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An Analysis of Airfreight Transshipment Connectivity at Incheon International Airport

인하대학교

물류학과

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2007년 2월
An Analysis of Airfreight Transshipment Connectivity at Incheon International Airport

by

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A THESIS
Submitted to the faculty of
INHA UNIVERSITY
in partial fulfillment of the requirements
for the degree of
MASTER

Department of Logistics
February 2007
An Analysis of Airfreight Transshipment Connectivity at Incheon International Airport

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(ABSTRACT)

After the deregulation of the aviation market in the United States in 1978, airlines took advantage of the possibilities of the liberalized market and reorganized their networks. Then hub-and-spoke networks are used in aviation market generally. The use of the hub-and-spoke network makes it feasible to amplify flight networks. Thus, a number of airlines can move places more then before through the networks. The Center of hub-and-spoke networks is some hub-airport. Such hub-airports function as connection between origin and destination airport. In the most case of hub-airports, it should be accompanied with the transferring for passengers and/or transshipment for cargos.
The purpose of this research is to investigate to evaluate the indirect connectivity of these networks at Incheon International Airport (ICN) as a hub-airport. In addressing these issues the task is to analyze the connectivity of flight schedules using a Wave-system structure and to estimate a connectivity index and the quality of that connectivity by employing the NETSCAN model. Then an evaluation is made of the discussion of these applied methodologies to meet this study’s key objective.

**Key words:** Airline Networks, Connectivity Index, Incheon International Airport, Indirect Connectivity, NETSCAN model, Wave-system Structure.
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Chapter 1.0 INTRODUCTION

The reconfiguration of airline networks into hub-and-spoke systems commenced with the deregulation of the aviation market in the United States during 1978. Since then hub-and-spoke networks are used in aviation market generally. Air carriers have transformed their networks into hub-and-spoke systems for both cost-saving and strategic reasons. The cost advantages of the hub-and-spoke network have been argued by Bittlingmayer (1990), and Brueckner and Spiller (1991). Hendricks and others (1995) have indicated that the reason for the emergence of hub-and-spoke networks has been the economics of density. Besides the cost saving, Oum and others (1995) have asserted that switching from a linear to a hub-and-spoke network is a dominant strategy in an oligopolistic setting and will be useful in deterring entry.

The use of the hub-and-spoke network makes it feasible to amplify flight networks. Amplification of networks can be implementing through the transfer of passengers, transshipment of cargo, or both. Within countries, the hub-and-spoke network has led to national efforts at developing hub-airports to capitalize on the effects of the economies of density. At present, most
national airlines have adopted hub-and-spoke networks (Oum et al., 1995; Zhang, 1996). These networks enable airlines to access more places than before. Hub-airports are located in the center of hub-and-spoke networks. These hub-airports function as connection between origin airport and destination airport. In the most case of hub-airports, it should be accompanied with the transferring for passengers and/or transshipment for cargos generally.
1. INTRODUCTION

1.1 Problem Statement

In a simple network linking one hub-airport and two spoke-airports, the hub-airport is in a monopoly position. But due to the development of multiple airline networking, another hub-airport establishing links to the two spoke-airports becomes possible. Thus, the original hub-airport has to compete against the potential hub-airport in the connecting flight market.

This situation has occurred in Korea. In 2001 the government opened Incheon International Airport (ICN) as a major hub-airport for Northeast Asia. Subsequently, other countries in Northeast Asia have recognized the importance of a hub-and-spoke network. In the process ICN’s position has been threatened.

Given ICN’s situation, this study investigates the airport’s functions and performance as a major hub-airport within the global hub-and-spoke network. Currently, there are a number of research papers that have focused on ICN’s passenger movement within the hub-and-spoke system. Only small number studies however investigated ICN’s airfreight transshipment. Specially, this research therefore considers the connectivity of ICN’s airfreight transshipment within a hub-and-spoke network. In this regard, the three
issues are examined in this study:

1. What is the pattern of airfreight transshipments at ICN?
2. How should the connectivity of ICN’s airfreight transshipments be estimated?
3. How applicable are the methodologies used in examining air passengers be applied to analyzing airfreight?
1. INTRODUCTION

1.2 Research Objectives and Scope

In addressing these issues the initial task is to analyze the connectivity of flight schedules using a Wave-system structure and estimating the quality of that connectivity by employing the NETSCAN model. Then an evaluation is made of the discussion of these applied methodologies to meet this study’s key objective.

In a bid to evaluate airfreight transshipment connectivity at ICN, this study focuses upon a series of limited goals to simplify the research task.

- Incheon International Airport
- Airlines except foreign airlines: Korean Airlines and Asiana Airlines
- Airfreight
- Transshipment
- Indirect Connection

The research focus is on the indirect connectivity of airfreight transshipment for national airlines based at ICN. Two important distinctions are made to simplify analysis of using adopted models. First, research is concentrated on the airfreight sector of air cargo service; airmail and air-express are excluded.
1. INTRODUCTION

from analysis. Secondly, transshipment connectivity is gauged in terms of indirect connections based on either the number of connected airports or connection times, or both time. The importance of indirect connections has increased given that hub-and-spoke networks have been used to amplify network. Thus, this research will be also focused on indirect connections.
1.3 Organization of Research

The remainder of the research is structured as follows:

Chapter 2 is devoted to outlining the general features of air cargo business, identifying its distinguishing characteristics and key features. Chapter 3 reviews the literature on subjects related to hub-and-spoke networks and outlines the methodology, including a review of previous work on each topic. Chapter 4 deals with the methodology which is applied to analyze indirect connections through ICN. Chapter 5 presents the results and interpretations related to the applied methodologies. Before the main methodologies Wave-system structure and NETSCAN model are applied, a series of preliminary analyses are executed. Then we investigate Wave-system structure for flight schedules of airfreight movements to analyze ICN’s indirect connectivity. As Wave-system structure does not encompass network quality, we adopt a NESCAN model to evaluate it. Chapter 6 concludes this study by summarizing the new findings and limitations from applying Wave-system structure and the NETSCAN model for freight; topics for further study are suggested. Figure 1.1 outlines the structure of this study.
1. INTRODUCTION

Figure 1.1  The Study’s Organization

- Literature Review
  - Hub-and-spoke Networks
  - Wave-system Structure
  - Network Quality

Findings from Reviewing Literature
(This study’s Features)

Data Collection & Synthesis

Air-cargo Business
(Forecasts & Features)

Preliminary Analyses
- Pattern of Transshipment Freight

Wave-system Structure

NETSCAN model

Results of Analyses

Discussion & Conclusion
In analyzing airfreight connectivity, we will apply the used methodologies used for analyzing passenger traffic are employed. Initially, attention is focused on validation of the chosen methodologies. As the main features for air cargo is known, we can find the proper assumption and transformation for methodologies.

Market forecasts for air cargo outstrip those for air passengers. Long-term forecasts from Airbus (2004) and Boeing (2006) predict a 5.9% and 6.1% annual growth rate for airfreight traffic over the next 20 years. In contrast, the respective annual growth rates for passenger are predicted to be 5.3% and 4.9%. In future of world aviation market, it means that air cargo market is more valuable than air passenger market. In particular, Asian countries have experienced strong growth rates in international air cargo since the Asian financial crisis of 1997-98. Indeed, the region is expected to lead all other international geographic markets in average annual air growth over the next 20 years (Ohashi et al., 2005).
‘Air cargo’ is defined as the total volume of freight, mail and express services transported by air (Wells, 1999). The definition includes freight-of-all-kinds (FAK), which covers small package counter services, express and priority reserved freight, and express services, and all classes of mail transported by the U.S Postal Service. ‘Air freight’ is defined as large package and cargo that does not have a high-priority as air-express shipments. ‘Air-express’ refers to small packages that have a higher priority to carriage than airfreight. Figure 2.1 presents the definition of air cargo.

