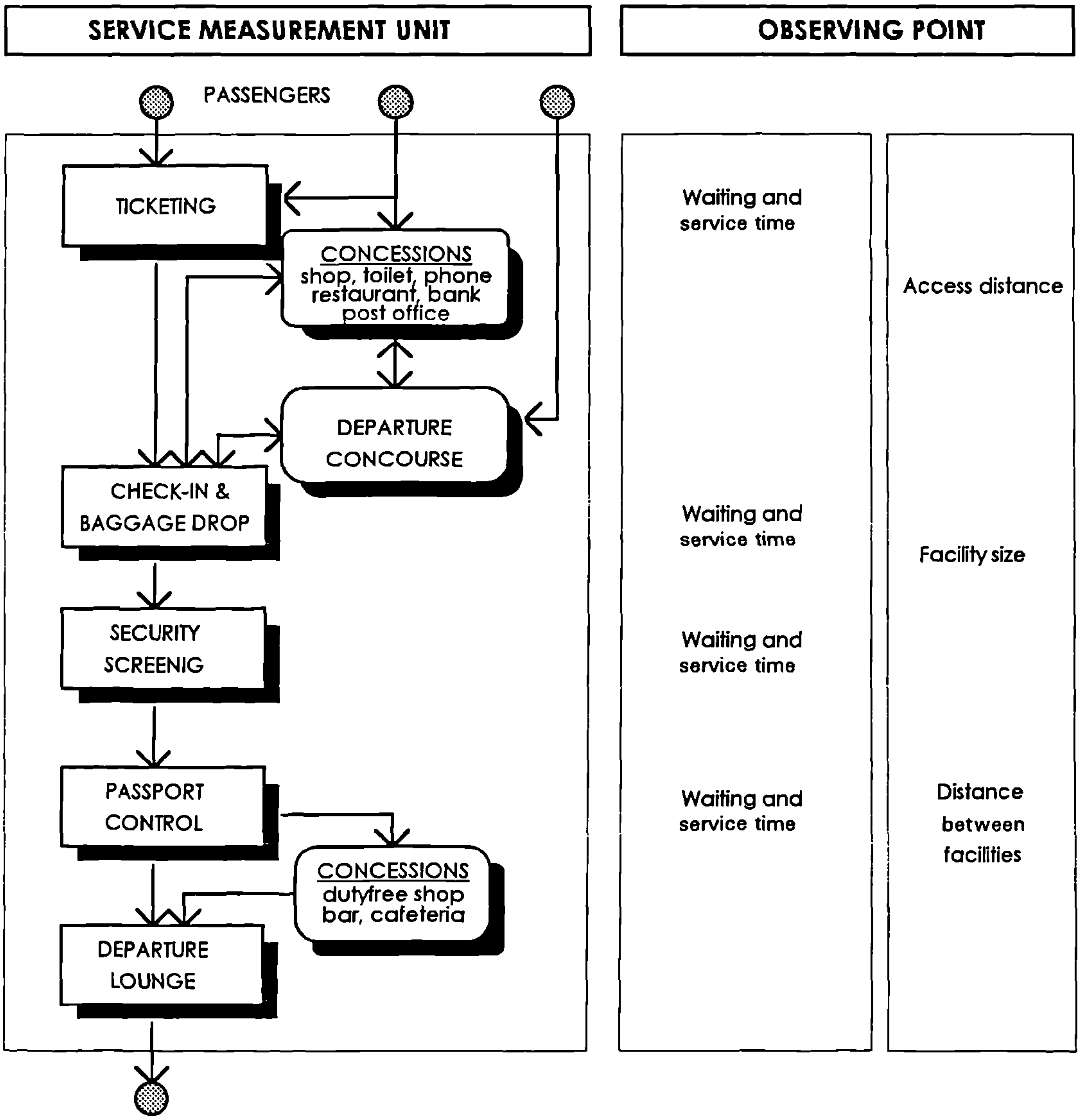
This research concentrates on the level of service evaluation in the airport landside system from the view point of passengers. To enhance the representativeness of the evaluation, the survey method is needed to be comprehensive. Hence, this study has implemented a detailed survey method called Tracing-Monitoring-Questionnaire (TRAMONIQ) survey. This method can be represented as a comprehensive or integrative technique for the service level evaluation at the airport landside system.

7.5.1.1 Idea of TRAMONIQ

The survey method of Tracing-Monitoring-Questionnaire(TRAMONIQ) can be defined as; "surveyor follows the movement of a passenger in the service measurement unit defined as the dimension from airport entrance gate to departure lounge. Simultaneously, the surveyor observes the service performance measurement of the passenger, for instance, waiting time, service processing time, and walking distance between facilities. In this idea, a passenger is acting as a 'client' in timing his or her own sequential movements as well as the surveyor as 'monitor'. Finally, at the departure lounge, surveyors carry on asking the questions using a questionnaire about the passenger's subjective perception of the provision of service level through each facility including ground access to airport. The respondent and monitored passenger at each service facility is the same one." <FIGURE 7-1> and <FIGURE 7-2> show the procedure for conducting the TRAMONIQ method in the airport and the passengers' movements in the airports as well as service measurement at each service facility respectively.



<FIGURE 7-1> THE PROCEDURE OF THE TRAMONIQ METHOD IN THE AIRPORTS



<FIGURE 7-2> TYPICAL PASSENGERS' FLOW AND SERVICE MEASUREMENTS

7.5.1.2 The Advantages and Difficulties of TRAMONIQ Survey

The advantages of the TRAMONIQ method are; (1) detailed information can be obtained by the tracing and monitoring of the passenger movements at each service activity facility, (2) the respondent for questionnaire and monitored passenger is identical so the reliability of data can be maximised, (3) it is possible to compare the passengers' perception of the provided service with actual measures of service performance.

The biggest difficulty in conducting the TRAMONIQ method is gaining the approval or authorisation of sensitive organisations such as the airport authority, and security screening and passport control agencies. Because surveyors must trace passengers' movements from check-in to departure lounge sequentially. The other difficulties are that it takes a long time per passenger, it is costly, and needs a lot of manpower.

7-5.2 Constructing the Questionnaire

Discussion on the questionnaire must begin at the start of the planning stages and will not end until the pilot surveys are completed. It is fair to say that question design is the survey director's most persistent headache, particularly since it is still so largely a matter of art rather than science.[Moser *et al.* 1986:308] Efficient planning will lead to the success of the surveys. Both the practical feasibility and the theoretical desirability of the surveys are considered. As an example, <FIGURE 7-3> is illustrated to help us in considering and remembering the procedures in questionnaire design.

The purposes of a questionnaire can be defined to measure some characteristics and the opinions of its respondents. A questionnaire is a highly structured data collection technique whereby each respondent is asked much the same set of questions. Because of this, questionnaires provide a very efficient way of creating a variable by case matrix for large samples but they are not the only method.[de Vaus 1991:80]

What is the aim of the research?

⇩

What information is required to fulfil these aims?

⇩

Undertake preliminary reading around the topic and initial fieldwork

⇩

What type of questionnaire will be used and how will sample be derived?

⇩

Consider the most appropriate questions to ask, which will depend upon the aims of the research, the target group and the time and resources at your disposal

⇩

Construct a first draft taking into account that pre-coded questions are easier to analyse and the order of questions is the best social-psychological sequence

⇩

Pilot the questionnaire and elicit the opinions of the subsample. Gain critical but supportive comments from those familiar with the design and analysis of questionnaires

⇩

Edit the questionnaire to check on form, content, and sequence of questions.
Make sure the questionnaire is neatly typed and all instructions and coding are clear and filter questions, if any, are understandable

⇩

Administer the questionnaire noting the dynamics of the interviews and comments of the interviewers(if used)

⇩

Analyse the questionnaire drawing upon statistical techniques

<FIGURE 7-3> AN OUTLINE OF STAGES IN QUESTIONNAIRE CONSTRUCTION [*Source*: May 1993:83]

7-5.2.1 Question Content

It is helpful to distinguish between four distinct types of question content: behaviour, beliefs, attitudes, and attributes[Dillman 1978:80]. Similarly, Ackroyd and Hughes[1983] defined such four headings as: factual, attitudinal, social psychological, and explanatory. Depending upon the goals and objectives of surveys, the precise type of information sought should be determined. The failure to distinguish adequately between these four types of information arises from a lack of clarity about the research question and inadequate conceptualisation[de Vaus 1991:82]. For example, if a survey is interested in exploring people's actual behaviour, a set of questions that in fact only taps beliefs or attitudes will be of little use.

In passenger surveys for the airport service level, the response of people to questions asked and their attitudes towards the subject matter dictate their replies. This research requires the survey questions to be mostly opinion and attitude questions with some attribute questions. Attitude questions are particularly sensitive[Mumayiz 1985:145-6], due to: first, uncertainty whether the respondent, in any meaningful sense, is aware of what is being asked about and 'knows' the answer. Second, a person's opinion on virtually any issue is many-sided, and probably there is no one correct answer to the survey question, but the answer the respondent gives, will largely depend on the aspect of the issue that is uppermost in the mind. Third, difficulty of assessing the intensity of opinions, and giving a reasonable estimation of the measure used. Last, influence of different aspects of questionnaire design on opinions.

Attitude surveys have moved away from an interest in the material conditions of the population, towards the use of surveys for gaining data on attitude[May 1993:68], for instance, what passengers think about the service level in the airport landside system in general and the affecting service factors at each service facility in particular. Hence, attitude questions try to establish what they think is desirable[de Vaus 1991:82]. An attitudinal focus might ask about attitudes regarding the provision service at the service facilities according to the passengers' judgement.

PART	ORDER
GENERAL INTRODUCTION PASSENGERS' PROFILES FLIGHT CHARACTERISTICS JOURNEY TO AIRPORT	Details of survey Nationality, Sex, Age Trip purpose, Trip experience Flight number, Destinations Origins, Time taken to make journey
PROCESSING CHECK-IN & BAGGAGE DROP SECURITY SCREENING PASSPORT CONTROL	Service processing time Complexity of procedures Courtesy of personnel No. of service facility Overall environment Service variablility
HOLDING WAITING AREAS AND LOUNGE	Crowding Information system Internal environment Seat availability Accessibility to concession
CIRCULATION INTER TERMINAL CIRCULATION TERMINAL CURB CIRCULATION	Waking distance Sign system Level changes Level of congestion Aids to handicapped Assistant facility to passengers Number of the pedestrian crossing
ACCESS GROUND ACCESS	Access time Travel comfort Availability of transport modes Cost to passengers
PARKING CAR PARKING	Space availability Simplicity of the access to car park Car park fare Sign system Linkage car park and terminal
CONCESSIONS CONCESSIONS	Access distance Variety for choice of things Functional display Retail costs to user Courtesy of personnel Visibility

<FIGURE 7-4> PARTIAL BREAKDOWN OF QUESTIONNAIRE

Attribute questions are designed to obtain information about the respondent's characteristics. Such questions would normally include information about their age, education, occupation, gender, ethnicity, marital status and so forth[de Vaus 1991:82]. For evaluation of the level of service at the airports it would be particular interesting to know attributes such as age, sex, nationality, trip distance, trip purpose, final destination, and other related information. All information requirements are grouped into seven parts. <FIGURE 7-4> shows which parts are determined, what order in which they are placed and the information that each part provided.

7-5.2.2 Selecting the Question Type

The response format is also an aspect of question construction. Normally, surveyors can consider the use of open or closed(forced-choice) questions. Open questions give respondents greater freedom to answer the question because they answer in a way that suits their interpretation[May 1993:78]. The closed or forced-choice questions give a limited number of possible answers to which a number of alternative answers are provided, from which respondents are to select one or more.

The choice of open or closed questions depends on many factors such as the question content, respondent's motivation, method of administration, type of respondents, access to skilled coders to code open-ended responses, and the amount of time available to develop a good set of unbiased responses There is no right or wrong approach.[de Vaus 1991:86-7] The finding of a comparison between open and closed questions stresses the importance of this point: "the failings of closed questions are more likely to be due to omissions of an important choice category, i.e., poor design, than to the use of the form in the first place"[SCPR 1981:7].

This research chose the type of closed or forced-choice question, because the characteristics of air passengers regarding the conduct of surveys are that they are usually under time pressure in the terminal and there is unwillingness in attitude to respond to the questions. Due to these difficulties, this survey tried to minimise the time spent and simplified the questions. This type of closed question is one suitable format for carrying out passenger surveys at an airport.

The advantages of closed questions are; (1) they are useful since they are quick to answer; (2) they do not discriminate against the less talkative and inarticulate respondents; (3) they are cheaper to use and analyse relative to open questions and they also permit comparability between people's answers. "A major limit of closed questions is that on some issues they can create false opinions either by giving an insufficient range of alternatives from which to choose or by prompting people with 'acceptable' answers. Further, the forced-choice approach is not very good at taking into account people's qualifiers to the answers they tick."[de Vaus 1991:86]

Within question design attitude scales are considered to play an important role. They consist of a set of statements which the researcher has designed and the respondent is then asked to agree or disagree with the pre-coded answers. Attitude scales divide people roughly into a number of broad groups with regard to a particular attitude which place people's answer on an 'attitude continuum' in relation to one another.

This research selected *Likert-style formats: rating scales* as a response format which is one of the most widely used approaches to providing responses for closed questions. This general approach involves providing people with statements, which have several response categories, and asking them to indicate various strengths of agreement or disagreement. The format can be explained verbally or diagrammatically. The response categories are assigned scores and the respondent attitude is measured by their total score.

In the passenger survey, respondents are asked to state their judgement and evaluation of the level of service provision regarding different factors at an airport service facility. They are asked to choose between several response categories such as *{short, bearable, long}* and *{good, tolerable, bad}*. A Likert-style scale, therefore, is more suitable for the airport passenger attitude measurement.

7-5.2.3 Designing the Questions

In deciding which questions to ask, it is necessary to take into consideration the difficulties in undertaking the survey. To obtain a high response rate the questions should be constructed so that they are unambiguous and the questionnaire is not long or complicated because the air passengers are under time pressure. To do this the goal of the survey must be clear in the researcher's own mind.

A good question possesses two important qualities: *reliability* and *validity*. In survey research, an important distinction is made between these two terms. A question is reliable if it evokes consistent responses, that is, if a person would answer the question the same way in subsequent interviews. One of the principal causes of unreliable responses is ambiguous wording of the question. The validity of a question is determined by whether the question actually measures the concept of interest.[Weisberg *et al.* 1977:43-44] Both the reliability and validity of the questions depend upon the objectives of the survey as well as dealing with the major factors under consideration when deciding how to word the questions.

The largest task in questionnaire design is avoiding bias but it is exceedingly difficult. To measure or collect accurate data, the questions should not be biased. Some related rules and general guidelines in question wording and design of the questionnaire are necessary to succeed with a specific survey in order to obtain a high representation of the real situation. A good example of these is summarised by Moser and Kalton[1986:318-331]:

- *Questions that are insufficiently specific*: Avoid asking a general question when an answer on a specific issue is wanted.

- *Simple language*: In choosing the language for a questionnaire the population being studied should be kept in mind so that technical terms and jargon are obviously to be avoided in surveys of the general population. Complex questions are typically long and complexity is certainly to be avoided but this does not mean that the shortest questions are necessarily the best.

- *Ambiguity*: Ambiguous questions, particularly double barrelled ones, are to be avoided at all costs. If an ambiguous word creeps in, different people will understand the question differently and will in effect be answering different questions.

- *Vague words*: Vague questions encourage vague answers. The meaning can easily be made more precise and vague words and phrases avoided, unless one is only seeking vague answers.

- *Leading questions*: Avoid the leading question, which by its content, structure or wording, leads the respondent in the direction of a certain answer. Equally, a question that suggests only some of the possible answers may lead in their direction. Furthermore, leading words have the risk that the general context of a question, the content of those preceding it and the tone of the whole questionnaire or interview can lead the respondent in a given direction.

- *Presuming questions*: Questions should not, generally speaking, presume anything about the respondent. They should not imply that he(she) necessarily possesses any knowledge or an opinion on the survey subject, or that he(she) engages in the activity about which he(she) is being asked.

- *Hypothetical questions*: People are not good at predicting their behaviour in a hypothetical situation and the prediction has somehow to be taken out of their hands and made by the researchers themselves-naturally on the basis of the information they have obtained.

- *Personalised questions*: It is often necessary to decide whether a question should be asked in a personalised form or not. So, personalised questions should always be carefully considered.

- *Embarrassing questions*: Subjects which people do not like to discuss in public present a problem to the questionnaire designer. Respondents are often embarrassed to discuss private matters, to give low-prestige answers, and to admit to socially unacceptable behaviour and attitudes.

- *Questions on periodical behaviour*: According to the period chosen, the respondents' answers will depend on the type of activity and on the extent to which one is willing to rely on the respondent's memory. In the case of the periodical questions, many people's answers might simply be an estimate of their average behaviour rather than the actual figure.

- *Questions involving memory*: Most factual questions to some extent involve the respondent in recalling information, questions associated with memory should always be carefully studied, because the degree of accuracy with which information is recalled is a basic determinant of quality of his(her) response.

Useful recommendations regarding the design of survey questionnaires are also suggested by Belson[1981] through an exploratory study. This study was conducted to investigate respondents' misunderstanding of 29 types of survey questions. It provided some significant considerations for the design of survey questions which are summarised as follows:

- Beware of the strong tendency of respondents to answer questions about their behaviour by what they usually do- as distinct from what they in fact do.

- Beware of the tendency of respondents to start answering as soon as they have heard or read enough to start formulating a reply.
- Beware of the tendency of respondents to narrow down broad concepts, especially vague ones, and to apply their own special qualifications to a question.
- Beware of the often strong influence of the question's content upon the interpretation of specific terms in that question.
- Beware of the distortion of the meaning of a wide range of terms of the sort frequently used in survey questions.
- Avoid loading the questionnaire with many differences or defining terms.
- Avoid offering long alternatives as possible answers to a question and questions which have alternative answers that could both be true.
- Avoid giving the respondent a difficult task to perform or a task that calls for a major memory effort.
- Avoid the use of different words if partly misheard in interviews or misunderstood in self-administered questionnaires.

The process of actual question wording itself is of central importance for the whole processing of the design of the questionnaire. In reality, questioning people is more like trying to catch a particularly elusive fish, by hopefully casting different kinds of bait at different depths, without knowing what goes on beneath the surface [Oppenheim 1973:49].

In this research, the guidelines and recommendations for the design of the survey questionnaires have been taken into consideration in preparing the passenger survey of Kimpo International Airport in Seoul. The questionnaire for a pilot survey is shown in Appendix 2. After having taken a pilot survey, a main survey questionnaire can be firmed up through the pilot survey, because the design of the main survey can be obtained and the problems in conducting it considered. The passenger surveys-pilot and main survey- were conducted by the Tracing-Monitoring-Questionnaire (TRAMONIQ) method. One of its procedures is the self-administered questionnaire survey in the departure lounge.

7-5.3 Pre-test of the Questionnaire

When a questionnaire has been developed, each question and the questionnaire as a whole must be evaluated in order to obtain the necessary knowledge to redesign the questionnaire and to anticipate some potential problems. Evaluating the questionnaire is called pilot testing or pre-testing.

Piloting aims to see how the survey works and whether changes are necessary before the start of the full-scale study. The pre-test provides a means of catching and solving unforeseen problems in the administration of the questionnaire, such as the phrasing and sequence of questions or its length. It may also indicate the need for additional questions or the elimination of others.[Kidder 1981:162] It is extremely difficult without piloting to find the uncovered problems and errors in a questionnaire. Normally, they can be defined through the pre-testing before final administration so that it is an important step in designing a survey.

Converse and Presser[1986] provide a useful discussion for pre-testing. They pointed out at least six pilot testing items for the evaluation of individual questionnaires. These are briefly summarised by de Vaus[1991:100-101]:

- *Variation*: If most people give similar answers to a question, it will be of little use in later analysis. It means low variation questions. Questions with low variation create serious problems at the data analysis stage and make it very difficult to correlate the analysis.

- *Meaning*: Check to ensure that respondents understand the intended meaning of the question and that surveyors understand the respondent's answer.

- *Redundancy*: If two questions measure virtually the same thing, only one is needed in the final questionnaire.

- *Scalability*: If a set of questions is designed to form a scale or index, check to ensure that they do. There is no point including items in the final questionnaire which do not belong to the scale for which they were designed.

- *Non-response*: The refusal of a large number of people to answer a particular question produces difficulties at the data analysis stage and can lead to serious reductions in sample size. This can arise for such reasons as; lack of clarity, too intrusive, and insufficient choices of response to questions.

- *Acquiescent response set*: Questions which ask respondents to agree or disagree with a statement can suffer from the tendency of respondents to agree with the statement, regardless of the question content that is called the 'acquiescent response set' problem. It is related to education and is of particular relevance when the research question involves an examination of the relationship between the set of questions and education. A way of detecting this problem is to ask completely contradictory questions and see how many respondents agree with both of them.

Finally, a pre-test before the main survey provides a definition of the suitability of the questions and the hidden problems in carrying out the main survey. Furthermore, it is the researcher's last safeguard against the possibility that the main survey may be inefficient[Moser *et al.* 1986:51].

A pilot survey was conducted at Terminal 2, Seoul Kimpo Airport. The objectives of this pilot survey were to explore the different aspects of gathering the required information, test the suitability of questionnaire, check the applicability of the proposed service measurement, and to detect any other useful information.

7-5.4 Determining Sample Size

When determining sample size in order to conduct a survey one is dealing with the most important statistical factor. Target sample size can be defined by the objectives of survey, approach and analysis methods, and expected outcomes. Therefore, one of the first questions that confronts the designer of a survey is how big the target sample size should be. It is considerably difficult to answer accurately.

The initial plan was to carry out the pilot survey by the proposed survey method that was Tracing-Monitoring-Questionnaire(TRAMONIQ) with randomly selected samples. The target sample size was set at approximately 20, because a pilot test of about 20-50 cases is reasonably sufficient to discover major flaws in a questionnaire before they damage the main survey[Rossi *et al.* 1983].

It is very difficult to conduct a survey at an airport, because it has to deal with a high security system. Applying the proposed method, Tracing-Monitoring-Questionnaire (TRAMONIQ), is extremely difficult, because the surveyor needs to pass through the service facilities such as security screening or passport control to trace and monitor the target passenger. Hence, sample size was confronted as the most important factor for statistical analysis. The required sample size depends upon details of the analysis. Not only total sample size but the different subgroups it contains also require sufficient numbers in each. As a rule of thumb try to ensure that the smallest subgroup has at least 50 to 100 cases[Hoinville *et al.* 1977:61] or 20 to 50 in the minor breakdowns[Rossi *et al.* 1983]. In this research, total sample size suggested around 100 cases. It was not too big but that was a possible maximum number by TRAMONIQ survey method under limited circumstances.

7-6 CONCLUSION

There are different means and methods to collect useful information at airports. The items of information sought are multiform in nature and vary in means of data collection. These characteristics depend to a large extent on their relative importance and their influence on the performance of the level of service at the airport landside system. Some factors that dictate the selection of a comfortable method should be considered. These factors can be determined by specific characteristics of the survey. The highest hurdle in an airport survey is the nature of the organisation. Co-operation and negotiation with all the airport-related organisations, in particular the governmental agencies is essential.

CHAPTER 8

APPLICATION OF THE PROPOSED METHODOLOGY

8-1 INTRODUCTION

This chapter describes the practical applications of the proposed methodology in order to evaluate the level of service at an airport landside system. This application has two main purposes. Firstly, it serves as a presentation of the practical aspects of the prime findings which apply to the methodology. Secondly, it allows a comparison between the real service performance indications using the multi-decision model and previous research. This chapter involves Seoul Kimpo Airport case study and comparison with the perception-response(P-R) model which has been developed by Mumayiz[1985].

8-2 CASE STUDY: KIMPO INTERNATIONAL AIRPORT IN SEOUL KOREA

8-2.1 Background of Air Transport in Republic of Korea

The Republic of Korea is a relatively small country similar in size to the small European countries such as Austria, Holland, Norway and Switzerland. It has a total land area of 99,117 km^2 (Korean peninsula 221,487 km^2). The possible air routes of domestic airlines do not exceed 520 km (323 mile). Domestic routes are connected to 12 airports which provide a regular scheduled passenger service. Three-quarters of them, typically the small ones have a low volume of service and they handle less than 30% of all domestic passenger traffic. The other airports are the core of the national system.

The air transport industry of Korea was launched in 1948. Prior to 1969, however, the industry was relatively unsophisticated. Since 1960, fluctuating government policy, economic conditions and a variety of international events has been stressful for the developing aviation industry.

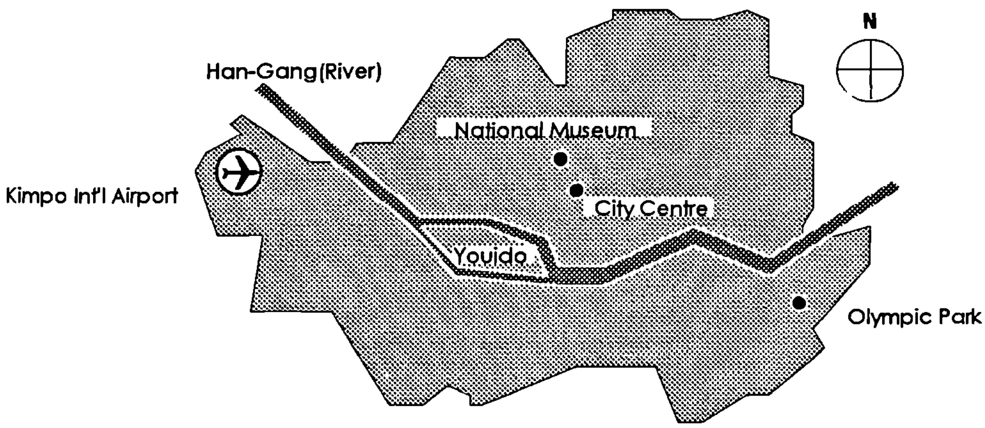
Until 1969, international passengers and cargo were dealt with by some foreign airlines such as Northwest Airlines, Japan Air Lines, Cathay Pacific Airways. In 1969, Korean Air Lines was established to achieve a role as an international airline for the benefit of the economy of Korea and to provide a successful scheduled service for customers. Asiana Air Lines was founded as the second air service company in February 1988.

The period 1967 to 1992 was characterised by an increasing number of flights and passengers, especially international passengers. Their numbers rose dramatically from 0.2 million in 1967 to 11.5 million in 1992. Cargo service has also speedily grown from 10 thousand tonnes in 1967 to 84.5 thousand tonnes in 1992. Korea has achieved the fastest civil aviation growth record in the world during the last two decades.

8-2.2 Kimpo International Airport

8-2.2.1 General Introduction

Kimpo International Airport(KIA) is situated on the north-west side of Seoul. Kimpo is approximately 17 km (10.5 miles) from the city centre, 950 km (590 miles) from Narita Airport in Japan and Beijing in China, and 1,600 km (995 miles) from Hong Kong. KIA is the gateway of Korea and it has also become a hub for Far East transit passengers between Asian and European or American routes.



<FIGURE 8-1> LOCATION OF KIMPO INTERNATIONAL AIRPORT IN SEOUL

In 1991, KIA was placed 27th out of approximately 300 airports world-wide in handling passengers, 120th in aircraft operations, and 9th in handling cargoes.[KAA 1993] Currently, the airport is a fully operational service for international and domestic passengers. It is fully operational, capable of handling 18 million passengers per year and 163 thousand aircraft operations per year respectively. The general details of KIA are shown in <TABLE 8-1>.

