The Spatial Changes of Global Network Based on the International Air Passenger Flows, 1992-2004

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Ho-Sang LEE

Abstract

This study aims to analyze the structural changes of the international air network in 1992 and 2004, and to examine the functional characteristics of the upper cities in the global network. For this purpose, a modified *social network analysis* model was devised in this study for use in the examination of the international air network. By using this model in analyzing the global network structure, the *international networkability* of each city and the connectivity of the air routes in the international air passenger network were estimated. Based on the results of structure analyses of the international air network, the *global networkability* and *regional networkability* of each city will be measured by classifying the international air routes of each city into those connected to the other cities in the same region and those connected to the cities in other regions. Lastly, the correlation between the results of *networkability* analyses and the socioeconomic attributes of each city is also analyzed. In the process of these analyses, the functions and roles carried out by *network cities* with a high degree of *international networkability* in the global network are also examined.

This *international networkability* is the quantitative measurement of the spatial interaction relationships in the international air network, without considering the characteristics of each city's flow pattern. As a result, it was observed that London, Paris, Frankfurt, Amsterdam, and New York were the *network cities* that were at the top in both years. Tokyo was included in class 1 in 1992, but not in 2004. Rome, Zurich, Singapore, Los Angeles, Hong Kong, and other cities were identified as the 2nd-class *network cities* in 1992, while Singapore, Tokyo, Madrid, Hong Kong, Bangkok, etc. were identified as the 2nd-class *network cities* in 2004. The *network cities* occupy the center of the global network, and the 1st-class *network cities* are connected to the 2nd-class *network cities*, which perform the function of hubs in each continent, thus uniting the whole world as one network.

The international air network can be largely divided into the Pacific Rim and the Atlantic Rim. In the case of the Pacific Rim, especially Asia, the single-center system centered on Tokyo became a multicenter system with the development of Singapore, Seoul, Hong Kong, and Bangkok, and the interactions among these cities became closer than before as well. In the Atlantic Rim, including Europe and America, the network was formed around London, Paris, New York, Frankfurt, and Amsterdam, and the concentration in London became stronger. In 2004, the interactions between the cities in Europe and Asia became stronger, and a network was formed in the Middle East, with Dubai as the center. Meanwhile, it was observed that the cities in Africa and South America had a weaker network system, which was based on the local regions in the international air network and not on other continents.

Based on such data, the multilayered structure of the global network and the connection patterns of its subnetworks were identified in this study. It was clarified that subnetworks form a network by using each continent as its local base. Each city's flow pattern by continent was also analyzed in this study, based on the connection structures of subnetworks, which shows that cities with a high networkability turn out to be different in each continent, and that certain cities have a high networkability only in certain continents. On the contrary, London, Paris, New York, Frankfurt, and Tokyo have a high networkability in every continent, and their *global networkability* is also high. The correlation analysis of the networkabilities and socioeconomic attributes of these cities confirmed that cities with a high networkability serve as centers on the regional or global level. It was also shown that Amsterdam, Madrid, Singapore, Seoul, Chicago, and Toronto function more strongly as centers on the continental or local level than on the global level.

Key words: Network analysis; Network city; Global network; Networkability; International air passenger flow

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Chapter One

Introduction

1.1 Research Background and Objectives

Global cities play pivotal roles in the world economy, and their central role is dictated by their powerful connection both with the world economy and with many other areas in the world. The international interactions built around global cities form not a domination-subordination relationship between cities but a network based on the functional complementarities between them. Thus, the growth of a metropolitan area in the present era of globalization can be explained by the international relationship of cities based on global interactions.

In light of the nature of globalization, global cities can grow through interactions between the cities that have functional relations in the global system of cities. Freidman (2001) understood globalization as a series of processes through which local economies are connected to a global information network and to a global market network. Therefore, the functional characteristics of the cities in the global network can be revealed, and the structure of the global network formed by these cities can be explained by analyzing the global patterns of the interactions between cities. Here, international central cities should be defined on the basis of a city's functional characteristics in the global network structure.

Many previous studies on global cities (world cities) or on the global urban system, however, are grounded in the traditional central place theory, focusing on the research that analyzes the hierarchy of cities, mostly based on their socioeconomic indicators (Kim and Yu, 2006). This approach can explain the global cities at the top tier, but it may have difficulty in explaining the growth of the cities at the lower tier. Graham and Marvin (1996) pointed out that the urban system, which in the past rested on Christaller's central place theory, is now, in the contemporary information age, turning into a hub-and-spoke network of cities. To complement their functions, global cities form a global city-region by establishing a network connection with the surrounding cities. This kind of city-region often crosses national boundaries and becomes connected to another global city or another global city-region. Each global city-region, equipped with global functions, is connected to the others through highly developed telecommunications and means of transportation. It constitutes time-space compression and results in the so-called tunnel effect. This is due to the interchanges between the cities that are included in the network and to the intervening opportunity that emerged in other cities (Nam, 2006).

Furthermore, the criteria that are used in determining which cities are global cities have been questioned. Moreover, the approach that is used in determining upper-tier cities (i.e., ranking the cities around the globe based on the data regarding their attributes) cannot sufficiently explain the structure of and the changes that occur in the global network. Therefore, this study aims to analyze the international relationship of the cities in the global network by using the indicators of international inter-city interactions.

Since the relationships between the cities in the global network are very complex and diverse, the characteristics of the global network could be understood by analyzing the structure of inter-city relations and the trends of serial changes, and the characteristics of global cities as the top nodes in the global flows of people, capital, goods, and information could be identified through the analysis of the inter-city network. Especially, the international air passenger network shows the inter-city interactions in the most comprehensive and visual way, analyzing the ordinary international connections among cities (Keeling, 1995; Lee, 2003; Smith and Timberlake, 1995). This international air network and its associated infrastructure is a visual symbol of the interactions between global cities and is an agent of globalization, and global hub airports improve the international competitive power of the cities (Abbott, 1993; Keeling, 1995; King, 1990; Nam, 2006; Pred 1977). Therefore, in the main metropolitan areas in the contemporary world, the international air network and its associated facilities are recognized as the basic infrastructure for the continuous growth of local or national economies, and large-scale international airports are competitively constructed.

It is very difficult to conceptualize the relationship between transport and global cities, despite the pivotal role of traffic in the global urban system. The theories on the role of transport in the global urban system have been suggested a strong correlation between good transport linkages and urban integration at the national, regional, and global levels (Owen, 1987). For example, the importance of transport in the capitalist world economy was implied in the world systems theory of Wallerstein (1983). And, transport is playing a significant role in the modernization theory, in that models of network growth have been developed in the way favorable to explain the economic growth of a country and its incorporation in the world economy (Taaffe *et al.*, 1973).

There has been, however, no precisely settled concept regarding the reasons why relations between transport and global cities are interactive and interdependent, even though theories on relations between transport and the growth of cities have been established to some extent. In those theories, transport was regarded only as stimulating the linkage of inter-city or inter-region for economic development (Dugonjic, 1989). Since global cities have a great power of control and management as over transnational businesses, they, though it seems paradoxical, maintain a development potential in two ways of centralization and decentralization. Such a hub-and-spoke function of two ways has relationship with transport. In addition, transport as being a necessary component – though not a sufficient one – for genesis, growth and change of global cities and economy, facilitates the movement of people, capital, goods and information through the global urban systems (Keeling, 1995; Nam, 2006).

The global urban system is the system in which the centers that are controlling and coordinating the world economy are functionally connected with one another. By playing their respective roles, which had been assigned to them according to their positions within the global urban system, these cities serve as nodal points through which capitals and information circulate and on which transnational corporations, international financial businesses, and high-degree service functions concentrate. Accordingly, these cities actively hold related international conferences and exhibitions and stimulate active interchanges of human and material resources. To accommodate these urban functions, these cities come to have a highly developed network of information and communication and a large-scale and up-to-date international airport (Kim and Yu, 2006). In other words, in this age of globalization, two important tasks that must be accomplished by modern cities are the construction of the infrastructure that is required for international socioeconomic activities and the improvement of the accessibility to worldwide network. This can be referred to as *international networkability* of cities.

As shown in Figure 1.1, the *international networkability* is one of the forces that drive or enable a city to achieve growth by globalizing it. The new world economy and the new information society made possible by globalization are developing new forms of spaces, such as megacities, global city-regions, and polycentricity urban regions. The emergence of these new forms of spaces will not only promote globalization but will also transform the global urban system into a polycentric structure. It implies that a functional network is further enhanced as the global urban system that is constructed around cities forms one network—that is, the global network. In this series of processes, the *international networkability* of cities is the necessary and

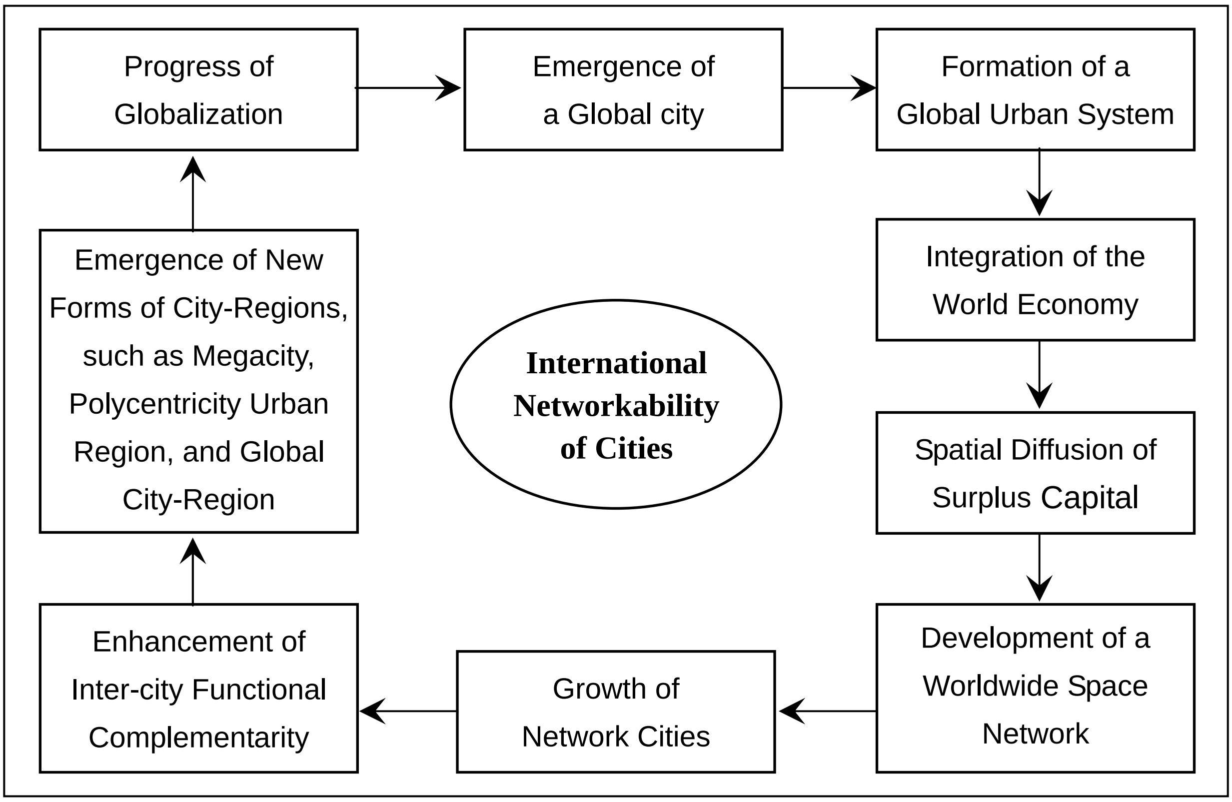

Figure 1.1 The growth mechanism of cities by the *international networkability*

sufficient condition. Accordingly, this study conducts positive analyses of the *international networkability* of cities and of the global network that is made up of these cities.

A few case studies on the global urban system made use of the data regarding the flow of international air transportation. Keeling (1995) empirically analyzed the global links of the world's cities and the importance of international air transportation in the global urban system. He analyzed the number of non-stop flights in 266 cities with metropolitan populations exceeding one million in 1992 and analyzed the global urban system with indices such as the number of air routes of each city per continent. Since his analyzing was done by the number of routes only, without consideration of the traffic volume of air routes or cities, there is a limit to explain the actual structure of air network and the interaction between cities. Short and Kim (1999) also analyzed the basic statistics of the major cities of the world, using the 1983, 1988, and 1994 ICAO data on international air passenger flows. They examined the total traffic, the number of air routes with more than 100,000 passengers and the distribution of air routes by continent, of each city, and then reviewed changes in them. Their methodology of research, as not essentially different from that of Keeling, is difficult to be adopted in analyzing the structure of the global urban system or the interaction between cities.

There has recently been research into the structure of the global urban system, which analyzes spatial interactions between cities of a global level through several kinds of network analyses. For instance, Smith and Timberlake (2002) analyzed the power of 22 global cities in the global urban system on the basis of the network analysis of the international air passenger flows from 1980 to 1997. They analyzed the centrality of each city (i.e., POWER score) on the international air network with the existing methodology of social network analysis. They explained each city's centrality by analyzing interactions between cities but couldn't explain in depth the relationship of interactions between them. Lee (2003) and Nam and Lee (2004), also, analyzed the interactions among 70 global cities, using the data on the international air passenger and freight flows in 1992 and 2001, and examined the global urban system and the flow patterns between global cities. They found out the relationship of interactions between cities through the analysis on the flow pattern of international air passengers and freight. The hierarchy of cities was presented through the analysis on the connection system of each city, but their researches have limited in explaining about the centrality of each city on the international air network. In addition, there are many studies that analyze the global urban system using the data regarding the international air transportation (Derudder and Witlox 2005a, 2005b; Matusmoto 2004; Smith and Timberlake 2001).

The previous studies focused mainly on, and analyzed, the flow patterns established around specific cities rather than the structure of the whole network, using the pattern of interactions. They also analyzed an international flow pattern limited to the interactions between the major cities around the world or focusing only on a limited area. To put it in another way, there can be a limit to the diagnosis of the functional characteristics of the cities belonging to a network and of the entire structure of the global network. This study is thus to analyze the spatial interaction between cities so that it can measure the centrality of the cities in the international air network and can examine the connectivity of air routes which show the degree of the relationship of interactions between the cities. That is, all the nodes and linkages constituting the global network are analyzed, and then based on this analysis, the network structure is presented.

Moreover, the existing research into the international air network over the world has analyzed the whole air network in the same light, not considering geographical character of each continent. For example, it ignored the facts that in Europe, there are many countries that have short distances between them, that there are so many islands in Asia, and that there are few countries in North America but that these countries have vast territories. In a word, it disregarded the possible influence of each continent’s geographic characteristics on the international air passenger flow.