The air cargo business, as cautioned by Otto (2005) is unlike the air passenger business. In 2001, little more than half of the world’s airfreight moved in freighters. Consequently, network planning for almost half of the available capacity is dictated by demands of the air passenger market. However, there are a number of characteristics that apply to passenger and cargo airlines alike. Investment in freighter and passenger fleet is
2. AIR CARGO BUSINESS

comparable. Both business models have to provide the same safety and security standards for crew and equipment. The development of these models is still incomplete because open sky agreements between all nations have get to be finalized.

There are also marked differences between the air cargo business and passenger business, as noted by Kadar and Larew (2003) for the following reasons.

- Airfreight is unidirectional. This directionality of airfreight corresponds with economic trade flows, which are unequal. Satisfaction of demand from Asia to North America, for example, translates into a gross oversupply of the market in the reverse direction. In 2003 air cargo flow from the Asian-Pacific region to North America vastly outweighed return demand. This inherent imbalance does not comply with the traditional return-flight concept of passenger airlines.

- Airfreight is heterogeneous and comes in varying shapes, weights and values. Accordingly, the range of transport demand is manifold compared with the narrow demand of passenger transport where are seat marking one passenger. Given the heterogeneous nature of air cargo shipments,
numerous different transport solutions have to be developed for air cargo. This heterogeneity of airfreight is regarded in a significantly higher complexity of processes.

- Cargo customers are concentrated, with a limited number of forwarding agencies accounting for the major share of air cargo demand, whereas countless individuals and companies purchase passenger tickets. The bargaining power of customers in the air cargo business is significantly higher than counterparts in the passenger business.

- Numerous companies are involved the air cargo transport chain to fulfill the required transport, handling, warehousing and customs tasks.

The differences of between air cargo and passenger are also noted by Doganis (2002). Since airfreight is much more heterogeneous than are passengers there are several ways of categorizing it. One may, for instance, consider the commodities being sent, or one can classify freight by the weight of individual consignments or by the speed of delivery required. As with passenger traffic, it is valuable to try to segment the freight market in terms of the motivation of the shipper rather than in terms of the product, since this has implications for the type of air freight services which need to be provided and for their pricing. Another aspect of this heterogeneity is that
freight comes in all shapes, sizes, densities and weights. There is no standard unit or size for a freight consignment or any standard unit of space. Freight density is crucial to the economics of air freight. Cargo payload on an aircraft is limited by weight, but also by volumetric capacity.

Air cargo business, as outlined by Ohashi and others (2005) is inherently competitive. This is because most cargo is indifferent to the routings between origin and destination except in cases of emergency. A shipper is not concerned whether a shipment goes from an origin airport to a destination airport via any airport as a transshipment point. A shipper only wants to have the cargo delivered within the expected time. Thus, freight forwarders choose among numerous routings and carriers to ship their cargo to the final destination. Therefore, there is more competition among airports for transshipment cargo than for passengers.
Chapter 3.0  LITERATURE REVIEW

This study focuses on evaluations of the indirect connectivity at Incheon International Airport (ICN). Indirect connectivity of hub-airports is defined as the number and efficiency of indirect connections generated by the existing flight schedule (Burghouwt and de Wit, 2005). Indirect connectivity depends primarily on flights scheduled within hub-and-spoke networks and secondarily on the quality of indirect connections. Therefore, this study concentrates on reviewing the literature on these topics relevant to the evaluation of indirect connectivity:

1. Hub-and-spoke Network
2. Wave-system structure
3. Network Quality

The third topic is included to employ a NETSCAN model to examine airfreight transshipments.
3. LITERATURE REVIEW

3.1 Hub-and-spoke Network

Airlines took advantage of the possibilities of the liberalized market and reorganized their networks in responding to the deregulations of the aviation market in 1978. A number of carriers restructured their networks from ‘point-to-point’ into ‘hub-and-spoke’ systems (Reynolds-Feighan, 1998, 2000). Increasingly, direct flights from medium-size airports to other medium-size airports were replaced by indirect flights through a central airport or ‘hub’. A key advantage of a hub-and-spoke network is that it provides an enormous ‘multiplier’ effect as to the number of city-pairs (Wells, 1999). This effect is demonstrated in Figure 3.1.

![Diagram of Point-to-Point Service Without Hub and Service via Cross-Connection (Hub)]


**Figure 3.1  Multiplier Effect of Hub Connections**

The number of connections from/to or via hub determines the maximum
number of indirect connections following the formula n(n-1)/2, where n
denotes the number of spoke-airports in the network. As a result of using the
network, airlines can move through a number of combinations from an origin
to a destination.

3.1.1 Connection Types

Three types of connections have been distinguished from hub-and-spoke
networks by Burghouwt and Veldhuis (2005): (1) Direct connections: flights
between airport A and airport B without a hub-transfer (A-B), (2) Indirect
connections: flights from A to B, but with a transfer at airport I (A-I-B), and
(3) Hub connections involve links through with a transfer at hub H between
origin C and destination B (C-H-B). Hub connections could consider a kind
of indirect connections. Figure 3.1 presents the variety of connections in
hub-and-spoke networks.
3.1.2 Spatial or Temporal Concentrations

A substantial amount of theoretical and empirical research has been carried out on airline network configurations. Most studies on airline network configurations focus on the spatial dimension of airline networks. Generally, the hub-and-spoke network is seen as a spatially concentrated network. In the hub-and-spoke network, routes are deliberately concentrated on a few key nodes in the network. However, an airline network needs both spatial and temporal concentration of flights to qualify as a hub-and-spoke network (Burghouwt and de Wit, 2005).

Only a small number of empirical studies have been undertook to measure temporal concentration within airline networks. Table 3.1 provides overview
of hub-and-spoke definitions of various studies to support the definition’s specification.

Table 3.1 Definition of the network according to various studies

<table>
<thead>
<tr>
<th>PAPER</th>
<th>OBJECT</th>
<th>SPATIAL/TEMPORAL CONCENTRATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bania, Bauer and Zlatoper (1998)</td>
<td>Airline</td>
<td>Spatial/temporal concentration</td>
</tr>
<tr>
<td>Berry, Carnall and Spiller (1996)</td>
<td>Airline</td>
<td>Spatial concentration</td>
</tr>
<tr>
<td>Bootsma (1997)</td>
<td>Airline</td>
<td>Spatial/temporal concentration</td>
</tr>
<tr>
<td>Burghouwt &amp; de Wit (2005)</td>
<td>Airline/Airport</td>
<td>Temporal concentration</td>
</tr>
<tr>
<td>Burghouwt &amp; Hakfoort (2001)</td>
<td>Airline/Airport</td>
<td>Spatial concentration</td>
</tr>
<tr>
<td>Burghouwt &amp; Hakfoort (2001)</td>
<td>Airline/Airport</td>
<td>Spatial concentration</td>
</tr>
<tr>
<td>Dennis (1998)</td>
<td>Airline</td>
<td>Spatial/temporal concentration</td>
</tr>
<tr>
<td>Goetz &amp; Sutton (1997)</td>
<td>Airline</td>
<td>Spatial concentration</td>
</tr>
<tr>
<td>Martin and Roman (2003, 2004)</td>
<td>Airline/Airport</td>
<td>Spatial concentration</td>
</tr>
<tr>
<td>O’Kelly (1998)</td>
<td>Airport</td>
<td>Spatial concentration</td>
</tr>
<tr>
<td>Oum, Zhang and Zhang (1995)</td>
<td>Airline</td>
<td>Spatial concentration</td>
</tr>
<tr>
<td>Veldhuis &amp; Kroes (2002)</td>
<td>Airline/Airport</td>
<td>Spatial/temporal concentration</td>
</tr>
</tbody>
</table>

A methodology for measuring the extent to which airlines operate hub-and-spoke networks has been provided by Bania and others (1998). These authors
take into account the network’s spatial concentration using the McShan-Windle index. Moreover, they consider every possible indirect connection as a viable connection, regardless of transfer time and routing factor.