<TABLE 8-1> GENERAL DETAILS OF KIMPO INTERNATIONAL AIRPORT

CATEGORY	TERMINAL 1	TERMINAL 2	DOMESTIC
Location	Longitude 126°47'59", Latitude 37°33'15"		
Navigational Aids	ILS, VOR/DME, NDB, RADAR, PAPI		
Approach Type	Category III		
Airport Space(m^2)	7,317,640		
Runways	14L 32R 3,600x45 m, 14R 32L 3,200x60 m		
Capacity('000s)	163 Aircraft Operations per Year		
Aircraft Parking Lots	80 Wide Body Aircraft		
Terminal Space(m^2)	72,220	93,581	35,188
Terminal Capacity(million)	7.2	9.32	1.41
Check-in Counter	90	56	35
Loading Bridges	8	8	4
Baggage Conveys	4	4	2
Car Park Space(m^2)	199,983		
Parking Capacity	4,964 Cars		

(*Source*: KAA Annual Report 1992)

KIA consists of Terminals 1 and 2, serving the international passengers, Domestic Terminal, and Cargo Terminal. Terminal 1 is served by 17 foreign airlines and

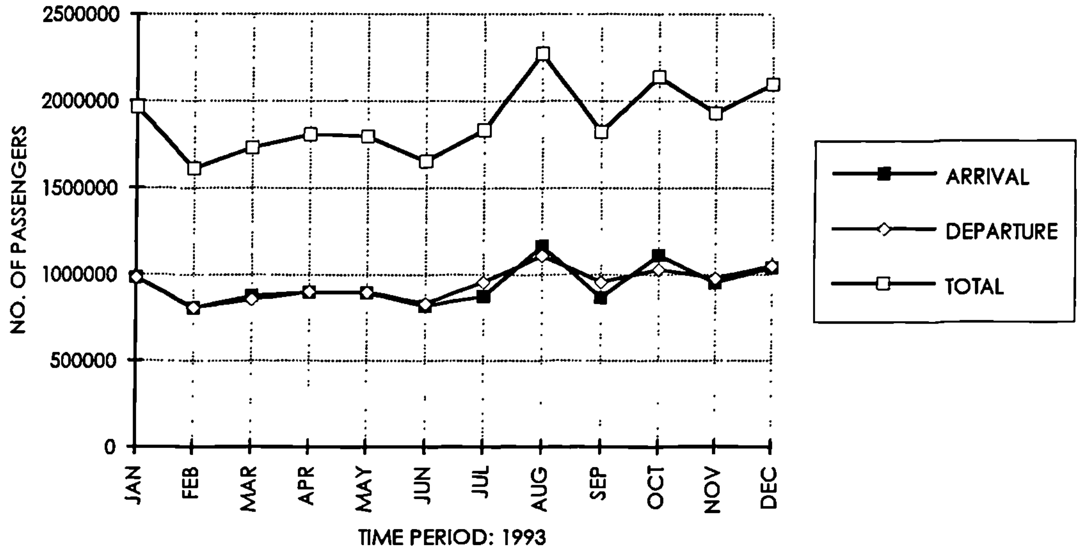
Terminal 2 two national airlines as well as 7 foreign airlines as scheduled service carriers. Its international passengers have grown greatly during the last few years. The current worry is that, the capacity of KIA will be saturated in the near future[KMI 1990].

KIA's operation is restricted by topographical conditions, the poor design of the airport and the layout of its facilities. There are two runways laid out in parallel. Unfortunately, they are very close(400 metres). This means that it is not possible for aircraft to land and take-off simultaneously. KIA, therefore, is unpleasant to operate and utilise. Furthermore, the direction of the runways lies towards mountains and is close to the demilitarised zone(DMZ) between south and north Korea.

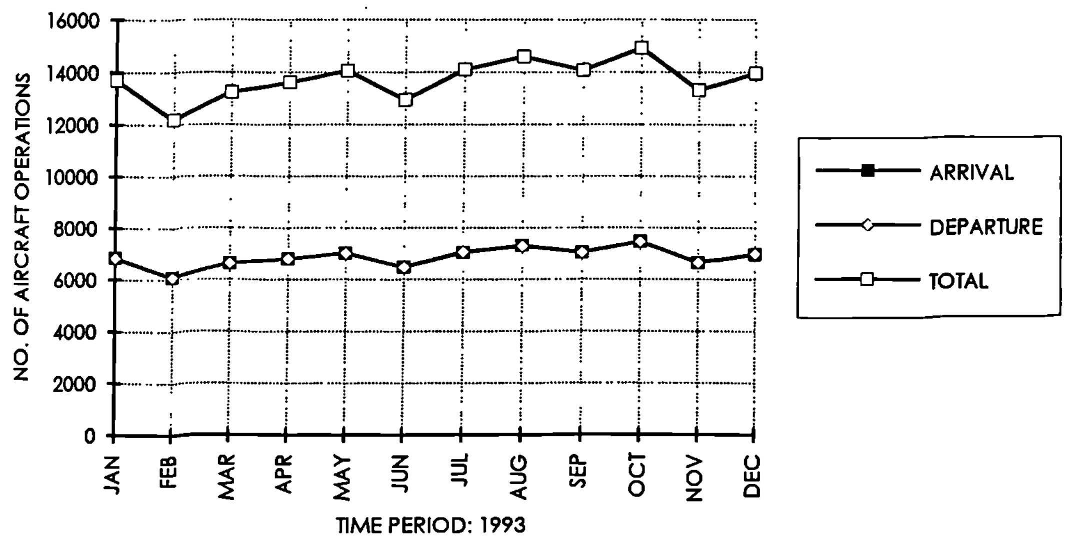
All passengers travel to the airport by road- bus, private car, airport bus, limousine, or taxi. Traffic jams and congestion on the main access road to the airport are a serious problem. To improve the accessibility of KIA, Seoul City Council and Seoul Underground Plc. are undertaking the construction of an underground, line 5 which will be completed in late 1994.

8-2.2.2 Traffic Characteristics of Kimpo International Airport

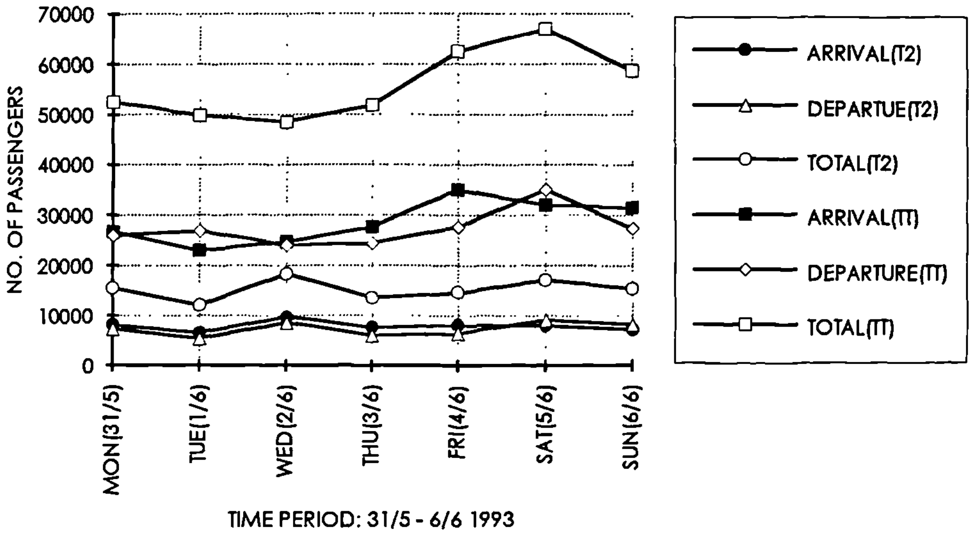
Kimpo International Airport(KIA) is the largest airport in Korea. It serves the metropolitan regions of Seoul. KIA handled approximately 21.3 million passengers, 52.44% of all passengers, and 0.15 million aircraft operations, which were 50.12% of all those in Korea, in 1992[KAA 1993]. Its international and domestic passengers accounted for approximately 9.86 million and 11.48 million respectively. These were in proportions of 85.89% and 39.29% of all international and domestic passengers in Korea. KIA handled a surplus demand of about 3.4 million which is 1.19 times over its maximum capacity in 1992. The physical capacity of the domestic passenger terminal is only 1.41 million, but the actual demands were 11.48 million which was about 8 times over the capacity. This may seem to be an extraordinary statistic, but it has been published as true in the KAA Annual Report 1992.



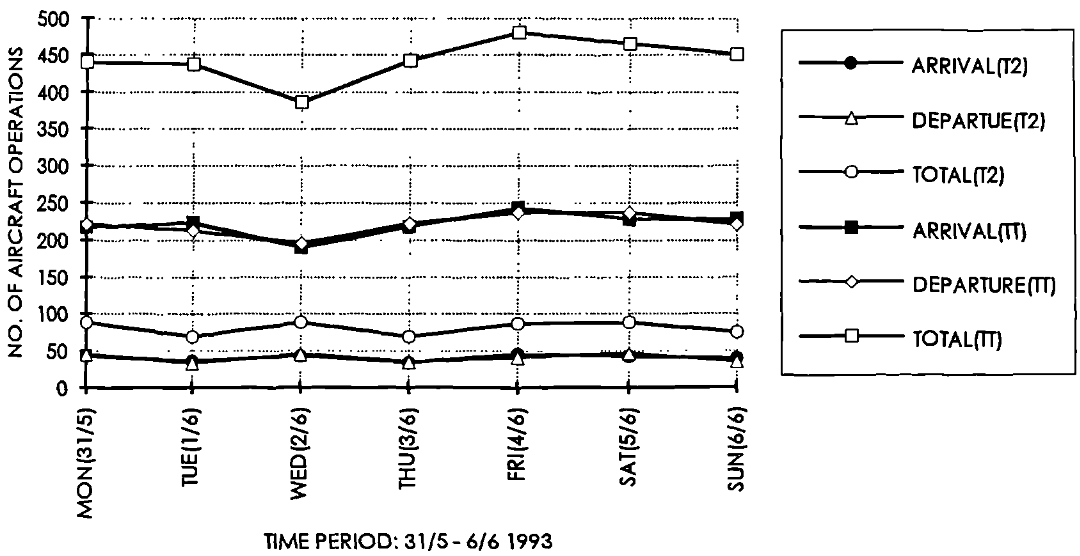
<FIGURE 8-2> ANNUAL PASSENGER TRAFFIC OF KIMPO INTERNATIONAL AIRPORT



<FIGURE 8-3> ANNUAL AIRCRAFT OPERATION TRAFFIC OF KIMPO INTERNATIONAL AIRPORT



<FIGURE 8-4> WEEKLY PASSENGER TRAFFIC OF KIMPO INTERNATIONAL AIRPORT



<FIGURE 8-5> WEEKLY AIRCRAFT OPERATION TRAFFIC OF KIMPO INTERNATIONAL AIRPORT

<FIGURE 8-2> portrays KIA's passenger traffic patterns of arrivals, departures, and total terminal passengers. Total passenger traffic peaks in relation to annual throughput, with August, October, and December being the busy months of the year carrying 28.72% of annual total passengers, while February and June carried only 14.43%. <FIGURE 8-3> shows annual aircraft operation throughput. The busiest month in 1993 for traffic was October, operating 9.05% and the lowest month was February carrying 7.39% in the year.

<FIGURE 8-4> presents a weeks traffic pattern for the airport terminal total(TT) and Terminal 2(T2) during the 31st May to 6th June 1993. The peak occurs at weekends, with Saturday being the busiest day of the week in terms of total terminal passengers. <FIGURE 8-5> shows the weekly pattern of aircraft operation traffic. The peak is also at the weekends.

8-2.3 Conducting the Pilot Survey

8-2.3.1 Survey Process

A pilot survey was conducted at Terminal 2, Kimpo International Airport in Seoul after gaining permission from the Korea Airports Authority(KAA). The questionnaire used(See APPENDIX 2) consisted of seven parts. Part 1 included general information such as nationality, sex, age, air travel experience, trip purpose, flight number, final destination, the start point of the passenger's journey, and the purpose of trip which were used to categorise the population according to these attributes. Parts 2 to 7 dealt with information about the service level in order to evaluate it through the passengers' subjective judgements at the different facilities; service processing, holding area, circulation, ground access to airport, concessions, and car parking facility.

The pilot survey covered the waiting and service time in the queue at each service facility; check-in and baggage drop, security screening, and passport control. Passengers responded to the questions by their own judgement regarding the provision of service at each facility in the airport landside system, according to the evaluation factors' categories; temporal or spatial, comfort, and the reasonable service factor.

8-2.3.2 Problems Identified in the Survey

This pilot survey was conducted at Terminal 2, Kimpo International Airport on 23 May 1993(Sunday). This survey took twenty-two total samples. Only ten of them, however, were useful responses. This was because seven cases missed out the target passengers at an airport service facility and 5 were incomplete. The response rate of the pilot survey was only 45.5 per cent. It was relatively low.

After the pilot survey was finished, a surveyors' meeting was held to discuss carrying out the main survey and questionnaire. Some problems were identified even though the planning of the survey had been given extensive guidance and the questionnaire carefully built. The surveyors' meeting extracted some problems for the passenger survey by the proposed method in this research. These are as follows:

o Tracing-Monitoring-Questionnaire(TRAMONIQ) survey method seemed too difficult to implement. The idea of this method was that the surveyor and passenger should move simultaneously from check-in desk to departure lounge in the airport. The active involvement of the surveyor with the departing passenger at high security areas in the airport such as security screening and passport control were not always welcomed by these organisations. The loss rate of passengers, 31.8%, was caused by this problem. The surveyor traced a specific passenger at a security screening facility or passport control, but was passed through in a different way. Sometimes the officers demanded that they show the authorised certification from the related organisation, survey questionnaire, or personal identification. While the surveyor supplied this requirement, the target passenger had already passed on into the area. Therefore, co-operation with airport related organisations and authorities was very important in order to conduct the main survey.

o The initial plan for the questionnaire survey was to conduct it at the departure lounge as a self-administered method. This method gave a time limit to passengers to complete the questionnaire. This research selected almost all of the landside system as its area and chose the multi-affecting factors for the level of service within it. This means that the questionnaire had to be expanded and contained a large number of questions. Due to this reason, five cases of the total samples, 22.7%, did not complete the questionnaire. To get rid of this problem in carrying out the main survey, the questionnaire survey method needed to be modified. The surveyors' meeting suggested that the surveyor could ask the questions when a target passenger finished a service activity and was then moving to another service procedure. For example, a target passenger finishes check-in and baggage drop service and then usually takes some time to use concessions, meet friends or relatives, take a meal, and so on until going onto the next service facility, i.e., security screening. During the break period, the surveyor can ask the questions about the experienced service. Also, the general information about the passengers' attributes can be asked at the same time. This alternative method can reduce the answering time for completing the questionnaire in the departure lounge.

o Regarding transport modes of ground access to the airport, six out of ten respondents(60%) who completed questionnaires had used public transport and four respondents(40%) had used a private car. But, only one passenger, who used a private car, drove himself to the airport and parked it at a car park. The other passengers were picked up by their family, friends, relatives, and others. This passengers' characteristic emerged as a difficulty when evaluating the level of service for the car park facility. In the main survey, therefore, this section was not considered.

o The target passenger should be a single traveller. Generally, at a service facility such as check-in and baggage drop or passport control. Group travellers, couples, friends, and other types of small groups used the service at the same time. If a respondent was one of these group travellers the response might not properly represent the subjective perception of the level of service as his/her own service performance.

8-2.4 Structure of the Questionnaire

Important considerations relevant to the passenger survey in the airports are the time constraints. An airport tends to be a very pressured environment for those passing through it and individuals always face time restrictions at each point in the process[Bolland 1991:28]. Hence, time consideration is the prime task in carrying out a passenger survey in the airports. The pilot survey elicited this as one of the major considerations in the airport survey. The questionnaire format, therefore, must be brief and clear. If the questionnaire is long and complicated, many respondents may be unable to complete it and will miss out some questions. This could mean that they are likely to be useless in the survey analysis.

The information required was determined by the experts' panel survey. After that an initial questionnaire for pre-test was designed, taking into consideration the variety of constraints and guidance. By way of the pilot survey, problems were identified for the conduct of the main survey. Finally, the main survey questionnaire(See APPENDIX 3) was built by modification of the initial one. The list of all information wanted and which it was possible to obtain is as follows:

Part 1: General Information

The first part of the questionnaire consisted of personal information; nationality, sex, age, air travel experience, the purpose of the trip, flight number, final destination, and the origin of the journey to the airport. Passengers are sensitive about supplying this type of information, particularly such personal profiles as nationality, age, and trip purpose and may have refused to respond to the questionnaire if questions were too specific or in-depth. The end of this part asked about the journey start time from origin and journey time to the airport. This is useful information for the level of service of ground access to the airport. The general information in Part 1 played a very important role in the analysis of the data as the categorical criteria.

Part 2: Service Processing

The questions in Part 2 provided information on the service processing activities in check-in and baggage drop, security screening, and passport control. The questions were divided into three categories based on the evaluation factors; time or spatial, comfort, and reasonable service factor. The first question about provided service time was defined by waiting time in the queue and time of each service. The second question asked about the complexity of the service procedure as the comfort factor. The final question considered the level of courtesy of personnel who served passengers as the reasonable service factor at each service facility. The answers to these closed questions selected one of three linguistic criteria categories such as; short, bearable, long; simple, acceptable, complicated; kind, tolerable, unkind.

Part 3: Holding Areas

This part dealt with waiting areas and departure lounges in the airport. The level of services at holding areas depends upon the airlines' time schedule. The numbers of passengers waiting for flight departures are subject to the number of aircraft served by the waiting area, aircraft seating capacity and load factors, passenger arrival time at the airport, and time length to departure. They have a substantial influence on perceived service level in these holding areas. This section was concerned with the degree of crowding at the passenger terminal as the spatial factor, the information system at the waiting areas as the comfort factor, and the internal environment as the reasonable service factor.

Part 4: Circulation

This part provided information for the intra terminal circulation and terminal kerbside circulation. The questions for intra terminal circulation were constituted by the three factoral categories. The first question was about the walking distance between service facilities at the airport terminal. The second was about the service level of the sign system such as directions, identification of locations, and so on. The final question was about the service level for provision of facilities for changing levels or movements by stairways, escalators, lifts as well as their frequency.

The questions for the terminal kerbside circulation had three different subjects; the distance passengers walked between terminal main entrance doors and the dropping point from ground transport mode as the spatial factor, the sign system at terminal curb as the comfort factor, and the degree of congestion by transport modes and people at the terminal curb area as the reasonable service factor.

Part 5: Ground Access to Airport

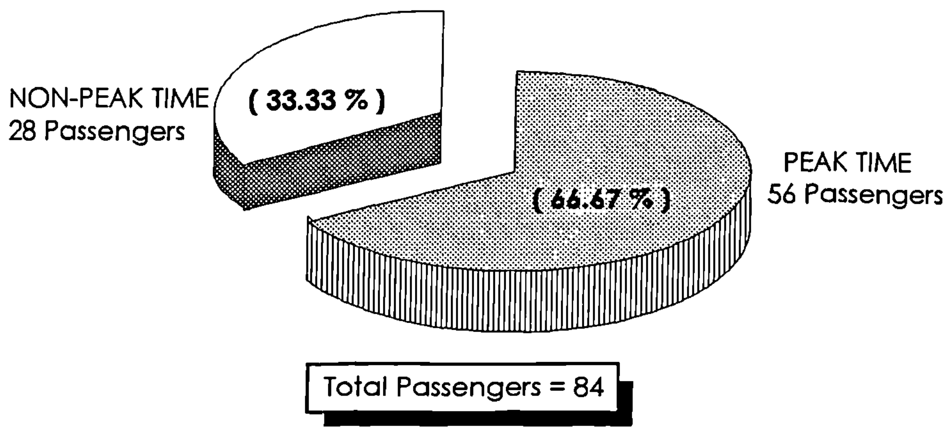
This part dealt with the ground access to the airport. Generally, the service levels for airport access are influenced by the extent of the public transport system available, passenger trip purpose, the availability of parking space and fees at the airport, and passengers' behaviour characteristics. The questions in this part consisted of the passengers' subjective perception of the ground access time to the airport, the availability of transport and the transit to get to the airport. Also, it provided the questions about the comfort category, i.e., access road conditions, congestion, and traffic sign system to the airport by private car or the comfort of public transport, i.e., vehicle occupancy, seat comfort, baggage loads, and vehicle internal environment.

Part 6: Concessions

Location, size, and access distance of concessions are commonly important factors that affect the level of service. The accessibility, the multifariousness of the choice, and the validity of a functional display or location of concessions were measured by passengers' subjective perception. Higher standard services mean that the efficiency of the passenger flows was felt to be satisfactory, whereas, lower levels can disrupt the smooth flow and was perceived by users to be unsatisfactory inside the terminal. The first question of this part were the passengers' perceptions about the distance walked

<TABLE 8-2> DISTRIBUTION OF RESPONDENTS

PASSENGER ATTRIBUTES		NON-PEAK TIME	PEAK TIME	TOTAL
Nationality	National	20	43	63
	International	8	13	21
Sex	Female	15	30	45
	Male	13	26	39
Trip Purpose	Business	15	22	37
	Non-business	13	34	47
Haul Length	Short Haul	13	27	40
	Long Haul	15	29	44
Trip Experience	Few Experiences	8	25	33
	More Experiences	20	31	51



<FIGURE 8-6> SAMPLE SIZE FOR THE MULTI-DECISION MODEL

8-3 APPLICATION OF MULTI-DECISION MODEL

This application has been concerned with the departing passengers in an airport system. The service activity facilities or components were referred to in the six different classes in chapter seven. The car park facility was with drawn as a result of the pilot survey. Hence, five service facilities were selected: (1) service processing - check-in and baggage drop, security check, and passport control; (2) holding areas; (3) circulation - intra terminal and kerbside; (4) airport access; (5) concessions.

8-3.1 Application Steps

The following is an example for application of the multi-decision model to evaluate the level of service at the airport landside system. All output steps were calculated by the multi-decision computer program.(see APPENDIX 4) This example is for total passengers at the peak period. This research has been categorised by five analysis attributes they are nationality, sex, trip purpose, air travel distance, and experience.

✈ ***Step One: Evaluation Factors, Service Criteria, and Service Facility***

The three main factors selected were temporal or spatial, comfort, and reasonable service:

F_e = { temporal or spatial(f_1), comfort(f_2), reasonable service(f_3) factors } .

The set of the service level criteria is defined as;

C_s = {criterion 1(c_1), criterion 2(c_2), criterion 3(c_3) } .

The detailed service facilities are represented in <TABLE 8-3>;

<TABLE 8-3> THE SELECTED SERVICE FACILITIES FOR DEPARTING PASSENGERS

SET OF FACILITY	DETAILS OF SERVICE FACILITY
$G_1 = \{ g_n \}, n=1,2,3$	g_1: check-in and baggage drop g_2: security screening g_3: passport control
$G_2 = \{ g_n \}, n=4$	g_4: Waiting areas
$G_3 = \{ g_n \}, n= 5,6$	g_5: intra terminal circulation g_6: kerbside circulation
$G_4 = \{ g_n \}, n=7$	g_7: airport ground access
$G_5 = \{ g_n \}, n=8$	g_8: concessions

Eight service facilities are considered here and Z_n is an initial input. According to a fuzzy mapping $f : F_e \rightarrow C_s$, a fuzzy matrix Z_n for total passengers at peak time is shown as;

$Z_n \in M_{9\times8}$ =

	f_1			f_2			f_3		
g_1	0.1071	0.5893	0.3036	0.3393	0.4286	0.2321	0.5714	0.2857	0.1429
g_2	0.4464	0.3571	0.1964	0.5179	0.3036	0.1786	0.5536	0.3214	0.1250
g_3	0.1607	0.4643	0.3750	0.4464	0.3929	0.1607	0.1964	0.6071	0.1964
g_4	0.2679	0.6786	0.0536	0.3929	0.3393	0.2679	0.1607	0.6964	0.1429
g_5	0.5000	0.2679	0.2321	0.4821	0.4107	0.1071	0.3036	0.6607	0.0357
g_6	0.3750	0.5714	0.0536	0.4643	0.5000	0.0357	0.1607	0.5536	0.2857
g_7	0.1786	0.3214	0.5000	0.2321	0.5357	0.2321	0.3214	0.4286	0.2500
g_8	0.2321	0.5000	0.2679	0.1964	0.1067	0.6429	0.0893	0.5000	0.4107

✈ *Step Two: Weighting Values*

The evaluation factor weighting values, W_f, were defined by the results of the expert panel survey. Three evaluation factors at each selected service facility were chosen. (see TABLE 5-10) They have their own criteria, $dC = \Sigma r \times w$, are the three top levels among the given factor sets. We can use these criteria as a standard of weighting values for each factor among them.