The international interaction between cities in the era of globalization needs to be thought at two levels: the international relationship of a global level and the one of a regional level. The international relationship taking place in a local region existed also before the globalization age, so when thinking of the original meaning of globalization, the global urban system of the present times can be understood after comprehending the international interaction at two levels. This study analyzed the spatial interaction between cities for the purpose of finding out functional differences between cities serving as a hub at a global level and those at a regional level in the international air network.

In this study, therefore, a network analysis model was developed for use in measuring the *international networkability* of individual cities and their interactions in the international air network. Using this model, the structural changes in the global network that occurred in 1992 and 2004 were analyzed. Also, *global networkability* and *regional networkability* were measured by analyzing of each city's flow pattern. Through this process, this study aims at examining the functional characteristics of the *network cities* that are the upper nodes in the global network.

1.2 Data and Research Method

This study used the 1992 and 2004 inter-city international air passenger flow data[1] created by ICAO (International Civil Aviation Organization) to analyze the world's network structure. To complement the technical defects of these data, the 1991 and 2005 datasets were added. Using the 1992 data, the OD matrix between 339 cities around the world was constructed, and using the 2004 data, that between 391 cities was constructed.

In the early 1990s, many events occurred that greatly impacted the world economic order, such as the dissolution of the Soviet Union, the signing and effectuation of NAFTA, the EC market integration, the GATT final agreement, and the establishment of the World Trade

Organization (WTO). In other words, in the early 1990s, the world's economic environment went through a series of major changes, such as the establishment of the WTO, which could be seen as the starting point of the integration of the world economy, and the appearance of regional integrated economic systems en bloc.

After the establishment of the WTO, regional trade agreements (RTA) rapidly spread by the year, and in 2005, it was reported that more than 50% of the trades around the world were trades within RTA. In the 21st century, the RTAs that are entered into in a certain area or only with the neighboring countries quickly turn into free-trade agreements (FTA), which predict the emergence of a new international trade order. Of the total of 162 cases of RTAs that had been reported to the WTO as of January 2005, 101 were FTAs. Therefore, 1992 and 2004 were important turning points for the development of the global economic system in the era of globalization and are thus important periods in understanding the changes of the global network. The early 1990s could be the initial phase in the era of globalization. Thus, in this study, this period is compared with the present period of the global network.

Recent studies, including those of Derudder and Witlox (2005a, 2005b) and Derudder *et al.* (2007), raised several problems in using the data of ICAO to analyze the global urban system. First, because the ICAO data deal only with international air routes, it is difficult to view the actual worldwide network using such data. Second, such data include only the flows of the regular non-stop flights; it does not include data regarding the flows of the irregular air routes as well as those of the non-member air routes of ICAO. Moreover, it cannot examine the flows of transfer passengers; as such, it can make mistakes in identifying the passengers' actual final destinations and origins. Derudder and Witlox (2005a) argued that these data problems could be solved through the use of GDS (global distribution system). GDS is electronic platforms used by travel agencies to manage air route bookings, hotel reservations, and car rentals. They show that because the MIDT (marketing information data transfer) data built by the GDS program contain diverse travel information, they can be used in analyzing the actual air network around the world.

Other problems could emerge, however, when MIDT data are used for analysis purposes. First, when a city holds special large-scale international events such as the Olympics or a world exposition, the city would have a very high level of centrality during a certain period. In other words, it is possible to overestimate a city's actual centrality depending on the time of the analysis. Second, the rate of dependency on air transportation in terms of the domestic transportation system varies by country or local. As such, when the flows of the domestic air routes are included, the actual city connection system may be shown differently in the part of the lower-tier network. In countries like the United States, where the domestic air network is well developed and the rate of flight usage for traveling between cities is high, this data could be very useful. As has been pointed out, the ICAO data exclude the traffic volume between the global U.S. cities, such as Chicago-New York or Los Angeles-New York (Derudder and Witlox, 2005a, Derudder *et al*., 2007).

Other errors could occur, however, if the urban system is analyzed only with the use of the data regarding the air network in a country or region with a high rate of usage of other means of public transportation, such as trains or buses. Since the focus of this study was to analyze the *international networkability* of metropolitan areas, domestic flows were excluded. Moreover, the regular international non-stop flights are operated based on the average traffic volumes between two cities, so these can be useful data for the analysis of the ordinary international interactions between cities. In air transportation, unlike with cars or trains, it is difficult to treat the volume of transfer flows as the number of transit passengers. When a city has a hub airport with a high volume of transfer flows, its centrality can be rated highly, which cannot be seen as an error in analysis. The volume of transfer flows can also be seen as the competitive power of hub airports because the growth of the airport-related industries can function as a factor for the growth of a given area. That is, a city that has a hub airport with a high volume of transfer flows is seen as equipped with an international air network, an infrastructure needed for international socioeconomic activities, and as thus having a potential to be developed as an international center.

It is true, however, that several problems can occur in the analysis of the global network using the ICAO data and the conventional analysis methods, such as the graph theory, factor analysis, and cluster analysis. The previously used methodologies for city system analysis cannot measure a city's centrality in the global network and have limitations in explaining the whole structure of the network. Most importantly, an analysis that relies solely on the traffic volumes of air routes or cities can distort the actual states with the geographic or socioeconomic specificity of a certain region in the world. Therefore, this study focuses not only on the traffic volume of air routes or cities but also on the number of cities connected with international non-stop flights.

Let us start from the hypothesis that a city with a high degree of *international networkability* would have not only a large volume of air flows but also a high number of international non-stop flights to many cities. When only the flows of international air routes are considered, as shown in the study conducted by Rimmer (1998), Dublin would be found to be a world city that is more significant than Chicago (Derudder *et al.*, 2007). This kind of problem can be addressed, however, when the number of cities that are connected through international non-stop flights is included in the calculation, as a variable. For example, in 2004, 17 cities were connected to Dublin via international air routes, and 39 cities were connected to Chicago, indicating that Chicago had a higher degree of *networkability* in that year. Therefore, in this study, a modified social network model was devised in such a way as to consider the number of international air routes connected to a city, and the traffic volume of flights, as variables that indicate a city's *international networkability* in the analysis of the international air network.

Social network analysis is a quantitative analysis method proposed in the field of sociology, in order to quantitatively analyze relations that are basically qualitative, such as those between people and groups. Recently, it has been used to analyze the flows of international commercial flights, international trades, or cities' spatial structures, and to understand the hierarchy that is formed through the interactions between cities (Lee and Kim, 2006).

One study that analyzed the global network using the *social network theory* was by Taylor (2004), who performed the network analysis among global cities with the connections of inter-city producer services as an indicator. Using the database on 100 companies and 315 cities established by the GaWC (Globalization and World Cities) research group, Taylor empirically analyzed the global network in the said study. However, the companies collected as research data are almost ones of the producer service sector, so since the industrial structure is varied per region or city, it is not in reason to apply the relationship of interactions of a specific business sector into the analysis on the urban network of regions or continents: for example, most Asian countries have an industrial structure focused on manufacturing, but if the functional differentiation in the global network is not taken into consideration and one index of a particular economic sector is used in explaining the interaction of the entire world, it could possibly involve a risk of only one aspect of the global network is considered. In the case of the network analysis aimed to global cities only, like the Taylor's work, an indicator of the producer service sector can have a specific meaning, but if a study where the network includes other cities as well as global cities analyzes up to cities of low classes, with indicators showing the features of global cities only, its results would be possibly biased or distorted.

In addition, Alderson and Beckfield (2004) examined the global urban system and the prestige and centrality of global cities based on the interactions between the head and branch offices of 500 multinational corporations. When spatial analysis is done with quantitative data such as traffic volume in such fields as geography, however, it is better to use a modified model than to use the equations of the *social network analysis* method without a spatial concept so as to make the most of the properties of the data or research subjects.

In this study, the social network model was modified so that it could be used to analyze the international air network. Such efforts led to the creation of the *global network analysis* (GNA) method. Using this new model, a series of analyses were carried out in terms of the connectivity of air routes, the *international networkability* of cities, the structure of the global network, and the connection system, using the data regarding the maximum connectivity between cities. In other words, the structure of the international air network was examined through the analysis of inter-city interactions, and the *network cities* were studied based on the functional characteristics in the network. Moreover, through serial analysis, the changes in the global network structure were examined. This study explored the functional characteristics of cities by carrying out a canonical correlation analysis of the socioeconomic attributes of *network cities* occupying higher nodal points in the network, and of the results of the interaction analyses of cities.

1.3 Structure of Research

This dissertation is organized into six chapters. The research flowchart, which outlines the flow of this study, is shown in Figure 1.2. Chapter one introduces a general overview of the study, including the statement of the problem, the main objectives of the study, and a brief outline of the structure of the research.

Chapter 2 theoretically and mathematically examines the GNA model, which can measure the *international networkability* of cities and interactions between cities. It first looks at the theoretical background of the existing *social network analysis* method and then explains the concept of GNA, which can be regarded as a revision of the *social network analysis*. It also designs numerical formulae of the GNA method and looks into the concepts that are present in an individual formula.

Chapter 3 measures the connectivity of international passenger air routes and the

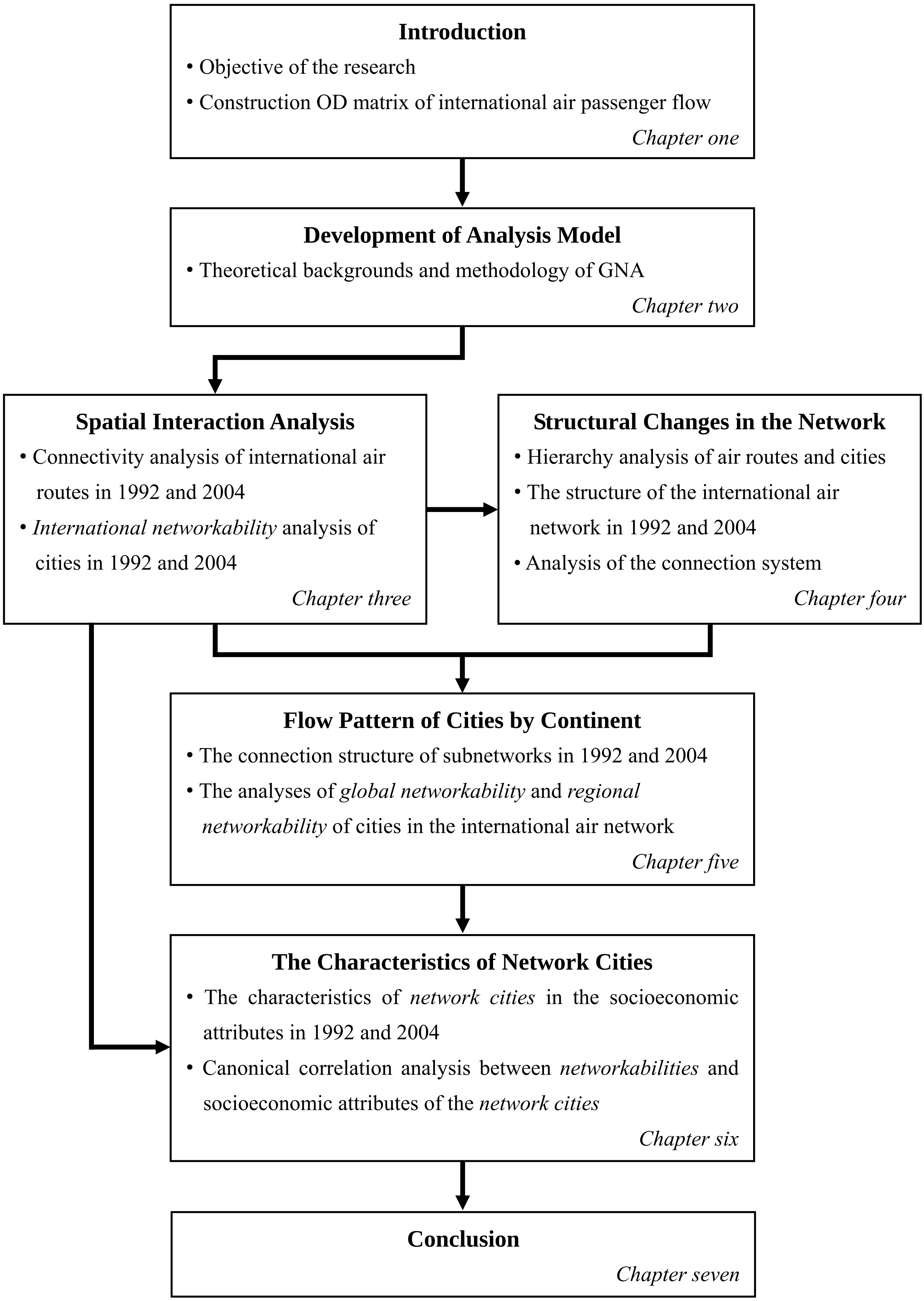

Figure 1.2 The research flowchart

international networkability of an individual city by using the numerical formulae created in Chapter 2. This helps in the examination of those cities that have a high degree of *international networkability*, as well as those international air routes that have a high degree of connectivity.

Based on the results of these examinations, in Chapter 4, a hierarchy analysis of cities and air routes is carried out, and then target cities and air routes are selected for use in the structural analysis of the international air network. The structure of the international air network is analyzed in this chapter using only those cities and air routes that are above certain levels. The reason for this is that although network analysis is made possible by the use of the OD data regarding all the cities and air routes included therein, the results of the analysis are so complicated that it is impossible to display all of them in maps and figures.

In Chapter 4, the whole structure of the international air network, where the results of the analyses carried out in Chapter 3 were used, is analyzed. How the global network was formed in 1992 and 2004, and what kind of structural changes occurred in those years, are also looked into. The connection system between cities is analyzed, using air routes that show the maximum connectivity of each city. The connection system, composed of individual cities in the international air network, and the changes that transpired therein, are also examined. The examination of the general structure of the international air network from various perspectives can contribute to the understanding of the interaction patterns of individual cities constituting the network.

In Chapter 5, the interaction patterns of cities are more specifically analyzed. The flow patterns of cities are analyzed by region through examining the connection structure of the subnetworks of the international air network. Based on the results of structure analyses of the international air network, the *global networkability* and *regional networkability* of each city will be measured by classifying the international air routes of each city into those connected to the other cities in the same region and those connected to the cities in other regions. In other words, the structure of the network is analyzed in Chapter 4, and the *networkabilities* of the individual cities constituting the network are measured in Chapters 3 and 5.