In dealing with the competitive position of the main European hub airports, Dennis (1998) distinguishes three factors that determine the success of a hub airport: markets served, geographical location and transfer times/schedule coordination. First, irrespective of locations and transfer times, the number of flights on two origin-and-destination pairs determines the number of indirect connections. Secondly, geographical location is critical. Dennis studies this aspect by computing the total number of passenger kilometers necessary to connect every hub with all other hubs in the system. Thirdly, having a good hub potential and geographical location would be sufficient to operate a successful hub. However, passengers are not prepared to wait for an indefinite time. Hence, transfers require the concentration of flight activity into a limited number of peaks or waves during the day to minimize waiting time. Dennis calculated the performance of the airline in generating an effective wave structure by computing the number of connections possible for each airline at each hub between the minimum connecting times and six hours as well as looking at the wave structure graphically.
The waiting time at a hub airport is dependent on three factors as stated by Rietveld and Brons (2001): frequency, the minimum connection time (MCT) and the time table co-ordination by the hub carrier. Knowing the MCT values for a certain connection, the frequency for the flights concerned and the waiting time for that connection, the level of timetable co-ordination can be derived. From the total number of operating hours per day and the frequency on the most frequent leg of the connection ($F_2$), an expected average waiting time can be computed ($T_h$). The deviation from the real waiting time minus the MCT is called alpha.

$$t_h = MCT + g \frac{T}{F_2} \quad \text{(3.1)}$$

$$\alpha = 1 - g \quad \text{(3.2)}$$

The problem of this approach is the fact that the study assumes that the observed frequency on the route is one of the determinants for the waiting time at the hub. This seems to be a right conclusion: average waiting time decreases as frequency decreases. However, frequency is not factor decisive for the waiting time ($T_h$) at the hub. It is the other way around: waiting time is decisive for the frequency. Airlines choose frequency based on O-D$^1$

$^1$ Origin-Destination (O-D)
demand and transfer demand. Both determine the wave-system structure (time table coordination) including the number of waves (Bootsma, 1997).

Ideally, every destination is being served in every wave. However, markets with very strong O-D demand may validate off-wave scheduling of these services. At the same time, connection with insufficient demand may result in connections not served in every wave. Without the time table coordination in the flight schedule/wave structure, certain frequencies would not be possible because of lack of O-D demand. The Rietveld and Brons-approach has been based on the inaccurate assumptions creating a loop in the model. The model measures the level of timetable coordination based on frequency that is the result of the same timetable coordination because it assumes that frequency is only generated by O-D demand. However, as stated before, frequency is the result of both O-D and transfer demand which is partly the result of the wave-system structure adopted by the airline.
3.2 Wave-system Structure

A Wave-system structure model to analyze the effect of indirect connectivity within hub-and-spoke networks has been developed by Bootsma (1997). The object of Bootsma’s investigation is to transfer passengers at a hub airport.

Bootsma uses the theoretical model of an ideal connection wave as the benchmark for analyzing the wave-system’s structure and its effects indirect connectivity. For the descriptive part of the analysis, Bootsma identifies the presence, timing and number of actual waves by identifying local maxima in the actual daily distribution of arriving and departing flights using a theoretical model of an ideal connection wave. For the measurement of indirect connectivity of an airline’s flights schedule, he proposed a number of yardsticks: the number of indirect connections, and the quality of those connections. One problem with this approach is the crude analysis of the quality of connections. A distinction is made between excellent, good and poor connections, based on waiting time at the hub. Finally, Bootsma did not consider the backtracking. Drawback of this model cannot gauge the quality of connections within networks.

Another study of the temporal concentrations in Europe’s aviation network
was investigated by Burghouwt and de Wit (2005). They analyzed the development and configuration of wave-system structures at airline hubs and distinguished between continental and intercontinental flights involved the transferring passengers. Their study, using the Official Airline Guide (OAG)\(^2\) data, found that a trend towards temporal concentration exists among European airlines resulting in the adoption, or intensification, of wave-system structures. Temporal concentration may increase the network’s competitive position in a deregulated market because of certain cost and demand advantages. This method of analysis has been extended by Park and others (2006) to study the connectivity of transferring passengers at ICN.

\(^{2}\) http://www.oag.com
3.3 Network Quality

The network condition of ICN has been evaluated by Park (2001). This research considered the relation of between the number of connected cities with 2,000 miles and total flight frequency per week, as equal condition. The Network Index (NI) used for analyzing the configuration of feeder routes in a hub-and-spoke network. A Network Index (NI) is made by using the number of connected cities \(C_c\) within 2,000 miles\(^3\) and flight frequency \(F_w\) per week.

\[
NI = \sum (F_w \times rF_w) + \sum (C_c \times rC_c) \tag{3.3}
\]

The concept of NETSCAN model to measure the competitive position of an airline or airport network has been developed by Veldhuis (1997). Inputs for this measure include the frequency of a connection (direct or indirect); the non-stop travel time; perceived travel time; maximum perceived travel time; and the transfer time. The measure scales indirect travel time to direct flight travel time, making it possible to comparisons between two using the NETSCAN model.

\(^3\) Criterion between short-haul and long-haul, See Park (2001)
According to the NETSCAN model, the quality of an indirect connection between airport A and airport B with a transfer at hub airport H is not equal to the quality of a direct connection between A and B. The transfer time equals at least the minimum connecting time, or the minimum time needed to transfer between two flights at hub H. A NETSCAN model measures the indirect connectivity as the quality of an indirect connection (see Figure 4.2).

Figure 3.3 Theoretical Structure of NETSCAN model
3.4 Findings from Reviewing Literature

In this study, the term of air cargo is used as total volume of freight and mail transported by air. Express service is excluded in our consideration. Moreover, characteristics of air cargo have been summarized by Kadar and Larew (2003) to highlight how its heterogeneity translates into significantly more complex processes than air passenger transport. Air cargo customers are concentrated by a limited number of forwarding agencies. As cargo is consolidated by forwarding agencies, the numbers of flights for cargo only involve three or four flights per day compared as its numerous passenger flights throughout the day. According to airline schedules, the operation frequency of freighters is planned for a week as a standard unit. For example, the America route’s frequencies are 44 flights per week. Thus, the basis unit for analyzing Wave-system structure is considered by the unit of a week.

Only a small number of studies have analyzed the temporal dimension of airline hub-and-spoke networks. These studies have either analyzed the structure of the airline flight schedule itself (Bootsma, 1997; Dennis, 1998) or aimed to assess the consequences of an actual flight schedule for: (a) the
level of indirect connectivity (Bootsma, 1997; Veldhuis, 1997); and (b) waiting time (Rietveld and Brons, 2001).

Transfer time and routing factor were not considered by Bania and others (1998). However, the transfer time at the hub and routing factors are essential elements in determining the hub-and-spoke system’s capacity and capability. Dennis’s (1998) methodology also does not take into account the effects of waiting time on the quality of a connection. Yet, Bootsma (1997) offered a very valuable methodology for describing the structure of an actual flight schedule. Indeed, Bootsma distinguished between a description of the temporal configuration of an airline network and an analysis of the effects of a certain temporal configurations on indirect connectivity. Therefore, we will make another distinction in this study. This distinction uses the Park (2001)’s criterion of distance of 2000 miles between long-haul and short-haul instead of a continental criterion favored by Bootsma. This methodology will be adapted in chapter 4. However, the methodologies of both Bania and other (1998), Dennis (1998), and Rietveld and Brons (2001) have been rejected for theoretical reasons.