Let the highest criterion be a numeric scale 1.0 and the other two criteria can be defined by a relative value to the highest one. For example, the decision criterion of time factor at the service facility is 15.3, complexity of service procedure is 13.6, and courtesy of personnel is 8.9 . Among them, the time factor criterion is the highest value so that it is weighted by a numeric scale of 1.0, complexity of procedure factor is 0.89 (=13.6/15.3) which is a relative value for the highest decision criterion, and courtesy factor 0.58 (= 8.9/15.3) . According to this method, the other factor weighting values can be defined as;

$$W_f = w^f_{nk} \in \mathbf{M}_{8\times3} = \begin{matrix} w^f\text{check-in} \\ w^f\text{security screening} \\ w^f\text{passport control} \\ w^f\text{waiting areas} \\ w^f\text{intra circulation} \\ w^f\text{kerbside circulation} \\ w^f\text{access} \\ w^f\text{concessions} \end{matrix} \begin{bmatrix} f_1 & f_2 & f_3 \\ 1.00 & 0.89 & 0.58 \\ 1.00 & 0.89 & 0.58 \\ 1.00 & 0.89 & 0.58 \\ 0.86 & 1.00 & 0.72 \\ 1.00 & 0.99 & 0.67 \\ 1.00 & 0.95 & 0.75 \\ 0.81 & 0.54 & 1.00 \\ 0.96 & 1.00 & 0.82 \end{bmatrix}$$

Also the facility or component weighting values can be defined by the same method for the consequence of the factor weighting values. The criteria for service facility are shown in <TABLE 5-7>. A fuzzy matrix for the facility weighting values, W_c , is given by;

$$W_c = w^c_n \in \mathbf{M}_{8\times1} = \begin{matrix} w^c\text{check-in} \\ w^c\text{security screening} \\ w^c\text{passport control} \\ w^c\text{waiting areas} \\ w^c\text{intra circulation} \\ w^c\text{kerbside circulation} \\ w^c\text{access} \\ w^c\text{concessions} \end{matrix} \begin{bmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 0.58 \\ 0.69 \\ 0.69 \\ 0.69 \\ 0.53 \end{bmatrix}$$

The weighting coefficient of the evaluation, W_e , is in role as a translation criterion. Multi-decision model has been defined by the linguistic criteria "good" and "bad". Therefore, input data is needed to translate to a good or bad level formulation. Suppose the weighting coefficients of the evaluation grade are:

$$W_e \in \mathbf{M}_{1\times3} = [\ 1.00 \quad 0.67 \quad 0.33\ ]$$

✈ Step Three: Input Data of Multi-decision Model

We can get a fuzzy decision matrix, $\tilde{Z}_n$, which has been defined by the initial input matrix Z_n and the factor weighting values (W_f) . That is represented as:

$$\tilde{Z}_n = W_f \cdot Z_n \in \mathbf{M}_{9\times8}$$

=

	f_1			f_2			f_3		
g_1	0.1071	0.5893	0.3036	0.3020	0.3814	0.2066	0.3314	0.1657	0.0829
g_2	0.4464	0.3571	0.1964	0.4609	0.2702	0.1589	0.3211	0.1864	0.0725
g_3	0.1607	0.4643	0.6750	0.3973	0.3496	0.1630	0.1139	0.3521	0.1139
g_4	0.2304	0.5836	0.0461	0.3929	0.3393	0.2679	0.1157	0.5014	0.1029
g_5	0.5000	0.2679	0.2321	0.4773	0.4066	0.1061	0.2034	0.4427	0.0239
g_6	0.3750	0.5714	0.0536	0.4411	0.4750	0.0339	0.1205	0.4152	0.2143
g_7	0.1446	0.2064	0.4050	0.1254	0.2893	0.1254	0.3214	0.4286	0.2500
g_8	0.2229	0.4800	0.2571	0.1964	0.1607	0.6429	0.0732	0.4100	0.3368

The final procedure of input data is the weighted-good matrix I_n . The matrix I_n can be used as input of the multi-decision model. It is shown as:

$$I_n = W_e \cdot \tilde{Z}_n \in \mathbf{M}_{8\times3} =$$

f_1	f_2	f_3
0.6021	0.6257	0.4698
0.7505	0.6944	0.4699
0.5955	0.6788	0.3875
0.6366	0.7086	0.4856
0.7561	0.7848	0.5079
0.7755	0.7705	0.4694
0.4527	0.3605	0.6911
0.6293	0.5163	0.4591

✈ *Step Four: Multi-decision Criteria*

The multi-decision criteria have been defined as five decisions. These five decisions are shown as;

If	$d_1 = f_1 \cap f_2 \cap f_3$	then	$Y = B_1(v)$: *Very Satisfactory*(VS) ,
If	$d_2 = f_1 \cap \{f_2 \cup f_3\}$	then	$Y = B_2(v)$: *More Satisfactory*(MS) ,
If	$d_3 = f_2 \cap f_3$	then	$Y = B_3(v)$: *Satisfactory*(S) ,
If	$d_4 = f_1 \cap \bar{f}_3$	then	$Y = B_4(v)$: *Less satisfactory*(LS) , and
If	$d_5 = \bar{f}_1 \cap \{\bar{f}_2 \cup \bar{f}_3\}$	then	$Y = B_5(v)$: *Unsatisfactory*(US) .

According to these criteria, we can get a fuzzy matrix R;

$R \in M_{8\times5} =$

	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8
d_1	0.4698	0.4699	0.3875	0.4856	0.5079	0.4694	0.3605	0.4591
d_2	0.6021	0.6944	0.5955	0.6366	0.7561	0.7705	0.4527	0.5163
d_3	0.4698	0.4699	0.3875	0.4856	0.5079	0.4694	0.3605	0.4591
d_4	0.5302	0.5301	0.5955	0.5144	0.4921	0.5306	0.3089	0.5409
d_5	0.3979	0.2495	0.4045	0.3634	0.2439	0.2245	0.5473	0.3707

By the translation rule of fuzzy interference reasoning $d_i(u, v) = 1 \wedge [1 - A_i(u) + B_i(v)]$, we get fuzzy multi-criteria matrices shown as:

o $d_1(u,v) \in M_{9\times11}$

=

0.5302	0.5303	0.5318	0.5383	0.5558	0.5927	0.6598	0.7703	0.9398	1.0000	1.0000
0.5301	0.5302	0.5317	0.5382	0.5557	0.5926	0.6597	0.7702	0.9397	1.0000	1.0000
0.6125	0.6126	0.6141	0.6206	0.6381	0.6750	0.7421	0.8526	1.0000	1.0000	1.0000
0.5144	0.5145	0.5160	0.5225	0.5400	0.5769	0.6440	0.7545	0.9240	1.0000	1.0000
0.4921	0.4922	0.4937	0.5002	0.5177	0.5546	0.6217	0.7322	0.9017	1.0000	1.0000
0.5306	0.5307	0.5322	0.5387	0.5562	0.5931	0.6602	0.7707	0.9402	1.0000	1.0000
0.6395	0.6396	0.6411	0.6476	0.6651	0.7020	0.7691	0.8796	1.0000	1.0000	1.0000
0.5409	0.5410	0.5425	0.5490	0.5665	0.6034	0.6705	0.7810	0.9505	1.0000	1.0000

o $d_2(u,v) \in M_{9\times 11}$

$$= \begin{bmatrix} 0.3979 & 0.4079 & 0.4379 & 0.4879 & 0.5579 & 0.6479 & 0.7579 & 0.8879 & 1.0000 & 1.0000 & 1.0000 \\ 0.3056 & 0.3156 & 0.3456 & 0.3956 & 0.4656 & 0.5556 & 0.6656 & 0.7956 & 0.9456 & 1.0000 & 1.0000 \\ 0.4045 & 0.4145 & 0.4445 & 0.4945 & 0.5645 & 0.6545 & 0.7645 & 0.8945 & 1.0000 & 1.0000 & 1.0000 \\ 0.3634 & 0.3734 & 0.4034 & 0.4534 & 0.5234 & 0.6134 & 0.7234 & 0.8534 & 1.0000 & 1.0000 & 1.0000 \\ 0.2439 & 0.2539 & 0.2839 & 0.3339 & 0.4039 & 0.4939 & 0.6039 & 0.7339 & 0.8839 & 1.0000 & 1.0000 \\ 0.2295 & 0.2395 & 0.2695 & 0.3195 & 0.3895 & 0.4795 & 0.5895 & 0.7195 & 0.8695 & 1.0000 & 1.0000 \\ 0.5473 & 0.5573 & 0.5873 & 0.6373 & 0.7073 & 0.7973 & 0.9073 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.4837 & 0.4937 & 0.5237 & 0.5737 & 0.6437 & 0.7337 & 0.8437 & 0.9737 & 1.0000 & 1.0000 & 1.0000 \end{bmatrix}$$

o $d_3(u,v) \in M_{9\times 11}$

$$= \begin{bmatrix} 0.5302 & 0.6302 & 0.7302 & 0.8302 & 0.9302 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.5301 & 0.6301 & 0.7301 & 0.8301 & 0.9301 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.6125 & 0.7125 & 0.8125 & 0.9125 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.5144 & 0.6144 & 0.7144 & 0.8144 & 0.9144 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.4921 & 0.5921 & 0.6921 & 0.7921 & 0.8921 & 0.9921 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.5306 & 0.6306 & 0.7306 & 0.8306 & 0.9306 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.6395 & 0.7395 & 0.8395 & 0.9395 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.5409 & 0.6409 & 0.7409 & 0.8409 & 0.9409 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \end{bmatrix}$$

o $d_4(u,v) \in M_{9\times 11}$

$$= \begin{bmatrix} 0.4698 & 0.7860 & 0.9170 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.4699 & 0.7861 & 0.9171 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.4045 & 0.7207 & 0.8517 & 0.9522 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.4856 & 0.8018 & 0.9328 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.5079 & 0.8241 & 0.9551 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.4694 & 0.7856 & 0.9166 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.6911 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \\ 0.4591 & 0.7753 & 0.9063 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 \end{bmatrix}$$

o $d_5(u,v) \in M_{9\times 11}$

$$= \begin{bmatrix} 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 0.9021 & 0.8021 & 0.7021 & 0.6021 \\ 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 0.9505 & 0.8505 & 0.7505 \\ 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 0.9955 & 0.8955 & 0.7955 & 0.6955 & 0.5955 \\ 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 0.9366 & 0.8366 & 0.7366 & 0.6366 \\ 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 0.9561 & 0.8561 & 0.7561 \\ 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 0.9755 & 0.8755 & 0.7755 \\ 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 0.9527 & 0.8527 & 0.7527 & 0.6527 & 0.5527 & 0.4527 \\ 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 0.9293 & 0.8293 & 0.7293 & 0.6293 \end{bmatrix}$$

Finally, the fuzzy multi-criteria decision matrix, $D(u, v) = \bigwedge_{i=1}^{5} d_i(u, v)$, determines the satisfaction membership $S_n(v)$ as shown:

$$S_n(v) = D(u_n, v) \cong \left(\bigcap_{i=1}^{5} d_i(u_n, v)\right) \in M_{8\times 11}$$

=	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
$\tilde{E}_1$	0.4698	0.5303	0.5318	0.5383	0.5558	0.5927	0.6598	0.7703	0.8021	0.7021	0.6021
$\tilde{E}_2$	0.4699	0.5302	0.5317	0.5382	0.5557	0.5926	0.6597	0.7702	0.9397	0.8505	0.7505
$\tilde{E}_3$	0.4045	0.6126	0.6141	0.6206	0.6381	0.6750	0.7421	0.8526	0.7955	0.6955	0.5955
$\tilde{E}_4$	0.4856	0.5145	0.5160	0.5225	0.5400	0.5769	0.6440	0.7545	0.8366	0.7366	0.6366
$\tilde{E}_5$	0.4921	0.4922	0.4937	0.5002	0.5177	0.5546	0.6217	0.7322	0.9017	0.8561	0.7561
$\tilde{E}_6$	0.4694	0.5307	0.5322	0.5387	0.5562	0.5931	0.6602	0.7707	0.9402	0.8755	0.7755
$\tilde{E}_7$	0.6395	0.6396	0.6411	0.6476	0.6651	0.7020	0.7691	0.7527	0.6527	0.5527	0.4527
$\tilde{E}_8$	0.4591	0.5410	0.5425	0.5490	0.5665	0.6034	0.6705	0.7810	0.8293	0.7293	0.6293

✈ *Step Five: Satisfaction Values*

For service facility g_1(check-in and baggage drop), from the first row in $S_n(v)$ we have the fuzzy subset E_1 of unit evaluation interval $V = [0, 1]$. The α-level set $E_{1\alpha} \in \tilde{E}_1$ is;

$$\tilde{E}_1 = \{0.4698 | 0.0,\ 0.5303 | 0.1,\ 0.5318 | 0.2,\ 0.5383 | 0.3,\ 0.5558 | 0.4,\ 0.5927 | 0.5,\ 0.6598 | 0.6,\ 0.7703 | 0.7,\ 0.8021 | 0.8,\ 0.7021 | 0.9,\ 0.6021 | 1.0\}.$$

According to the point value for each $E_{n\alpha}$, $P(E_n) = \frac{1}{\alpha_{\max}} \int_{v=1}^{V} M(E_{n\alpha})\Delta\alpha$, we can calculate the α-level set $E_{n\alpha}$ and mean values of it and the differences of each α-level (Δα) are shown in <TABLE 8-4> . At last, we have satisfaction values $P(E_n)$. The satisfaction value for check-in and baggage drop service facility(g_1) at the airport, $P(E_1)$, is calculated as:

$$\begin{aligned} P(E_1) = 1/0.8021(&[0.50\times0.4698]+[0.55\times0.0605]+[0.60\times0.0015]+[0.65\times0.0065] \\ &+[0.70\times0.0175]+[0.75\times0.0369]+[0.80\times0.0094]+[0.75\times0.0577] \\ &+[0.80\times0.0423]+[0.75\times0.0682]+[0.80\times0.0318]) \\ = 0.5915& \end{aligned}$$

<TABLE 8-4> THE α-LEVEL SETS AND MEAN VALUES

n(V)	RANGE OF α	$E_{n\alpha}$	$n(E_{n\alpha})$	$M(E_{n\alpha})$	Δα
1	0.0000<α≤0.4698	.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0	11	0.50	0.4698
2	0.4698<α≤0.5303	0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0	10	0.55	0.0605
3	0.5303<α≤0.5318	0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0	9	0.60	0.0015
4	0.5318<α≤0.5383	0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0	8	0.65	0.0065
5	0.5383<α≤0.5558	0.4 0.5 0.6 0.7 0.8 0.9 1.0	7	0.70	0.0175
6	0.5558<α≤0.5927	0.5 0.6 0.7 0.8 0.9 1.0	6	0.75	0.0369
7	0.5927<α≤0.6021	0.6 0.7 0.8 0.9 1.0	5	0.80	0.0094
8	0.6021<α≤0.6598	0.6 0.7 0.8 0.9	4	0.75	0.0577
9	0.6598<α≤0.7021	0.7 0.8 0.9	3	0.80	0.0423
10	0.7021<α≤0.7703	0.7 0.8	2	0.75	0.0682
11	0.7703<α≤0.8021	0.8	1	0.80	0.0318

We can get the other satisfaction values using the same procedures of calculation, respectively. They are shown in <TABLE 8-5> .

<TABLE 8-5> SATISFACTION VALUES AT EACH SERVICE FACILITY

SERVICE FACILITY (g_n)	SATISFACTION VALUE $P(E_n)$
Check-in and Baggage Drop (g_1)	0.5915
Security Screening (g_2)	0.6379
Passport Control (g_3)	0.5698
Waiting Areas (g_4)	0.6099
Intra terminal Circulation (g_5)	0.6452
Terminal Kerbside Circulation (g_6)	0.6404
Airport Access (g_7)	0.5009
Concessions (g_8)	0.5978

✈ *Step Six: Indication of Evaluation*

The ideal maximum satisfaction, $P_{max}(E)$, can be calculated by a unique passenger's response in which all passengers answer the highest or most positive grade of the questions. When input data uses this special condition, the satisfaction value is 0.9233. Therefore, we can get the unsatisfied distances, $U_d(n) = P_{max}(E) - P(E_n)$, which are:

$U_d(n)$	$P_{max}(E) - P(E_n)$
1	0.3318
2	0.2854
3	0.3535
4	0.3134
5	0.2781
6	0.2829
7	0.4224
8	0.3255

Finally, we have the weighted-unsatisfactory distance $WU_d(n) = [P_{max}(E)-P(E_n)] \times W_c$ which considered facility weighting value(W_c) regarding the degree of importance for the service performance at each facility. The weighted-unsatisfactory distances are represented in <TABLE 8-6> .

<TABLE 8-6> THE WEIGHTED-UNSATISFACTORY DISTANCES

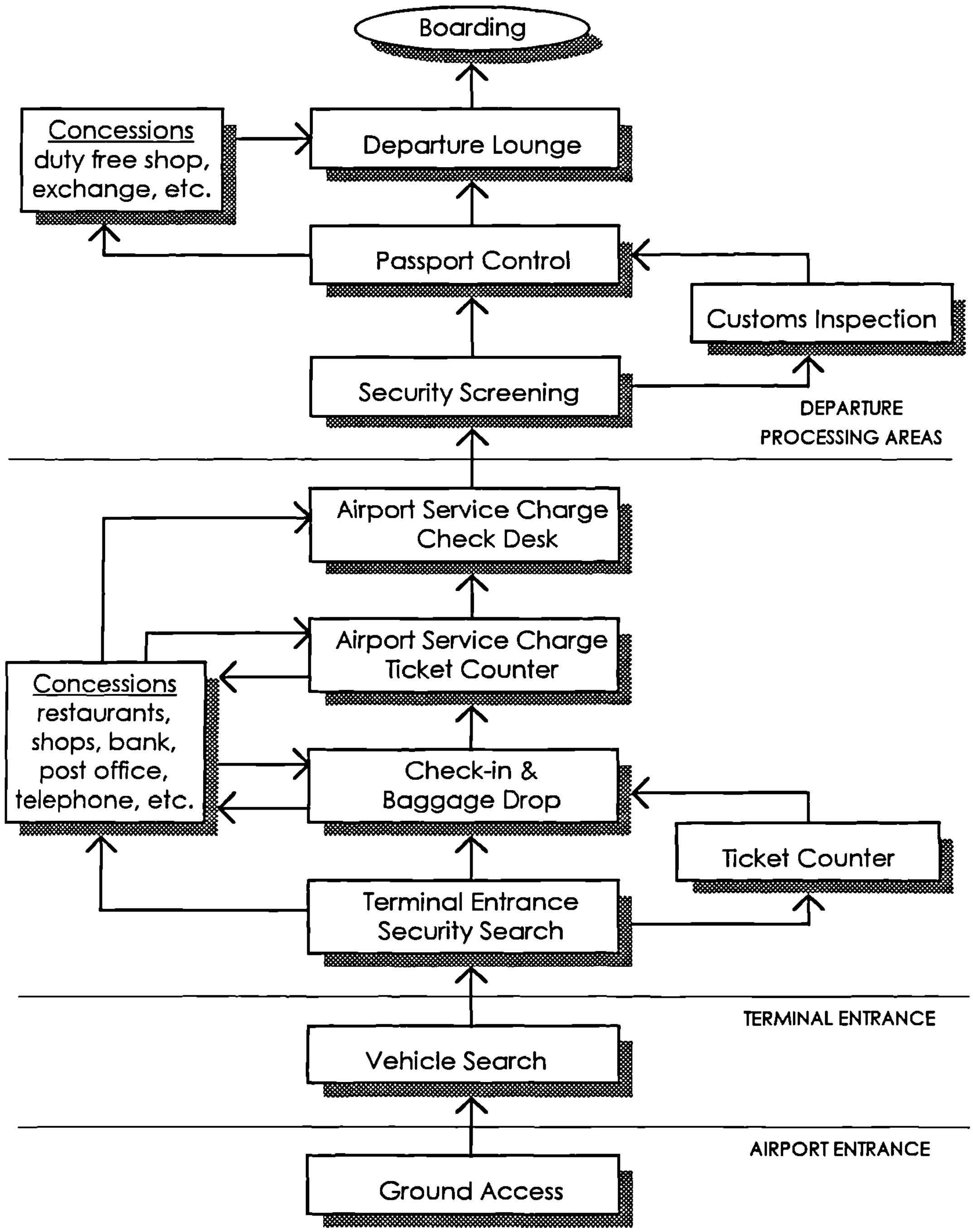
SERVICE FACILITY	UNSATISFIED DISTANCE	FACILITY WEIGHTING VALUE	WEIGHTED-UNSATISFACTORY DISTANCE
Check-in & Baggage Drop	0.3318	1.00	0.3318
Security Check	0.2854	1.00	0.2854
Passport Control	0.3535	1.00	0.3535
Waiting Areas	0.3134	0.58	0.1818
Intra terminal Circulation	0.2781	0.69	0.1919
Kerbside Circulation	0.2829	0.69	0.1952
Airport Access	0.4224	0.69	0.2915
Concessions	0.3255	0.53	0.1725

8-4 RESULTS OF IMPLEMENTATION AND COMPUTATION

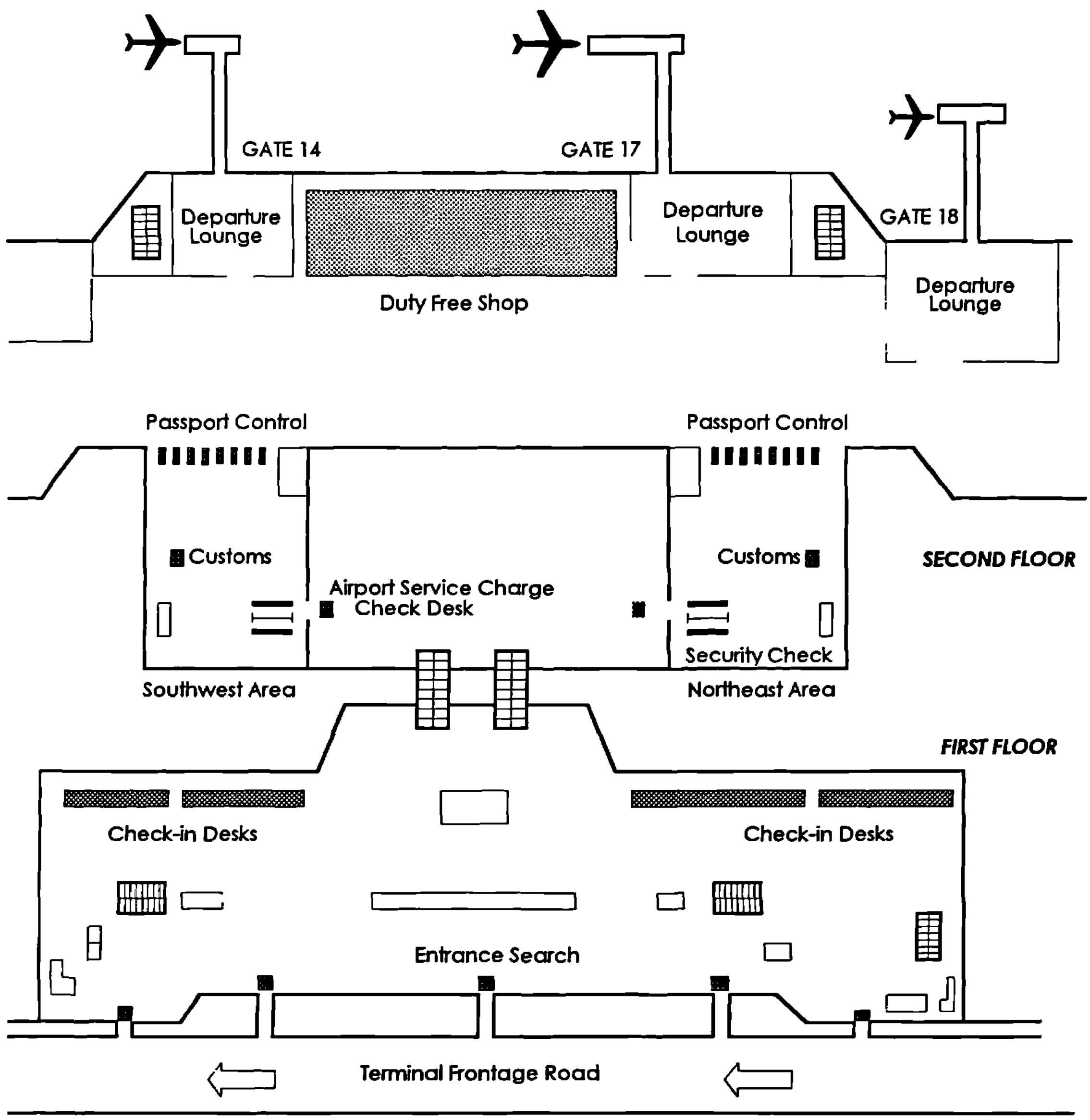
The results of the application of the multi-decision model are presented in this section. Information compiled from the passenger survey at Kimpo International Airport (KIA) in Seoul was conducted and analysed. The first analysis deals with the level of service evaluation aspect, the passenger's viewpoint using the multi-decision model. The second uses the perception-response model to compare previous research with the results of this study.

The terminal layout and service procedures for the departing passengers at KIA Terminal 2 are shown in <FIGURE 8-7, 8-8>. We find evidence of a strange service procedure which is the airport service charge to passengers (7,200 won ≅ £6.00). Usually, most airports in advanced nations charge this when the passengers purchase their air tickets from airlines or related agencies in co-operation with them. This unusual service procedure is seen to be a cause of a lower service level and of passengers' inconvenience. Many passengers particularly inexperienced ones are confused by this procedure but they have to endure it. All passengers should hand their ticket to the checking desk in front of the entrance gates for departure processing areas. The queue at the ticket check-in desk is significantly long during terminal peak periods. A few passengers are waiting in the queue without a ticket because they did not understand that they had to buy it, although the Airport Authority provides an airport information leaflet. Passengers in this case undoubtedly perceived this as a poor level of service. To avoid this confusion, the Airport Authority should provide clearer information to passengers using audio-visual or other suitable methods.

Another required service to passengers that definitely makes for inconvenience is the terminal entrance search. This is a security check of all passengers hand luggage. It is an understandable security search at an airport but it seems to be over-protective when we consider that one of the airport roles or objectives is to provide high standard services to its users, without any inconvenience.



<FIGURE 8-7> SERVICE PROCEDURE FOR DEPARTURE PASSENGERS AT KIA TERMINAL 2



<FIGURE 8-8> SERVICE FACILITY LAYOUT FOR DEPARTURE AT KIA TERMINAL 2

8-4.1 Multi-decision Model

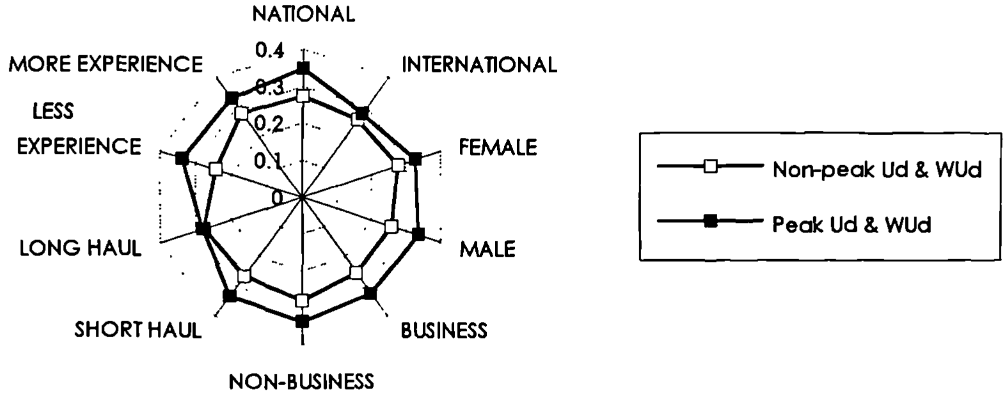
For international departing passengers at the airport landside system, a multi-decision model was constructed for the eight selected service facilities. The group categories for analysis which were set, were five passenger's attributes such as; nationality - Korean vs. foreigner; sex; the purpose of trip - business vs. non-business; haul length - short vs. long haul; trip experience - less vs. more experience. Also, time periods were covered such as peak and non-peak in terms of the passenger traffic volume.

8-4.1.1 The Service Facilities

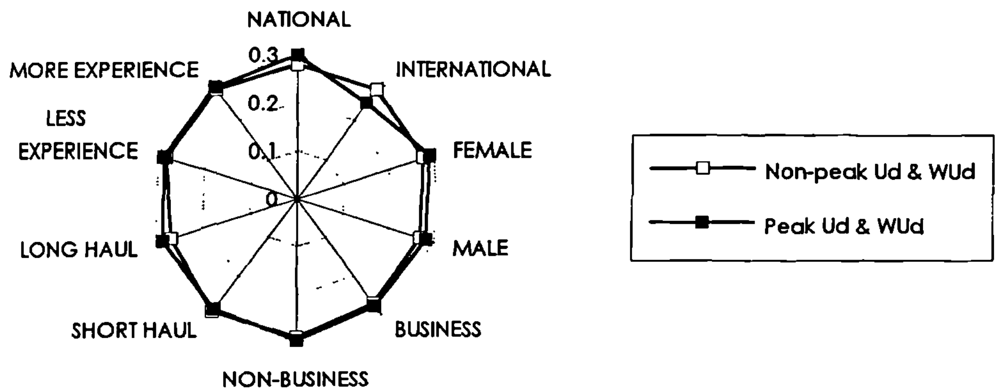
For international departures, a multi-decision model was constructed for eight service facilities. The unsatisfied and weighted-unsatisfactory distances (for definitions see SECTION 6-3.2.5 ~ 6) are equal at service processing, facilities-check-in and baggage, security screening, and passport control, because the component or facility weighting value(W_c) is defined as 1.0 .