In Chapter 6, the interrelationship of the results of *networkability* analyses with the socioeconomic attributes of each city is also analyzed. In the process of such analyses, the functions and roles carried out by *network cities* with a high degree of *international networkability* in the global network are also examined.

Chapter 7 presents the main findings of the study in relation to the research objectives, and the conclusions that could be derived from such findings. A number of suggestions for further research are also offered in this chapter.

Chapter Two
Global Network Analysis and Methodology

2.1 Theoretical Backgrounds of the Global Network Analysis

The *social network analysis* method is used to understand the nodality, forms, and behaviors of the agents that compose a network in the whole network structure, and to examine the structural status or power formed by the relations between organizations, regions, and countries in terms of the analysis of interpersonal interactions or relations (Adams, 1998; Breiger, *et al.*, 2003; Capineri and Kamann, 1998; Scott, 2000). The significance of the *social network analysis* method rests in its ability to answer the following essential question: How has the world in which we are living been shaped? As regards this essential question, social science has paid attention to two factors ("structure" and "action") and has continued to explain the roles of each of these factors. The *social network analysis* method can be used to explain the interdynamics of this structure and action (Son, 2005; Wasserman and Faust, 1994).

Social network analysis can be defined as the relation network that connects agents. This relation network between agents is the result of the action choices made by those agents, but these, at the same time, restrict their subsequent action choices. That is, there is an interaction between action and structure, and attention must thus be paid to the dynamics of how the actions performed by agents change as the structure changes. To put it differently, the social network is the same "structure" that was built through the interactions between agents. This structure is not "given" but is obviously constructed as a substance by agents. It in turn puts restrictions on agents' actions and on their interactions.

It is for this very reason that the social network theory specifically approaches duality of structure, one of the cardinal concepts in social science. Invented by Giddens (1984), an English social scientist, the concept of duality of structure refers to the idea that "structure is both the medium of action and the product of reproduced action." According to Giddens' structuration theory, structure imposes action but is simultaneously reproduced by the imposed action. If the duality of structure concept is applied to the social network and is recast, it can be said that while the social network affects agents, these agents play the role of the subject to maintain and change the social network (Scott, 2000; Son, 2005).

This study applies the concept of *social network analysis* to examine the spatial interactions between regions. In other words, it intends to analyze what kind of international functions and roles the cities around the world have in the structure of the global network, and to analyze what kind of network these cities construct. In principle, the network methodology allows the simultaneous analysis of multiple patterns of flows, exchanges, or linkages between cities to illuminate the pattern of the connections between them as well as the structure of the whole network (Smith and Timberlake, 2002).

Of course, the space of a city cannot be the subject itself indicated in the social network. It can, however, be considered one factor of the global network because it is the spatial background against which actions are performed. This study analyzes the above-explained *international networkability* of cities using the structural aspects of the international air network and the interaction patterns shown between individual cities. This chapter intends to theoretically and mathematically examine the model that is required for these analyses.

Global network analysis (GNA), the modified social network model, basically follows the conceptual definition of *social network analysis*. The *social network analysis* method measures qualitative relations by converting them to quantitative matrices and analyzing them, using such indicators as the number of connecting lines, the number of connected nodes, and the distance between the nodes in a network. *Social network analysis* evolved from the effort to operationalize the concept of social structure. Social structures, which are the regularities in the patterns of social interaction and in persistent relationships, arise "from the aggregated effects of individual interactions" (Smelser, 1988).

That is, the *social network analysis* was devised for use in the analysis of a nonquantitative network from a sociological perspective, such as interpersonal or intergroup relations. As such, no spatial and geographic concept can be found therein. Therefore, when the network analysis is performed using quantitative data like traffic volume, a few problems can emerge, such as having an unnecessary matrix conversion process, carrying out an analysis without spatial concepts, and being unable to consider the characteristics of the data.

In this study, a modified model was devised to address the aforementioned problems and to analyze the international air network. This modified model uses the total number of international flights and traffic volume in a city, as well as the traffic volume for each air route, as basic indicators. Moreover, analyses of cities' *international networkability* and of inter-city connectivity are carried out in one operation process. That is, GNA is an analysis method that measures each city's *international networkability* by examining inter-city spatial interaction, and that examines the structure of the international air network by analyzing the flow patterns between those cities with a high degree of *international networkability*.

2.2 Methodology of Global Network Analysis

In theory, GNA starts from the concept of *prestige centrality*[2] in previous *social network analysis*. *Prestige centrality* measures centrality in consideration of not only an agent's direct and indirect connections but also the centrality of those other agents that are connected to an agent. *Prestige centrality* uses the notion that a single connection to an agent with a high level of influence or power can increase one's influence more than one's connections to many other agents. In the international air network, a city's influence means a city's *international networkability*. When a route is opened to a hub city with regular flights to numerous cities around the world and with a large volume of flows, many people can travel to many regions around the world via that hub city, and the city's *international networkability* in the global urban system improves. For any city, the improvement of its *international networkability* means that more development opportunities are presented to it in terms of socioeconomic activities centering on the city, which could lead to the growth of the city, thus creating a virtuous circular structure.

In this study, instead of using the equation of *prestige centrality*, a model that can be used in analyzing *international networkability* was devised in consideration of the characteristics of the international air flow data. That is, it examines which city is connected to how many cities in the international flight network, what the traffic volume of flight in a certain city is, and which connected city has much traffic volume. Therefore, a city's *international networkability* would mean a city's international air networkability, which is shown in the international air network.

To analyze this *international networkability*, a city's *local centrality* and the connectivity of international air routes, which measures a city's direct relations in a network, should first be examined. Here, the *local centrality* (L_i) of city i is measured based on the number of cities connected to it via non-stop flights, and the total traffic volume in the city. Its equation is as follows:

$$L_i = \frac{t}{g-1} \times \sqrt{\frac{F_i}{M_g}}, \tag{2-1}$$

where

g is the total number of cities in the whole network,

t is the number of cities directly connected to the city i,

M_g is average total traffic of all cities, and

F_i is total traffic in the city i.

In this study, g is 339 cities in 1992 and 391 cities in 2004. M_g is 1,233 thousand passengers in 1992 and 1,756 thousand passengers in 2004.

One city's *local centrality* refers to the direct connections in the international air network. The *local centrality* in this study is a value obtained by multiplying the *degree centrality*[3] (the number of nodes connected to a node), which is used in previous *social network analysis*, with the standardized value of the mean flow obtained from the total traffic of the nodes. In other words, the *local centrality* is measured by how many cities are connected to a certain city via non-stop flights in the whole network, and by the total traffic volume of the city. In this study, therefore, the 'local' isn't the concept of geographical scale but means one part of the whole network that means the limited area formed by the direct-connection relationships between cities.

Degree centrality in *social network analysis* is measured only by the number of cities connected to city i via the international flights. Using only this method, however, it is difficult to differentiate the centrality of each city because of the characteristics of the regular international air data. To express the actual centrality, the total traffic of city i should be included in the calculation rather than using only the number of international air routes.

Next, the connectivity of international flights is analyzed based on the *local centrality* of two cities and the traffic volume between them. That is, it does not measure only the connections with the traffic of international flights but includes the *local centrality* of two cities as a variable in the calculation. The equation for the connectivity (C_{ij}) between two cities, *i* and *j*, is:

$$C_{ij} = \frac{f_{ij}}{m} \times L_i \times L_j \;, \tag{2-2}$$

where

m is average traffic of all air routes,

f_{ij} is round-trip traffic between city *i* and *j*, and

L_i is the *local centrality* of city *i* and L_j is that of city *j*.

Here, m is 115 thousand passengers in 1992 and 172 thousand passengers in 2004.

In the previous researches, the interactions between two cities were often explained solely on the basis of the traffic volume between such cities. That is, previous urban-system studies that used such methods as the graph theory and the factor analysis determined this connectivity on the basis of only the inter-city traffic, but this study gives weight to the *local centrality* of destinations and origins to draw connections between cities with a high *international networkability*. In this method, a city's *international networkability* is rated highly when a city is connected to many cities via international air routes than when a city has a relatively large number of passengers and a small number of international flights, provided the number of passengers is the same. This process allows the interactions between upper-tier cities with a high *international networkability* to be drawn. In this study, connectivity refers to how strongly two cities are connected in the air network. Therefore, connectivity analysis does not take into consideration the direction of each flight.

Since *local centrality* includes the total traffic of each city, connectivity analysis can include the indirect flow of travels to another city via a given city. Of course, it does not examine the specific connections to the final destinations of each trip, but a city with a high *local centrality* basically has a high degree of accessibility to travel to another city via that city. Therefore, having much traffic with cities with a high degree of *local centrality* indicates an increase in one's *international networkability* (i.e., traveling to other areas via the given city).

International networkability (N_i), the networkability of city i in the international air network, can be calculated with *local centrality* and connectivity. The *international networkability* of city i is the sum of the connectivity of all the international flights connected to city i and its equation can be as follows:

$$N_i = \sum_{j=1}^{g} \left\{ \frac{f_{ij}}{m} \times L_i \times L_j \right\} = \sum_{j=1}^{g} C_{ij} \,, \qquad (2\text{-}3)$$

where

m is average traffic of all air routes,

f_{ij} is round-trip traffic between city i and j,

L_i is the *local centrality* of city i and L_j is that of city j, and

C_{ij} is the connectivity between city i and j.

In this study, the *international networkability* of cities means the international air centrality of cities. It can be analyzed by using indices such as how many other cities a certain city is connected to in the international air network, the traffic volume of air routes, or whether the traffic in a certain city is much or little. The *international networkability* of a city can also be analyzed on the basis of its relative importance in the entire network rather than on the basis of the absolute value of the traffic or of the air route number.

Therefore, the *international networkability* of city i is not only determined by its air traffic volume or the number of its air routes but varies based on the strength of the city's interactions with other cities. This is because when cities are compared in terms of which among them interact most with the local cities in their neighboring countries and which interact most with the central cities in the world, a big difference can be seen between the importance of the former and that of the latter in the global network.

For example, suppose that the number of international flights and the total traffic volume in two cities, *i* and *j*, are the same, while the international flights of *i* are connected to the metropolitan areas in major countries or those with a much traffic volume of air flow, and the international flights of *j* are connected to the local cities in the neighboring countries. Moreover, suppose that both cities, to a certain extent, perform the function of a hub but have different levels of prestige and influence in the world air network. In an extreme instance, when the operations in the two airports are completely stopped, the situation in city *i* may have to adjust the international air routes around the world, but the situation in city *j* may affect only a small number of international flights in certain areas. Therefore, all hub airports have an equivalent level of functions or centrality, and the use only of traffic volume in explaining the differentiated functions of each city that is shown in the air network has limitations.

Moreover, when each city's *local centrality* is given much weight, it becomes easier to extract the connections between those cities in the global network with a high *international networkability*. Furthermore, because each city's *local centrality* is used in the analysis of *international networkability*, much weight can be given to the indirect flow. That is, *international networkability* is calculated with the flows among not only the nodes that are directly connected but also the nodes that are indirectly connected. As such, *international networkability* measures a wide-area networkability of a city in the world air network.

Figure 2.1 shows this conceptual difference between *local centrality* and *international networkability*. *Local centrality* analyzes only the direct-connection relations while *international networkability* also examines the indirect-connection relations between cities in whole network.

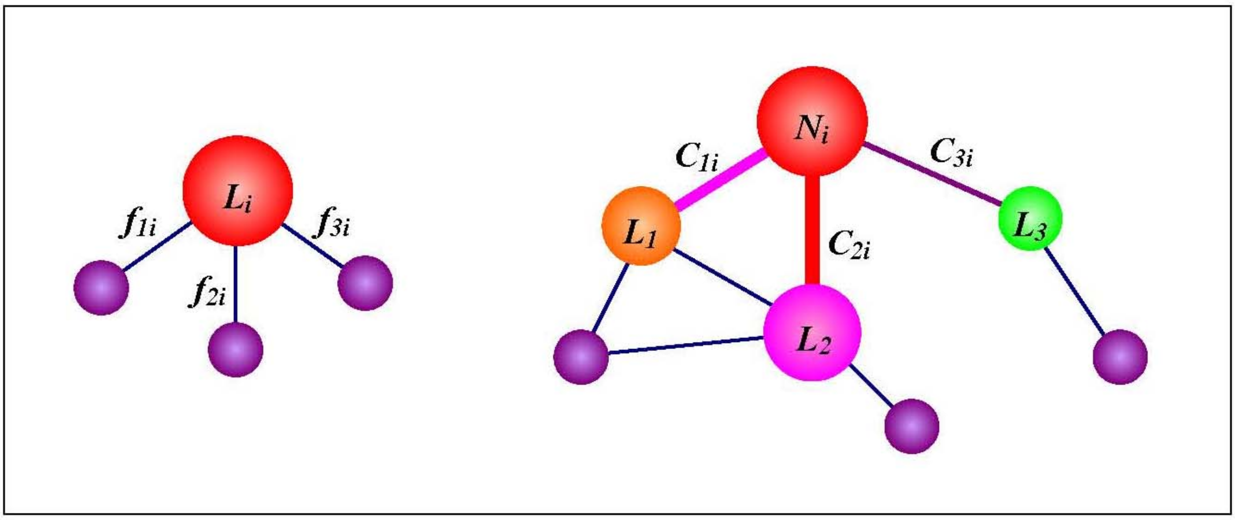

Figure 2.1 The concepts of *local centrality* (L_i) and *international networkability* (N_i)

**Note*: f_{ai} is the round-trip flows between city *i* and city *a*, and C_{ai} is the connectivity between the two cities.

Therefore, *international networkability* increases as the interaction with those cities with a large number of international flights and a much traffic volume becomes stronger; and having a strong interaction with those cities with a high degree of *local centrality* means performing a central function in the network or having high accessibility to other areas or to a center in the global network. A city's *international networkability* can be a significant element in increasing its competitive power or in improving the position of the multinational corporations in the contemporary world economic system. That is, *international networkability* can be interpreted as a scale for evaluating a city's international prestige in the international air network.

In sum, GNA can be used to analyze the *international networkability* of cities based on their interactions with other cities. To measure *international networkability*, *local centrality* must first be measured. This *local centrality* is the intercity relationship within a local network which is formed by only the direct-connection relationships between cities. Then, by adding the traffic of each air route and the weight value of the *local centrality* of the beginning and ending points, the connectivity of each flight can be analyzed. Lastly, by adding the connectivity of all the flights in every city, the *international networkability* of each city can be measured.