A measure of network quality has proved its utility. Drawbacks of the methodology, however, stem from assumptions on the valuation of time to
make comparisons possible between indirect and direct connectivity. Consequently, a simplified NETSCAN model for airfreight is used to assess the effects of temporal configurations on an airline’s network. As another measure of network quality, Park’s (2001) Network Index (NI) did not consider any factor related to time, this methodology was also rejected in measuring our study.

Thus, we will use a Wave-system structure to analyze the temporal concentration of hub-and-spoke networks with the consideration outlined above. Then we will estimate the quality of indirect connectivity by employing the NETSCAN model for airfreight.
This study comprises three analytical steps. First, we analyze the air cargo transshipment of ICN\(^6\) providing the study’s context: origin-and-destination; constitution and density of freight; aircrafts using transshipment of airfreight; and others. Then, a Wave-system structure is used to analyze the number of indirect connections in the airline flight schedule. Finally, we also use a NETSCAN model to analyze and quantify the performance of air transport networks.

\(^6\) ICN: Incheon International Airport, Korea
4. METHODOLOGY

4.1 Data Collection and Synthesis

This study is based on the data set derived from both IIAC\(^7\) and two national airlines\(^8\) of Korea for the period between April 1 and April 15, 2006. Initially, the data set were used by identifying the pattern of air cargo\(^9\) transshipment operations. The data set contains variables, which include airline, flight number, arrival time, department time, origin airport, destination airport, air cargo’s volume, and used aircraft type. For our analysis, we took all flights departing and arriving. IIAC data provides all kinds of flights served by all airlines at ICN\(^{10}\) during the period. This data will be used by identifying the pattern of airfreight transshipment. Minimum connection times will be also derived from the actual scheduled flights of two national airlines during the stated period.

---

\(^7\) IIAC: Incheon International Airport Corporation, Korea
\(^8\) National Airlines of Korea: Korean Airlines, Asiana Airlines
\(^9\) In this study, the term of air cargo is considered as total volume of freight and mail transported by air. Express service is excluded in our consideration.
\(^{10}\) ICN: Incheon International Airport, Korea
4. METHODOLOGY

4.2 Preliminary Analyses

A series of preliminary analyses and modeling was undertaken to identify key characteristics embodied in the collected data set. We analyze the air cargo transshipment of ICN providing the study’s context: origin-and-destination; constitution and density of freight; aircrafts using transshipment of airfreight; and others. Initially, the patterns of airfreight transshipment processing at ICN are analyzed to identify the configuration of T/S freight of ICN. Then, an origin-and-destination analysis is undertaken to comprehend the origin and destination airports for transshipped freight at ICN. Finally, we identify the density of freight and the type of aircraft used in transshipments.
4.3 Wave-system Structure of Airfreight

As noted before, following Bootsma’s (1997) thesis, a wave-system structure comprised number of waves, the timing of the wave and the structure of an individual wave. A connection wave is also defined as a complex of incoming and outgoing flights, structured such that all incoming flights connect to all outgoing flights. Figure 4.1 presents the structure of a theoretical connection wave based on the distance criterion.

\[ t_1 = C - T + (1/2)Tc \]
\[ t_2 = C + (1/2)Tc \]
\[ t_3 = C - Mi + (1/2)Mc \]
\[ t_4 = C - (1/2)Mc \]
\[ t_5 = C \]
\[ t_6 = C + (1/2)Mc \]
\[ t_7 = C + Mi - (1/2)Mc \]
\[ t_8 = C + (1/2)Tc \]
\[ t_9 = C + Ti - (1/2)Tc \]

A(t) = number of flights that still have to arrive at the hub at time t;
D(t) = number of flights that still have to depart from the hub at time t;
4. METHODOLOGY

C = Wave Center,
Mi = minimum connecting time for long-haul flights;
Mc = minimum connecting time for short-haul flights;
Ti = maximum connecting time for long-haul flights;
Tc = maximum connecting time for short-haul flights

Source: Bootsma (1997)

Figure 4.1 Structure of Theoretical Connection Wave

Three elements determine the structure of such a connection wave: (1) the minimum connection time for short-haul and long-haul flights, (2) maximum connection times, and (3) maximum number of flights that can be scheduled per time period. Further, these connection times for short-haul and long-haul flights is estimated by the using times in the applied NETSCAN model for airfreight.

Connections have to meet minimum connecting times (M). Then, a trade-off has to be made between the maximum acceptable connection time (T) for the airline and the maximum number of flights that can be scheduled in a time period (A(t)+D(t)). Since no airport has unlimited peak capacity, adding new flights to the edges of the waves involves long waiting times, which may be unacceptable for transfer cargo (Dennis, 2001).
In addition to Wave-system structure, we also develop a connectivity index (CI). The connectivity index is applied to measure the relation of flights between arrival and departure at ICN. The mathematical model is derived from the gap of flights between arrival and departure.

\[
CI = \sqrt{\sum_{t=1}^{24} \left[ \left( \frac{A_t}{AA} \right) - \left( \frac{D_{t+LUT}}{AD} \right) \right]^2} \tag{4.1}
\]

where:

- \(A_t\) = number of flights that still have to arrive at the hub at time \(t\);
- \(D_{t+LUT}\) = number of flights that still have to arrive at the hub at time \(t+2\);
- \(LUT\) = Loading and Unloading Time;
- \(t\) = time slots that varied from 1 to 24 in a day;
- \(AA\) = average flights of the sum total \(A_t\);
- \(AD\) = average flights of the sum total \(D_t\).

Because the effect of different size for operating flights was existed, the effect should be eliminated to analyze the connectivity. Thus, the number of flights for each time slot \((A_t)\) was divided by average number of each total flight for arrival \((AA)\) or departure \((AD)\). Loading and Unloading time \((LUT)\) can be distinguished by different transshipment pattern: Freighter-
Freighter, Freighter-Passenger Fleet and Passenger Fleet-Passenger Fleet. This time is also given by data set of national airlines (see Table 4.1). However, we did not consider each kind of T/S freight. Thus, we assume two that flights within 2 hours on flight schedule can not transship. Moreover, we do not consider any time for take-off and landing.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Average Processing Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAX¹¹ Fleet → PAX Fleet</td>
<td>1 hour</td>
</tr>
<tr>
<td>PAX Fleet → Freighter</td>
<td>1 hour 30 minutes</td>
</tr>
<tr>
<td>Freighter → Freighter</td>
<td>2 hours</td>
</tr>
</tbody>
</table>

In relation with the interpretation of results, a connectivity index assigns a figure more than 0. If the number of arrival flights equal to the number of departure flights, a connectivity index is given the maximum quality index of 0. The connectivity index of an indirect connection will always be upper than 0. It is due to extra time added by transshipment. Thus, a connectivity index is to be lower than others, the connectivity is analyzed as better than others.

¹¹ PAX: Passenger
4. METHODOLOGY

4.4 NETSCAN model of Airfreight

The NETSCAN model is applied to measure the quality of a network’s indirect connections. The mathematical model is derived from applications to passenger transport (Veldhuis, 1997).

\[
\text{MAXT} = (3-0.075 \times \text{NST}) \times \text{NST} \quad (4.2)
\]

\[
\text{PTT} = \text{FLY} + 3 \times \text{TRF} \quad (4.3)
\]

\[
\text{QUAL} = 1 - \frac{\text{PTT} - \text{NST}}{\text{MAXT} - \text{NST}} \quad (4.4)
\]

where:

- MAXT = Maximum perceived travel time of passenger;
- NST = Non-stop travel time of passenger;
- PTT = Perceived travel time of passenger;
- FLY = Flying time;
- TRF = Transfer time;
- QUAL = Quality Index.