Check-in and Baggage Drop

<FIGURE 8-A-1> shows the unsatisfied and weighted unsatisfactory distances for each attributive profile of the passengers at the check-in and baggage drop service facility. Overall unsatisfied distances were longer at peak than at non-peak times. The highest unsatisfied distance, which means the worst service level, was 0.2809 of non-business respondents at non-peak and 0.3479 of national travellers at peak time respectively. The shortest distance was 0.2427 at non-peak and 0.2787 at peak period of time. These distances were defined as differences between an ideal maximum satisfaction value (0.9233) and the passenger's actual satisfaction at each service facility. The unsatisfied distance gaps between two periods of time were quite large. The major reason was caused by the different service time for check-in and baggage drop service at KIA. The average service time at non-peak times was just about 8 minutes (waiting time = 2 min. 16 sec. + service time = 5 min. 36 sec.), but around 22 minutes (waiting time = 13 min. 46 sec. + service time = 8 min.) at busy hours respectively.



<FIGURE 8-A-1> UNSATISFIED AND WEIGHTED-UNSATISFACTORY DISTANCES FOR CHECK-IN AND BAGGAGE DROP SERVICE



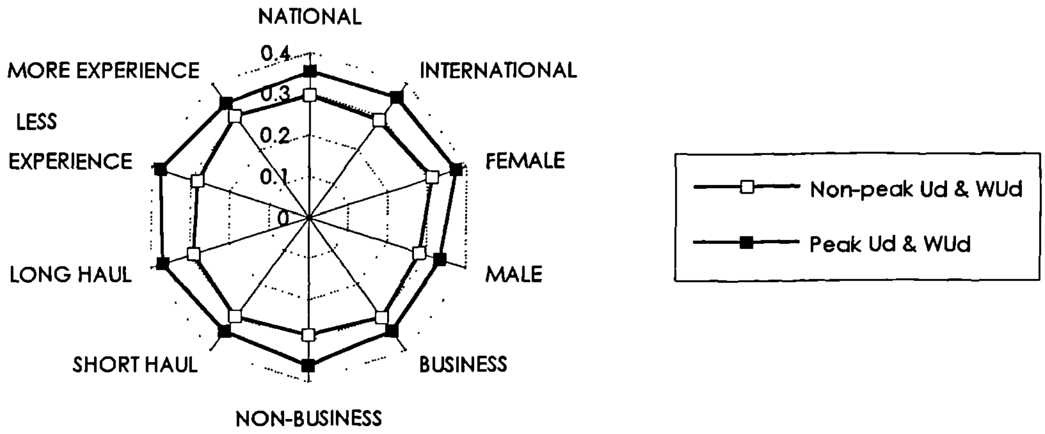
<FIGURE 8-A-2> UNSATISFIED AND WEIGHTED-UNSATISFACTORY DISTANCES FOR SECURITY SCREENING SERVICE

✈ *Security Screening*

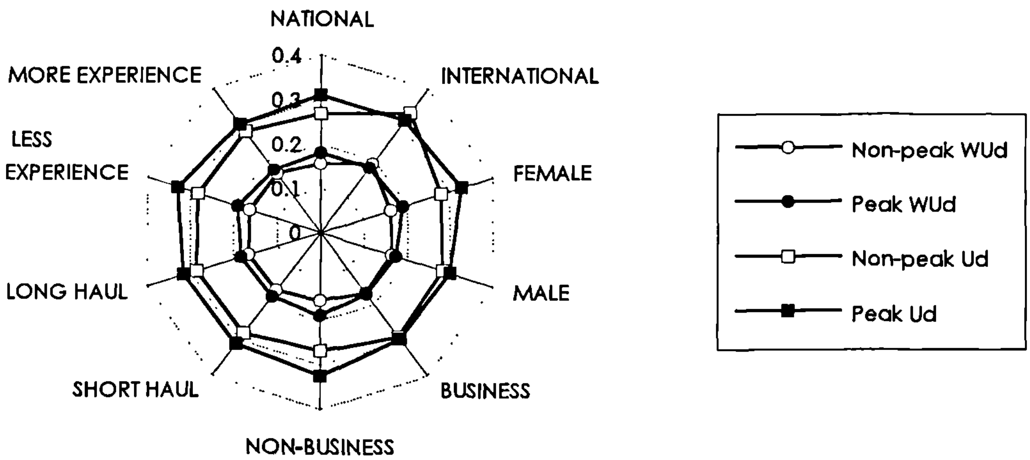
<FIGURE 8-A-2> gives the indications of satisfaction for the level of service at the security screening. Both unsatisfied distances during peak and non-peak time were similar and stable in each respondent's profile. KIA Terminal 2 has provided a flexible operation for security screening. During non-peak time, it serves only one facility to passengers, but two service facilities operate during busy periods. According to the different operations, they can take short time service performance. Average service times at peak and non-peak periods were around 1 minute (waiting time = 20 sec. + service time = 42 sec.) and roundly 1 min. 30 sec (waiting time = 52 sec. + service time = 41 sec.) respectively. This fact was greatly contributed to by a foreigner who showed the shortest unsatisfied distance at peak time in terms of the most satisfactory.

✈ *Passport Control*

<FIGURE 8-A-3> illustrates the degree of satisfaction for the passport control service at KIA Terminal 2. There are divided into two departure processing areas; north-east and south-west which are displayed in <FIGURE 8-8>. This research has considered only the north-east processing area as a survey bailiwick. It supplies eight passport control desks. During the busy traffic period, the whole facility is available to passengers. The average service time at the passport control facility was approximately 2.5 minutes (waiting time = 1 min. + service time = 1 min. 36 sec.) at non-peak time and 5.5 minutes (waiting time = 3 min. 41 sec. + service time = 1 min. 34 sec.) at peak time respectively. Therefore, it was not dominated by provision service time but by the length of waiting queue. We can find out the different perceptions in respondents' profile; sex and experience of the air trip. The unsatisfied distances of male travellers were 0.2814 and 0.3338 at non-peak and peak time respectively which were the shortest distances in each time criterion. However, female respondents were 0.3132 at non-peak and 0.3739 at peak time which were the longest and the second longest unsatisfied distances respectively.



<FIGURE 8-A-3> UNSATISFIED AND WEIGHTED-UNSATISFACTORY DISTANCES FOR PASSPORT CONTROL SERVICE



<FIGURE 8-A-4> UNSATISFIED AND WEIGHTED-UNSATISFACTORY DISTANCES FOR WAITING AREAS SERVICE

Less experienced passengers, who have travelled by air at KIA only one or two times, were rather more satisfied than the more experienced ones under similar average service times at non-peak; 2 min. 30 sec. for those the less experience and 2 min. 40 sec. for the more experienced. At peak time, they perceived a lower satisfactory level(0.3772) than the more experienced (0.3405) . The reason was likely to be time spent in the service facility, because the average service times at passport control were slightly different, around 5.5 minutes for the less experienced and 4.5 minutes for the more experienced respondents. More time spent by the less experienced respondents stemmed from misunderstanding the need to complete an embarkation card and submit it. Some of them did not complete it, so they spent extra time doing it in the passport control service area. This affected and was perceived to be a lower level of service in terms of the complexity of the service procedure.

✈ ***Waiting Areas***

<FIGURE 8-A-4> demonstrates the unsatisfied and weighted-unsatisfactory distances in terms of the passenger's satisfaction level for each area. Passenger waiting areas include departure lounges, terminal lobbies, and the departure concourse or hall. The shortest distance at non-peak was 0.2684 of both national and non-business respondents it was 0.1557 for the weighted-unsatisfied distance(WU_d). The longest one was 0.3334(0.1934) for a foreign traveller. At peak time, the shortest distance was 0.2971(0.1723) for business passengers and the longest was 0.3284(0.1905) for those the less experience ones respectively.

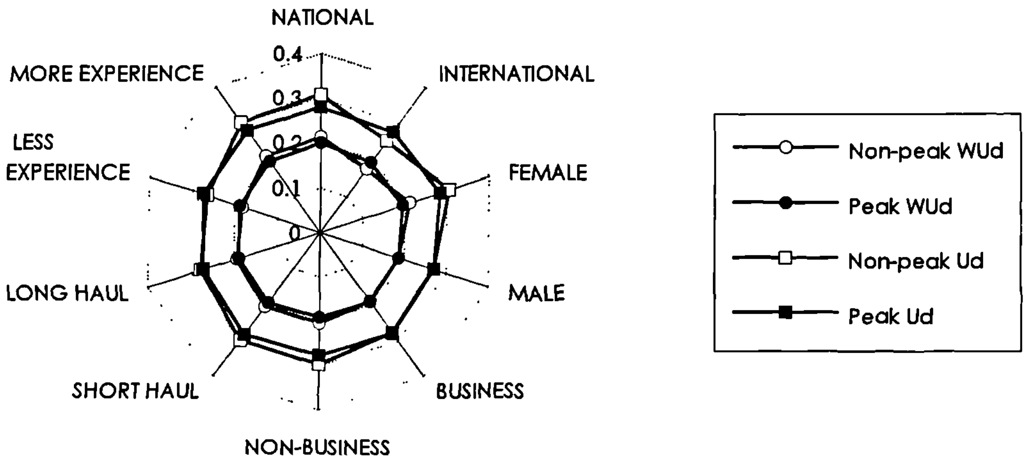
The various levels of service at waiting areas were demonstrated by the different respondent's profiles; nationality, sex, and the purpose of trip. International travellers perceived them as the most unsatisfactory during non-peak time; while national respondents replied at the most satisfactory level. So, both responses were idiosyncrasies, but they had similar satisfaction levels at peak time. The levels of satisfaction for male and female respondents were near to the average at non-peak, but female travellers were rather more unsatisfactory (0.3267|0.1895) than the others(0.2993|0.1736) at peak period time. Passengers whose purpose for the trip was business showed constant satisfaction level at all times, however, the others were quite varied between 0.2684(0.1557) which was the highest satisfaction level at non-peak and 0.3243(0.1881) which was the second lowest at peak.

✈ *Intra Terminal Circulation*

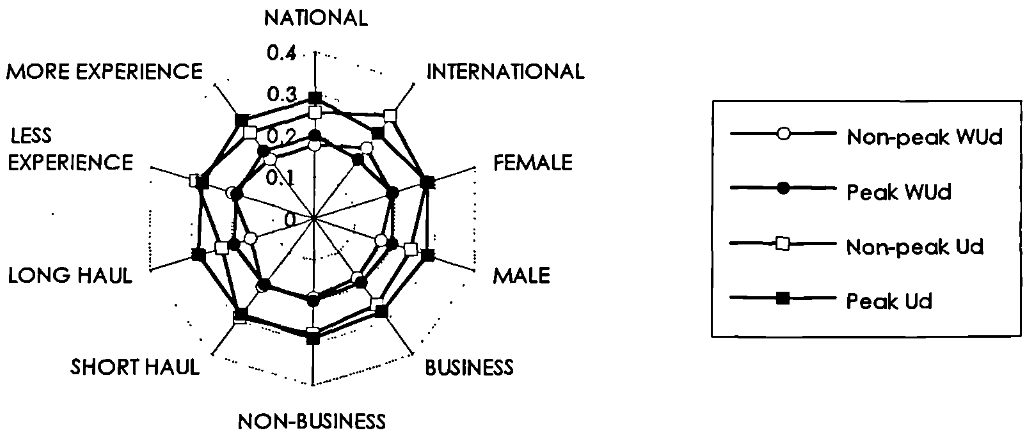
<FIGURE 8-A-5> shows the output of the multi-decision model for the level of service in intra terminal circulation. We can roughly sketch the circulation flows of departure passengers in <FIGURE 8-8> . Terminal 2 configures a linear system under simple terminal design concept. The considered evaluation factors for the facility were walking distances between service facilities, sign system, and level changes. The respondents' satisfactions demonstrated an overall approximate output at peak and non-peak times. The satisfaction values showed noticeably dissimilar levels at non-peak time about the passenger's attributive profile of sex and air trip experience. There were 0.3076(0.2122) of national and 0.2516(0.1736) of international passengers and 0.2650(0.1829) of the less experienced travellers and 0.3023(0.2086) of more experienced ones. The unsatisfied distances of both national and more experienced respondents were longer at non-peak time. This meant that they perceived a better service quality during terminal peak time. We can also find a similar result in the case of female respondents.

✈ *Kerbside Circulation*

We find a fluctuated output in <FIGURE 8-A-6> even though these are the shortest distances amongst the considered facilities. KIA Terminal 2 has a fairly simple kerbside circulation and is easy to access for the terminal main entrance from its kerb, as well as to the car park. Passenger dropping points from all public transport modes are located near to the terminal entrance gates, because they are served by the terminal frontage road.



<FIGURE 8-A-5> UNSATISFIED AND WEIGHTED-UNSATISFACTORY DISTANCES FOR INTRA TERMINAL CIRCULATION SERVICE



<FIGURE 8-A-6> UNSATISFIED AND WEIGHTED-UNSATISFACTORY DISTANCES FOR KERBSIDE CIRCULATION SERVICE

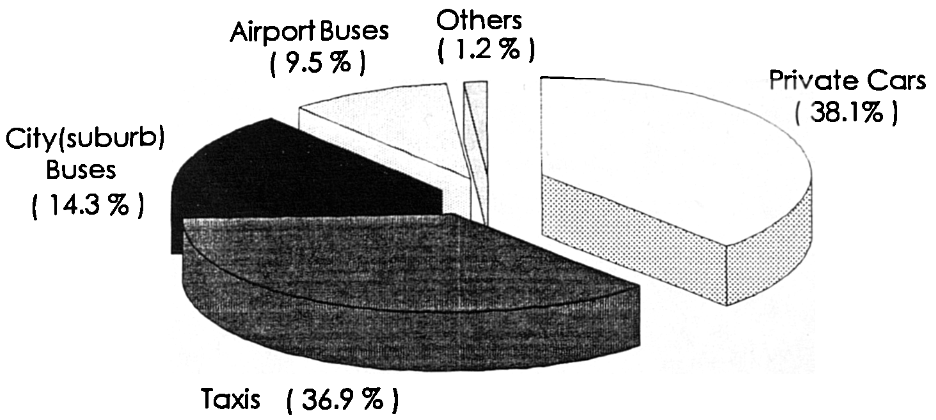
The unsatisfied and weighted-unsatisfactory distances for national travellers was relatively short as 0.2548(0.1758), but international respondents were the longest at 0.3046(0.2102) at non-peak time. There were totally different responses for the sign system at the terminal kerbside as a comfort factor. 87.5 % of international respondents answered with the lowest service level at non-peak, but only 46.15 % at peak time. Short haul and the less experienced passengers had a slightly better satisfactory level at peak time.

✈ *Airport Access*

<FIGURE 8-A-7> shows a steady output for the airport access service. That is the highest unsatisfied distance amongst the selected facilities of service levels. This output was independent of peak and non-peak periods of time, because the airports busy time did not correspond with the rush hours in the Seoul metropolis. Normally, Terminal 2 reaches busy passenger traffic between 10:00 - 11:00 in the morning and 18:00 - 19:00 in the afternoon. Furthermore, airport access roads especially in city centre connection routes experience congestion almost all the time during the day. This is a serious problem for both passengers and airport operators.

Transport modes to access KIA are private cars, taxis, city buses, suburb buses, airport buses, and hotel bus services. Public transport provides various service standards at different fares. Taxis supply two types of service which are medium-sized and deluxe taxis. City buses are served by general and city express buses. There are three types of airport buses; KAL limousine, airport limousine, and the airport express buses. All of them provide transit between the airport and the city of Seoul. Suburb buses link the satellite cities of Seoul and the airport. Private cars and taxis are dominant as the main transport modes to access the airport and accounted for three quarters of the total of used transport modes. <FIGURE 8-9> displays an in depth breakdown of the transport modes used by the respondents to the survey.

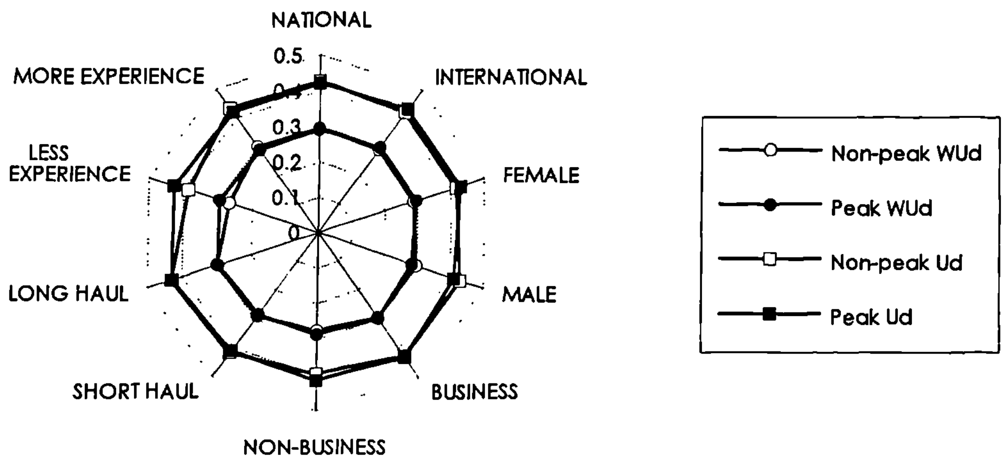
In the passenger's profile sex and experience, a varying result was illustrated. Female and the less experienced passengers responded with a higher satisfaction level than did males and more experienced travellers at the non-peak time; otherwise, they were slightly more satisfied than the others at peak time. However, time classifications for airport access are not significantly influenced by the service level in this case.



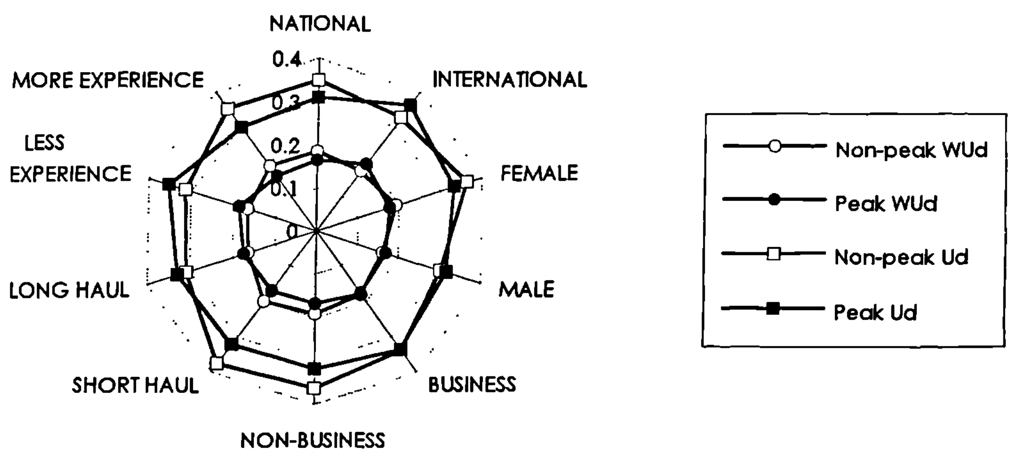
<FIGURE 8-9> BREAKDOWN OF TRANSPORT MODES USED

✈ *Concessions*

<FIGURE 8-A-8> depicts a varying result of the service level evaluation for the airport's concessions. The considered evaluation factors- access distance, variety of choice, and functional display of concessions are likely to be independent of peak or non-peak time traffic. The level of service for concessions can be determinated by a passenger characteristic such as behaviour, knowledge, or experience. It will be affected to a far greater extent by a poor service if they have more information about concessions and conditions so that they are more likely to expect a service.



<FIGURE 8-A-7> UNSATISFIED AND WEIGHTED-UNSATISFACTORY DISTANCES FOR AIRPORT ACCESS SERVICE



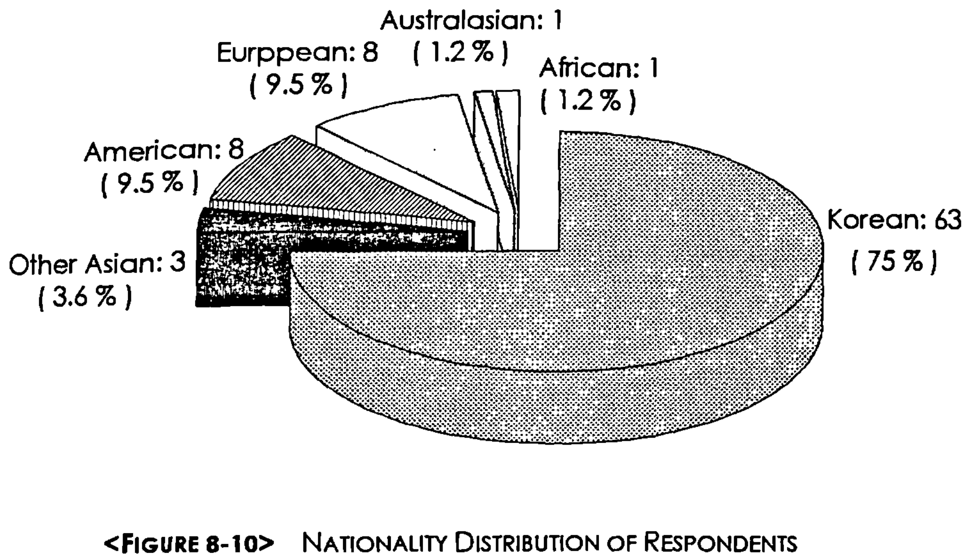
<FIGURE 8-A-8> UNSATISFIED AND WEIGHTED-UNSATISFACTORY DISTANCES FOR CONCESSIONS' SERVICE

8-4.1.2 The Attributes of Passengers

The multi-decision model was applied to the airport landside system and has considered the international departure passengers as the target investigation. The unsatisfied and weighted unsatisfactory distances in terms of passenger's satisfaction were obtained as the output of its model. The results were drawn by five attribute profiles of passengers such as nationality, sex, purpose of trip, journey length, and air trip experience. The weighted-satisfactory values or weighted-unsatisfactory distances will provide very practical information for the operation of the airport. They were considered as an important valuation of each service facility and the level of service.

✈ *Nationality*

The survey included responses from 84 passengers belonging to 63 Korean and 21 foreigners. The nationality distribution of respondents is shown in <FIGURE 8-10> .



<FIGURE 8-10> NATIONALITY DISTRIBUTION OF RESPONDENTS

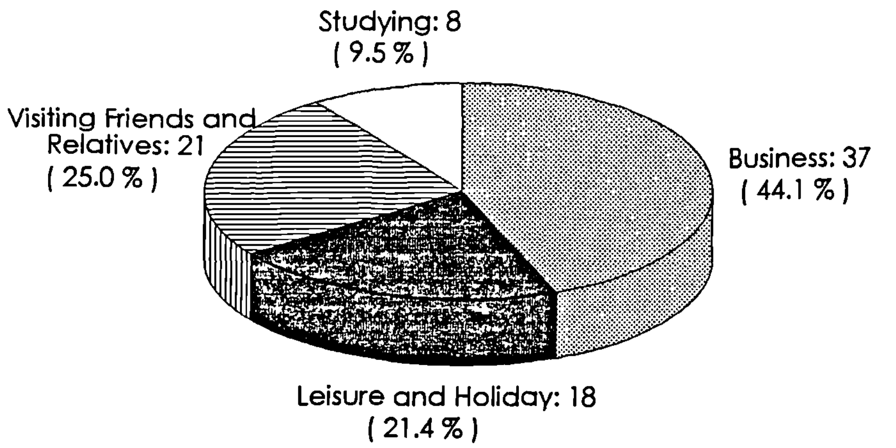
Broadly, nationality profiles were grouped into two analytical types of passengers; national and international respondents. <FIGURE 8-B-1 ~ 8-B-4> indicate the satisfaction levels for the provision of services to national and international respondents. For unsatisfied and weighted-unsatisfactory distances from the passenger's viewpoint, airport access(g_7) and passport control service(g_3) were the lowest for nationals at peak and international respondents at non-peak time respectively. There were also lower service levels for the others. However, terminal circulation(g_5, g_6) showed higher passenger satisfaction both at terminal, peak and non-peak time.

Sex

<FIGURE 8-B-5 ~ 8-B-8> gives a breakdown of the satisfaction values, unsatisfied, and weighted-unsatisfactory distances for the sex of the passenger's attribute profile. The average satisfaction levels were similar features for passenger sex profile at peak and non-peak time. Men's unsatisfied distance was the shortest(0.2925) at non-peak time. It meant they perceived the provision service through the airport landside system with the highest satisfaction level. Passport control service(g_3) and ground access to the airport(g_7) received the lowest satisfaction level from female respondents. Ground access service to the airport(g_7) was ranked at the lowest level by male respondents at terminal peak as well as non-peak time. Check-in and baggage drop service(g_1) and passport control(g_3) were given relatively lower status than the others at terminal peak period time. Terminal kerbside circulation(g_6) was ranked at a higher level of service overall.

Purpose of Trip

The breakdown of respondents in accordance with the purpose of trip is displayed in <FIGURE 8-11> . <FIGURE 8-B-9 ~ 8-B-12> which describe the satisfaction level and unsatisfied distances for the purpose of trip as a passenger attribute. Business travellers were 44.1 % as the largest group, 25.0 % were visiting friends and relatives, 21.4 % were on holidays or leisure, and 9.5 % were students. This profile was divided into two attributes in order to analyse input data: business and non-business travellers. Thus the non-business profile included the travellers on holiday or leisure, visiting friends or relatives, and studying. Ground access to the airport(g_7) was given the lowest service level in terms of passenger satisfaction for all the profiles. When each weighting value was given to the service facility that can be represented by the weighted-unsatisfactory distances, service processing facilities(g_1 , g_2 , g_3) were ranked at a lower level of service by all the passengers.



<FIGURE 8-11> BREAKDOWN OF THE PURPOSE OF TRIP

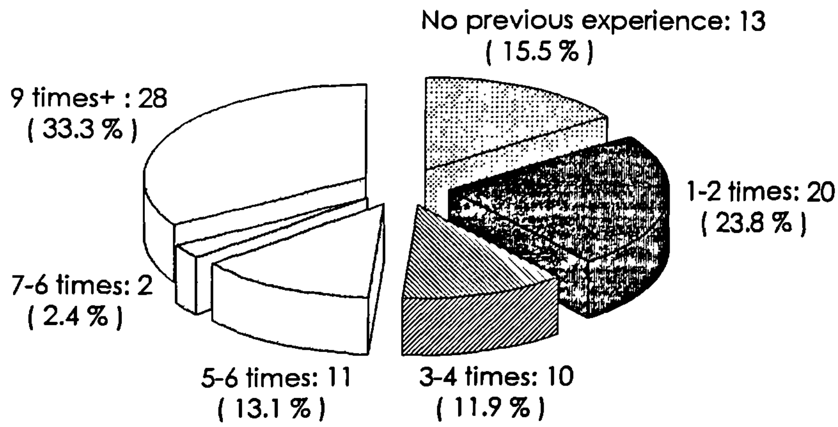
Haul Length

<FIGURE 8-B-13 ~ 8-B-16> indicates the perceived level of service for the length of journey attribute. Satisfaction values of long haul passengers (0.6280: non-peak, 0.6029: peak) showed slightly higher levels than the short haul passengers (0.6081: non-peak, 0.6021: peak). Broadly, terminal circulation services(g_5, g_6) were ranked at a relatively higher level. Airport ground access(g_7) was the lowest satisfaction level for

the considered passenger profile. For the weighted-unsatisfactory distances, service processing facilities(g_1, g_2, g_3) as well as airport ground access(g_7) were positioned at the lower levels. Waiting areas(g_4) and concessions(g_8) were given shorter weighted-unsatisfactory distances for all profiles.