Thus, it has been shown herein that the *international networkability* of cities and the connectivity of international air routes can be calculated. This is a more effective method of analysis compared to the method involving the construction of a hierarchy between cities and air routes, based only on the standard of the number of passengers, in the selection of cities and air routes that perform structurally more important functions in the international air network.

Chapter Three

Spatial Interaction in the International Air Network

3.1 Analysis of the International Air Flow in 1992-2004

This chapter analyzed the connectivity of international air routes and the *international networkability* of cities based on the international air passenger flows in 1992 and 2004, using GNA, which was examined in the previous chapter. Before the analyses of connectivity and *networkability*, this section examines the general state of the international air passenger flow and analyzes the *local centrality* of cities in 1992 and 2004.

Table 3.1 shows the top 25 cities in terms of the total number of passengers by city, the number of regular international non-stop flights, and the *local centrality* in 1992. In the total air traffic of each city in that year, London had 38 million passengers, the largest number of passengers in that year. Paris ranked second (21 million), followed by Tokyo (20 million), Frankfurt (16 million), New York (15 million), and Hong Kong (14 million). On the other hand, in terms of the number of regular international non-stop flights in the same year, London, Paris,

Table 3.1 The top 25 cities in terms of international passenger air flow in 1992

Rank	City	Number of Passengers (Thou.)	City	Number of Air Routes	City	Local Centrality
1	London	38,252	London	124	London	2.04
2	Paris	21,001	Paris	122	Paris	1.49
3	Tokyo	19,721	Frankfurt	119	Frankfurt	1.28
4	Frankfurt	16,300	Amsterdam	82	Amsterdam	0.72
5	New York	14,783	Rome	71	New York	0.71
6	Hong Kong	14,064	Zurich	71	Tokyo	0.67
7	Singapore	13,420	New York	69	Zurich	0.53
8	Amsterdam	10,889	Tokyo	57	Rome	0.53
9	Los Angeles	9,025	Brussels	54	Singapore	0.50
10	Bangkok	8,354	Singapore	51	Hong Kong	0.39
11	Seoul	8,058	Madrid	48	Los Angeles	0.38
12	Zurich	7,929	Bangkok	47	Bangkok	0.36
13	Miami	7,758	Los Angeles	47	Brussels	0.34
14	Rome	7,709	Miami	45	Miami	0.33
15	Taipei	6,404	Vienna	45	Madrid	0.32
16	Madrid	6,327	Milan	43	Milan	0.27
17	Copenhagen	6,141	Copenhagen	41	Copenhagen	0.27
18	Brussels	5,670	Hong Kong	39	Seoul	0.26
19	Milan	5,624	Munich	37	Vienna	0.25
20	Honolulu	4,769	Dubai	36	Munich	0.18
21	Kuala Lumpur	4,443	Seoul	35	Athens	0.17
22	Chicago	4,227	Jeddah	34	Kuala Lumpur	0.16
23	Vienna	4,223	Cairo	33	Mexico City	0.16
24	Toronto	4,136	Geneva	33	Geneva	0.16
25	Sydney	4,117	Athens	32	Sydney	0.16

Source: ICAO, 1992, On-Flight Origin and Destination.

and Frankfurt showed the largest numbers. They had 124, 122, and 199 non-stop flights, respectively. Amsterdam (82) ranked next, followed by Rome (71), Zurich (71), New York (69), and Tokyo (57). These data show that the cities in Europe have relatively more regular non-stop flights compared to the cities in other continents. This will be examined more closely in the next chapter.

Simply put, what should be noted here is that there are considerable differences between a city's rank according to the total number of passengers and its rank according to the number of regular non-stop flights. As aforementioned, because regular international non-stop flights are operated on the basis of the average traffic volume between two cities, the fact that there are many regular non-stop flights between two cities implies that these two cities internationally and actively interact with each other at all times. Accordingly, when measuring the centrality of a city in the international air network, it would be more reasonable to calculate it by considering the number of regular non-stop flights of each city along with the total number of its passengers.

As shown in Table 3.1, Tokyo ranked third in the number of passengers in 1992, but it ranked eighth in the number of air routes in the same year. This tendency appears in Asian cities (e.g., Hong Kong, Seoul, Taipei, and Kuala Lumpur), which suggests that the flow pattern of passengers using regular international non-stop flights is limited to some regions.

On the other hand, while Amsterdam ranked eighth in the number of passengers in 1992, it ranked fourth in the number of air routes in the same year. This tendency appears many times in European cities (e.g., Zurich, Rome, Madrid, Brussels, and Vienna). It can be understood that European cities interact with many regions, although they have relatively fewer passengers compared to Asian cities. In other words, in this study, that a city has a high degree of centrality in the international air network does not necessarily mean that it has a large amount of flow. It also implies that, from the perspective of the whole network, the more actively a city interacts with many other cities, the higher its centrality is.

Local centrality analyzes only the direct-connection relationships of cities in the international air network, based on the traffic volume and the number of air routes a city has. Therefore, it refers only to the local relationships of a city in the limited area. In the analysis of the centrality of 339 cities in 1992, using the formula of *local centrality* explained in the previous chapter, London was shown to have a 2.04 centrality, which makes it first in rank. Paris ranked second (1.49), followed by Frankfurt (1.28), Amsterdam (0.72), New York (0.71), and Tokyo (0.67).

Table 3.2 displays the results of the analysis of the international air passenger flows in 2004. In the total air traffic, London was shown to have had 63 million passengers, the largest number of passengers in 2004. Paris ranked second (36 million), followed by Frankfurt (27 million), Amsterdam (24 million), Singapore (24 million), Tokyo (23 million), and New York (21 million).

The comparison of the number of passengers of cities in 1992 and that in 2004 showed that London had an increase of 24 million, the largest increase in the number of passengers in those years. Paris ranked second (15 million), followed by Amsterdam (13 million), Frankfurt (11 million), Seoul (10 million), and Singapore (10 million). As for the rate of increase in the number of passengers, Shanghai had an increase of 4,691%, which was the largest rate of increase then. Dubai had an increase of 345%, Barcelona 138%, Seoul 126%, and Munich 126%. Generally speaking, the numbers of passengers in Europe increased by a large margin in the existing centers, which ranked the highest, such as London and Paris, whereas the numbers of passengers in Asia sharply increased in those cities that can be regarded as new international centers, such as Seoul, Singapore, Shanghai, and Dubai.

In terms of the number of regular international non-stop flights, London, Paris, and Frankfurt recorded the largest numbers. They had 139, 112, and 105 air routes, respectively. Amsterdam ranked second (86), followed by New York (80), Singapore (69), and Madrid (66). The comparison of the numbers of regular non-stop flights in 1992 showed that Moscow had an

Table 3.2 The top 25 cities in terms of international passenger air flow in 2004

Rank	City	Number of Passengers (Thou.)	City	Number of Air Routes	City	Local Centrality
1	London	62,671	London	139	London	2.13
2	Paris	35,925	Paris	112	Paris	1.30
3	Frankfurt	27,258	Frankfurt	105	Frankfurt	1.06
4	Amsterdam	23,706	Amsterdam	86	Amsterdam	0.81
5	Singapore	23,533	New York	80	New York	0.71
6	Tokyo	22,603	Singapore	69	Singapore	0.65
7	New York	20,922	Madrid	66	Seoul	0.50
8	Hong Kong	19,888	Seoul	61	Madrid	0.48
9	Seoul	18,234	Los Angeles	56	Tokyo	0.45
10	Bangkok	17,583	Toronto	52	Hong Kong	0.42
11	Madrid	14,227	Bangkok	51	Bangkok	0.41
12	Los Angeles	12,100	Moscow	50	Los Angeles	0.38
13	Dubai	11,720	Dubai	49	Dubai	0.33
14	Miami	9,987	Hong Kong	49	Toronto	0.30
15	Zurich	9,499	Tokyo	49	Zurich	0.29
16	Copenhagen	9,207	Zurich	48	Copenhagen	0.25
17	Toronto	8,894	Mexico City	46	Miami	0.25
18	Osaka	8,589	Munich	45	Munich	0.24
19	Kuala Lumpur	8,469	Copenhagen	43	Moscow	0.24
20	Munich	7,814	Istanbul	42	Mexico City	0.22
21	Chicago	7,594	Barcelona	41	Kuala Lumpur	0.22
22	Shanghai	7,317	Miami	41	Barcelona	0.21
23	Barcelona	7,099	Chicago	39	Chicago	0.21
24	Stockholm	6,338	Kuala Lumpur	39	Osaka	0.20
25	Mexico City	6,240	Stockholm	38	Istanbul	0.19

Source: ICAO, 2004, On-Flight Origin and Destination, the secure site (http://icaosec.icao.int) of the ICAO.

increase of 39, which was the largest increase in that year. Shanghai ranked second (31), followed by Beijing (29), Toronto (27), Seoul (26), and Osaka (24). On the other hand, Rome recorded a decrease of 52 in the number of its regular non-stop flights, and a decrease of about 5 million in the number of its passengers. In terms of the decrease in the number of regular non-stop flights, Brussels ranked second (35), followed by Milan (30), Jeddah (29), Nairobi (25), Zurich (23), and Geneva (20).

In the analysis of 391 cities' *local centrality* in 2004, London was shown to have a *local centrality* of 2.13, which was the highest. Paris ranked second (1.30), followed by Frankfurt (1.06), Amsterdam (0.81), New York (0.71), and Singapore (0.65). Compared to the 1992 analysis, many changes occurred in the cities' ranks in the 2004 analysis. Among the top 25 cities, Moscow ranked 93rd in 1992 but rose to 19th in 2004, which was the biggest rise in the cities' ranks. Osaka (55→24), Toronto (32→14), Dubai (26→13), Seoul (18→7), and Barcelona (33→22) also rose in rank. On the other hand, Milan drastically fell from 16th in 1992 to 93rd in 2004. Geneva (24→79), Brussels (13→59), Rome (8→53), Athens (21→32), and Vienna (19→28) also fell in rank.

European cities, in particular, drastically fell in rank in terms of *local centrality*. As shown in the changes in the numbers of their passengers and air routes, the numbers of passengers increased by a large margin in the European centers that ranked highest, but there was no big change in the numbers of their air routes. On the other hand, the numbers of passengers and of air routes in the European centers that occupied low ranks drastically decreased, which suggests that the air flow pattern in Europe is concentrated on certain regions. Among Asian cities, Tokyo, which had the highest *local centrality* in 1992, ranked lower than both Singapore and Seoul in 2004. This suggests that in Asia, as opposed to Europe, the air flow pattern is multipolarized. This tendency also appears in the results of the analysis of the *international networkability* of cities, whose details will be examined in the section 3.3.

3.2 The Changes in Connectivity of Air Routes

This section analyzes the connectivity of the international air routes and looks into some changes that have transpired in such connectivity. Using the formula of connectivity that was explained in the previous chapter, this study came up with the following figures: 1,822 air routes in 1992 and 1,991 in 2004. In this study, the connectivity was measured not only on the basis of the traffic volume between two cities but by adding the weight values of the two cities' *local centrality* based on the results of centrality analysis in previous section. Therefore, the fact that the numbers of passengers of two air routes are different does not necessarily mean that their connectivity is also different.

Table 3.3 shows the top 25 international air routes based on the number of passengers in 1992 and 2004. In 1992, the London-Paris line (3.2 million), the Hong Kong-Taipei line (2.4 million), and the London-New York line (2.3 million) had the largest numbers of passengers. In 2004, the London-New York line (3.5 million), the Amsterdam-London line (3.4 million), and the London-Paris line (2.6 million) had the largest flows.

The examination of the changes that transpired in the numbers of passengers in the international air routes between 1992 and 2004 revealed that the number of passengers of the Amsterdam-London line increased by the largest margin. The survey also showed that some air routes had an increase of more than 1 million, including the Bangkok-Singapore line (1.4 million), the Dubai-London line (1.3 million), the London-New York line (1.2 million), the Shanghai-Tokyo line (1.2 million), the London-Malaga line (1.2 million), and the Barcelona-London line (1.2 million). On the other hand, the number of passengers of the Dublin-London line decreased by a large margin (870 thou.), as well as those of the Taipei-Tokyo line (740 thou.), the London-Paris line (720 thou.), the Honolulu-Tokyo line (520 thou.), and the Hong Kong-

Table 3.3 The top 25 international air routes of passengers in 1992 and 2004

Rank	1992			2004		
	International Air Routes		Passengers (Thou.)	International Air Routes		Passengers (Thou.)
1	London	－Paris	3,285	London	－New York	3,543
2	Hong Kong	－Taipei	2,352	Amsterdam	－London	3,351
3	London	－New York	2,311	London	－Paris	2,580
4	Honolulu	－Tokyo	2,130	Hong Kong	－Taipei	2,452
5	Kuala Lumpur	－Singapore	2,072	Bangkok	－Singapore	2,437
6	Hong Kong	－Tokyo	1,932	Seoul	－Tokyo	2,421
7	Seoul	－Tokyo	1,917	Bangkok	－Hong Kong	1,808
8	Amsterdam	－London	1,748	Kuala Lumpur	－Singapore	1,763
9	Dublin	－London	1,722	Barcelona	－London	1,663
10	Bangkok	－Hong Kong	1,672	Frankfurt	－London	1,657
11	Jakarta	－Singapore	1,273	London	－Madrid	1,623
12	Frankfurt	－London	1,214	Madrid	－Paris	1,612
13	New York	－Paris	1,183	Tokyo	－Honolulu	1,610
14	Hong Kong	－Manila	1,118	London	－Malaga	1,533
15	Singapore	－Tokyo	1,082	Hong Kong	－Singapore	1,527
16	Taipei	－Tokyo	1,075	New York	－Paris	1,525
17	Bangkok	－Singapore	1,055	Dubai	－London	1,501
18	Hong Kong	－Singapore	1,043	Hong Kong	－Tokyo	1,433
19	Los Angeles	－Tokyo	1,040	Hong Kong	－Manila	1,425
20	London	－Los Angeles	1,039	Jakarta	－Singapore	1,422
21	Brussels	－London	1,001	Chicago	－London	1,412
22	London	－Tokyo	908	Shanghai	－Tokyo	1,365
23	London	－Zurich	867	Osaka	－Seoul	1,260
24	Bangkok	－Tokyo	851	London	－Munich	1,239
25	Frankfurt	－New York	837	Bangkok	－Seoul	1,197

Source: ICAO, 1992, On-Flight Origin and Destination.

ICAO, 2004, On-Flight Origin and Destination, the secure site (http://icaosec.icao.int) of ICAO.

Tokyo line (500 thou.).