According to Veldhuis (1997), Transfer time has been triple counted, to calculate perceived travel time. By triple-counting transfer time, the perceived travel time is longer than actual travel time for indirect flights. To
account for perceived travel time for every single frequency a 'quality index' is defined. In case the total perceived travel time is equal to the normal non-stop time on that route the quality index equals 1. Of course, it is the case for non-stop flights. If total perceived travel time exceeds certain limits, defined as a function of non-stop travel time, this index equals zero. Normal non-stop time is calculated using the coordinates of origin and destination airports, from which distance can be derived. Maximum perceived travel time is determined as a function of non-stop travel time. For a one hour non-stop flight this time limit is defined at 3 hours, and for a 12 hour flight this limit goes as high as 24 hours. Note that non-stop times have been calculated for city-pairs even where non-stop flights are technically not possible (Veldhuis, 1997).

Because this model is only used for passengers, the model is changed here for cargo. Initially, item 4.2 in the model has to be replaced with maximum transportation time by airlines as a proxy. Maximum transportation time, between origin and destination airport, presented by airlines is given by data set of national airlines (see Table 4.2).
4. METHODOLOGY

Table 4.2 MAXT presented by Airlines

<table>
<thead>
<tr>
<th>Origin Region</th>
<th>Destination Region</th>
<th>MAXT (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHINA</td>
<td>American Continent</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Southeast Asia</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>Europe</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Oceania</td>
<td>48</td>
</tr>
<tr>
<td>JAPAN</td>
<td>American Continent</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Southeast Asia</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>Europe</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Oceania</td>
<td>48</td>
</tr>
<tr>
<td>Southeast Asia</td>
<td>American Continent</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Europe</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Oceania</td>
<td>72</td>
</tr>
</tbody>
</table>

In relation to processing T/S freight, the time factors at a transshipment airport are noted by Ohashi and others (2005). According to Ohashi and others (2005), the three important elements of the time factors are: (1) flight time, (2) loading/unloading time, and (3) waiting time caused by schedule delay. Flight time is generally determined by route distance. The schedule delay indicates how many hours on average a shipment has to wait at an airport before catching the next flight.
4. METHODOLOGY

Connecting time\(_i\) = \((n_i+1) \times \text{(expected schedule delay)}\)\(_i\)

s.t: \((n_i+1) \times \text{(expected schedule delay)}\)\(_i\)  

\(> (L/UL \text{ time})\)\(_i\)  

\(> n_i \times \text{(expected schedule delay)}\)\(_i\)

where:

Connecting time = the time that a shipment has to stay on route \(i\)

\(n_i\) = the number of scheduled flights that have to be missed for route \(i\) in order for a shipment to go through reloading and other process

L/UL time = Loading/unloading time

These considerations refer to replace with the transfer time (TRF) of NETSCAN model. LUT is applied from the data, which is used to measure connectivity index.

In this regard, the mathematical model is changed from applications to airfreight transport. Moreover, the terms used in mathematical model are also changed for airfreight.
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\[ ITT = FLT + WAT \] (4.5)

\[ QUAL = 1 - \frac{(ITT-DTT)}{(MAXT-DTT)} \] (4.6)

where:

- \( MAXT \) = Maximum Transportation Time presented by airlines;
- \( DTT \) = Direct Transportation Time (Non-stop);
- \( ITT \) = Indirect Transportation Time;
- \( FLT \) = Flight Time;
- \( LUT \) = Loading and Unloading Time;
- \( WAT \) = Waiting Time for the next available flight;
- \( QUAL \) = Quality Index.

Consequently, indirect transportation time can be estimated by using the formula in 4.5 in place of the formula in 4.3.

In relation with the interpretation of results, a NETSCAN model assigns a quality index to every connection, ranging between 0 and 1. A direct connection\(^{12}\) is given the maximum quality index of 1. The quality index of an indirect connection will always be lower than 1. It is due to extra time added by transshipment. If the additional transportation time of an indirect

\(^{12}\) Non-stop flight
connection exceeds a certain threshold, the quality index of the connection equals 0. Thus, the threshold of a certain indirect connection between two airports depends on the transportation time of a theoretical direct connection between two airports. In other words, the maximum indirect transport times exceeds the direct transportation time between two airports (Veldhuis, 1997).
Chapter 5.0  RESULTS OF ANALYSES

5.1 Preliminary Analyses

The key findings from the preliminary analyses are discussed.

Figure 5.1 presents the pattern of total air cargo volume handled by all airlines at ICN\(^ {\text{13}}\). Transshipment freight comprises 48 per cent of total air cargo. It almost approximates to the share of general freight.

![Air Cargo Volume at ICN](image)

**Figure 5.1 Pattern of Air cargo Volume at ICN**

Figure 5.2 describes the configuration of airlines engaged in handling transshipment freight at ICN. National airlines dominate transshipments

\(^{13}\) ICN: Incheon International Airport, Korea
Korean Airlines (KAL) and Asiana Airlines (AAR). Collectively, they account for 93 per cent of transshipment freight handed at ICN. Foreign airlines handle the remainder. The type of aircraft used for processing T/S\textsuperscript{14} freight at ICN is also shown in Figure 5.2. Only two kinds of aircraft are distinguished: passenger and freight. More than half of all T/S freight is handed by freighters. However, belly cargo handed in passenger aircraft comprises a respectable share.

Figure 5.2 Handled Types of T/S Freight at ICN

Figure 5.3 shows the results of an origin-and-destination flow analysis T/S freight handed at ICN. Specifically, an examination of logistics patterns of Korea’s air cargo by Ha and others (2005) shows that Korea-America routes comprise the largest market. However Korea-China routes constitute the

\textsuperscript{14} Transshipment (T/S)
fastest growing market. In 2003 the rate of cargo transshipment relative to total cargo treatment at ICN was 42.6 per cent. An analysis of T/S regional patterns shows that the T/S rate related to Europe is relatively low. Outbound T/S from Incheon is primarily destined to USA; similar proportions are destined to China and Japan. Inbound T/S to Incheon originates mainly from Japan, USA, and Southeast Asia (Ha et al., 2005). These patterns also present that airfreight is unidirectional, as demonstrated by Kadar and Larew (2003).

![Figure 5.3 Flows of T/S Freight via ICN](image)

In our analysis, the result is analyzed somewhat similar with Ha and others (2005). T/S freight is derived largely from China, including Hong Kong’s
transshipment freight (33 per cent) and Southeast Asia (23 per cent). The balance is derived from the America (17 per cent) and Japan (15 per cent). T/S freight destined for USA constitutes the highest volume of T/S freight. The highest volume of outgoing T/S freight from ICN moves to the American continent. The American continent comprises 44 per cent, Europe almost 17 per cent, Southeast Asia 17 per cent, and Japan 10 per cent. Thus, the majority of T/S freight of ICN is comprised of China-American continent routes.