✈ *Experience*

This is one of the most important passenger profiles in evaluating level of service. Passenger's perception for the provision service through the airport can create a different response according to level of experience. In this analysis, it was classified into two attributes where travellers with less experience, those who have journeyed up to two times at KIA, and the more experienced who have travelled three times or more. <FIGURE 8-12> illustrates the experience distribution of respondents. Experienced respondents (nine times or more) were 33.3 % their purpose of trip was dominated by business 57.4 % ; and 25 % were visiting friends or relatives.



<FIGURE 8-12> DISTRIBUTION OF RESPONDENTS FOR AIR TRIP EXPERIENCE AT KIA

<FIGURE 8-B-17 ~ 20> shows the satisfaction values and unsatisfied distances for the experienced respondents using the multi-decision model. The average satisfaction level for the less experienced respondents was high. The check-in and baggage drop service(g_1) at terminal non-peak time was 0.6804(0.2429). This was the highest level. However, the satisfaction or unsatisfied distance for the ground access to the airport was at the lowest level for all passengers whatever their experience profiles. When the facility weighting value was considered it was an important degree in its effect on the level of service. Service processing facilities(g_1, g_2, g_3) and ground access(g_7) were at relatively low levels.

✈ ***Total Passengers***

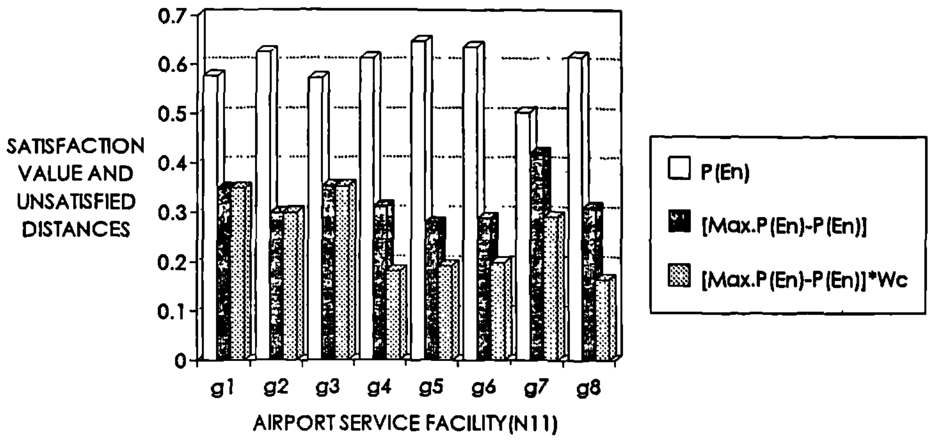
Finally, input data for the multi-decision model was analysed by total passengers for terminal non-peak and peak time. The results can be used as very reliable information for the operation of the airport landside system together with the concept of the level of service. The multi-decision model supplies the service level evaluation for the provision service through the system according to each facility in it. Practically, the analysis of the peak period will help to enhance and improve the current service level. <FIGURE 8-B-21 ~ 22> indicates the passengers' satisfaction levels for each service facility. The average satisfaction value for respondents at non-peak time was 0.6179(0.3054) and the shortest unsatisfied and weighted-unsatisfactory distance were 0.2627 of intra terminal circulation service and 0.1634 for waiting areas. However, airport ground access was the longest distance in the case of both distances. Concessions' service was at a low satisfaction level when weighting value was not considered, but it was the third when ranked with the facility weighting value. We find that the processing facilities (g_1, g_2, g_3) show low service level in weighted-unsatisfactory distance. For peak period of time, ground access(g_7), passport control(g_2), check-in and baggage drop(g_1) indicated a low level of service at each facility. When factor weighting values were considered, all of the service processing services and the airport ground access(g_7) were ranked at the bottom levels. The airport operators and managers should be carefully looking these poor service level facilities.

<TABLE 8-7> UNSATISFIED AND WEIGHTED-UNSATISFACTORY DISTANCES FOR TOTAL RESPONDENTS: NON-PEAK TIME

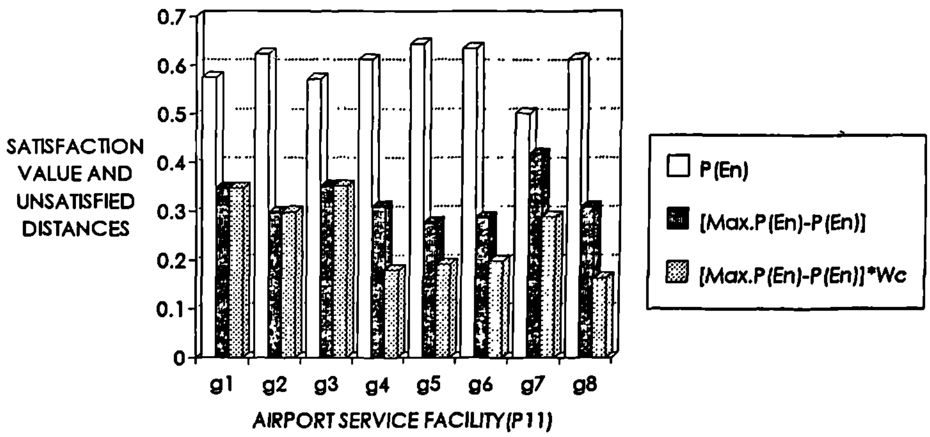
UNSATISFIED DISTANCE			WEIGHTED-UNSATISFACTORY		
RANKING	FACILITY	DISTANCE	RANKING	FACILITY	DISTANCE
1	Kerbside Circulation(g_6)	0.2627	1	Waiting Areas(g_4)	0.1634
2	Check-in(g_1)	0.2690	2	Kerbside Circulation(g_6)	0.1813
3	Security Screening(g_2)	0.2799	3	Concessions(g_8)	0.1833
4	Waiting Areas(g_4)	0.2817	4	Terminal Circulation(g_5)	0.1972
5	Terminal Circulation(g_5)	0.2858	5	Check-in(g_1)	0.2690
6	Passport Control(g_3)	0.2931	6	Security Screening(g_2)	0.2799
7	Concessions(g_8)	0.3458	7	Passport Control(g_3)	0.2931
8	Ground Access(g_7)	0.4252	8	Ground Access(g_7)	0.2934

<TABLE 8-8> UNSATISFIED AND WEIGHTED-UNSATISFACTORY DISTANCES FOR TOTAL RESPONDENTS: PEAK TIME

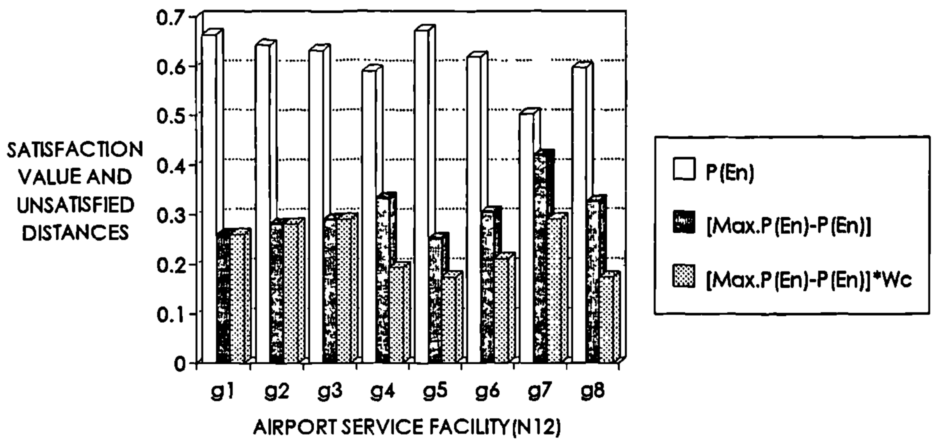
UNSATISFIED DISTANCE			WEIGHTED-UNSATISFACTORY		
RANKING	FACILITY	DISTANCE	RANKING	FACILITY	DISTANCE
1	Terminal Circulation(g_5)	0.2781	1	Concessions(g_8)	0.1725
2	Kerbside Circulation(g_6)	0.2829	2	Waiting Areas(g_4)	0.1818
3	Security Screening(g_2)	0.2854	3	Terminal Circulation(g_5)	0.1919
4	Waiting Areas(g_4)	0.3134	4	Kerbside Circulation(g_6)	0.1952
5	Concessions(g_8)	0.3255	5	Security Screening(g_2)	0.2854
6	Check-in(g_1)	0.3318	6	Ground Access(g_7)	0.2915
7	Passport Control(g_3)l	0.3535	7	Check-in(g_1)	0.3318
8	Ground Access(g_7)	0.4224	8	Passport Control(g_3)	0.3535



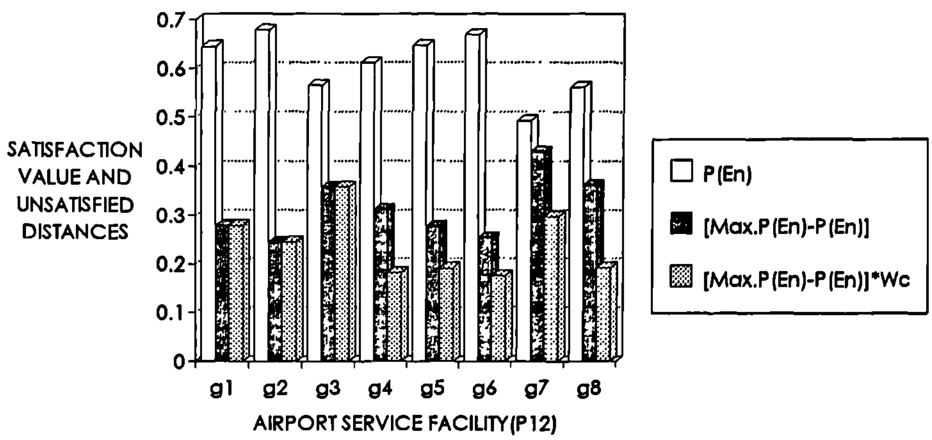
<FIGURE 8-B-1> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF NATIONAL PASSENGERS FOR NON-PEAK HOURS (SS=20)



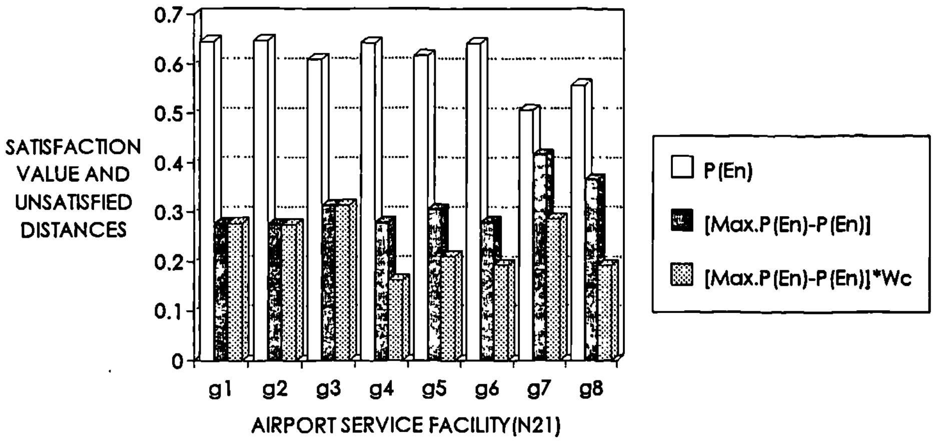
<FIGURE 8-B-2> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF NATIONAL PASSENGERS FOR PEAK HOURS(SS=43)



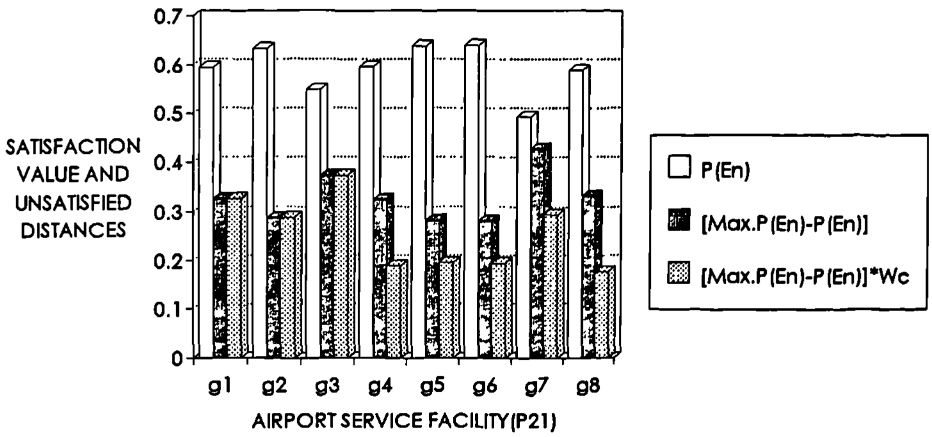
<FIGURE 8-B-3> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF INTERNATIONAL PASSENGERS FOR NON-PEAK HOURS(SS=8)



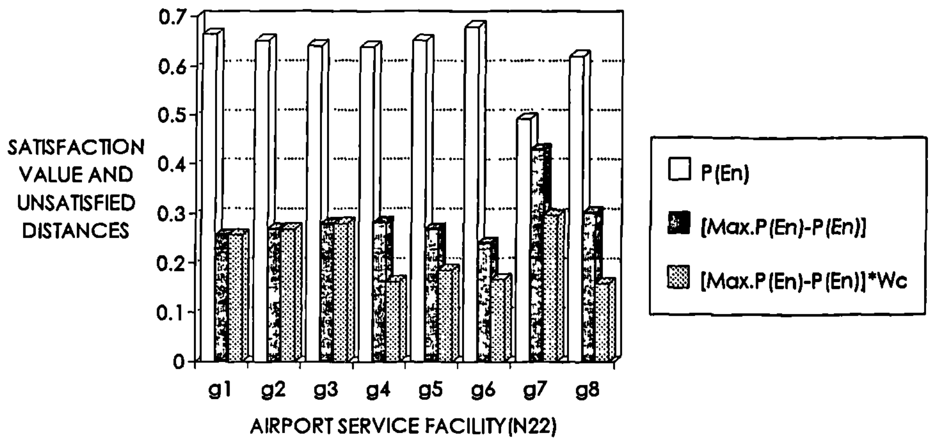
<FIGURE 8-B-4> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF INTERNATIONAL PASSENGERS FOR PEAK HOURS(SS=13)



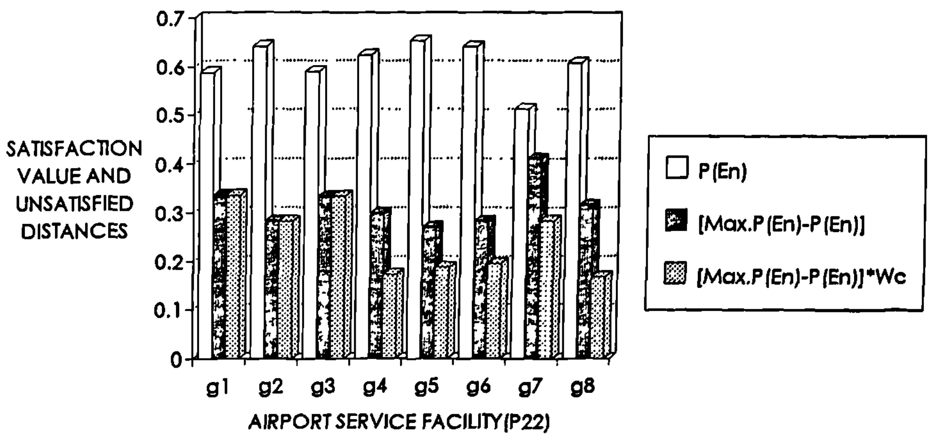
<FIGURE 8-B-5> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF FEMALE PASSENGERS FOR NON-PEAK HOURS(SS=15)



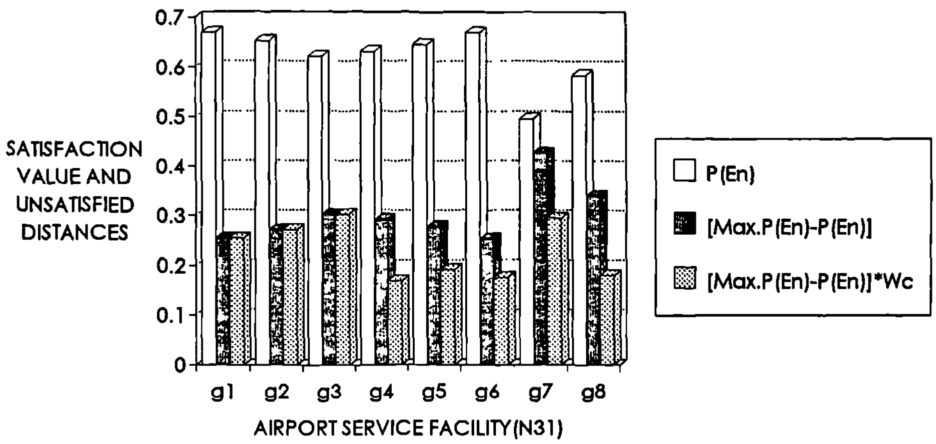
<FIGURE 8-B-6> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF FEMALE PASSENGERS FOR PEAK HOURS(SS=30)



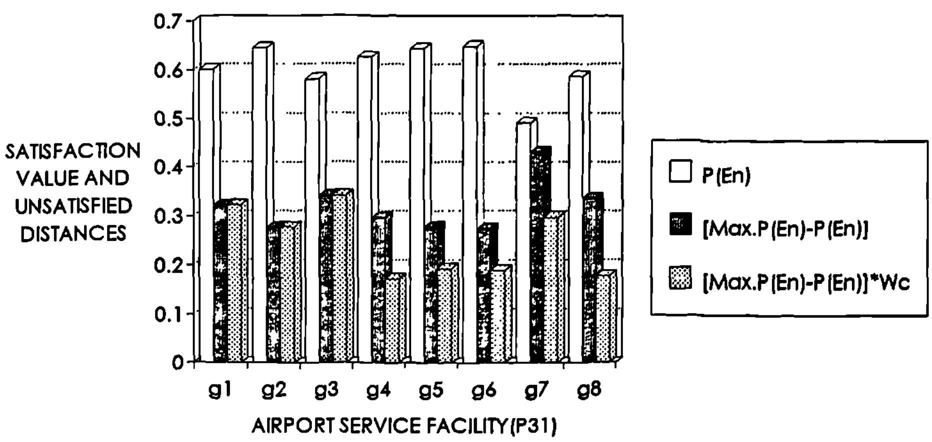
<FIGURE 8-B-7> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF MALE PASSENGERS FOR NON-PEAK HOURS(SS=13)



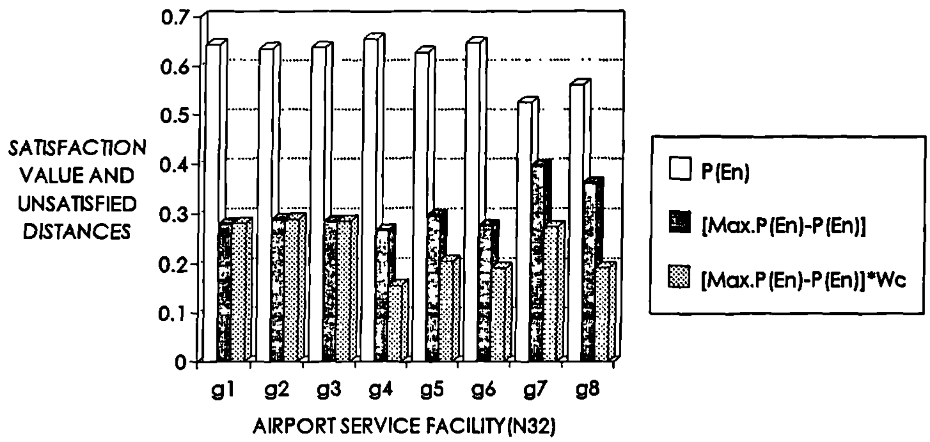
<FIGURE 8-B-8> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF MALE PASSENGERS FOR PEAK HOURS(SS=26)



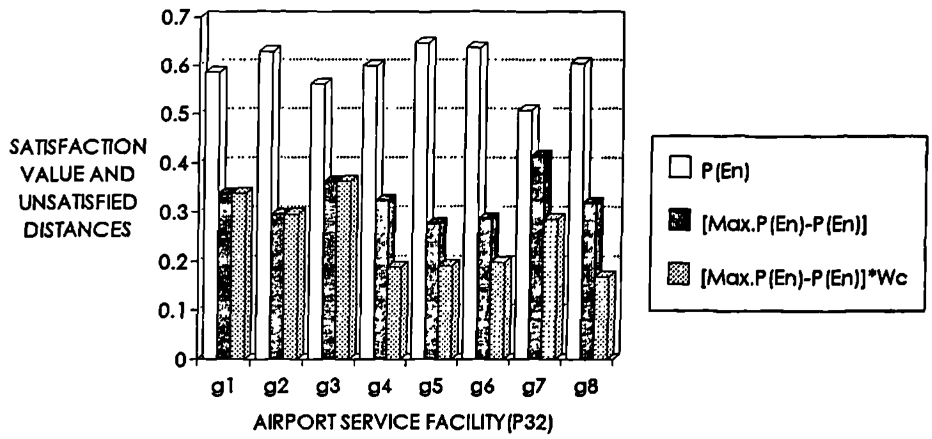
<FIGURE 8-B-9> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF BUSINESS PASSENGERS FOR NON-PEAK HOURS(SS=15)



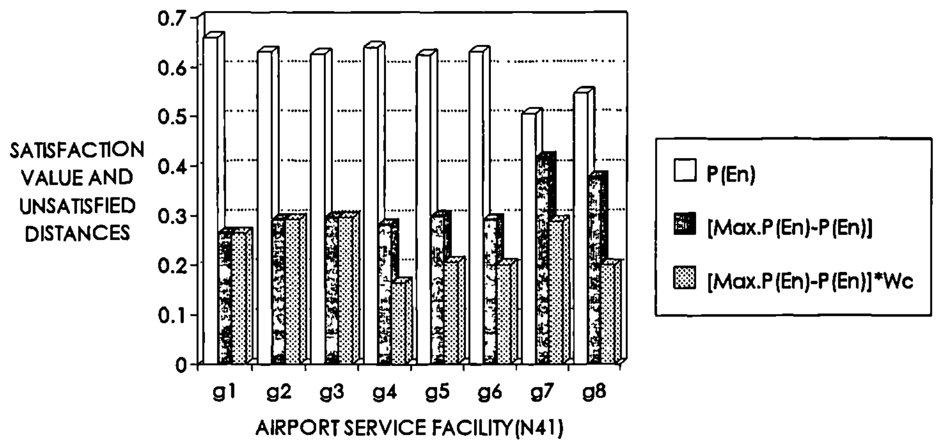
<FIGURE 8-B-10> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF BUSINESS PASSENGERS FOR PEAK HOURS(SS=22)



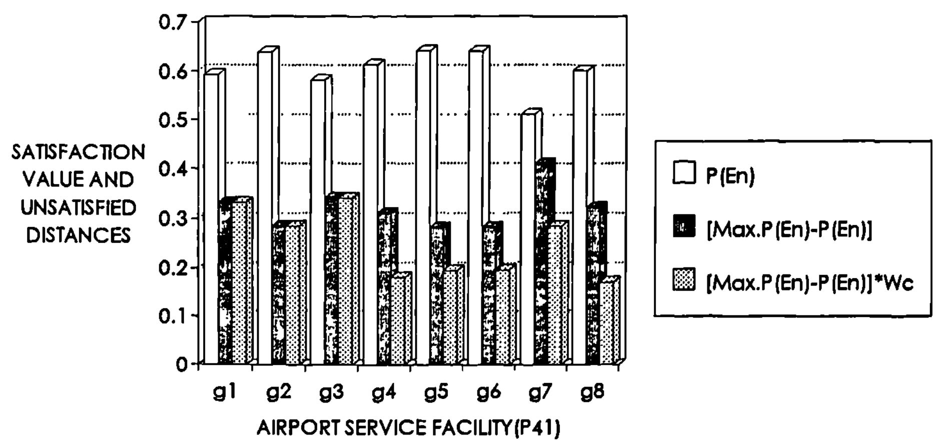
<FIGURE 8-B-11> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF NON-BUSINESS PASSENGERS FOR NON-PEAK HOURS(SS=13)



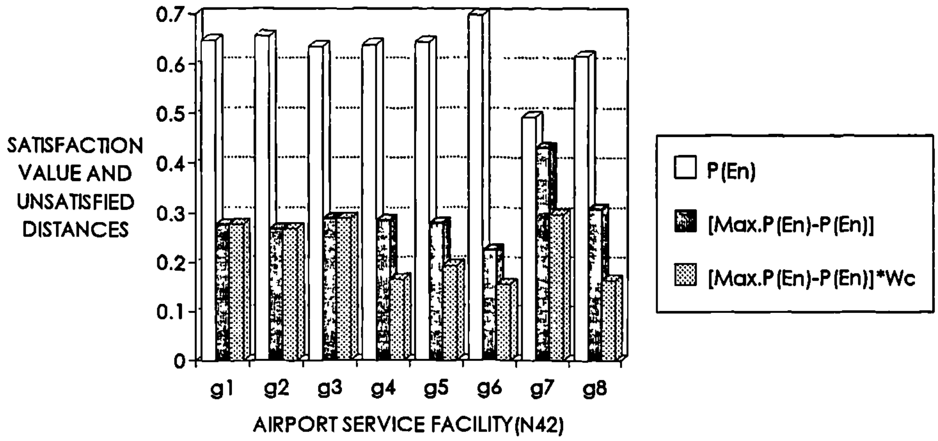
<FIGURE 8-B-12> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF NON-BUSINESS PASSENGERS FOR PEAK HOURS(SS=34)



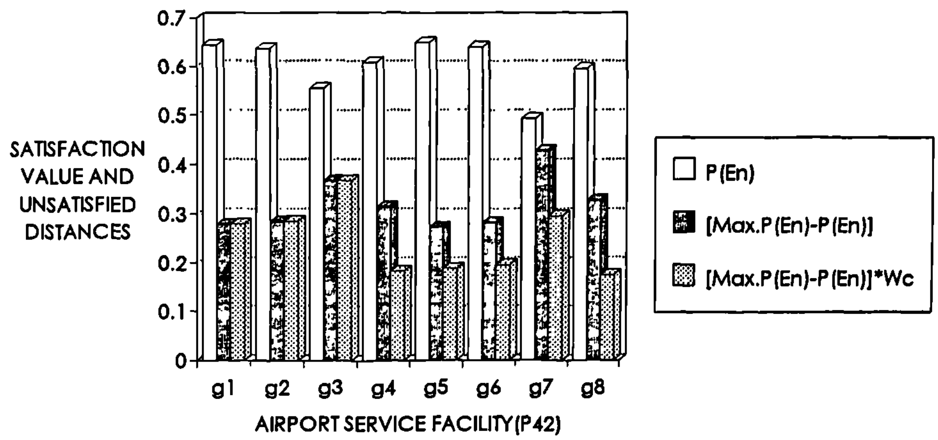
<FIGURE 8-B-13> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF SHORT HAUL PASSENGERS FOR NON-PEAK HOURS(SS=13)