The examination of the changes in the rank order of the top 25 air routes between 1992 and 2004 revealed that all the air routes' ranks drastically changed. Large jumps in rank were shown by the Shanghai-Tokyo line (371→22), the London-Dubai line (213→17), the London-Malaga line (123→14), the Seoul-Bangkok line (117→25), and the Barcelona-London line (69→9). On the other hand, some air routes fell in rank by a large margin, including the Tokyo-Taipei line (16→293), the Brussels-London line (21→131), the Tokyo-Singapore line (15→67), and the Dublin-London line (9→57).

Table 3.4 shows the connectivity of air routes and the changes that transpired in them between 1992 and 2004. In both years, the connectivity of the London-Paris line was the highest, and in terms of the number of international air routes, among the top 25 lines, that with London as the origin or the destination was the highest. This indicates that London was the city with the highest relative importance in the international air network from 1992 to 2004. Moreover, in both years, the Paris, New York, Frankfurt, and Amsterdam lines that connected to London had the highest connectivity. This suggests that the international lines formed around London were the core ones in the international air network in 1992 to 2004.

The examination of the connectivity of the international passenger air routes in 1992 revealed that the connectivity of the air routes between London and Paris in that year was 87.157, which was much higher compared to that of the other air routes. The London-New York line ranked second (29.086), followed by the Frankfurt-London line (27.682), the Amsterdam-London line (22.438), and the London-Tokyo line (10.910). On the whole, the international air routes that were connected to European cities had a very high connectivity. Among the top 25 air routes in 1992, 21 turned out to be connected to European cities.

Among the air routes that had no connection with European cities, only four were included in the top 25 air routes in 1992. These four lines were the Hong Kong-Tokyo line, the Singapore-

Table 3.4 The changes in the connectivity of international air routes in 1992-2004

Rank	1992			2004			Change in Connectivity[1]
	International Air Routes		Connectivity	International Air Routes		Connectivity	
1	London	－Paris	87.157	London	－Paris	41.392	-45.765
2	London	－New York	29.086	Amsterdam	－London	33.533	11.095
3	Frankfurt	－London	27.682	London	－New York	30.987	1.901
4	Amsterdam	－London	22.438	Frankfurt	－London	21.710	-5.972
5	London	－Tokyo	10.910	London	－Madrid	9.658	5.192
6	New York	－Paris	10.853	New York	－Paris	8.135	-2.718
7	Frankfurt	－Paris	9.689	London	－Singapore	7.468	3.613
8	London	－Zurich	8.226	Frankfurt	－Paris	7.380	-2.308
9	London	－Los Angeles	6.959	Hong Kong	－London	6.122	—[2]
10	Frankfurt	－New York	6.602	Dubai	－London	6.018	5.330
11	London	－Rome	6.486	Madrid	－Paris	5.849	3.093
12	Brussels	－London	6.104	Amsterdam	－Paris	5.619	-0.261
13	Amsterdam	－Paris	5.880	London	－Los Angeles	5.142	-1.817
14	Paris	－Rome	5.174	London	－Tokyo	5.042	-5.868
15	Paris	－Tokyo	4.572	Barcelona	－London	4.342	3.267
16	London	－Madrid	4.466	Frankfurt	－New York	4.295	-2.307
17	London	－Miami	4.453	London	－Toronto	3.825	2.580
18	Hong Kong	－Tokyo	4.426	Bangkok	－Singapore	3.789	2.132
19	London	－Singapore	3.856	London	－Munich	3.724	1.690
20	London	－Milan	3.472	Chicago	－London	3.628	2.156
21	Paris	－Zurich	3.200	London	－Zurich	3.453	-4.772
22	Singapore	－Tokyo	3.166	Bangkok	－London	3.304	1.632
23	Seoul	－Tokyo	2.983	Copenhagen	－London	3.216	0.341
24	New York	－Tokyo	2.972	Seoul	－Tokyo	3.190	0.207
25	Amsterdam	－Frankfurt	2.959	Paris	－Tokyo	2.913	-1.658

[1] Change of Connectivity = (Connectivity in 2004) – (Connectivity in 1992)

[2] The Hong Kong-London line was excluded in the 1992 survey because it was classified as a domestic air route then.

Tokyo line, the Seoul-Tokyo line, and the New York-Tokyo line. What could perhaps explain why the connectivity of those air routes that connected to European cities in 1992 was high is the fact that European cities with a developed international air network have a relatively higher *local centrality* compared to cities in other continents. Consequently, it turned out that the air routes that were connected to European cities occupied high positions in the network.

As in 1992, in terms of the connectivity of the international passenger air routes in 2004, the London-Paris line recorded the highest value (41.392). The Amsterdam-London line ranked second (33.533), followed by the London-New York line (30.987) and the Frankfurt-London line (21.710). In 1992, there was a big difference between the connectivity of the London-Paris line and those of other lines. This difference, however, drastically decreased in 2004 because the connectivity of the London-Paris line decreased to less than half of its 1992 connectivity. This may be attributed to the fact that, as shown in Table 3.3, the number of passengers of the London-Paris line decreased by 71 million because of the inauguration of Eurostar, whose details will be examined in the next section..

The examination of the changes in the ranks of the top 25 air routes revealed that the Dubai-London line ascended from the 81st rank in 1992 to 10th in 2004. Besides, it was found that the Barcelona-London line (64→15), the London-Toronto line (52→17), the Bangkok-Singapore line (43→18), and the Chicago-London line (44→20) rose significantly in rank.

On the other hand, the Brussels-London line (12→122), the London-Rome line (11→99), the Paris-Zurich line (21→61), and the London-Zurich line (8→21) fell in rank. It turned out that all the air routes that were connected to Tokyo fell in rank. These included the Singapore-Tokyo line (22→49), the Hong Kong-Tokyo line (18→41), the Paris-Tokyo line (15→25), the London-Tokyo line (5→14), and the New York-Tokyo line (24→33). It was also noted that six air routes connected to Tokyo were included in the top 25 air routes in 1992 whereas the number decreased to three in 2004.

The examination of the change in connectivity revealed that the connectivity of the London-Paris line (−45.765) drastically declined. In addition, the connectivity of the Frankfurt-London line (−5.972), the London-Rome line (−5.910), the London-Tokyo line (−5.868), the Brussels-London line (−5.691), the Paris-Rome line (−4.957), and the London-Zurich line (−4.772) declined. The line with the connection that increased the most was the Amsterdam-London line (11.095), followed by the Dubai-London line (5.330), the London-Madrid line (5.192), the London-Singapore line (3.613), and the Barcelona-London line (3.267).

Overall, the connectivity of the London lines were high and one of the reasons for this is that London's *local centrality* value is exceptionally higher than those of the other cities. It may have also resulted, however, from the characteristics of GNA, which was devised to lead to an understanding of the central structure of the international air network. That is, it is connected to the nodes with high centrality in the network and extracts the lines with high flows to aid in the understanding of the central structure of the whole network.

In this study, the connectivity refers to an air route's position in the world air network. That is, an air route that is connected to a city with a high centrality can be said to have a high accessibility to another city in the air network. Accordingly, although two air routes may have the same number of passengers, their positions in the air network may be entirely different, depending on what cities are connected by the air route. As shown in Tables 3.3 and 3.4, therefore, the air route rank in terms of the number of passengers is different from the air route rank in terms of connectivity.

For example, Table 3.3 shows that the Honolulu-Tokyo line had 2.1 million passengers in 1992 (rank no. 4), whereas the Hong Kong-Tokyo line had 1.9 million passengers (rank no. 6). The former had a larger flow, but the connectivity of the Honolulu-Tokyo line was 1.239 (rank no. 53) while that of the Hong Kong-Tokyo line was 4.426 (rank no. 18). The latter had a higher connectivity. Both of them connected Tokyo to other cities, but depending on whether it connected to a city like Hong Kong, whose *local centrality* was high, or to a city like Honolulu, whose *local centrality* was low, the connectivity value of the air route turned out to be very different. In other words, while the Honolulu-Tokyo line had a larger flow in the 1992 international air network than the Hong Kong-Tokyo line did, the Hong Kong-Tokyo line occupied a more important position in the 1992 network than the Honolulu-Tokyo line did.

Through the use of this method, the characteristics of the air routes that connect global cities and those that fly to international tourist areas can be differentiated. It is difficult to explain the differences between the two types of lines by referring solely to the number of passengers in the individual lines. Since global cities such as London and New York serve as international tourist attractions as well, they are visited by a number of tourists. The global cities, however, have international interactions not only in tourism sector but in other various sectors including culture, economy, society and policy, whereas those air routes to international tourist areas like Honolulu and Malaga carry mostly passengers for sightseeing. Since ICAO data, of course, are not classified per purpose of flight service, it is impossible to analyze the data per travel purpose of passengers. But, it is apparent that passengers visiting international tourist areas show a tendency of being distributed on specific regions, unlike cases of global cities. The number of regular international air routes also is helpful in deciding whether it is a global city or a tourist area functioning specially as a sightseeing one. Generally, tourist areas have a smaller number of regular international non-stop flights than global cities, thus also showing lower values of *local centrality*.

For example, in Table 3.3, when the ranking is decided based only on the number of passengers, international tourist cities such as Honolulu and Malaga, and those cities that can hardly be considered global centers, such as Manila, Jakarta, and Kuala Lumpur, rank highly. In the connectivity ranking, however, which is decided by considering both the number of passengers and the *local centrality*, those air routes that connect international centers rank highly.

Whatever travel purposes of passengers per air route, this study puts its focus on how many cities a city has active interactions with. A city that has free interactions with many cities can be thought to be one with a great development potential and competitiveness.

Consequently, to understand the structure of the global network and define a city doing a central function especially in the era of globalization is possible through the analysis of international interactions between cities, rather than through the hierarchical analysis of cities based on only their socioeconomic indices. In this study, therefore, an analysis of the interaction relationships between high-ranking cities with a high centrality can be done by analyzing their connectivity.

3.3 The Changes in International Networkability of Cities

Basically, connectivity is the connection volume of the international air route between two cities, and *international networkability* is the sum of the connectivity of all air routes of a city. As such, the change in a city's *international networkability* can be explained by the change in the connectivity of its air routes. In this study, *international networkability* means the city's position in the international air network. The analysis of the *international networkability* based on the results of the aforementioned analysis of connectivity.

Table 3.5 summarizes the *international networkability* of the top 25 cities in 1992 and 2004. In 1992, London ranked first (255.37) and Paris ranked second (150.69), followed by Frankfurt (71.78), New York (61.79), Amsterdam (42.80), and Tokyo (42.41). In 2004, London also ranked first (223.90), followed by Paris (98.42), Frankfurt (71.41), Amsterdam (56.18), and New York (56.16). That is, London, Paris, and Frankfurt had the highest *international networkability* in both years, followed by Amsterdam, New York, Singapore, and Tokyo.

Table 3.5 The top 25 cities in terms of the *international networkability* in 1992-2004

Rank	1992		2004		Change in International Networkability*
	City	International Networkability	City	International Networkability	
1	London	255.368	London	223.902	-31.466
2	Paris	150.691	Paris	98.423	-52.268
3	Frankfurt	71.783	Frankfurt	61.406	-10.377
4	New York	61.788	Amsterdam	56.176	13.373
5	Amsterdam	42.803	New York	56.164	-5.624
6	Tokyo	42.406	Singapore	27.138	10.079
7	Rome	20.815	Tokyo	23.526	-18.881
8	Zurich	20.028	Madrid	22.891	10.720
9	Singapore	17.060	Hong Kong	20.342	5.814
10	Los Angeles	14.889	Bangkok	17.269	5.641
11	Hong Kong	14.528	Seoul	15.936	8.653
12	Madrid	12.171	Los Angeles	12.290	-2.599
13	Bangkok	11.628	Dubai	9.827	8.559
14	Brussels	11.611	Zurich	8.733	-11.296
15	Milan	10.066	Toronto	8.264	5.118
16	Copenhagen	7.666	Barcelona	8.207	5.490
17	Miami	7.320	Copenhagen	7.313	-0.353
18	Seoul	7.283	Munich	6.843	2.725
19	Vienna	5.997	Chicago	6.732	3.216
20	Geneva	4.412	Kuala Lumpur	4.782	1.827
21	Munich	4.118	Miami	4.442	-2.878
22	Athens	3.803	Stockholm	4.126	1.157
23	Chicago	3.516	Moscow	4.001	3.887
24	Toronto	3.146	Istanbul	3.333	1.799
25	Stockholm	2.968	Prague	3.311	2.777

* Change in International Networkability = (International Networkability in 2004) – (International Networkability in 1992)

An examination of the distribution of the top 25 cities in 1992 by continent revealed that 15 of them were in Europe, 5 were in Asia, and 5 were in North America. In 2004, however, the number of European cities in the list fell to 13, while the number of Asian cities rose to 7, with no changes in North America. Most of the top 11 cities in 2004 were European and Asian cities, which clearly indicate the increase in the networkability of the Asian cities. This result supports Asia's economic growth in the world economy.

The total traffic in Asian cities rapidly increased during this period. The traffic volumes in Shanghai, Seoul, Osaka, and Bangkok increased by 4,691%, 126%, 120%, and 110%, respectively; those in Singapore, Hong Kong, and Tokyo increased by 75%, 41%, and 15%, respectively. This change in flows is confirmed by the change in international flights. The non-stop flights between the United States and Northeast Asia used to be concentrated on Tokyo and Hong Kong, where people also transferred, but the non-stop flights to Seoul, Shanghai, and Beijing increased in recent years.

It was also found that the number of cities connected to Seoul through non-stop flights increased by 74%. This cannot be explained solely by Korea's economic development, but it should be understood that the international interactions became more active because of the economic growth that occurred in other Asian countries, such as China and a number of Southeast Asian countries. On the contrary, the increase in the flow rate of Tokyo was relatively low owing to its relatively lower degree of networkability as the flows were distributed to other international airports in and out of Japan, including Seoul, Hong Kong, Shanghai, and Osaka.

There are various possible reasons for the emergence of such new international flight services or for the increasing number of passengers in the aforementioned cities, but these fundamentally resulted from the strengthened interactions between the two regions to which these cities belong. Therefore, the international interactions among certain Asian cities became more active due to the economic development that occurred in the Asian countries where these cities could be found. Unlike the traffic or the absolute number of air routes, *international networkability* is analyzed based on a city's relative weight in the global network. As such, it is understood that the networkability of Asia in the global network considerably increased compared to other continents.

Table 3.5 shows the changes in each city's *international networkability*. The cities whose *international networkability* increased significantly were Amsterdam, Madrid, Singapore, Seoul, and Dubai. This highlights the growth of new international economic centers. On the other hand, the cities with a significantly decreased *international networkability* were Paris, London, Rome, Tokyo, Zurich, Brussels, and Frankfurt.