Further, the pattern divided by the criterion of distance is also illustrated in Figure 5.4. T/S freight for short-haul flights is derived largely from China (66 per cent) and Japan (30 per cent). On the other hand, T/S freight for long-haul flights is derived from Southeast Asia (41 per cent) and the American continent (34 per cent). In the case of outgoing T/S freight, the volume from ICN moves to Japan (47 per cent) and China (43 per cent) within 2,000 miles. The highest volume among region over 2,000 miles from ICN moves to the American continent (56 per cent). Consequently, T/S freight of ICN is derived from short-haul flights and moved to long-haul flights. In particular, the largest volume of T/S freight moved from China to the American continent.
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Figure 5.4  Flows of T/S Freight by a criterion of 2,000 miles
5. RESULTS OF ANALYSES

5.2 Wave-system Structure

Figure 5.5 illustrated Wave-system structure for the flights of airfreight transshipment at ICN. Before a criterion of comparison between short-haul and long-haul was applied, this figure was considered by both freighter and passenger fleet handled at ICN. The arriving and departing waves are shown in this figure.

![Wave-system Structure](image)

**Figure 5.5** ICN’s Wave-system Structure

Waves of ICN were totally distributed at between 4:00 and 22:00. Seven somewhat temporal concentrations for arriving and three departing flights were identified in this figure. However, if the loading and unloading time is
considered as the minimum connection time\(^{15}\), waves could be estimated for three sets: (a) arriving at between 04:00 and 06:00 / departing at between 09:00 and 10:00, (b) arriving at 11:00 as well as 08:00 / departing at 13:00, and (c) arriving at between 13:00 and 17:00 / departing at between 18:00 and 20:00. These waves presented that airfreight should be held no longer than 4 hours on average before departing from ICN. These patterns were shown in Table 5.1.

<table>
<thead>
<tr>
<th>Status</th>
<th>Temporal Concentration</th>
<th>Status</th>
<th>Temporal Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrival</td>
<td>04:00 – 06:00 (a)</td>
<td>Departure</td>
<td>09:00 – 10:00 (a)</td>
</tr>
<tr>
<td></td>
<td>08:00 (a) or (b)</td>
<td></td>
<td>13:00 (b)</td>
</tr>
<tr>
<td></td>
<td>11:00 (b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13:00 / 15:00 / 17:00 (c)</td>
<td></td>
<td>18:00 – 20:00 (c)</td>
</tr>
<tr>
<td></td>
<td>22:00 (a)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Further, as noted before, Wave-system structure applied by the criterion of distance was illustrated in Figure 5.6. First of all, in short-haul flights, five arriving waves were identified. There were also three departing waves of short-haul flights. Arriving waves were concentrated at 4:00, 11:00, 15:00,

\(^{15}\) We assumed that flights within 2 hours on the schedules of airlines could not be transshipped T/S freight at ICN.
17:00, and 22:00. Departing waves were also concentrated in three groups. Conversely, in long-haul flights, there were five arriving waves and four departing waves.

Moreover, as the flows of T/S freight were considered in preliminary analyses, we could also examine the relation of between arriving waves of short-haul flights and departing waves of long-haul flights. The temporal concentrations of four sets somewhat were identified: (a) arriving at 4:00 / departing at between 09:00 and 11:00, (b) arriving at 11:00 / departing at 13:00, (c) arriving at 15:00 and 17:00 / departing at 16:00, and (d) departing at between 22:00 and 23:00.

Figure 5.6  Wave-system Structure for Short- and Long-haul Flights
5. RESULTS OF ANALYSES

Table 5.2 Temporal Concentrations for Short- and Long-haul Flights

<table>
<thead>
<tr>
<th>Status</th>
<th>Temporal Concentration</th>
<th>Status</th>
<th>Temporal Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short-haul Flights</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrival</td>
<td>04:00 (a)</td>
<td>Departure</td>
<td>09:00 – 10:00</td>
</tr>
<tr>
<td></td>
<td>11:00 (b)</td>
<td></td>
<td>13:00 – 14:00</td>
</tr>
<tr>
<td></td>
<td>15:00 / 17:00 (c)</td>
<td></td>
<td>18:00 – 19:00</td>
</tr>
<tr>
<td></td>
<td>22:00 (a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Long-haul Flights</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrival</td>
<td>05:00 – 06:00</td>
<td>Departure</td>
<td>09:00 – 11:00 (a)</td>
</tr>
<tr>
<td></td>
<td>08:00</td>
<td></td>
<td>13:00 (b)</td>
</tr>
<tr>
<td></td>
<td>11:00</td>
<td></td>
<td>15:00 – 20:00 (c)</td>
</tr>
<tr>
<td></td>
<td>15:00</td>
<td></td>
<td>22:00 (d)</td>
</tr>
<tr>
<td></td>
<td>17:00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Further, these patterns of waves could be distinguished by the type of aircraft in use (See Figure 5.7). The types of aircraft were divided into two types; (1) freighter and (2) passenger fleet. In case of the fourth set among temporal concentrations for short- and long-haul flights as provided in Table 5.2, it was considered by the effect of freighter schedule as shown in Figure 5.7. This pattern means that freighter schedule was concentrated at between 22:00 and 23:00 in long-haul flights. The number of freighter flights in total was shown as less than 20 flights in both short- and long-haul flights.

---

16 The fourth set among temporal concentration between short- and long-haul flights presents (d) in Table 5.2.
However, in the case of departing waves for long-haul flights, freighter’s waves were greatly increased between 22:00 and 23:00. However, in distinction of aircraft type, waves of long-haul flights were also indistinctive.

Figure 5.7  Wave-system Structure for Types of Aircraft (ICN)

Table 5.3 and 5.4 provide temporal concentrations for schedules of freighter
and passenger fleet. These concentrations were divided into the criterion of distance.

<table>
<thead>
<tr>
<th>Table 5.3 Temporal Concentrations (Freighter)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Status</strong></td>
</tr>
<tr>
<td>Short-haul Flights</td>
</tr>
<tr>
<td>Arrival</td>
</tr>
<tr>
<td>Long-haul Flights</td>
</tr>
<tr>
<td>Arrival</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Table 5.4 Temporal Concentrations (PAX Fleet)</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td><strong>Status</strong></td>
</tr>
<tr>
<td>Short-haul Flights</td>
</tr>
<tr>
<td>Arrival</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Long-haul Flights</td>
</tr>
<tr>
<td>Arrival</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

The temporal concentrations of passenger fleet’s flights were presented similarly with total Wave-system structure of ICN (See Table 5.1 and 5.4).
However, because long-haul flights were existed as shown in the low level, the temporal concentrations of long-haul flights were indistinctive. The whole pattern of waves outlined that the number of short-haul flights are more than the number of long-haul flights.

In addition, we also analyzed the Wave-system structure for national airlines as shown in Figure 5.8. The data in Figure 5.8 were used in flights schedule of KAL\(^{17}\) and AAR\(^{18}\). There were numerical values of a vertical axis, which the number of flights for each time slot divided by average number of each total flight for arrival and departure. Thus, the effect of size for operating flights between KAL and AAR was eliminated. The average number of total flights for arrival and departure was shown in Table 5.5.

<table>
<thead>
<tr>
<th align="left">Table 5.5 Average Number of Total Flights for Airlines</th>
</tr>
</thead>
<tbody>
<tr>
<td align="left"></td>
</tr>
<tr>
<td align="left">--------------------------</td>
</tr>
<tr>
<td align="left"><strong>Korean Airlines</strong></td>
</tr>
<tr>
<td align="left"><strong>Asiana Airlines</strong></td>
</tr>
</tbody>
</table>

KAL’s operating spread was distributed wider than AAR (See Figure 5.8).

KAL’s waves were also more complex than AAR. Further, Table 5.6

\(^{17}\) KAL: Korean Airlines
\(^{18}\) AAR: Asiana Airlines
provided temporal concentrations for airlines in Korea. The temporal concentrations were presented by four or five sets.