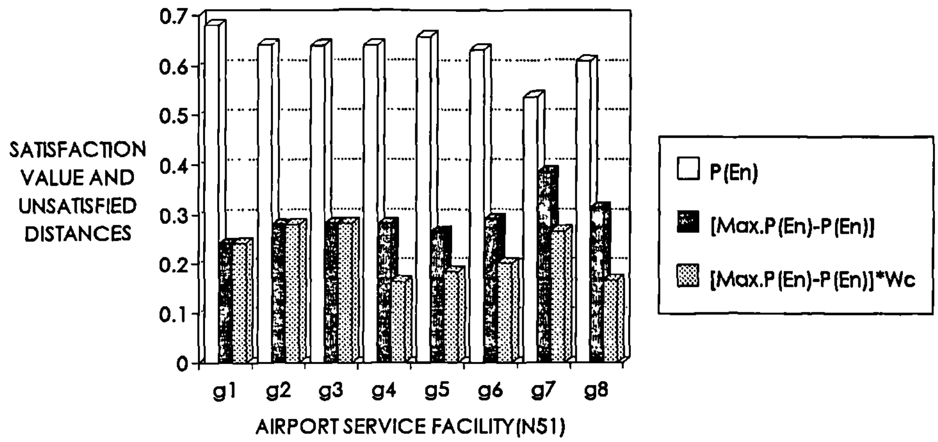
<FIGURE 8-B-14> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF SHORT HAUL PASSENGERS FOR PEAK HOURS(SS=27)



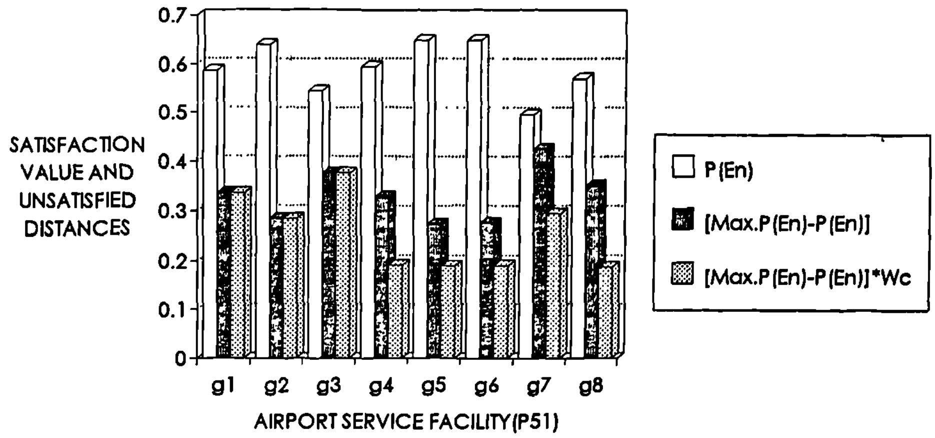
<FIGURE 8-B-15> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF LONG HAUL PASSENGERS FOR NON-PEAK HOURS(SS=15)



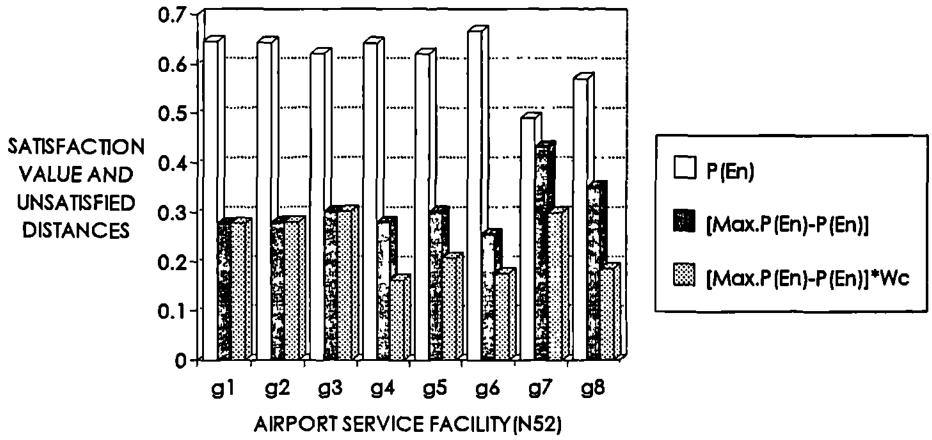
<FIGURE 8-B-16> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF LONG HAUL PASSENGERS FOR PEAK HOURS(SS=29)



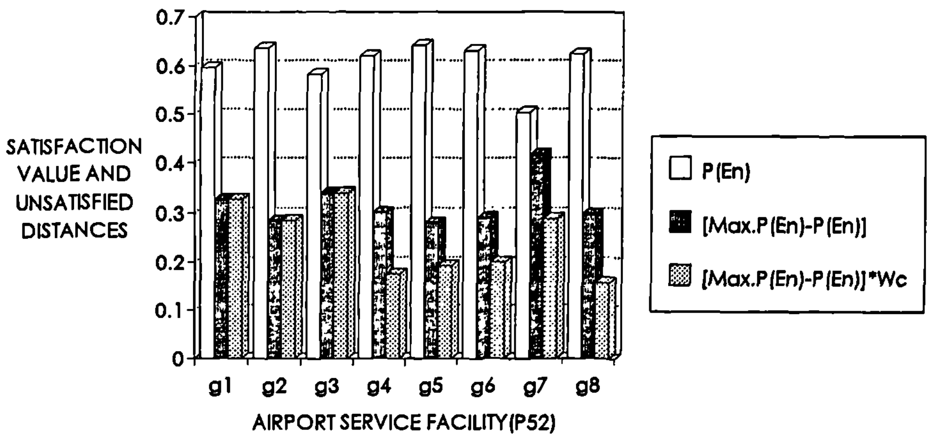
<FIGURE 8-B-17> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF LESS EXPERIENCE PASSENGERS FOR NON-PEAK HOURS(SS=8)



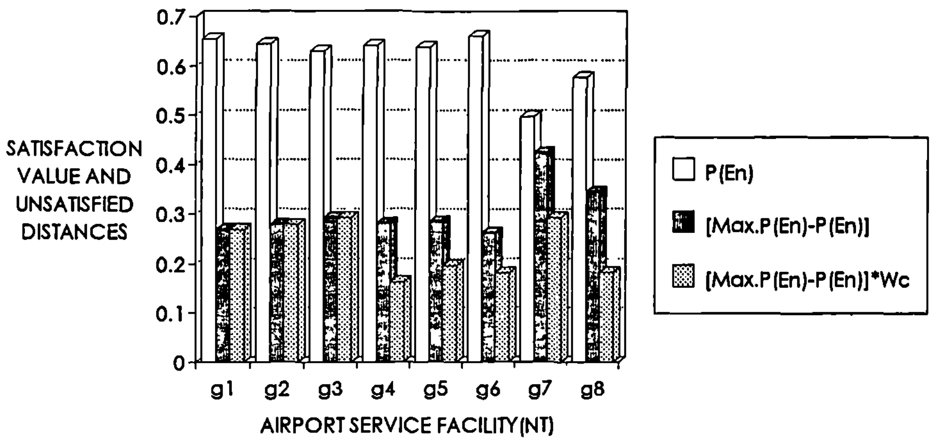
<FIGURE 8-B-18> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF LESS EXPERIENCE PASSENGERS FOR PEAK HOURS(SS=25)



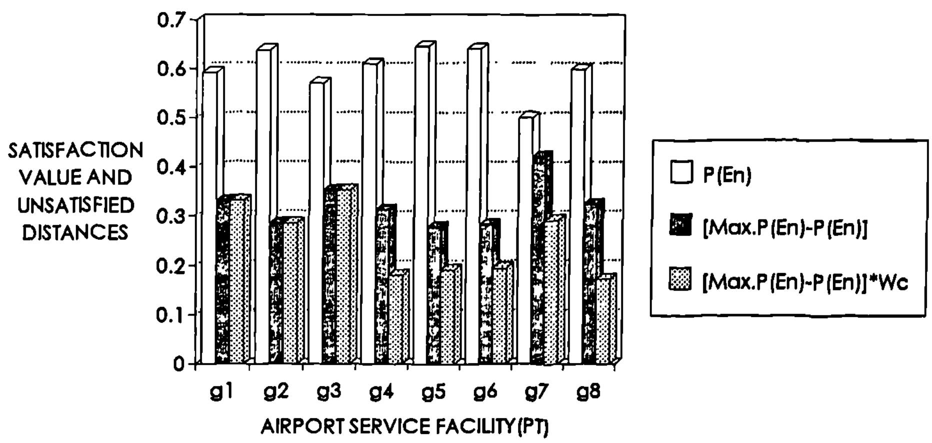
<FIGURE 8-B-19> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF MORE EXPERIENCE PASSENGERS FOR NON-PEAK HOURS(SS=20)



<FIGURE 8-B-20> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF MORE EXPERIENCE PASSENGERS FOR PEAK HOURS(SS=31)



<FIGURE 8-B-21> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF TOTAL PASSENGERS FOR NON-PEAK HOURS(SS=28)



<FIGURE 8-B-22> SATISFACTION VALUE AND UNSATISFIED DISTANCES OF TOTAL PASSENGERS FOR PEAK HOURS(SS=56)

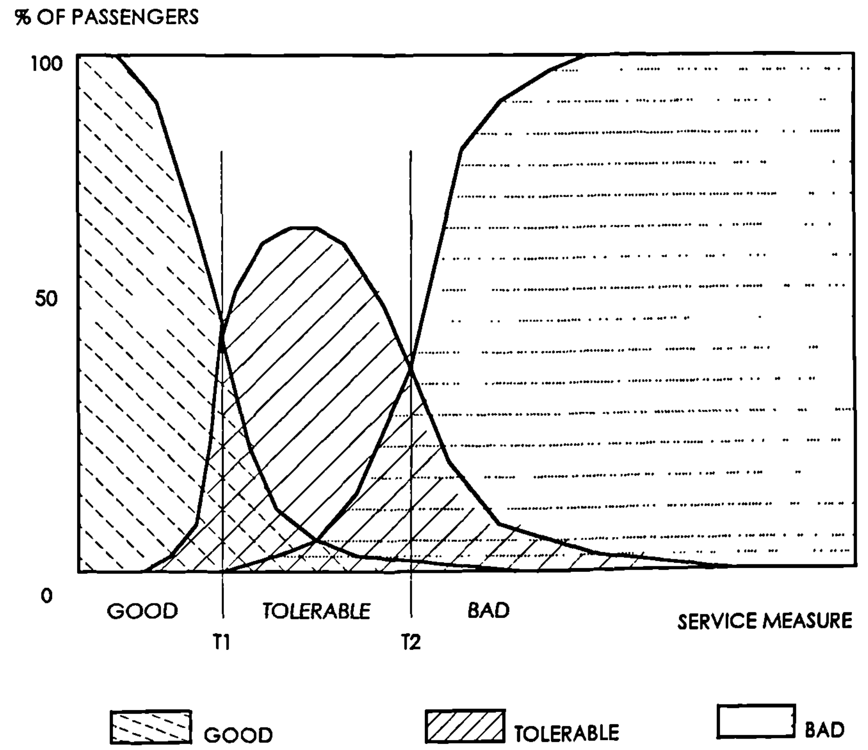
8-4.2 Application of Perception-Response Model

The perception-response(P-R) model was suggested by Mumayiz[1885] and defined as the graphical presentation of the collective attitudes of a category of passengers towards the range of operational service at a facility. The model is expressed in terms of *perception* of the passenger population of different amounts of the service measure and their *response* to the respective service conditions classified into distinct levels of satisfaction with service.[Mumayiz 1985:93] He attempted to tie the passengers" perceptions of level of service to the time spent in processing the components at an airport terminal using three linguistic criteria - good; tolerable; bad. The conceptual diagram is shown in <FIGURE 8-13>.

Service standards were established by time values: T1 and T2. These time values were achieved by examining the three curves representing passengers' responses to the service. The opinions of passengers towards a different duration of time in particular processing facilities was plotted in terms of response curves. From these curves, the points at which there was a shift in perception of the majority of passengers from one state to another was defined as the point of change of level of service. Thus, the level was predominantly perceived as good from service measure 0 to T1, and bad beyond T2. Between T1 and T2 the service was tolerable.

The limitations of the P-R model work were suggested by Ashford[1988]. Furthermore, we can find another limitation of the model in that the questionnaire and survey method does not precisely reflect the passengers' perceptions by their responses, because a time lag existed between the service perceived and the passenger response. The mail-back questionnaire survey for the P-R model had different time bases, thus the passenger's perception was at an airport terminal, but the response was at home or in other places after their journey was finished. The results of the model could be distorted if the time lag was relatively long. For example, if a passenger took 20 minutes for a check-in service and then replied to the questionnaire after the trip that meant they were depending upon their memory. The response, therefore, possesses the possibility that time is perceived as longer or shorter than the real service which measured 20 minutes.

The problem of time lag was overcome using the proposed method in this study which was the TRAMONIQ survey method. That attempted to minimise the time lag and the passengers' service time was measured by the surveyors who then asked about it in order to derive their instant perception. The input data through the TRAMONIQ survey method applied the Perception-Response(P-R) model as here.



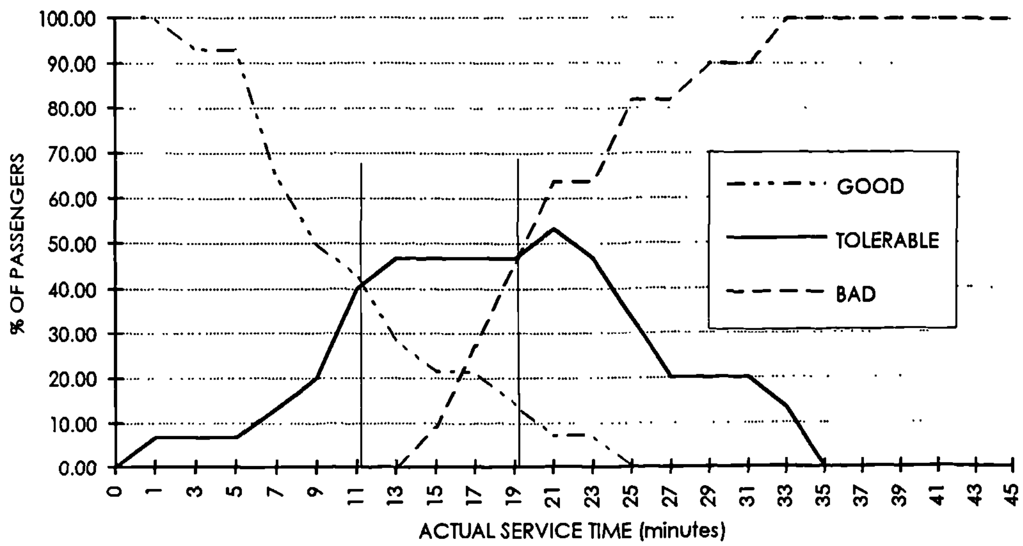
<FIGURE 8-13> CONCEPTUAL DRAWING OF PERCEPTION-RESPONSE MODEL

<TABLE 8-9> LEVEL OF SERVICE FRAMEWORK FOR INTERNATIONAL DEPARTURE CHANNEL: KIMPO VERSUS BIRMINGHAM INTERNATIONAL AIRPORT

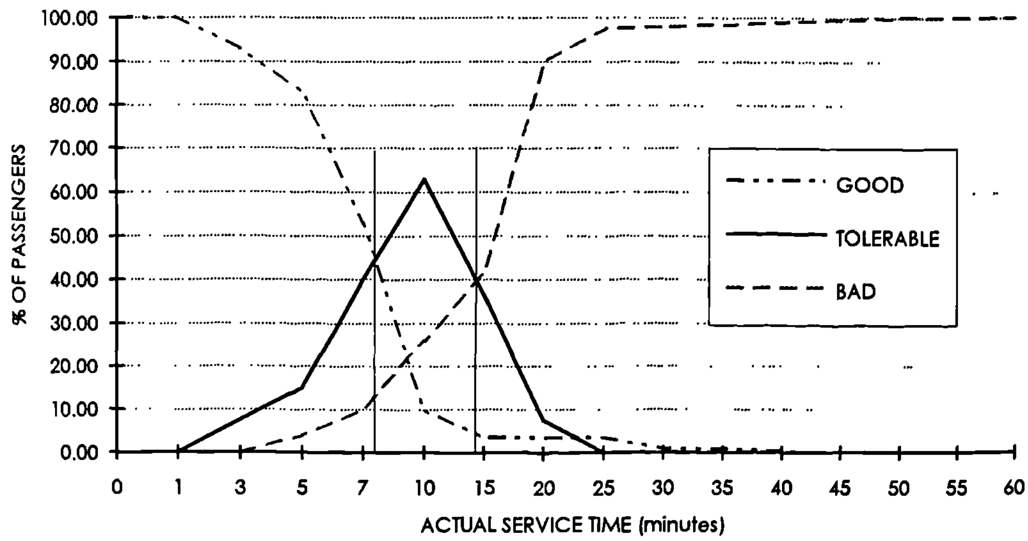
SERVICE FACILITY	AIRPORT	FIGURE №	TOTAL TIME SPENT (minutes) GOOD/TOLERABLE (T1)	TOLERABLE/BAD (T2)
CHECK-IN (SHORT HAUL)	Kimpo	8-C-1	11	19
	Birmingham	8-C-2	7.5	14
CHECK-IN (LONG HAUL)	Kimpo	8-C-3	13.5	22.5
	Birmingham	8-C-4	15	25
SECURITY SCREENING	Kimpo	8-C-5	1.25	1.75
	Birmingham	8-C-6	6.5	10.5
PASSPORT CONTROL	Kimpo	8-C-7	2.75	4.5
	Birmingham	8-C-8	6.5	10.5

For departures, the P-R model was applied to airline check-in and baggage drop, security screening, and passport control. <FIGURE 8-C-1 ~ 2> show the P-R model for scheduled short or European flights and <FIGURE 8-C-3 ~ 4> for scheduled long haul flights. <FIGURE 8-C-5 ~ 6> show security screening and <FIGURE 8-C-7 ~ 8> are for passport control. <TABLE 8-9> shows those service standards for Kimpo and Birmingham International Airport respectively. This is a practical comparison even though they have a decade time gap and there are different characteristics in the airports.

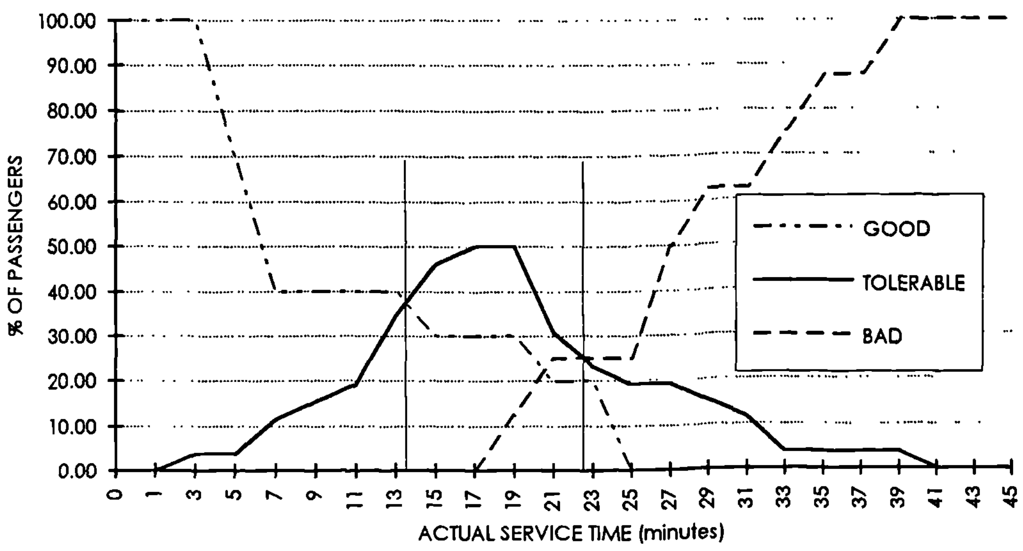
Scheduled-short haul passengers for airline check-in and baggage drop service at Kimpo International Airport(KIA) are treated with much higher T1 and T2 than scheduled-European passengers' at Birmingham International Airport(BIA), but service standards for the scheduled-long haul at KIA were lower in service than BIA.



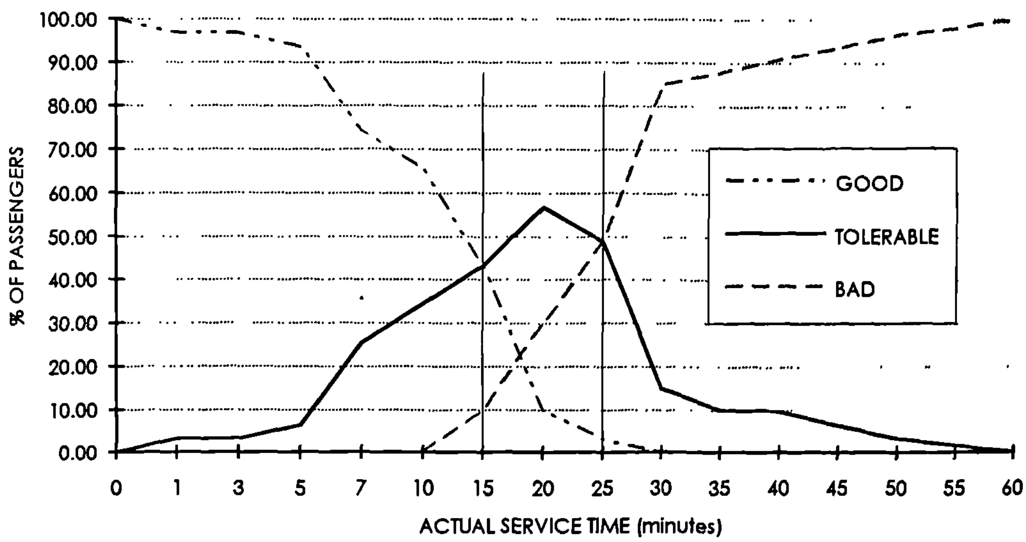
<FIGURE 8-C-1> P-R MODEL FOR CHECK-IN AND BAGGAGE DROP SERVICE (SHORT HAUL)



<FIGURE 8-C-2> P-R MODEL FOR CHECK-IN AND BAGGAGE DROP SERVICE (SCHEDULED-EUROPEAN: MUMAYIZ)



<FIGURE 8-C-3> P-R MODEL FOR CHECK-IN AND BAGGAGE DROP SERVICE (LONG HAUL)

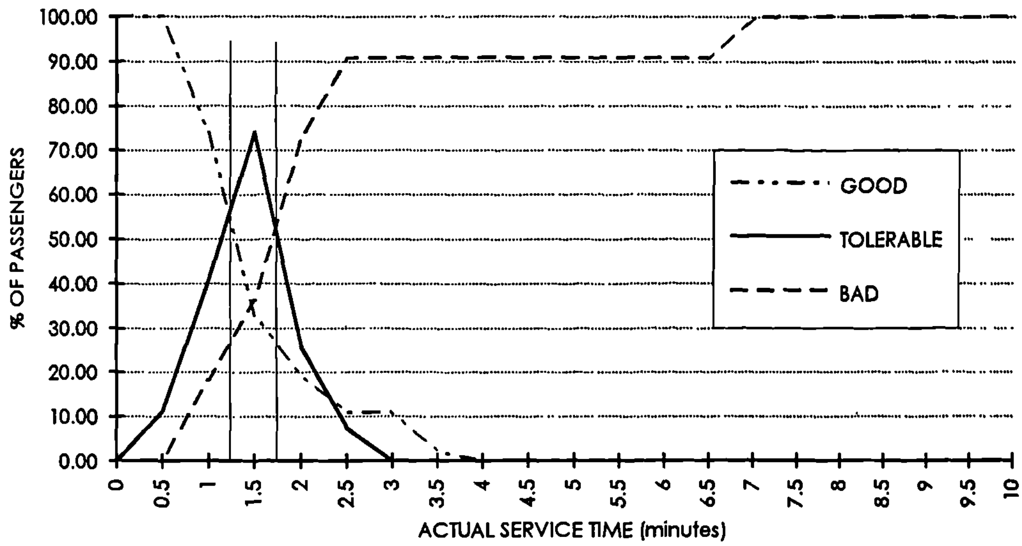


<FIGURE 8-C-4> P-R MODEL FOR CHECK-IN AND BAGGAGE DROP SERVICE (SCHEDULED-LONG HAUL: MUMAYIZ)

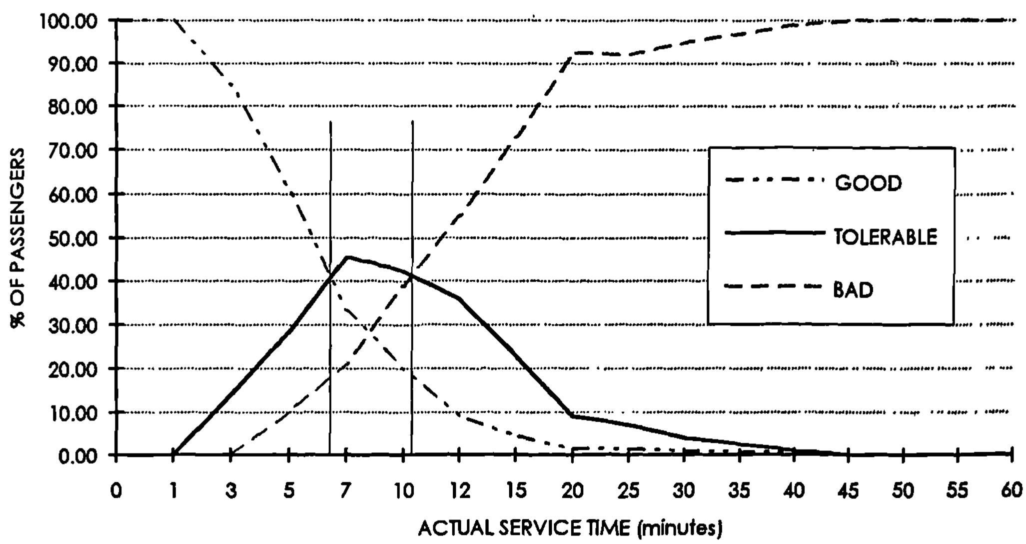
Service standards for security screening showed a noticeably different behaviour. KIA's service standards had significantly lower T1 and T2 values than those shown by BIA's results. Service standards for security screening at KIA showed a narrow margin of the tolerable region between 1.25 and 1.75 minutes, but BIA's standards were 6.5 and 10.5 minutes with a wide tolerable region. The average service time for security screening at KIA was 1 minute 33 seconds at terminal busy periods and 1 minute 2 seconds at non-busy times.