The decrease in the *international networkability* of the European cities is particularly evident. This can be explained by the impact of international express trains, such as Eurostar, which opened in 1994. The traffic volume of the London-Paris and Brussels-London routes, which overlap with that of Eurostar, drastically decreased from 3.3 million to 2.6 million passengers and from 1 million to 0.6 million passengers, respectively. Figure 3.1 shows the changes in the number of Eurostar passengers. The number of Eurostar passengers in 1995 was 2.9 million, and it exceeded 7 million in 2000. Eurostar carried 7.27 million passengers in 2004. The number of Eurostar passengers thus increased 2.5 times in 2004 from 1995. Eurostar carried more than 8 million passengers in 2007, and the number of its passengers continues to increase. Based on the 2004 data, the number of Eurostar passengers has a share rate of 65% of the transportation between London and Paris and a share rate of 56% of the transportation between London and Brussels (Transport Statistics Great Britain, 2004 Edition).

What perhaps explains why the number of Eurostar passengers is higher than the number of international air passengers is the fact that Eurostar takes its passengers from the center of London to the center of Paris, considered the central hubs of the European world, in only two hours. Taking into account the hours it would take for one to go to the airport as well as the

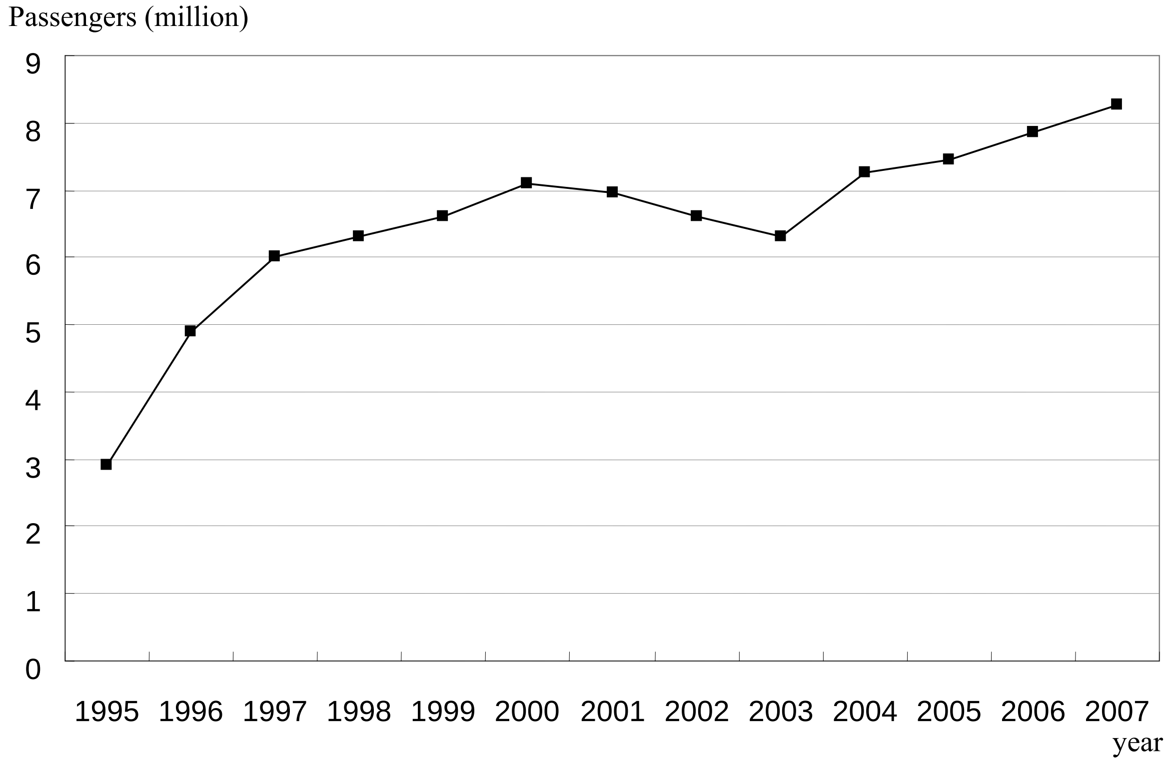

Figure 3.1 Changes in the number of Eurostar passengers (1995-2007)

Source: Department for Transport, 2008, *Transport Statistics Great Britain, 2008 Edition*.

cumbersome airplane boarding procedures, it would take more than four hours for one to fly to Paris from London. The observed on-time arrival rate of Eurostar is 91.5%, whereas that of the air routes flying from London to Paris or the other way around is less than 75%. For this reason, Eurostar appeals to the business passengers with the slogan “Travel via the reliable Eurostar system when you are on a business trip.” Eurostar expects the number of its patrons to increase by about 25%, and the number of its passengers to be more than 10 million, by 2010, if it succeeds in reducing the running time of its trains to about two hours and 15 minutes (The Financial Times, January 2008 issue).

That is to say, people travel by Eurostar rather than by airplane when they move from London to Paris or the other way around. Especially, it is remarkable that among all the existing regular international non-stop flights, the international air routes between London and Paris recorded the largest number of passengers in 2004 despite the general effect of the emergence of Eurostar on air route services. This implies that there is a strong interaction relationship between London and Paris. Besides an international air route system, there are also other developed means of land transportation between the two cities, such as an international railway system. This suggests that the interaction relationships between European cities are in fact much stronger than the connectivity that is shown in the international air network. London and Paris, in 2004, were maintaining the highest networkability each and the greatest connectivity between them, regardless of effects of Eurostar, so it looks impractical to think the global hub function of those cities to be weakened. As shown in the section 3.1, the decreased *local centrality* of a lot of European cities is one of factors making the *international networkability* of London and Paris relatively decreases.

Moreover, when the connections of cities with decreased networkabilities by route increased along with the connectivity of European cities to cities in other continents, the connectivity between European cities considerably declined. On the contrary, the decline of the *international networkability* of Tokyo, New York, Los Angeles, and Miami was primarily caused by the decrease in their connections to cities in other continents. This can be explained in the following way: The networkability of the previous hub cities decreased as the air flows that used to be focused on the previous centers were distributed to the new hub cities.

International networkability is calculated based on the flows among not only those nodes that are directly connected but also those nodes that are indirectly connected. As such, it measures the wide-area networkability of a city in the world air network. That is, each city's total traffic, the number of its non-stop flights, and its *local centrality* are the indices that are measured only on the basis of the direct-connection relationships of cities in the air network. *International networkability*, however, is an index that shows the comprehensive status of each nodal point in the international air network because each city's indirect-connection relationships are also considered in its analysis.

For example, in Table 3.1, Amsterdam's *local centrality* (0.72) is almost the same as New York's (0.71) in 1992. In terms of *international networkability* in Table 3.5, however, there is a big difference between Amsterdam, whose *international networkability* is 42.80, and New York, whose *international networkability* is 61.79 in 1992. While New York has a larger traffic volume than Amsterdam does, Amsterdam has more regular non-stop flights than New York does. For this reason, their *local centralities* are said to be the same.

Considering, however, the differences between the two aforementioned cities based on their connection patterns in the whole structure of the network, it can be seen that New York has a large traffic volume in its relationships to cities with a high degree of *local centrality*, such as London, Paris, and Frankfurt, whereas Amsterdam has strong connection relationships to European cities with a low degree of *local centrality*.

Thus, the fact that a city has strong interactions with cities with a high degree of *local centrality* in the network implies that it has a high degree of accessibility both to the central regions and to other regions in the whole network. For this reason, a city's position and influence in the network cannot be fully explained only in terms of its direct-connection relationships. Therefore, *international networkability* can be regarded as a standard by which a city's international position in the whole world's international air network can be measured.

In the comparison of *local centrality* and *international networkability* in 1992, New York, Rome, Los Angeles, and Geneva ranked higher in terms of *international networkability* than in terms of *local centrality*, whereas Amsterdam, Zurich, Miami, Moscow, and Osaka ranked lower in terms of *international networkability* than in terms of *local centrality*. In the 2004 analysis, while Tokyo, Barcelona, Chicago, and Istanbul ranked higher in terms of *international networkability* than in terms of *local centrality*, Seoul, Miami, Moscow, and Osaka ranked lower in terms of *international networkability* than in terms of *local centrality*.

These results are due to the *local centrality* of a partner city to which each city is connected. In other words, even if cities have the same number of air routes and the same traffic volume, the *international networkability* of each of such cities is different according to the *local centrality* of its partner city, with which it has a connection. The reason for this is that the higher the *local centrality* and the larger the traffic of a city are, the higher its *international networkability*. This will help in understanding the connection relationship between cities with a high degree of centrality in the international air network, which is composed of complicated connection relationships.

For instance, in the comparison of the *local centrality* of Seoul and that of Tokyo in 2004, Seoul ranked higher than Tokyo in terms of *local centrality*, whereas Tokyo ranked higher than Seoul in terms of *international networkability*. These results are well shown in the flow patterns of the two cities: Seoul has passengers relatively fewer than Tokyo's but more international air routes to local cities of China and Japan than Tokyo has, so there are more regular international air routes than in Tokyo; on the contrary, Tokyo has more passengers and international air routes to the American and European cities, and has fewer air routes to Northeast Asia, compared to Seoul. This implies that although Seoul serves as a hub in the northeast Asian region, Tokyo has stronger connection relationships with the cities in other continents that have high centrality.

In this way, each city's differentiated hub function can be explained by comparatively analyzing the *local centrality* and the *international networkability* of cities. Therefore, the GNA model devised in this study is not for mechanically analyzing and measuring existing air data, but for finding out the spatial interaction between cities which takes place on the global network, considering characteristics of interaction patterns of each city in the international air network.

Chapter Four
Structural Changes in the International Air Network

4.1 Hierarchy Analysis of Air Routes and Cities

4.1.1 Hierarchy Analysis of International Air Routes

In the previous chapter, the *international networkability* of cities and the connectivity of the international air routes were analyzed, and on the basis of the results of such analysis, cities and air routes were classified. To examine the multilayered structure of the international air network, based on the results of these analyses, this chapter analyzes the structure and connection system of the international air network and the changes that transpired in them in 1992 and 2004. That is, an analysis of the structural aspects of the international air network is undertaken herein.

To understand the structure of the international air network and the main connections therein based on the results of the analysis of the connectivity of air routes, the hierarchy of international air routes was first examined. Analyzing the hierarchy of air routes and cities is a method to understand in a simpler way the analysis results on connectivity and networkability and the multilayered structure of the global network. As shown in Figure 4.1, the air routes were

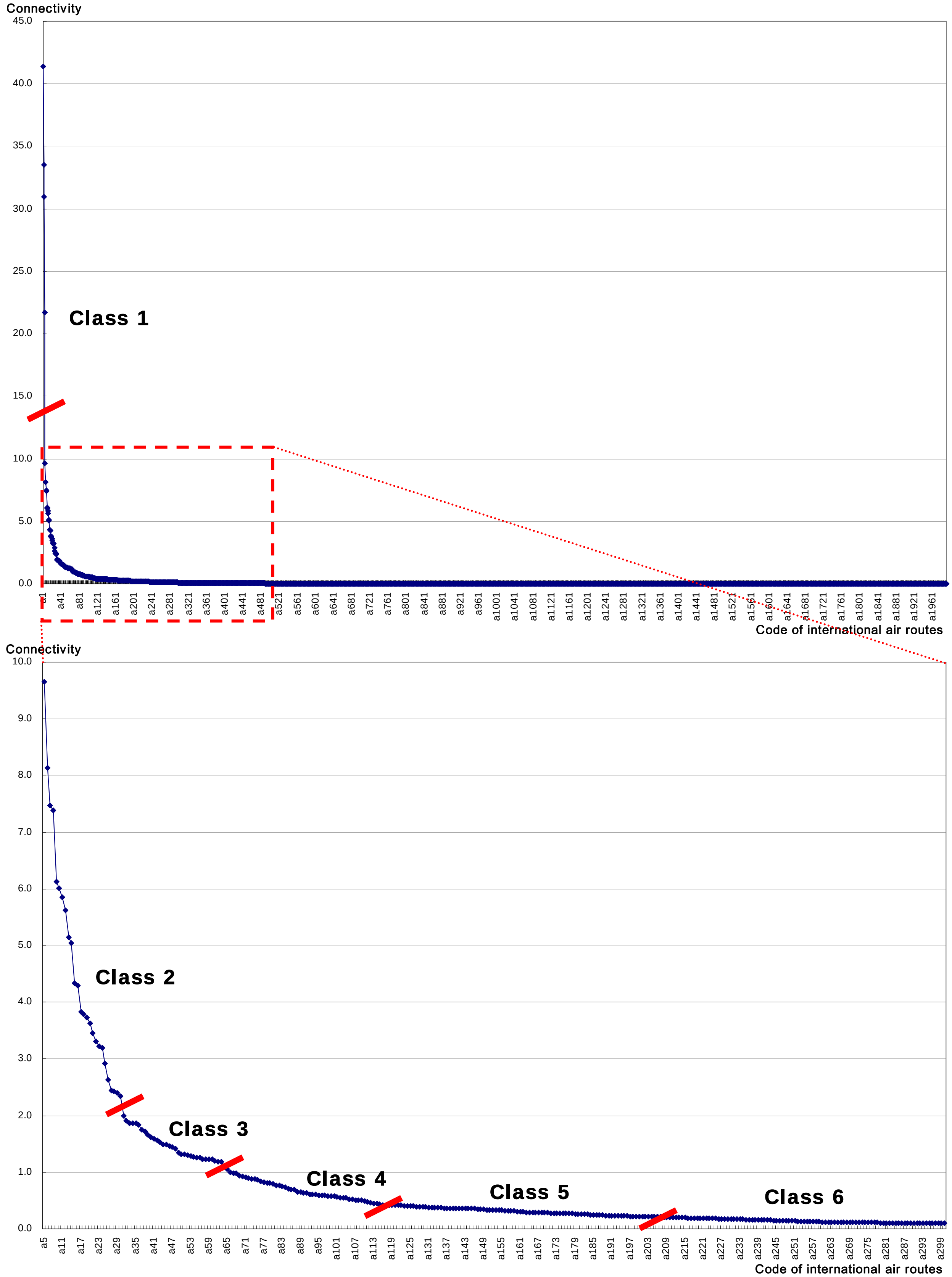

Figure 4.1 The rank-size graph of connectivity of international air routes in 2004

classified by identifying the turning points in the rank-size graph that rates connectivity of air routes in 2004. The air routes in 1992 were also classified in the same way as applied to those of 2004.