Figure 5.8  Wave-system Structure for National Airlines in Korea
5. RESULTS OF ANALYSES

<table>
<thead>
<tr>
<th>Table 5.6 Temporal Concentrations for National Airlines</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Status</strong></td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td><strong>Korean Airlines</strong></td>
</tr>
<tr>
<td>Arrival</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Departure</td>
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<td></td>
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<tr>
<td></td>
</tr>
</tbody>
</table>

Further, these wave-system structures could be suggested by an index. Table 5.7 provided the connectivity index (CI) in related with ICN. As analyzing the gap of flights between arrival and departure, the value of connectivity index was compared. If the value was smaller than others, the connectivity was analyzed to be better than others.

The results of ICN, which was estimated by using the formula in 4.1, were shown in Table 5.7. The total flights of ICN included both KAL and AAR was the highest connectivity (3.89). However, in the case of particular
5. RESULTS OF ANALYSES

airlines, KAL was 5.96 and AAR was 6.66. The connectivity was lower than total flights’ connectivity. In case of AAR’s connectivity index, because the gaps of flight density between arrival and departure varied widely, CI was presented as the lowest index. In particularly, although AAR’s wave sets had one more than KAL’s wave sets, the AAR’s connectivity was worse than KAL’s.

In addition, when T/S freight was divided into the type of aircraft in use, passenger fleet’s connectivity (4.61) was greater than freight’s connectivity (6.21). This result was caused by the lower density of flight schedules for freighter as shown in Figure 5.7.

Table 5.7 Results of Connectivity Index

<table>
<thead>
<tr>
<th>Incheon International Airport</th>
<th>Connectivity Index (CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total flights of ICN</td>
<td>3.89</td>
</tr>
<tr>
<td>Freighter</td>
<td>6.21</td>
</tr>
<tr>
<td>Passenger Fleet</td>
<td>4.61</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>National Airlines in Korea</th>
<th>Connectivity Index (CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korean Airlines (KAL)</td>
<td>5.96</td>
</tr>
<tr>
<td>Asiana Airlines (AAR)</td>
<td>6.66</td>
</tr>
</tbody>
</table>
5. RESULTS OF ANALYSES

5.3 NETSCAN model

The quality of indirect connection could be estimated by a NETSCAN model. Initially, the airports of both origin and destination were chosen by the criterion of T/S freight volume. The chosen airports were shown in Figure 5.9. These results were based on the pattern of T/S freight executed by preliminary analyses.

The highest volume, handled incoming T/S freight to ICN, was derived by HKG\(^{19}\). Moreover, almost outgoing T/S freight was comprised by airports of North America. Both JFK\(^{20}\) and LAX\(^{21}\) comprised a respectable share among these selected airports. Thus, six airports among origin and destination airports were chosen: HKG, TYO\(^{22}\), BKK\(^{23}\), JFK, LAX, and CHI\(^{24}\). Each airport considered to be represented as each origin and destination region.

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19 HKG: Hong Kong (Chek Lap Kok International)
20 JFK: New York (John F. Kennedy), NY, USA
21 LAX: Los Angeles International Airport, CA, USA
22 TYO: Tokyo (Metropolitan Area), Japan
23 BKK: Bangkok (Don Muang International), Thailand
24 CHI: Chicago (Metropolitan Area), IL, USA
According to these six airports, a NETSCAN model is used to estimate the quality of indirect connection for these routes (See Table 5.8). These routes selected a criterion of the largest T/S freight volume among routes, as shown in Figure 5.9.
5. RESULTS OF ANALYSES

Table 5.8 Selected Routes for NETSCAN model

<table>
<thead>
<tr>
<th>Origin Airport</th>
<th>T/S Airport</th>
<th>Destination Airport</th>
</tr>
</thead>
<tbody>
<tr>
<td>HKG</td>
<td>JFK / LAX / CHI</td>
<td></td>
</tr>
<tr>
<td>TYO</td>
<td>ICN</td>
<td>JFK / LAX</td>
</tr>
<tr>
<td>BKK</td>
<td>JFK / LAX</td>
<td></td>
</tr>
</tbody>
</table>

The results analyzed by NETSCAN model was presented in Table 5.9. The best quality index’s route was HKG-ICN-JFK route. The worst quality index’s route was also HKG-ICN-CHI route. Specially, the quality index of BKK-ICN-JFK route was also over 0.94.

Quality index had an effect on the gap of between DTT\textsuperscript{25} and ITT\textsuperscript{26}. In other words, the more the gap was increased, the more quality index was decreased. In these results, because MAXT\textsuperscript{27} was set to be excessive, ICN’s network quality for indirect connection was relatively highly distributed as the level of between 0.83 and 0.95. For example, on HKG-ICN-CHI route, this route’s gap of between DTT and ITT was the largest time (10 hours) period among selected routes. Thus, the quality index was shown as the lowest level. Moreover, quality index depended on the configuration of flight schedule,

\textsuperscript{25} Direct Transportation Time (DTT)  
\textsuperscript{26} Indirect Transportation Time (ITT)  
\textsuperscript{27} Maximum Transportation Time (MAXT) was presented by airlines.
5. RESULTS OF ANALYSES

WAT\textsuperscript{28}. However, in relation to the results of NETSCAN model, the regional route and T/S freight volume seemed not to be related with the quality index for the configuration of network.

Table 5.9 Results of NETSCAN model

<table>
<thead>
<tr>
<th>ROUTES \textsuperscript{(Indirect Connection)}</th>
<th>MAXT \textsuperscript{(hour)}</th>
<th>DTT \textsuperscript{(hour)}</th>
<th>ITT \textsuperscript{(hour)}</th>
<th>FLT\textsuperscript{29} \textsuperscript{(hour)}</th>
<th>WAT \textsuperscript{(hour)}</th>
<th>QUAL\textsuperscript{30}</th>
</tr>
</thead>
<tbody>
<tr>
<td>HKG-ICN-JFK \textsuperscript{(Direct Connection)}</td>
<td>72</td>
<td>18.75</td>
<td>21.35</td>
<td>15.92</td>
<td>5.43</td>
<td>0.95</td>
</tr>
<tr>
<td>HKG-ICN-LAX</td>
<td>72</td>
<td>12.50</td>
<td>18.52</td>
<td>14.17</td>
<td>4.35</td>
<td>0.90</td>
</tr>
<tr>
<td>HKG-ICN-CHI</td>
<td>72</td>
<td>14.00</td>
<td>24.12</td>
<td>17.12</td>
<td>7.00</td>
<td>0.83</td>
</tr>
<tr>
<td>TYO-ICN-JFK</td>
<td>72</td>
<td>12.50</td>
<td>20.53</td>
<td>15.00</td>
<td>5.53</td>
<td>0.86</td>
</tr>
<tr>
<td>TYO-ICN-LAX</td>
<td>72</td>
<td>8.00</td>
<td>16.98</td>
<td>13.25</td>
<td>3.73</td>
<td>0.87</td>
</tr>
<tr>
<td>BKK-ICN-JFK</td>
<td>72</td>
<td>17.00</td>
<td>20.22</td>
<td>16.42</td>
<td>3.80</td>
<td>0.94</td>
</tr>
<tr>
<td>BKK-ICN-LAX</td>
<td>72</td>
<td>14.50</td>
<td>21.04</td>
<td>15.00</td>
<td>6.37</td>
<td>0.89</td>
</tr>
</tbody>
</table>

\textsuperscript{28} Waiting Time for the next available flight (WAT)
\textsuperscript{29} Flight Time (FLT)
\textsuperscript{30} Quality Index = 1-(ITT/DTD)/(MAXT-DTT)
5. RESULTS OF ANALYSES

5.4 Implications

As noted before, indirect connectivity was defined as the number and efficiency of indirect connections generated by existing flight schedule (Burghouwt and de Wit, 2005). Following this definition of indirect connectivity, we used the two methodologies, which were the Wave-system Structure and the NETSCAN model, to analyze the indirect connectivity for T/S freight. These methodologies had been applied in examining the indirect connectivity of air passengers. In addition, we also developed the connectivity index to analyze indirect connectivity. According to the used methodologies, there were the following implications.