This fact probably derived from the different survey methods. The Birmingham airport survey was conducted using a grading system with stated periods of time e.g., 1, 3, and 5 minutes and then passengers ticked a different symbolic expression to indicate the grading good, tolerable, and bad. By this method, we can find the passengers' recognition of their time spent and the actual service time at a service facility were not synchronal that means passengers had misconstrued how long they spent. For example, a passenger took one minute for security screening but then recognised it to be a much longer time than the actual service time. It could easily lead to misjudgement if the questionnaire contained stated time scales to be ticked by respondents. This fact probably reflected the behaviour of passengers at BIA. The proposed method in this study, TRAMONIQ, approached with a different idea. Each service time at each facility was recorded by the surveyors who then asked about it using three linguistic criteria; short, bearable, and long. This method accurately mirrored the realities of the passengers' perceptions.

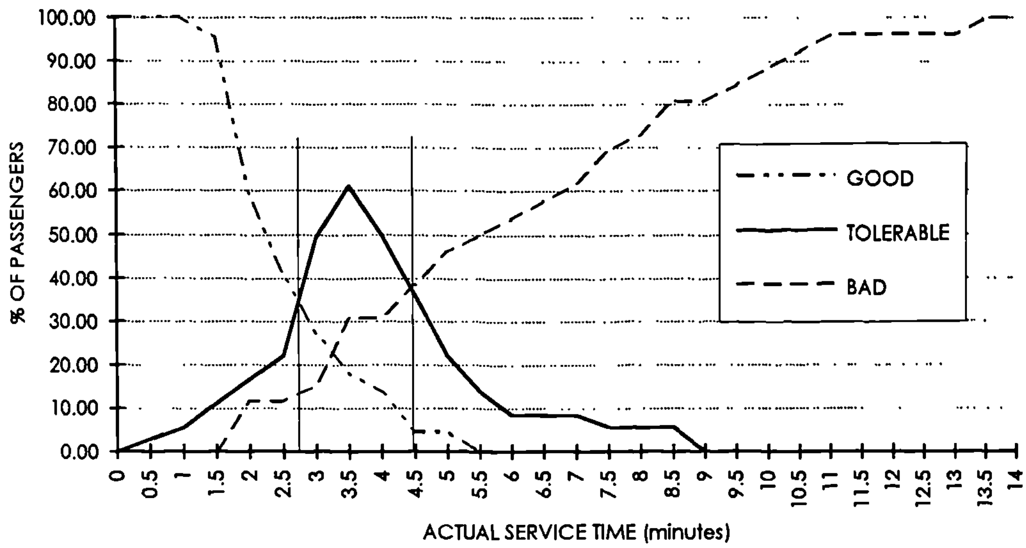
Finally, the service standards for passport control also showed significantly different behaviours. The service level standards T1 and T2 were 2.75 and 4.5 minutes at KIA respectively. BIA's standards were 6.5 and 10.5 minutes which were exactly the same values as for the a security screening service. It is difficult to understand why the same results were produced both at security check and at passport control. Normally, the passport control service requires more time than security screening. The average service time for it at KIA was 4 minutes 53 seconds at peak times and 2 minutes 37 seconds at non-peak. The different passenger behaviour was caused by the problem mentioned above.



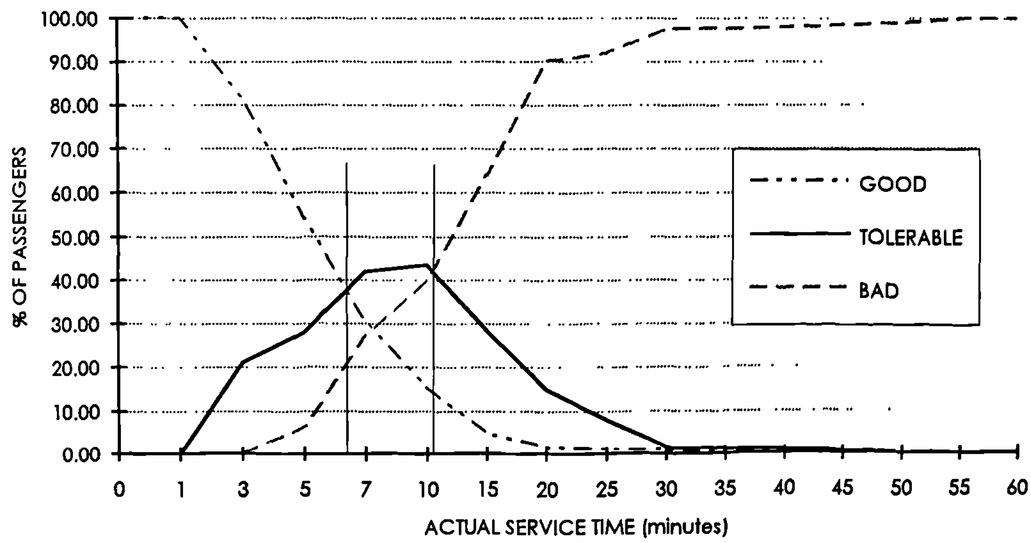
<FIGURE 8-C-5> P-R MODEL FOR SECURITY SCREENING SERVICE



<FIGURE 8-C-6> P-R MODEL FOR SECURITY SCREENING SERVICE (MUMAYIZ)



<FIGURE 8-C-7> P-R MODEL FOR PASSPORT CONTROL SERVICE



<FIGURE 8-C-8> P-R MODEL FOR PASSPORT CONTROL SERVICE (MUMAYIZ)

8-5 CONCLUSION

This chapter describes the applications of the proposed methodology to the real field as a case study. Aspects of the application are divided into three main discussions which are firstly, the panel of experts as the foundation stage for the production of useful information; secondly, the application of a multi-decision model as a main procedure; finally, the comparison of outcomes of the multi-decision model with the previously observed study using the P-R model. Thus this chapter includes the source of information used, different aspects of implementation, and the interpretation of results and findings. The results and findings use the proposed methodology and demonstrate the various features in order to provide significant resources for airport operators, managers, and planners.

CHAPTER 9

CONCLUSIONS

9-1 SUMMARY AND CONCLUSIONS

The level of service concept has been applied to the selected components of the airport landside system. The interest in level of service in the airport system indicates a strong impetus to pass on from concentration on simple physical service standards which are defined by either spatial or temporal conditions to one that directly incorporates the perception of air passengers. This trend has now become a major issue, because the prime objective of airports has become concentrated on maximum user satisfaction and on providing a high standard of service. The findings of this research have been drawn from a comprehensive approach which was the multi-decision model using Fuzzy Sets Theory. Certain findings were realised and conclusions reached that could be of guidance to future researchers dealing with 'realities' giving a wider and in depth consideration of the level of service evaluation. Furthermore, the practical techniques could provide useful information to airport operators, managers, and also to academics. The derived conclusions of the case study are as follows:

The methodology proposed in this research can provide a practical and applicable approach to evaluation of the level of service in an airport system. In particular, it has dealt with how one can convert the qualitative measures such as comfort and reasonable factors to finite scales using linguistic variables and approximate reasoning mathematics. These measures were very constructive when applied to the service level especially when the research focused on the passenger's perception, because the current concept of the level of service requires standards to be based on the passenger's perception. Therefore, the application of the fuzzy sets theory has been investigated as even more flexible and adaptable to deal with the level of service through the airport system. According to the limitations associated with information on the level of service in the whole of an airport system, the proposed methodology when applied to the specific areas proved to be manageable and reasonable and straight-forward in implementation.

The service facilities at the landside system have been found to have different degrees of importance. The case study concluded that service processing facilities, airport internal and kerbside circulation, and ground access to the airport were of a rather high degree of importance at the airport landside system. This fact provides useful knowledge to practitioners dealing with the reality of the provision of service facilities. It helped to select those evaluation factors with fairly risk free information and those that were comprehensive, also those worthy of wide and careful consideration. Each service facility's degree of importance in terms of its bearing on the level of service must necessarily be considered in order to confirm the accuracy, validity, and representativeness of the evaluation.

The factors affecting the level of service at airports are a broad range and have different weighting values in each service component. This recognition allowed the validation to use the multi-decision model in order to improve the practical operations and management in the real-world. Most attempts associated with studying service level evaluation have previously concentrated mainly on establishing tools for the service time spent and the space provided at each service provision facility. One of the outcomes of this research, however, has been the designation of different weighting values in terms of affecting the degree of the level of service. This could have important implications for the actual service performance at the airport landside system from an operational view point.

Airports present serious difficulties for attempts to obtain data and to conduct a passenger survey. This was a major hurdle to this research for the improvement and enhancement of current service practices. This research proposed a detailed survey method, Tracing-Monitoring-Questionnaire(TRAMONIQ), through security sensitive areas such as central security screening and passport control. Difficulties were actually experienced on many occasions when conducting the survey at the airport. These difficulties were mainly caused due to airport security.

The passenger's perceptions depended upon their cultural background and their operational philosophies. Furthermore, the passengers' recognition of time spent at a service facility was not equal to the real measured time. This fact has been found when making comparisons with other survey methods. A previous research has been done using the passenger perception-response(P-R) model. It conducted a questionnaire survey with the given time scale questions. It provided time ranges and then responders choose one of them using their personal judgement. This research has been conducted by the tracing-monitoring-questionnaire method. It was an extremely difficult method to implement, but it provided actual data on the passengers' perceptions. The surveyor traced the target passenger and measured the time spent at each service procedure, and then asked about the provision services. Comparison of results of the two methods show a totally different perception of service standards, in particular for the security screening service and for the passport control. TRAMONIQ survey results were 1.25 minutes for standard T_1 and 1.75 for T_2 at security screening service. The P-R model showed 6.5 and 10.5 minutes respectively.

The results of the multi-decision model indicated the satisfaction values, unsatisfactory distances, and the weighted-unsatisfactory distances. These were the vital and essential pieces of information for understanding and assessing the service provision of the airport landside system. These were the fundamental considerations of the undertaking. According to the attributes of the service facilities and respondents, these indications showed slight differences. In practice the weighted unsatisfactory distances to the desirable maximum level are a most important source of information. The distances were associated with the factoral weighting values as well as with the component weighting values. That means the weighted unsatisfactory distances can be applied directly to the actual service performance at the case airport and other airports which have functionally and practically similar characteristics.

The idea of a multi-decision model has the potential to deal with not only the measurable and quantitative factors which affect the level of service, but also any other qualitative service measures. The multi-decision model based on fuzzy sets theory is quite powerful and provides a strict mathematical framework for vague conceptual phenomena by neutral linguistic variables.

9-2 RECOMMENDATIONS FOR FUTURE STUDY

In this study investigation, a number of limitations have been identified and these suggestions for future research are recommended.

The findings were obtained from a relatively small sample of respondents. This is a significant limitation of the research to the validity of the results. Obviously, airports maintain a high security system along with many data protections. For greater certainty of the validity of the model application, a reasonable sample size to analyse the breakdown in each case or attribute would be necessary. This is only possible with strong co-operation from the airport authority, governmental agencies, and other participating organisations.

The multi-decision model has been applied to evaluate the level of service at the airport landside system. It is quite a strong methodology, but it is not a perfect model to convert quantitative variables to the fuzzy measurement, in particular the fuzzy relations interference rules. The fuzzy interference is still being investigated by mathematicians, computer engineers, and other experts in order to obtain better results or rules. If they provide a more powerful rule, it can then be applied to other fields of interest in order to improve and enhance the current service practices.

In this work, the multi-decision model was built with three selected service factors from the panel of experts. Moreover, the factor weighting values and component weighting values were also set by the panel. Therefore, there was no possibility of investigating any interaction between the user's and the expert's points of view. The most effective way of determining this would be by conducting passenger perception surveys rather than expert's.

Throughout this work, certain assumptions were made regarding the landside system, five target sub-systems, and three evaluation factors, primarily for the availability of data collection and for ease in conducting a passenger survey. However, it would seem more realistic and accurate if whole systems were assigned for departing and arrival air passengers. It is obvious that undertaking this kind of research needs to be done on a group research basis rather than by a personal attempt. Evidently, the effect of the selected evaluation factors was quite significant and undoubtedly influenced the characteristics of the level of service at the airports. A more comprehensive and integrated method to obtain the evaluation sets is required in order to provide better knowledge and understanding of this interesting subject.

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APPENDIX 1

EXPERT SURVEY QUESTIONNAIRE

EXPERT SURVEY QUESTIONNAIRE

Questionnaire No.	________
Expert Name	________
Date	________

Dear Sir,

I am undertaking research into the evaluation of the service level in an airport. This research is considering the airport landside system as a service providing area and the passengers' perception of the provision of service within it. To evaluate the level of service for the airport landside system, this research essentially needs a weighting value for each service facility and an evaluation factor. This will be basic information for this evaluation research.

Please base the answers to this questionnaire, which includes three parts, on your professional knowledge. I hope for your assistance and will be grateful if you can answer this questionnaire. Thank you for your co-operation.

PARK, Yong Hwa *Research Student*
Department of Transport Technology, Loughborough University of Technology, ENGLAND

PART 1: GENERAL

This section refers to the general background.

1-1 What is your professional identity in the airport field?

- ❑ Planner ❑ Manager or operator
- ❑ Designer ❑ Academic researcher
- ❑ Other(Specify): [ ]

1-2 How long have you worked in this field?

- ❑ less than 3 years ❑ 3-6 years ❑ 7-10 years
- ❑ 11-14 years ❑ 15 or more years

PART 2: COMPONENT WEIGHTING VALUE

This section refers to the weighting value for airport landside facilities to provide service to its users; passengers.

Please give ranking to the following service facilities regarding the degree of importance in affecting the level of service in an airport landside system. For example, if you think that the service processing facility is the most important one, ground access to airport is the next important, and holding facility is the next ...... You should give the ranking as;

Ranking	*Service Component*
[1]	Service processing facility
[3]	Holding facility
[ ]	Circulation facility
[2]	Accessing
[ ]	

2-1 Please give a ranking for each of the following service components based upon your expert knowledge.

[ ] *Service processing facilities*; check-in and baggage drop, security screening, and passport control.

[ ] *Holding facilities*; waiting areas.

[ ] *Circulation facility*; intra terminal circulation and terminal curb circulation.

[ ] *Ground access* to airport.

[ ] *Car park facilities.*

[ ] *Concessions* in terminal; restaurants, shop, public facilities, and so on.

PART 3: FACTOR WEIGHTING VALUE

This section refers to the weighting values for the evaluation factors. The researcher has already selected the evaluation factors such as temporal/spatial factors, comfort factors, and reasonable service factors.

Please give also ranking to the following evaluation factors in each service facility based upon the degree of importance for affecting the level of service of the airport landside system. For example, in waiting areas, if you think that crowding is the most important factor for the service level evaluation, internal environment is the next important, and the information system is also but not so important factor. You should mark the ranking as;

Ranking (Degree of Importance)	*Evaluation Factors in waiting areas*
[1]	Crowding
[3]	Information system
[2]	Internal environment

- Ranking 1: the most important factor.
- Ranking 2: the next important factor.
- Ranking 3: also but not so important factor.

◎ *Please give an important ranking in each blank.*

3-1 **Service Processing Facilities:** check-in and baggage drop, security screening, and passport control.

[ ] *Service processing time*; waiting time in the queue and serving time.

[ ] *Complexity of service procedure* at check-in and baggage drop, security screening, and passport control.

[ ] *Courtesy of personnel.*

[ ] *Number of service facility(desk)*

[ ] *Overall environment;* noise, air condition, humidity etc.

[ ] *Service variability*

3-2 **Holding Facilities:** waiting areas and departure lounge in terminal building.

[ ] *Crowding*; the degree of crowdedness.

[ ] *Information system*; aircraft-related information such as origins/destinations, departures/arrivals, flight number, departure gate, and so on, and audio service.

[ ] *Internal environment*; air condition, lighting system, noise, etc.

[ ] *Seat availability*

[ ] *Accessibility to concessions*

✓

3-3 **Circulation:** intra terminal circulation and terminal kerb circulation.

✓

a) Intra terminal circulation

[ ] *Walking distance*; between entrance doors and check-in desks, check-in desks and security screening, security screening and passport control, and passport control and departure lounge.

[ ] *Sign system*; direction, identification locations and etc.

[ ] *Level changes*; going up or down by escalators, stairways, or lift.

[ ] *Crowding*

[ ] *Aids to handicapped*

[ ] *Assistant facility to passenger for circulation*

b) Terminal kerb circulation

[ ] *Walking distance* to entrance doors from dropping point by ground transport modes.

[ ] *Sign system*; direction, identification locations, etc.

[ ] *Level of congestion* by people and transport modes at terminal kerb.

[ ] *Number of the pedestrian crossings* at terminal kerb

3-4 Ground access to airport

[ ] *Trip time*; affect on congestion and delay time.

[ ] *Availability of transport modes.*

[ ] *Cost to passengers*; transport fares.

[ ] *Comfort*

3-5 Concessions

[ ] *Access distance*; between concessions and waiting areas.

[ ] *Variety and choice*; satisfaction for users' needs.

[ ] *Cost to user*; concessions' retail prices to customers.

[ ] *Courtesy of personnel*

[ ] *Clearness*

[ ] *Display of goods or location of the concessions* ✓

3-6 Car park facilities

[ ] *Availability of parking space.*

[ ] *Simplicity of access* from the airport main entrance to car park facilities.

[ ] *Cost to user*; parking fare.

[ ] *Sign system.*

[ ] *Connection system*; between car park facility and passenger terminal.

APPENDIX 2

PILOT SURVEY QUESTIONNAIRE

PASSENGER SURVEY QUESTIONNAIRE

Surveyor	________
Questionnaire No.	________
Date	________

Dear Passengers,

We are carrying out a survey to evaluate the level of service at this airport. We wish to know how passengers respond to the evaluation factors; these are time/space factors, comfort factors, and reasonable service factors in the different facilities of the airport.

Please consider answering this questionnaire based upon your judgement of the provision of service at this airport. We hope for your assistance and co-operation and will be grateful if you answer this questionnaire, which will not take you long to complete. Your answers will be valuable for the future management and operation of this airport system.

The questionnaire may be returned to this survey assistant or placed in the box in the departure lounge or gate.

Thank you so much for your co-operation.

Department of Transport Technology
Loughborough University of Technology, England

❑ ***Please tick or describe in the blanks.***

PART 1: GENERAL

1-1 What is your nationality?

❑ Korean ❑ Other Asian ❑ American(south & north)
❑ European ❑ Australasian ❑ African

1-2 Sex? ❑ Male ❑ Female

1-3 In which category of age do you belong?

❑ less than 20 ❑ 20-29 ❑ 30-39
❑ 40-49 ❑ 50-59 ❑ 60 or more

1-4 How many times, if ever, have you travelled by air from this airport?

❑ 0 ❑ 1-3 ❑ 4-6
❑ 7-9 ❑ 10-12 ❑ 13 or more

1-5 What is the purpose of your trip?

❑ Business ❑ Leisure or holiday
❑ Studying ❑ Visiting friends or relatives
❑ Other (Specify): [ ]

1-6 What is your flight number? ______________

1-7 Where is your final destination? ______________

1-8 Where did you start your journey to this airport? ________________
(Example: SeoKyo-dong, Seoul or Kansuk-dong, Incheon)

PART 2: SERVICE PROCESSING

This section refers to processing activities in check-in and baggage drop, security screening, and passport control.

2-1 **Check-in and Baggage drop**

a) What do you think about the service time (= waiting time in the queue + serving time), you spent for check-in and baggage drop in this airport terminal?

❑ short ❑ bearable ❑ long

b) What did you feel about the complexity of the service procedure at the check-in and baggage drop facility?

❑ simple ❑ acceptable ❑ complicated

c) What was the level of courtesy of personnel who served you at the check-in and baggage drop service component?

❑ kind ❑ tolerable ❑ unkind

2-2 **Security Screening**

a) What do you think about the service time (= waiting time in the queue + serving time), you spent for security screening in this airport terminal?

❑ short ❑ bearable ❑ long

b) What did you feel about the complexity of the service procedure at the security screening facility?

❑ simple ❑ acceptable ❑q complicated

c) What was the level of courtesy of personnel who served you at the security screening service component?

❑ kind ❑ tolerable ❑ unkind

2-3 **Passport Control**

a) What do you think about the service time (= waiting time in the queue + serving time), you spent for passport control in this passenger terminal?

❑ short ❑ bearable ❑ long

b) What did you feel about the complexity of the service procedure at the passport control facility?

❑ simple ❑ acceptable ❑ complicated

c) What was the level of courtesy of personnel who served you at the passport control service component?

❑ kind ❑ tolerable ❑ unkind

PART 3: HOLDING AREA

This section refers to waiting areas and departure lounges.

3-1 What did you think of the degree of crowding at the waiting areas and departure lounge in this passenger terminal?

❑ uncrowded ❑ bearable ❑ crowded

3-2 What was the information system like? i.e., audio and visual details of aircraft origins/destinations, flight number, scheduled time, and so on, at the waiting areas.

❑ good ❑ tolerable ❑ bad

3-3 What was your opinion of the internal environment, i.e., air conditioning, lighting system, noise, interior decoration, viewing, etc., at the waiting areas and departure lounge?

❑ good ❑ tolerable ❑ bad

PART 4: CIRCULATION

This section refers to the intra terminal circulation and terminal kerb circulation.

4-1 Intra Terminal Circulation

a) What did you feel about the distance you walked between service facilities, i.e., between entrance doors and check-in desk or security screening and passport control?

❑ short ❑ bearable ❑ long

b) How did you feel about the sign system, i.e., directions or identification of locations in the intra terminal circulation facility?

❑ good ❑ tolerable ❑ bad

c) What was the service level for provision of facilities to change level, i.e., going up or down by stairways, escalators, or lifts and frequency of level changes in the intra terminal circulation facility?

❑ good ❑ tolerable ❑ bad

4-2 Terminal Kerb Circulation

a) What did you feel about the distance you walked between terminal main entrance doors and the dropping point from ground transport mode, i.e., bus, taxi, private car, and others?

❑ short ❑ bearable ❑ long

b) How did you feel about the sign system at terminal kerb, i.e., directions or identification of locations?

❑ good ❑q tolerable ❑ bad

c) What was the degree of congestion by transport modes and people at the terminal kerb(entrances & drop off points) in this airport?

❑ low ❑ moderate ❑ high

PART 5: GROUND ACCESS TO AIRPORT

This section refers to the ground access to this airport.

5-1 What did you think of the ground access time to this airport?

❑ short ❑ bearable ❑ long

5-2 What was the availability of transport and transit to get to this airport?

❑ good ❑ tolerable ❑ bad

5-3 Did you use a private car to get this airport?

❑ Yes ❑ No (❑ taxi, ❑ bus, ❑ airport bus or limousine, ❑ other)

* ***If yes, carry on 5-3.1 and then go to PART 6, 7,***
if no, please carry on 5-3.2 and then go to PART 6.

5-3.1 What did you feel about the comfort to this airport by private car, i.e., the access road condition, congestion, traffic sign system etc.?

❑ good ❑ acceptable ❑ bad

5-3.2 What did you feel about the comfort for public transport, i.e., vehicle occupancy, seat comfort, baggage loads, vehicle internal environment and so on?

❑ good ❑ acceptable ❑ bad

PART 6: CONCESSIONS

This section refers to the concessions such as restaurants, bars, shop, telephone, etc., in this airport terminal.

6-1 What did you feel about the distance you walked between concessions and waiting areas in this terminal building?

❑ short ❑ bearable ❑ long

6-2 Was the choice and variety of things at the concessions satisfactory for your needs?

❑ satisfactory ❑ tolerable ❑ unsatisfactory

6-3 What did you think of the functional display and location of the concessions in this airport?

❑ good ❑ acceptable ❑ bad

PART 7; CAR PARKING

This section refers to the car park facilities in this airport.

7-1 What do you think of the availability of space for car parking in this airport?

❑ good ❑ tolerable ❑ bad

7-2 What do you think of the simplicity of access from the main entrance of this airport to the car park?

❑ good ❑ acceptable ❑ bad

7-3 What do you think of the linkage or connection system between car park and the passenger terminal? i.e., weather protected walkways, escalators, moving sidewalks, and other mechanical assistants.

❑ good ❑ acceptable ❑ bad

APPENDIX 3

PASSENGER SURVEY QUESTIONNAIRE

✈ PASSENGER SURVEY QUESTIONNAIRE

Surveyor	____________
Questionnaire No.	____________
Date	____________

Dear Passengers,

We are carrying out a survey to evaluate the level of service at this airport. We wish to know how passengers respond to the evaluation factors; these are time/space factors, comfort factors, and reasonable service factors in the different facilities of the airport.

Please consider answering this questionnaire based upon your judgement of the provision of service at this airport. We hope for your assistance and co-operation and will be grateful if you answer this questionnaire, which will not take you long to complete. Your answering will be valuable for the future management and operation of this airport system.

The questionnaire may be returned to this survey assistant Thank you so much for your co-operation.

Department of Transport Technology
Loughborough University of Technology, England

❑ ***Please tick or describe in the blanks.***

PART 1: GENERAL

1-1	What is your nationality?	❑ Korean ❑ Australasian ❑ American(south & north)	❑ Other Asian ❑ European ❑ African

1-2	Sex?	❑ Male	❑ Female

1-3	In which category of age do you belong?	❑ less than 20 ❑ 30-39 ❑ 50-59	❑ 20-29 ❑ 40-49 ❑ 60 or more

1-4	How many times, if ever, have you travelled by air from this airport?	❑ 0 ❑ 3-4 ❑ 7-8 ❑ 11 or more	❑ 1-2 ❑ 5-6 ❑ 9-10

1-5	What is the purpose of your trip?	❑ Business ❑ Studying ❑ Other (Specify): [ ]	❑ Leisure or holiday ❑ Visiting friends or relatives

1-6	What is your flight number?	

1-7	Where is your final destination?	

1-8	Where did you start your journey to this airport? (Example: SeoKyo-dong, Seoul or Kansuk-dong, Incheon)	

1-9	How long did you take to travel from your starting point to this airport?	❑ less than 30 min. ❑ 1:00-1:29 min. ❑ 2:00-2:29 min. ❑ 3 hours or more	❑ 30-59 min. ❑ 1:30-1:59 min ❑ 2:30-2:59 min.

1-10	How long before your departure time did you start to travel to this airport?	❑ less than 1 hour ❑ 1:30-1:59 min. ❑ 2:30-2:59 min.	❑ 1:00-1:29 min. ❑ 2:00-2:29 min. ❑ 3 hours or more

PART 2: SERVICE PROCESSING

This section refers to processing activities in check-in and baggage drop, security screening, and passport control.

2-1 Check-in and Baggage drop

(a)	What do you think about the service time (= waiting time in the queue + serving time), you spent for check-in and baggage drop in this airport terminal?	❑ short ❑ bearable ❑ long

(b)	What did you feel about the complexity of the service procedure at the check-in and baggage drop facility?	❑ simple ❑ acceptable ❑ complicated

(c)	What was the level of courtesy of personnel who served you at the check-in and baggage drop service component?	❑ kind ❑ tolerable ❑ unkind

2-2 Security Screening

(a)	What do you think about the service time (= waiting time in the queue + serving time), you spent for security screening in this airport terminal?	❑ short ❑ bearable ❑ long

(b)	What did you feel about the complexity of the service procedure at the security screening facility?	❑ simple ❑ acceptable ❑ complicated

(c)	What was the level of courtesy of personnel who served you at the security screening service component?	❑ kind ❑ tolerable ❑ unkind

2-3 Passport Control

(a)	What do you think about the service time (= waiting time in the queue + serving time), you spent for passport control in this passenger terminal?	❑ short ❑ bearable ❑ long

(b)	What did you feel about the complexity of the service procedure at the passport control facility?	❑ simple ❑ acceptable ❑ complicated

(c)	What was the level of courtesy of personnel who served you at the passport control service component?	❑ kind ❑ tolerable ❑ unkind

PART 3: HOLDING AREAS

This section refers to waiting areas and departure lounges.