As shown in Table 4.1, the international air routes in 1992 and 2004 were divided into six classes, and the air routes up to class 5 were included in the analysis of the global network structure. That is, the air routes in classes 1-5 were used to examine the multilayered hierarchical structure of the global network. Out of the 1,822 international air routes in 1992, 206 were drawn, and 207 lines were drawn from the 1,991 international air routes in 2004. In both years, the Paris, New York, Frankfurt, and Amsterdam lines that were connected with London were categorized as class 1 lines. This shows that the international lines around London make up the core part of the international air network.

In the 1992 classification of international air routes, class 2 consisted of 25 air routes, including the London-Tokyo line, the New York-Paris line, the Frankfurt-Paris line, and the London-Zurich line. Class 3 included 35 air routes, among them the Amsterdam-New York line, the Los Angeles-Tokyo line, the London-Vienna line, and the Geneva-London line. Sixty-two air routes belonged to class 4, including the London-San Francisco line, the Madrid-New York line, the Frankfurt-Madrid line, and the Bangkok-Paris line. Eighty air routes were classified as class 5 air routes, including the Tokyo-Rome line, the Frankfurt-Seoul line, the Amsterdam-Brussels line, and the Istanbul-Paris line. Finally, class 6 included 1,616 air routes whose connectivity was very low.

In the 2004 classification of international air routes, class 1 included the following four air routes: the London-Paris line, the Amsterdam-London line, the London-New York line, and the Frankfurt-London line, which were the same air routes that were included in class 1 in the 1992 classification. Class 2 had 26 air routes, including the London-Madrid line, the New York-Paris line, the London-Singapore line, and the Frankfurt-Paris line. Thirty-three air routes were

Table 4.1 The hierarchical division of international air routes by connectivity

Class	1992		2004	
	International Air Routes	Total	International Air Routes	Total
1	London-Paris, London-New York, Frankfurt-London, Amsterdam-London	4	London-Paris, Amsterdam-London, London-New York, Frankfurt-London,	4
2	London-Tokyo, New York-Paris, Frankfurt-Paris, London-Zurich, London-Los Angeles, Frankfurt-New York, London-Rome, Brussels-London, Amsterdam-Paris, Paris-Rome, Paris-Tokyo, London-Madrid, London-Miami, etc.	25	London-Madrid, New York-Paris, London-Singapore, Frankfurt-Paris, Hong Kong-London, **Dubai-London**, Madrid-Paris, Amsterdam-Paris, London-Los Angeles, London-Tokyo, **Barcelona-London**, etc.	26
3	Amsterdam-New York, Los Angeles-Tokyo, London-Vienna, Geneva-London, New York-Rome, Bangkok-Hong Kong, London-Munich, Frankfurt-Zurich, Bangkok-Tokyo, Frankfurt-Rome, Hong Kong-Singapore, etc.	35	**Frankfurt-Madrid**, **London-Prague**, *New York-Tokyo*, London-Stockholm, **Barcelona-Paris**, Bangkok-Hong Kong, **Singapore-Paris**, Bangkok-Frankfurt, **Amsterdam-Madrid**, *Frankfurt-Tokyo*, *Hong Kong-Tokyo*, etc.	33
4	London-San Francisco, Madrid-New York, Frankfurt-Madrid, Bangkok-Paris, Lisbon-London, Munich-Paris, Paris-Vienna, Miami-Frankfurt, Hong Kong-Paris, Amsterdam-Rome, Copenhagen-Frankfurt, etc.	62	Istanbul-London, *Copenhagen-Paris*, Chicago-Frankfurt, *Los Angeles-Tokyo*, Madrid-New York, *Frankfurt-Los Angeles*, **Frankfurt-Toronto**, Los Angeles-Seoul, New York-Seoul, Lisbon-Paris, **Dubai-Frankfurt**, etc.	52
5	Tokyo-Rome, Frankfurt-Seoul, Amsterdam-Brussels, Istanbul-Paris, Vienna-Zurich, Hong Kong-Los Angeles, Frankfurt-Istanbul, Geneva-Frankfurt, Chicago-Tokyo, Athens-Rome, Copenhagen-Zurich, etc.	80	**Mexico City-New York**, **Bangkok-Kuala Lumpur**, Manchester-Paris, *London-Nice*, **Beijing-Seoul**, Hong Kong-Los Angeles, *Brussels-London*, Amsterdam-Stockholm, **Osaka-Paris**, Amsterdam-Munich, etc.	92
6	Buenos Aires-London, Munich-Zurich, Cairo-Rome, Bangkok-Zurich, Madrid-Tokyo, London-Prague, Amsterdam-Barcelona, Paris-Warsaw, London-Montreal, London-Stuttgart, Osaka-Hong Kong, Budapest-Frankfurt, etc.	1616	Frankfurt-Kuala Lumpur, *Frankfurt-Helsinki*, *Honolulu-Tokyo*, *Frankfurt-Warsaw*, *Cairo-Paris*, *Berlin-Paris*, London-Shanghai, Bangkok-Shanghai, Amsterdam-Oslo, Los Angeles-Osaka, London-Lyon, etc.	1784
The number of air routes up to class 5 / sum : 206/1822			207/1991	

* The list of air routes was arranged based on the connectivity sizes.

* The italicized air route names refer to those air routes that fell in class in 2004, and those in boldface refer to those air routes that rose in class in the same year.

classified as class 3 air routes, including the Frankfurt-Madrid line, the London-Prague line, the New York-Tokyo line, and the London-Stockholm line. Fifty-two air routes belonged to class 4, including the Istanbul-London line, the Copenhagen-Paris line, the Chicago- Frankfurt line, and the Los Angeles-Tokyo line. Class 5 had 92 air routes, including the Mexico City-New York line, the Bangkok-Kuala Lumpur line, the Manchester-Paris line, and the London-Nice line. Finally, class 6 included 1,784 air routes, those with the lowest connectivity, such as the Frankfurt-Kuala Lumpur line, the Frankfurt-Helsinki line, the Honolulu-Tokyo line, and the Frankfurt-Warsaw line.

4.1.2 Hierarchy Analysis of Cities

To understand the structure of the global network and the main connections between cities based on the results of the analysis of the *international networkability* of cities, the hierarchy of cities was first examined. As shown in Figure 4.2, cities were classified by identifying the turning points on the rank-size graph that rates *international networkability* of cities in 2004. The cities in 1992 were also classified in the same way as applied to those of 2004.

As shown in Table 4.2, the cities were classified into five groups in both years. In 1992, London, Paris, Frankfurt, New York, Amsterdam, and Tokyo constituted the first class, which had the highest *international networkability*. The second class consisted of 13 cities, including Rome, Zurich, Singapore, Los Angeles, and Hong Kong. The third class had 22 cities, including Geneva, Munich, Athens, Chicago, and Toronto. Thirty-five cities belonged to the fourth class, including Buenos Aires, Berlin, Jakarta, Washington, D.C., Oslo, and Manchester. All the rest of the 263 cities were classified into the same group, the fifth class, because the *international networkability* differences between them were much smaller compared to those between the cities included in the other classes.

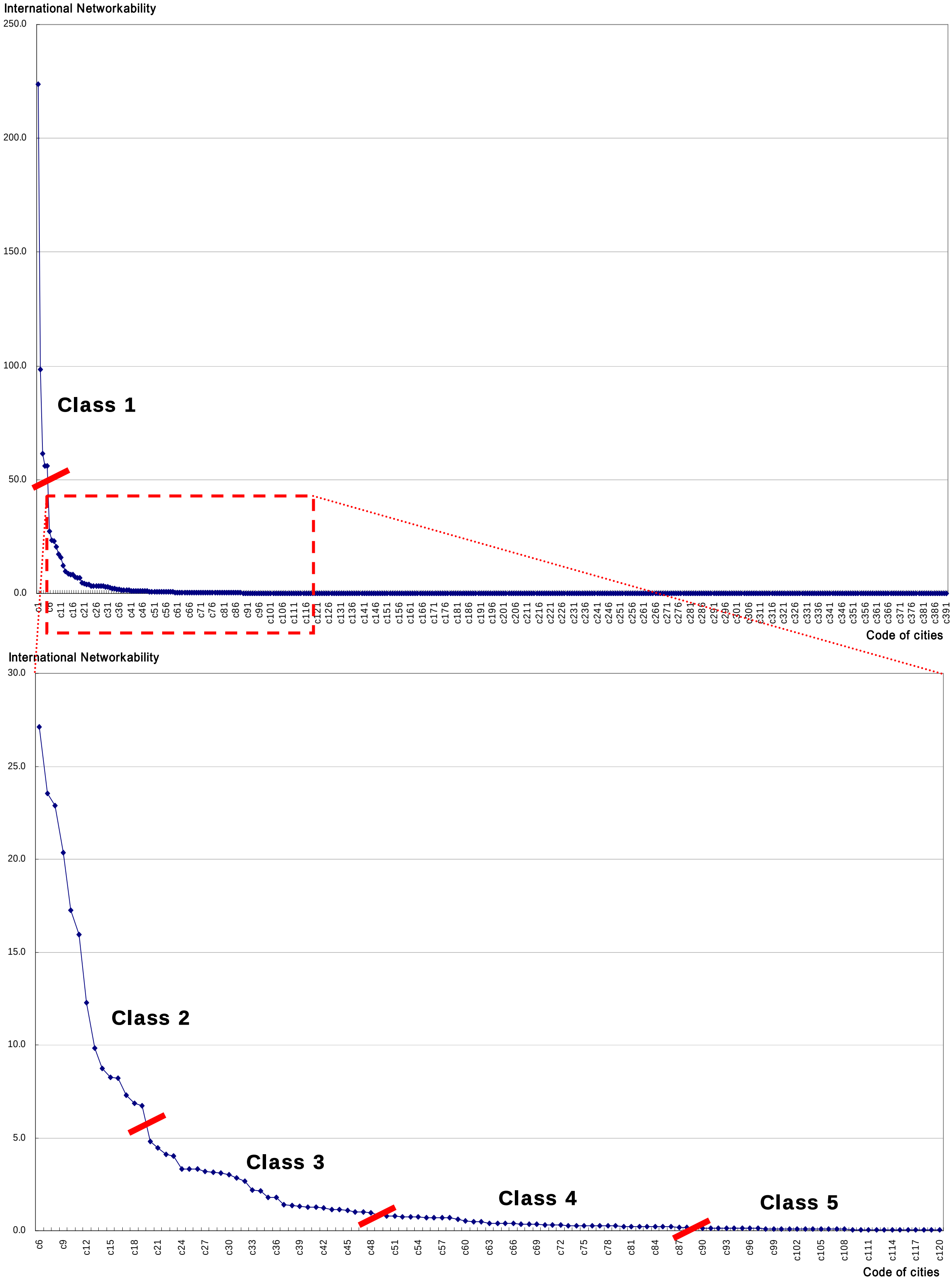

Figure 4.2 The rank-size graph of *international networkability* of cities in 2004

Table 4.2 The hierarchical division of cities by the *international networkability*

Class	1992		2004	
	City	Total	City	Total
1	London, Paris, Frankfurt, New York, Amsterdam, Tokyo	6	London, Paris, Frankfurt, Amsterdam, New York	5
2	Rome, Zurich, Singapore, Los Angeles, Hong Kong, Madrid, Bangkok, Brussels, Milan, Copenhagen, Miami, Seoul, Vienna	13	Singapore, *Tokyo*, Madrid, Hong Kong, Bangkok, Seoul, Los Angeles, **Dubai**, Zurich, **Toronto**, **Barcelona**, Copenhagen, **Munich**, **Chicago**	14
3	Geneva, Munich, Athens, Chicago, Toronto, Stockholm, Kuala Lumpur, Barcelona, Lisbon, San Francisco, Manila, Sydney, Taipei, Cairo, Dusseldorf, Dublin, etc.	22	Kuala Lumpur, *Miami*, Stockholm, **Moscow**, Istanbul, **Prague**, Lisbon, San Francisco, **Shanghai**, Athens, **Osaka**, *Vienna*, **Beijing**, **Washington**, Mexico City, **Sao Paulo**, etc.	29
4	Buenos Aires, Berlin, Jakarta, Washington, Oslo, Manchester, Warsaw, Hamburg, Rio de Janeiro, Nice, Sao Paulo, Boston, Montreal, Delhi, Budapest, Caracas, etc.	35	*Mumbai*, Houston, **Tel Aviv**, Delhi, Kuwait, **Johannesburg**, *Geneva*, Berlin, *Brussels*, *Taipei*, Montreal, **Atlanta**, Nice, Larnaca, **Malaga**, Hamburg, Jakarta, **Santiago**, etc.	40
5	Bogota, Cologne, Gothenburg, Atlanta, Lagos, Santiago, Malaga, Moscow, Colombo, Denpasar, Venice, Birmingham, Perth, Hanover, Porto, San Jose, Mauritius, etc.	263	*Milan*, Gothenburg, Philadelphia, Mauritius, Cancun, Guangzhou, San Jose, Perth, Colombo, *Santo Domingo*, San Salvador, Guam Island, Denpasar, Dhaka, Sofia, etc.	303
Number of cities up to class 4 / the sum ; 76/339			88/391	

* The list of cities is arranged based on the size of their *international networkability*.
* The italicized cities had a fall in class in 2004, and the boldface cities had a rise in class in the same year.

In 2004, the first class was composed of London, Paris, Frankfurt, Amsterdam, and New York, and the second class had 14 cities, among them Singapore, Tokyo, Madrid, Hong Kong, and Bangkok. Twenty-nine cities, including Kuala Lumpur, Miami, Stockholm, Moscow, and Istanbul, belonged to the third class, and the fourth class included 40 cities, among them Mumbai, Houston, Tel Aviv, Delhi, Kuwait, and Johannesburg. The 303 cities in the fifth class had very low degrees of *international networkability*, and the differences between them were insignificant, such as in the 1992 data.

In the analysis of the international air network structure, the cities up to class 4 were considered. Seventy-six out of the total of 339 cities in 1992, and 88 out of the 391 cities in 2004, were selected. The network structure could be analyzed based on the air OD data regarding all the cities and air routes that are included therein. The results of such analysis, however, are so complicated that not all of them can be shown in maps or figures. It is for this reason that this study intends to analyze the international air network structure by using only those cities and air routes that rank above a certain level.