Firstly, the Wave-system structure could analyze the relation between arrival and departure fights. However, in case of T/S freight, the number of flights for freighters presented small numbers. Thus, when the Wave-system structure for T/S freight was investigated, both freighter and passenger fleet should be considered together.

Secondly, because the Wave-system structure was shown by some illustrations, the connectivity could not be directly explained. Accordingly, the necessity of the connectivity index was suggested to explain clearly the
connectivity.

Thirdly, the connectivity index was presented by an index following the definition of indirect connectivity. The connectivity index explains clearly about the connectivity. However, the connectivity index had some limitations. First, if the number of time slot, which the number of flights were zero, was increased, the connectivity index could be better. Then, we assumed that the loading and unloading time was a minimum connection time and used the criterion of 2 hours. In this regard, the connected flights over 2 hours were not considered in the connectivity index. In other words, the extra time was not considered except for the loading and unloading time.

Fourth, the connectivity index was useful for the comparison between airports. However, because the freight between airlines was not transshipped except for the relation of alliances, the index was not the absolute index.

Finally, in the case of NETSCAN model, MAXT was estimated to be higher than ITT. Thus, the result of quality could be shown as risen generally in the estimation of indirect connectivity. Further, the results were influenced by the configuration of flight schedule. Specially, in BKK\(^{31}\)-ICN-JFK\(^{32}\) route,

\(^{31}\) BKK: Bangkok (Don Muang International), Thailand
because both WAT and the gap of between DTT and ITT were slight, the quality was presented higher than others.

In generally, this study analyzed the indirect connectivity relating to the time. Accordingly, the cost-based analysis was excluded in this study. Another limitation was related with data restrictions. Because of data restrictions for other hub-airports, we could not analyze the connectivity of ICN objectively.

32 JFK: New York (John F. Kennedy), NY, USA
We investigated three issues: the pattern of airfreight transshipments at ICN\(^\text{33}\); the estimation of the connectivity for ICN’s airfreight transshipments; and application of the methodologies used in examining air passengers.

This study has produced the following discussions and conclusions. Initially, T/S airfreight at ICN was concentrated on China-North America route. A series of preliminary analyses were used to investigate the pattern of air cargo at ICN. T/S freight was almost exclusively handled by national airlines: Korean Airlines (KAL) and Asiana Airlines (AAR). Further, both dedicated freighter and passenger aircraft were used to process T/S freight. T/S freight volume handled by type of aircraft at ICN was processed between freighters (55 per cent) and belly cargo (45 per cent) handled in passenger fleet.

Then, two methodologies were used; a wave-system structure, and a NETSCAN model, to evaluate indirect connectivity of airfreight transshipment. In relation to applying the methodologies, the Wave-system

\(^{33}\) ICN: Incheon International Airport, Korea
structure could analyze flows and situation about the connectivity of ICN. In particular, a connectivity index was measured by the gap between arrival and departure flights. Further, the quality of indirect connection was estimated by the NETSCAN model.

There were the results of methodologies in use. The wave-system structure of scheduled flights of airfreight transshipment at ICN showed the three sets’ temporal concentrations of between arriving and departing waves. These concentrations represented that airfreight should wait an average of 4 hours to depart from ICN.

Further, the waves of passenger fleet’s flights were presented similarly with total Wave-system structure of ICN. The temporal concentration as well as indirect connectivity of ICN in networks was depended on operating the scheduled flights of passenger fleet. However, freighters transported over a half of the total T/S freight by a small number of flights. As shown by the type of aircraft in use, the volume of T/S freight handled by freighter was also higher than by passenger fleet. The relation between arriving waves of short-haul flights and departing waves of long-haul flights was totally identified by the temporal concentrations of four sets. In the case of long-

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34 As Table 5.1 compared with Table 5.4 in the section of results of analyses, we could analyze this result.
haul flights, the Wave-system structures were not clear. Moreover, the connectivity among freighters was hardly identified.

In addition, there were the results of the connectivity index. The total flights of ICN including both KAL and AAR were the highest rate of connectivity (3.89). In particularly, KAL’s CI\(^{35}\) was 5.96 and AAR’s CI was 6.66. The connectivity was lower than total flights’ connectivity. In case of the type of used aircraft, passenger fleet’s connectivity (4.61) was greater than freight’s connectivity (6.21).

Because the quality of network connectivity, as noted before, was not explained by the Wave-system structure, a NETSCAN model was used to quantify the quality of networks. In the results of a NETSCAN model, first of all, seven routes were chosen by the size of T/S freight volume: (1) HKG-ICN-JFK, (2) HKG-ICN-LAX, (3) HKG-ICN-CHI, (4) TYO-ICN-JFK, (5) TYO-ICN-LAX, (6) BKK-ICN-JFK, and (7) BKK-ICN-LAX.

The results of NETSCAN model were presented: the connectivity of both HKG-ICN-JFK and HKG-ICN-LAX was identified as higher than others. In

\(^{35}\) Connectivity Index (CI)
the case of HKG-ICN-CHI route, as both WAT\textsuperscript{36} and the gap of between DTT\textsuperscript{37} and ITT\textsuperscript{38} were thoroughly investigated, the connectivity in its route was identified as the lowest.

In these routes, because MAXT\textsuperscript{39} was set to be excessive by airlines, ICN’s network quality for indirect connection was relatively highly distributed by contrast with quality index of direct connection. Moreover, the quality index also depended on the flight schedule. However, the regional route or T/S freight volume seemed not to be related with quality index.

According to these results of methodologies, the most important activity to increase the connectivity of ICN was to be rescheduled by both IIAC\textsuperscript{40} and airlines. Then, because WAT was a factor controlling quality index, another activity for developing the connectivity of ICN should be considered by decreasing WAT.

The results of this study must be qualified because restrictions and problems were experienced. Data restrictions hampered the application of the wave-

\textsuperscript{36} Waiting Time for the next available flight (WAT)  
\textsuperscript{37} Direct Transportation Time (DTT)  
\textsuperscript{38} Indirect Transportation Time (ITT)  
\textsuperscript{39} Maximum Transportation Time (MAXT) was presented by airlines.  
\textsuperscript{40} IIAC: Incheon International Airport Corporation, Korea
system structure. As air cargo is heterogeneous, each kind of freight has different transshipment pattern: Freighter-Freighter, Freighter-Passenger Fleet and Passenger Fleet-Passenger Fleet. Indeed, further study is necessary to consider the T/S pattern. Another issue was that there was no consideration of the relationship between airline alliances such as SkyTeam Cargo and WOW\textsuperscript{41}. Moreover, there were two national airlines in Korea. These airlines could not be transshipped across themselves. According to these aspects, the connectivity of ICN will be decreased more and more. Thus, if the incorporation between two airlines is possible, the unification of airlines is suggested to increase the connectivity of ICN.

This study may be helpful for ICN in identifying their market position as a hub airport. Another application would be to evaluate effectiveness of rescheduling to improve connectivity.

\textsuperscript{41} SkyTeam Cargo is the air cargo alliance comprised by eight partner airlines: AeroMexico, Air France Cargo, Alitalia cargo, CSA cargo, Delta Air Logistics, KLM cargo, Korean Air Cargo, and NWA Cargo. Another air cargo alliance is WOW. Four airlines comprised the alliance: Lufthansa Cargo, SAS cargo, SIA cargo, and JAL cargo.
REFERENCES


REFERENCES

311-318.


REFERENCES