3-1	What did you think of the degree of crowding at the waiting areas and departure lounge in this passenger terminal?	❑ uncrowded ❑ bearable ❑ crowded

3-2	What was the information system like? i.e., audio and visual details of aircraft origins/destinations, flight number, scheduled time, and so on, at the waiting areas.	❑ good ❑ tolerable ❑ bad

3-3	What was your opinion of the internal environment, i.e., air conditioning, lighting system, noise, interior decoration, viewing, etc., at the waiting areas and departure lounge?	❑ good ❑ tolerable ❑ bad

PART 4: CIRCULATION

This section refers to the intra terminal circulation and terminal kerb circulation.

4-1 Intra Terminal Circulation

(a)	What did you feel about the distance you walked between service facilities, i.e., between entrance doors and check-in desk or security screening and passport control?	❑ short ❑ bearable ❑ long

(b)	How did you feel about the sign system, i.e., directions or identification of locations in the intra terminal circulation facility?	❑ good ❑ tolerable ❑ bad

(c)	What was the service level for provision of facilities to change levels or movements (i.e., going up or down by stairways, escalators, or lifts) and frequency of level changes in the intra terminal circulation facility?	❑ good ❑ tolerable ❑ bad

4-2 Terminal Kerb Circulation

(a)	What did you feel about the distance you walked between terminal main entrance doors and the dropping point from ground transport mode, i.e., bus, taxi, private car, and others?	❑ short ❑ bearable ❑ long

(b)	How did you feel about the sign system at terminal kerb, i.e., directions or identification of locations?	❑ good ❑ tolerable ❑ bad

(c)	What was the degree of congestion by transport modes and people at the terminal kerb(entrances & drop off points) in this airport?	❑ low ❑ moderate ❑ high

PART 5: GROUND ACCESS TO AIRPORT

This section refers to the ground access to this airport.

5-1	What did you think of the ground access time to this airport?	❑ short ❑ bearable ❑ long

5-2	What was the availability of transport and transit to get to this airport?	❑ good ❑ tolerable ❑ bad

5-3	Did you use a private car to get this airport?	❑ Yes	❑ No (❑ taxi ❑bus ❑ airport bus or limousine ❑ other)

✱ *If yes, please carry on Q5-3.1, and if no, go to Q5-3.2.*

5-3.1	What did you feel about the comfort to this airport by private car, i.e., the access road condition, congestion, traffic sign system etc.?	❑ good ❑ acceptable ❑ bad

5-3.2	What did you feel about the comfort for public transport, i.e., vehicle occupancy, seat comfort, baggage loads, vehicle internal environment and so on?	❑ good ❑ acceptable ❑ bad

PART 6: CONCESSIONS

This section refers to the concessions such as restaurants, bars, shop, telephone, etc., in this airport terminal.

6-1	What did you feel about the distance you walked between concessions and waiting areas in this terminal building?	❑ short ❑ bearable ❑ long

6-2	Was the variety of choice of things at the concessions satisfactory for your needs?	❑ satisfactory ❑ tolerable ❑ unsatisfactory

6-3	What did you think of the functional display or arrangement of goods and location of the concessions in this airport?	❑ good ❑ acceptable ❑ bad

APPENDIX 4

COMPUTER PROGRAM

```
/**********************************************************************************************
```

COMPUTER PROGRAM FOR MULTI-DECISION MODEL

PARK, YONG HWA
DEPARTMENT OF TRANSPORT TECHNOLOGY
LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY
ENGLAND

```
**********************************************************************************************/

#include "base_2.h"


double b[5][8],c1[8][11],c2[8][11],c3[8][11],c4[8][11],c5[8][11],m[8][11];
double P[8];
FILE *output;

/*************************************************/

main()

{
   int gd=DETECT,gm,i;
   initgraph(&gd,&gm,"");

   read_input_data();
   getch();
    display_first_matrix();
    getch();
            find_c1();
            getch();
                    find_c2();
                    getch();
                            find_c3();
                            getch();
                    find_c4();
                    getch();
            find_c5();
            getch();
   find_m();
   getch();

  for(i=1;i<=8;++i){
     find_each_p(i);
     getch();
  }

  find_P();
  getch();

  closegraph();
}
```

```
/*********************************************
 INPUT DATA FOR MULTI-DECISION MODEL
*********************************************/

/**EVALUATION FACTOR
        f1: TIME OR SPATIAL FACTOR
                f2: COMFORT FACTOR
                        f3: REASONABLE SERVICE FACTOR **/

/**SERVICE FACILITY OF THE AIRPORT LANDSIDE SYSTEM
        g1: CHECK-IN & BAGGAGE DROP  g2: SECURITY SCREENING        g3: PASSPORT CONTROL
        g4: WAITING AREAS            g5: INTER-TERMINAL CIRCULATION
        g6: KERBSIDE CIRCULATION     g7: GROUND ACCESS             g8: CONCESSIONS **/

    read_input_data()
    {
      float x,y,z;
      double f1,f2,f3;
      int i,aa,yy=30;
      char tmm1[40],tmm2[40],tmm3[40],tmm[60];
      FILE *input;
      char *title[]={"g1","g2","g3","g4","g5","g6","g7","g8"};

      setlinestyle(0,0,3);
      line(0,40,500,40);
      line(80,0,80,300);
      outtextxy(60,20,"            f1            f2            f3");
      for(i=1;i<=8;++i){
              yy=yy+30;
        outtextxy(40,yy,title[i-1]);
      }

      input=fopen("input.dat","r");
      output=fopen("output.dat","w");
      fscanf(input,"%s\n",&tmm);

      aa=strlen(tmm);
      aa=aa+19;
              fprintf(output,"      ");
                      for(i=1;i<=aa;++i) fprintf(output,"*");
                              fprintf(output,"\n");
                              fprintf(output,"     Input Data Title : %s\n",tmm);
                      fprintf(output,"      ");
              for(i=1;i<=aa;++i) fprintf(output,"*");
      fprintf(output,"\n");

      for(i=1;i<=8;++i)
        {
        fscanf(input,"%f %f %f\n",&x,&y,&z);
              fprintf(output,"        %6.4f %6.4f %6.4f\n",x,y,z);
                      sprintf(tmm1,"%11.4f",x);
                              sprintf(tmm2,"%11.4f",y);
                                      sprintf(tmm3,"%11.4f",z);
```

```
        aa=30+30*i;
              outtextxy(100,aa,tmm1);
                     outtextxy(232,aa,tmm2);
                            outtextxy(348,aa,tmm3);

        f1=(double) x; f2=(double) y; f3=(double) z;
              find_d1(i,f1,f2,f3);
                     find_d2(i,f1,f2,f3);
                            find_d3(i,f1,f2,f3);
                     find_d4(i,f1,f2,f3);
              find_d5(i,f1,f2,f3);
      }

      fclose(output);
      fclose(input);

      settextstyle(0,0,2);
      outtextxy(0,400,"INPUT DATA TITLE : ");
      outtextxy(300,400,tmm);
      settextstyle(0,0,0);
   }
```

/**********************************

MULTI-DECISION CRITERIA RULES

***********************************/

/**$d_1 = \min[f_1, f_2, f_3]$: **Very Satisfactory*********/**

```
   find_d1(i,f1,f2,f3)
   double f1,f2,f3;
   int i;
   {
     double min;
      min=f1;
             if(f2<min) min=f2;
                    if(f3<min) min=f3;
     b[1][i]=min;
   }
```

/**$d_2 = \min[f_1, \max(f_2, f_3)]$: **MORE SATISFACTORY*********/**

```
   find_d2(i,f1,f2,f3)
   double f1,f2,f3;
   int i;
   {
     double min,max;
      max=f2;
             if(f3>max) max=f3;
                    min=f1;
                           if(max<min) min=max;
     b[2][i]=min;
   }
```

```
/**d3 = min[ f2, f3] : SATISFACTORY**********/

    find_d3(i,f1,f2,f3)
    double f1,f2,f3;
    int i;
    {
      double min;
       min = f2;
              if(f3 < min) min = f3;
      b[3][i] = min;
    }

/**d4 = min[f1, 1-f3] : LESS SATISFACTORY**********/

    find_d4(i,f1,f2,f3)
    double f1,f2,f3;
    int i;
    {
      double min;
       min = 1.0-f3;
              if(f1 < min) min = f1;
      b[4][i] = min;
    }

/**d5 = min[1-f1, max(1-f2, 1-f3)] : UNSATISFACTORY**********/

    find_d5(i,f1,f2,f3)
    double f1,f2,f3;
    int i;
    {
      double min,max,aa,bb;
       max = 1.0-f2;
              aa = 1.0-f3;
                     if(aa > max) max = aa;
                            bb = 1.0-f1;
                                   min = bb;
                                          if(max < min) min = max;
      b[5][i] = min;
    }

/*************************************************/


    display_first_matrix()
    {
     char tmm[50];
     int i,j,x,y,yy = 40;
     char *title[] = {"d1","d2","d3","d4","d5"};
```

```
clearviewport();
setlinestyle(0,0,3);
outtextxy(50,20,"      g1     g2     g3     g4      g5     g6     g7     g8");
line(0,40,640,40);
line(20,0,20,180);
  for(i=1;i<=5;++i){
          yy=yy+20;
                  outtextxy(0,yy,title[i-1]);
}

output=fopen("output.dat","a+");
for(i=1;i<=3;++i) fprintf(output,"\n");
fprintf(output,"      **********************\n");
fprintf(output,"      [STEP 1]  d x g Matrix\n");
fprintf(output,"      **********************\n");
fprintf(output,"\n");
fprintf(output,"         g1    g2    g3    g4    g5    g6    g7    g8\n");
fprintf(output,"         -------------------------------------------------------------\n");
for(i=1;i<=5;++i)
  fprintf(output,"    d%d | %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f\n"
                  ,i,b[i][1],b[i][2],b[i][3],b[i][4],b[i][5],b[i][6],b[i][7],b[i][8]);
fclose(output);

for(i=1;i<=5;++i)
  for(j=1;j<=8;++j){
          sprintf(tmm,"%11.4f",b[i][j]);
                  if(i==1){
                          if(j<=4) y=60;
                                  else    y=260;
                                                  }
                  if(i==2){
                          if(j<=4) y=80;
                                  else    y=280;
                                                  }
                  if(i==3){
                          if(j<=4) y=100;
                                  else    y=300;
                                                  }
                  if(i==4){
                          if(j<=4) y=120;
                                  else    y=320;
                                                  }
                  if(i==5){
                          if(j<=4) y=140;
                                  else    y=340;
                                                  }

    if(j==1 || j==5) x=50;
    if(j==2 || j==6) x=200;
    if(j==3 || j==7) x=350;
    if(j==4 || j==8) x=500;

    outtextxy(x,y,tmm);
   }
}
```

```
/***********************************
 MULTI-DECISION CRITERIA MATRIX
***********************************/

/***************/
    find_c1()
/***************/

    {
      int i,j,x,y;
      double v,b1;
      char tmm[50];

      for(j=1;j<=8;++j){
              v=-0.1;
                    for(i=1;i<=11;++i){
                          v=v+0.1;
         b1=v*v*v*v;
         {
         double min;
              min=1.0-b[1][j]+b1;
                    if(1.0<min) min=1.0;
         c1[j][i]=min;
         }
       }
     }

     draw_for_c();

     for(i=1;i<=8;++i)
       for(j=1;j<=11;++j){
         sprintf(tmm,"%11.4f",c1[i][j]);
         y_value_for_c(i,j,&x,&y);
         outtextxy(x,y,tmm);
       }

     settextstyle(0,0,2);
     outtextxy(100,450,"D1(b1,v1)");
     settextstyle(0,0,0);

     output=fopen("output.dat","a+");
     for(i=1;i<=3;++i) fprintf(output,"\n");
     fprintf(output,"     ************************\n");
     fprintf(output,"     [STEP 2]  g x v Matrix\n");
     fprintf(output,"     ************************\n");
     fprintf(output,"\n");
     fprintf(output,"     (1) D1(b1,v1)\n");
     fprintf(output,"\n");
     fprintf(output,"      0.0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0\n");
     fprintf(output,"     ----------------------------------------------------------\n");
     for(i=1;i<=8;++i)
       fprintf(output,"    g%d | %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f\n",
                       i,c1[i][1],c1[i][2],c1[i][3],c1[i][4],c1[i][5],c1[i][6],c1[i][7],c1[i][8],c1[i][9],c1[i][10],c1[i][11]);
     fclose(output);
   }
```

```
/***************/
    find_c2()
/***************/


   {
     int i,j,x,y;
     double v,b1;
     char tmm[50];

     for(j=1;j<=8;++j){
             v=-0.1;
                     for(i=1;i<=11;++i){
                             v=v+0.1;
         b1=v*v;
         {
         double min;
               min=1.0-b[2][j]+b1;
                     if(1.0<min) min=1.0;
         c2[j][i]=min;
         }
       }
     }



      draw_for_c();

      for(i=1;i<=8;++i)
        for(j=1;j<=11;++j){
          sprintf(tmm,"%11.4f",c2[i][j]);
          y_value_for_c(i,j,&x,&y);
          outtextxy(x,y,tmm);
        }

      settextstyle(0,0,2);
      outtextxy(100,450,"D2(b2,v2)");
      settextstyle(0,0,0);

      output=fopen("output.dat","a+");
      for(i=1;i<=3;++i) fprintf(output,"\n");
      fprintf(output,"     (2) D2(b2,v2)\n");
      fprintf(output,"\n");
      fprintf(output,"        0.0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0\n");
      fprintf(output,"       -------------------------------------------------------\n");
      for(i=1;i<=8;++i)
        fprintf(output,"    g%d | %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f\n",
                i,c2[i][1],c2[i][2],c2[i][3],c2[i][4],c2[i][5],c2[i][6],c2[i][7],c2[i][8],c2[i][9],c2[i][10],c2[i][11]);

      fclose(output);

   }
```

```
/***************/
    find_c3()
/***************/


    {
      int i,j,x,y;
      double v,b1;
      char tmm[50];

      for(j=1;j<=8;++j){
                v=-0.1;
                        for(i=1;i<=11;++i){
                                v=v+0.1;
          b1=v;
          {
          double min;
                min=1.0-b[3][j]+b1;
                        if(1.0<min) min=1.0;
          c3[j][i]=min;
          }
        }
      }



       draw_for_c();

       for(i=1;i<=8;++i)
         for(j=1;j<=11;++j){
           sprintf(tmm,"%11.4f",c3[i][j]);
           y_value_for_c(i,j,&x,&y);
           outtextxy(x,y,tmm);
         }

       settextstyle(0,0,2);
       outtextxy(100,450,"D3(b3,v3)");
       settextstyle(0,0,0);

       output=fopen("output.dat","a+");
       for(i=1;i<=3;++i) fprintf(output,"\n");
       fprintf(output,"      (3) D3(b3,v3)\n");
       fprintf(output,"\n");
       fprintf(output,"           0.0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0\n");
       fprintf(output,"      -------------------------------------------------------------\n");
       for(i=1;i<=8;++i)
         fprintf(output,"     g%d | %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f\n",
                        i,c3[i][1],c3[i][2],c3[i][3],c3[i][4],c3[i][5],c3[i][6],c3[i][7],c3[i][8],c3[i][9],c3[i][10],c3[i][11]);

       fclose(output);

     }
```

```
/***************/
    find_c4()
/***************/


    {
      int i,j,x,y;
      double v,b1;
      char tmm[50];

      for(j=1;j<=8;++j){
              v=-0.1;
                      for(i=1;i<=11;++i){
                              v=v+0.1;
         b1=sqrt(v);
         {
         double min;
              min=1.0-b[4][j]+b1;
                      if(1.0<min) min=1.0;
         c4[j][i]=min;
         }
       }
     }



     draw_for_c();

     for(i=1;i<=8;++i)
       for(j=1;j<=11;++j){
         sprintf(tmm,"%11.4f",c4[i][j]);
         y_value_for_c(i,j,&x,&y);
         outtextxy(x,y,tmm);
       }

     settextstyle(0,0,2);
     outtextxy(100,450,"D4(b4,v4)");
     settextstyle(0,0,0);

     output=fopen("output.dat","a+");
     for(i=1;i<=3;++i) fprintf(output,"\n");
     fprintf(output,"      (4) D4(b4,v4)\n");
     fprintf(output,"\n");
     fprintf(output,"           0.0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0\n");
     fprintf(output,"        -----------------------------------------------------------\n");
     for(i=1;i<=8;++i)
       fprintf(output,"     g%d | %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f\n",
                     i,c4[i][1],c4[i][2],c4[i][3],c4[i][4],c4[i][5],c4[i][6],c4[i][7],c4[i][8],c4[i][9],c4[i][10],c4[i][11]);

     fclose(output);

  }
```

```
/****************/
    find_c5()
/****************/

    {
      int i,j,x,y;
      double v,b1;
      char tmm[50];

      for(j=1;j<=8;++j){
              v=-0.1;
                      for(i=1;i<=11;++i){
                              v=v+0.1;
          b1=1.0-v;
          {
          double min;
                min=1.0-b[5][j]+b1;
                      if(1.0<min) min=1.0;
          c5[j][i]=min;
          }
        }
      }



      draw_for_c();

      for(i=1;i<=8;++i)
        for(j=1;j<=11;++j){
          sprintf(tmm,"%11.4f",c5[i][j]);
          y_value_for_c(i,j,&x,&y);
          outtextxy(x,y,tmm);
        }

      settextstyle(0,0,2);
      outtextxy(100,450,"D5(b5,v5)");
      settextstyle(0,0,0);

      output=fopen("output.dat","a+");
      for(i=1;i<=3;++i) fprintf(output,"\n");
      fprintf(output,"      (5) D5(b5,v5)\n");
      fprintf(output,"\n");
      fprintf(output,"          0.0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0\n");
      fprintf(output,"          ----------------------------------------------------------\n");
      for(i=1;i<=8;++i)
        fprintf(output,"     g%d | %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f\n",
                i,c5[i][1],c5[i][2],c5[i][3],c5[i][4],c5[i][5],c5[i][6],c5[i][7],c5[i][8],c5[i][9],c5[i][10],c5[i][11]);

      fclose(output);

    }
```

```
/******************/
   draw_for_c()
/******************/

   {
      char *title[]={"g1","g2","g3","g4","g5","g6","g7","g8"};
      int i,y=40;

      clearviewport();
      outtextxy(50,20," 0.0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0");
      line(0,40,640,40);
      line(20,0,20,210);
      for(i=1;i<=8;++i){
         y=y+20;
         outtextxy(0,y,title[i-1]);
      }
   }

   y_value_for_c(int i,int j,int *x,int*y)
   {
      if(i==1){
            if(j<=6) *y=60;
                  else  *y=270;      }
      if(i==2){
            if(j<=6) *y=80;
                  else  *y=290;      }
      if(i==3){
            if(j<=6) *y=100;
                  else  *y=310;      }
      if(i==4){
            if(j<=6) *y=120;
                  else  *y=330;      }
      if(i==5){
            if(j<=6) *y=140;
                  else  *y=350;      }
      if(i==6){
            if(j<=6) *y=160;
                  else  *y=370;      }
      if(i==7){
            if(j<=6) *y=180;
                  else  *y=390;      }
      if(i==8){
            if(j<=6) *y=200;
                  else  *y=410;      }

      if(j==1 || j==7) *x=20;
      if(j==2 || j==8) *x=120;
      if(j==3 || j==9) *x=220;
      if(j==4 || j==10) *x=320;
      if(j==5 || j==11) *x=420;
      if(j==6) *x=520;
   }
```

```
/***************/
    find_m()
/***************/

    {
      int i,j,x,y;
      double aa,bb,cc,dd,ee,min;
      char tmm[50];

      for(i=1;i<=8;++i){
              for(j=1;j<=11;++j){
                      aa=c1[i][j];
                              bb=c4[i][j];
                                      cc=c3[i][j];
                                              dd=c4[i][j];
                                                      ee=c5[i][j];

         min=aa;
             if(bb<min) min=bb;
                     if(cc<min) min=cc;
                             if(dd<min) min=dd;
                                     if(ee<min) min=ee;
         m[i][j]=min;
       }
      }

      draw_for_c();

      for(i=1;i<=8;++i)
        for(j=1;j<=11;++j){
          sprintf(tmm,"%11.4f",m[i][j]);
          y_value_for_c(i,j,&x,&y);
          outtextxy(x,y,tmm);
        }

      settextstyle(0,0,2);
      outtextxy(100,450,"D(b,v)");
      settextstyle(0,0,0);

      output=fopen("output.dat","a+");
      for(i=1;i<=3;++i) fprintf(output,"\n");
      fprintf(output,"     ****************************************\n");
      fprintf(output,"     [STEP 3]  Multi-Decision Criteria Matix\n");
      fprintf(output,"     ****************************************\n");
      fprintf(output,"\n");
      fprintf(output,"        0.0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0\n");
      fprintf(output,"     ------------------------------------------------------------\n");
      for(i=1;i<=8;++i)
        fprintf(output,"     g%d | %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f %6.4f\n",
                     i,m[i][1],m[i][2],m[i][3],m[i][4],m[i][5],m[i][6],m[i][7],m[i][8],m[i][9],m[i][10],m[i][11]);
      fclose(output);
    }
```

```
/****************************************
 α LEVEL SET AND MEAN VALUES
****************************************/
```

```
find_each_p(int no)

{
  double min[13],v[12][12],sum_v=0.0,delta_alpa[12],M_en[12],Multi[12],max_m=-999.0;
  int i,j,num[12],x=80,y=30;
  char tmm[40];
  char *title_1[]={"g1","g2","g3","g4","g5","g6","g7","g8"};
  char *title_2[]={"  (1) g1","  (2) g2","  (3) g3","  (4) g4","  (5) g5","  (6) g6","  (7) g7","  (8) g8"};

  min[1]=0.0;
  for(j=1;j<=11;++j) min[j+1]=999.0;

  for(j=1;j<=11;++j){
        for(i=1;i<=11;++i)
     if(m[no][i]>min[j] && m[no][i]<min[j+1]) min[j+1]=m[no][i];
  }

  for(j=1;j<=11;++j)
        for(i=1;i<=11;++i) v[j][i]=-999.0;
  for(i=1;i<=11;++i){
        for(j=1;j<=11;++j)
     if(m[no][j]>min[i]) v[i][j]=0.1*j-0.1;
  }

  for(i=1;i<=11;++i) num[i]=0;

  for(i=1;i<=11;++i){
        for(j=1;j<=11;++j)
     if(v[i][j]!=-999.0) num[i]=num[i]+1;

   for(j=1;j<=11;++j)
     if(v[i][j]!=-999.0) sum_v=sum_v+v[i][j];
        if(num[i]>0) M_en[i]=sum_v/num[i];
        if(num[i]==0) M_en[i]=0.0;

   delta_alpa[i]=min[i+1]-min[i];
   Multi[i]=sum_v*delta_alpa[i];

   sum_v=0.0;
 }

 for(i=1;i<=11;++i)
   if(m[no][i]>max_m) max_m=m[no][i];

 P[no]=0.0;
 for(i=1;i<=11;++i)
   P[no]=P[no]+M_en[i]*delta_alpa[i];
 P[no]=P[no]/max_m;
```

```
  clearviewport();
  outtextxy(0,20," Level                    En                    N    M(En) delta_alpa");
  line(0,40,640,40);
  for(i=1;i<=11;++i){
    y=y+30;
    sprintf(tmm,"%6.4f",min[i]);
    outtextxy(0,y,tmm);
    sprintf(tmm,"%6.4f",min[i+1]);
    outtextxy(0,y+10,tmm);
    for(j=1;j<=11;++j){
      if(v[i][j]!=-999.0){
        sprintf(tmm,"%3.1f ",v[i][j]);
        outtextxy(x,y,tmm);
        x=x+32;}
    }
    x=80;
    sprintf(tmm,"%2d",num[i]);
    outtextxy(450,y,tmm);
    sprintf(tmm,"%4.2f",M_en[i]);
    outtextxy(500,y,tmm);
    sprintf(tmm,"%6.4f",delta_alpa[i]);
    outtextxy(562,y,tmm);
  }

  settextstyle(0,0,2);
  outtextxy(100,450,title_1[no-1]);
  settextstyle(0,0,0);

  output=fopen("output.dat","a+");
  for(i=1;i<=3;++i) fprintf(output,"\n");
  if(no==1){
     fprintf(output,"     **********************************************\n");
     fprintf(output,"     [STEP 4] The Alpa Level Set and Mean Values \n");
     fprintf(output,"     **********************************************\n");
     fprintf(output,"\n");}
  fprintf(output,"%s",title_2[no-1]);
  fprintf(output," \n");
  fprintf(output,"     Level                En                    N  M(En) delta_alpa\n");
  fprintf(output,"     ---------------------------------------------------------------------------------\n");
  for(i=1;i<=11;++i){
   fprintf(output,"    %6.4f ",min[i]);
   for(j=1;j<=11;++j){
     if(v[i][j]!=-999.0) fprintf(output," %3.1f",v[i][j]);
     if(v[i][j]==-999.0) fprintf(output,"    ");}
   fprintf(output," %2d",num[i]);
   fprintf(output," %4.2f",M_en[i]);
   fprintf(output," %6.4f\n",delta_alpa[i]);
   fprintf(output,"    %6.4f\n",min[i+1]);
   fprintf(output,"\n");
  }

  fclose(output);
}
```

```
/***************************
 SATISFACTION VALUES
****************************/

   find_P()
   {
      int i,y=30;
      char tmm[30];
      char *title[]={"g1","g2","g3","g4","g5","g6","g7","g8"};

      clearviewport();
      line(0,40,500,40);
      line(80,0,80,300);
      outtextxy(60,20,"            P");
      for(i=1;i<=8;++i){
         y=y+30;
         outtextxy(40,y,title[i-1]);
      }

      y=30;
      for(i=1;i<=8;++i){
         y=y+30;
         sprintf(tmm,"%6.4f",P[i]);
         outtextxy(140,y,tmm);
      }

      output=fopen("output.dat","a+");
      for(i=1;i<=3;++i) fprintf(output,"\n");
      fprintf(output,"    ******************************************\n");
      fprintf(output,"    [STEP 5] The Satisfaction Values \n");
      fprintf(output,"    ******************************************\n");
      fprintf(output,"\n");
      fprintf(output,"           P        \n");
      fprintf(output,"    --------------------\n");
      fprintf(output,"    g1    %6.4f      \n",P[1]);
      fprintf(output,"    g2    %6.4f      \n",P[2]);
      fprintf(output,"    g3    %6.4f      \n",P[3]);
      fprintf(output,"    g4    %6.4f      \n",P[4]);
      fprintf(output,"    g5    %6.4f      \n",P[5]);
      fprintf(output,"    g6    %6.4f      \n",P[6]);
      fprintf(output,"    g7    %6.4f      \n",P[7]);
      fprintf(output,"    g8    %6.4f      \n",P[8]);
      fclose(output);
   }

end
```