Considering the changes that occurred in each class, the cities in class 1 with the highest *international networkability* in both years were London, Paris, Frankfurt, Amsterdam, and New York, and Tokyo was the only city that dropped to class 2 in 2004. The rest of the classes, except for class 1, show considerable changes in composition, and about half of the cities in classes 2-4 moved across classes. The changes in the composition of class 2 are especially noteworthy: Most of the cities in class 2 in 1992 were European cities, but more than half of the cities in the same class in 2004 were in the Asia-Pacific region. In other words, while most of the cities in classes 1 and 2 in 1992 were European cities, the 2004 figures suggest that as the networkability of the Asian-Pacific cities increased, a structural change occurred in the global network.

The examination of the class changes by city revealed that Moscow, Shanghai, and Beijing moved from class 5 in 1992 to class 3 in 2004, a significant jump, while Milan and Brussels moved from class 2 to class 5 and class 4, respectively, a considerable fall. In addition, those cities whose positions on the stage of the international economy became stronger, such as Dubai, Toronto, Barcelona, Munich, Chicago, Manchester, Vancouver, and Sao Paulo, moved to the higher classes. On the other hand, more cities, including Miami, Vienna, Rome, Mumbai, Geneva, and Taipei, fell to the lower classes in 2004 than in 1992. Overall, the Asian and American cities moved upward while the European cities showed a downward move.

4.2 Analyses of Structure of the International Air Network

4.2.1 The Structure of International Air Network in 1992

In this section, the structural changes that occurred in the international air network between 1992 and 2004 will be examined. Figures 4.3 and 4.4 show the connection patterns of the international air network in 1992 and 2004, respectively. These figures were made based on the results of the hierarchy analysis of air routes and cities in the previous section. These figures show the main connections in the international air network using the cities belonging to classes 1-4 and the international air routes belonging to classes 1-5. Among the cities in class 4, when the connection of the cities based on the lines belonging to classes 1-5 could not be understood, the lines belonging to class 6, those with the maximum connection values, were used.

As shown in Figure 4.3, the international air network in 1992 was formed around the class 1 cities: Tokyo, New York, London, Paris, Frankfurt, and Amsterdam. These six cities composed the central axis of the international air network in 1992. The connections between the cities in class 1 were all high, indicating that the networks that had been formed around these six cities were the most significant parts of the international air network then. Moreover, these six cities

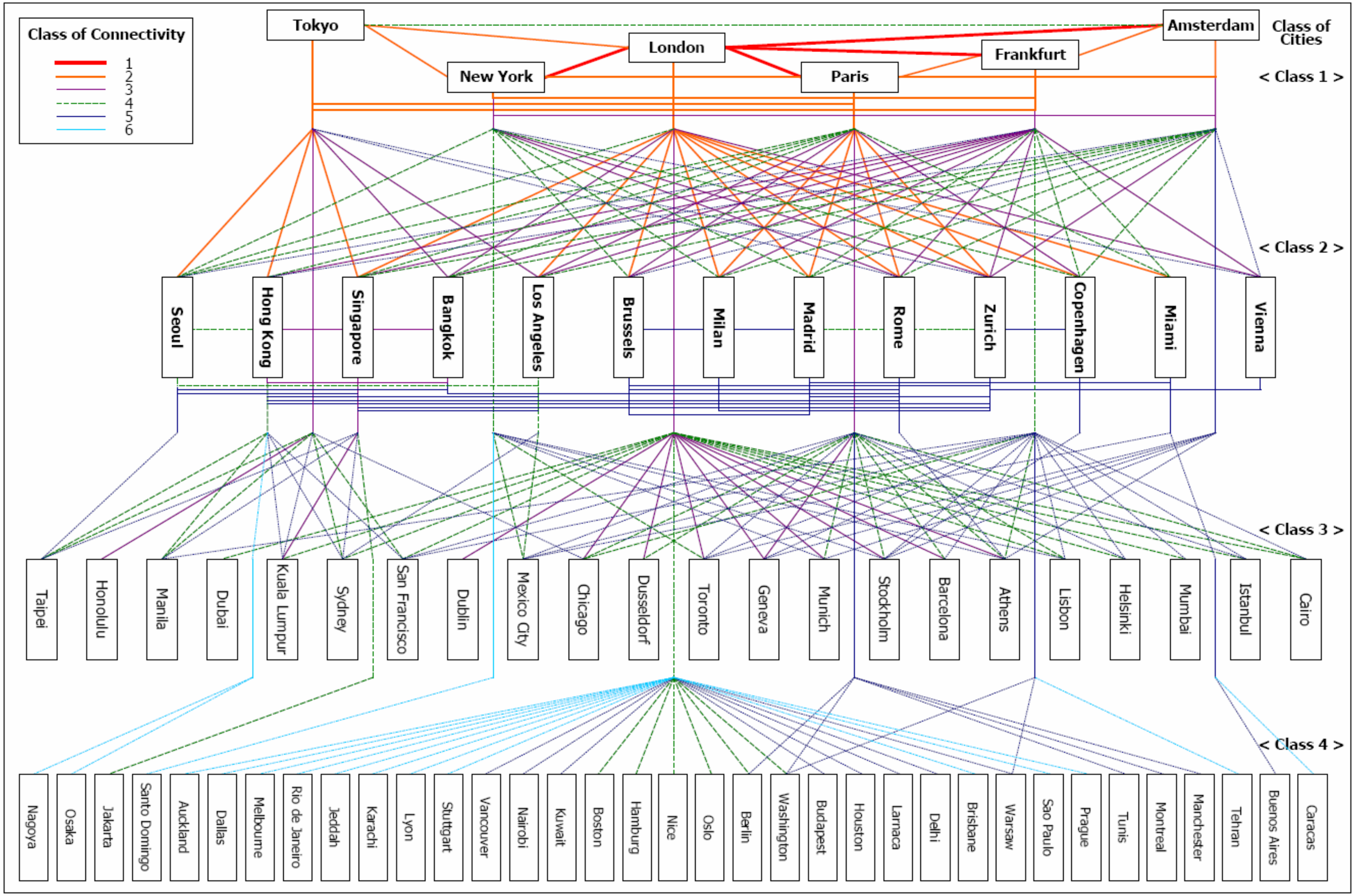

Figure 4.3 The connection patterns of the international air passenger network in 1992

were the *network cities* with the highest degree of nodality in the 1992 international air network.

In 1992, class 2 consisted of 13 cities, including Singapore, Hong Kong, Los Angeles, Rome, and Madrid. The air routes with high connectivity were mostly connected to the cities in class 1. The internal connections between the cities in class 2 were divided into two groups of networks: that in the European and Atlantic coasts and that in the Asian and Pacific coasts. The Asian and American cities, such as Hong Kong, Singapore, Los Angeles, and Miami, formed separate subnetworks. On the other hand, the European cities in class 2 did not form a separate subnetwork, but their connection patterns were concentrated on the European networks around London, Paris, and Frankfurt. The examination of the overall connection patterns of the network revealed that the lines were concentrated on the cities belonging to classes 1 and 2. Therefore, these cities are seen as the *network cities* that performed hub functions in the 1992 international air network.

Under today's globalization, the geographic range of activities has expanded, the meaning of borders has become tenuous, and the functional integration of economic activities occurs at a global scale. Due to globalization, cities interact with cities in other countries or regions, beyond national borders, and the global cities are generally defined as the places that play the role of centers that promote globalization. A core function of global cities or international central cities, however, is to make connections with external economies, and a city's external economy develops the scale of the local economies therein, transforming the city from a domestic center to an international one.

In this process, inter-city and inter-regional interactions are vital. While the most important cities also have the most important airports, the extensive fiber-backbone networks that support the Internet have been deployed within and between major cities as well. These have created not only a physical-transport network but also a vast planetary infrastructure network, which has become crucial to the global economy (Rutherford *et al.*, 2004). Therefore, one of the main infrastructure or outcomes that connect a city to an external economy is an international air route and its associated facilities, and a city's *international networkability* and interaction patterns, which are shown in the international air network, can be important scales that will allow the understanding of a city's prestige and function in the global network.

In the contemporary world, the range of inter-city interactions varies from the local level to the global level, and such interactions occur in various fields. As a result of this kind of inter-city interactions, multilayered networks are formed at a global scale, and a hierarchy appears among international cities. The cities that may be considered the upper nodes in the network, and those in the upper classes, have developed into global cities, and the global urban system has been reorganized around these global cities.

The so-called global cities or international centers can be seen as international *network cities*, and *international networkability* is an engine for the growth of *network cities* and of their core functions. Batten (1995) notes that the global economy is a nurturing and innovative class of polycentric urban configuration, which he calls *network city*. He defines a *network city* as a city that evolves when two or more previously independent cities that are potentially complementary in function strive to cooperate and become significant-scope economies, aided by fast and reliable corridors of transport and communications infrastructure.

Hence, a *network city* is the mutual arena in the global flows, such as the flow of people, capital, goods, information, and knowledge, and it can be a metropolitan area so as to activate the international connection between regions with highly developed infrastructure (e.g., transportation and communication). Since a *network city* becomes more vigorous with functional interactions, such as complementation, connection, and combination, it can grow and sustain a new form of megalopolis. This is represented by Castells (1996) in his work on the "network society." He describes therein a space of flows existing on several levels, starting with the basic electronic infrastructure, in which the world city network represents one of the higher levels of spatial organization. It has a potential for creating an alternative metageography (Taylor, *et al.*, 2002).

As for the connection pattern of the cities of class 3, they were observed to have strong relations with geographically close cities; they were found to have stronger connection relationship particularly with *network cities* on the same continent as them. Unlike the cities of classes 1 and 2, the cities of class 3 showed remarkably weak connection relationship with cities of the same class or ones of lower classes. Most cities of class 4 had relations with the 1st-class *network cities* and relatively weak interaction with the cities of classes 2 and 3. They were similar as the cities of class 3, in that the cities had strong connection relationship with nearby cities from the geographical viewpoint.

To be more specific, in 1992, the connection pattern of the international air network is centered on the *network cities* of classes 1 and 2. The 1st-class *network cities* show its connection pattern as the spatial ranging over the world, while the 2nd-class *network cities* show stronger interactions with the cities on the same continent. The cities of classes 3 and 4, which have a relatively low *international networkability*, form a local network connected with some *network cities* only.

4.2.2 The Structure of International Air Network in 2004

Figure 4.4 shows the connection patterns of the international air network in 2004, in which New York, Frankfurt, London, Paris, and Amsterdam formed class 1, and in which the most notable change was that Tokyo, which belonged to class 1 in 1992, moved to class 2. In other words, while the international air network in 1992 was formed with six *network cities* in class 1 serving as the central axes, only five cities formed the central axis in 2004. London still had greater prestige than the other *network cities* in 2004, and the subnetwork of London consisted of

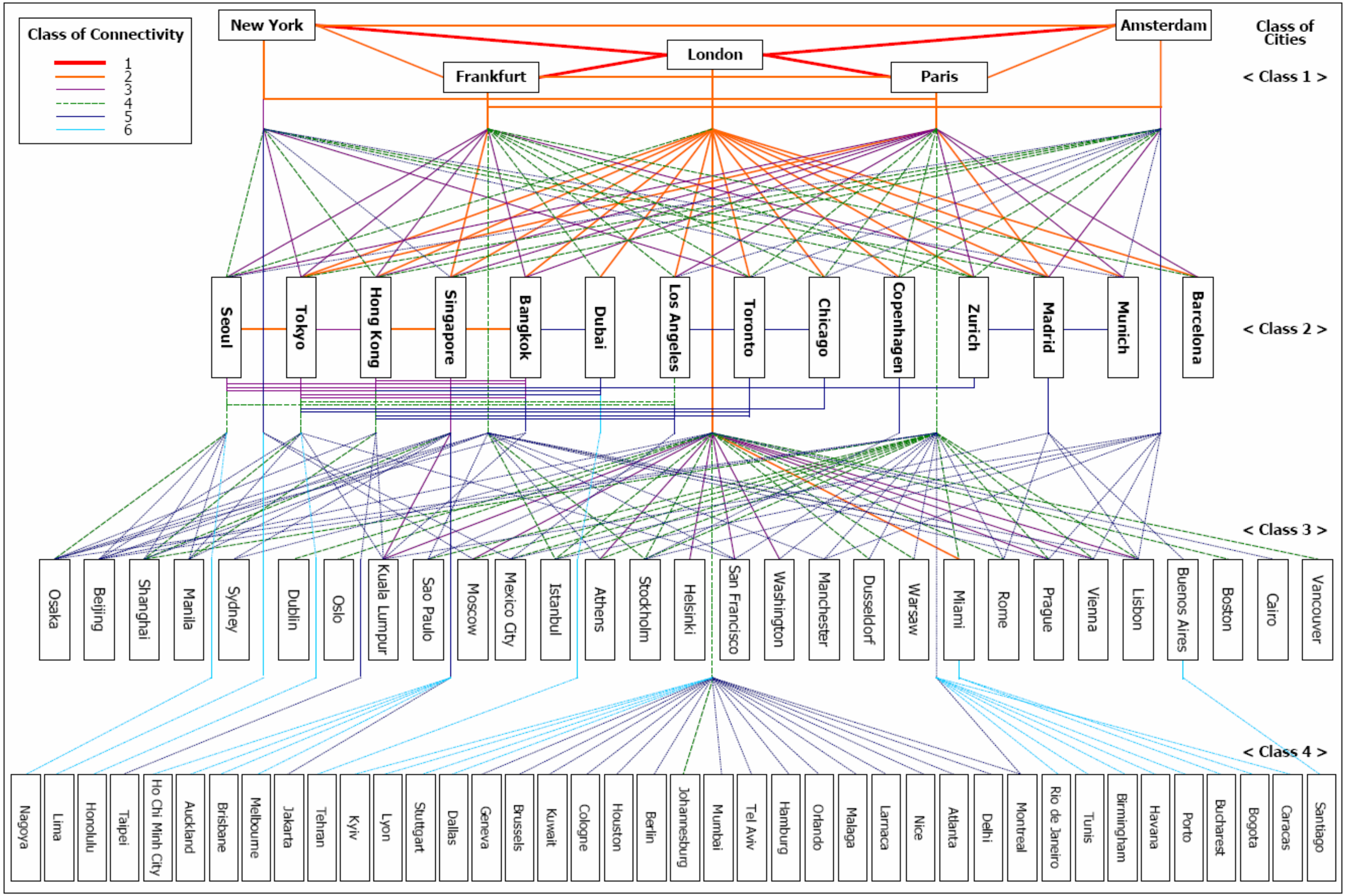

Figure 4.4 The connection patterns of the international air passenger network in 2004

those lines with high-level connections compared to other *network cities*, such as Paris or Frankfurt.

In both years, the subnetwork of London had the largest scale, followed by those of Paris, Frankfurt, and Amsterdam. Many European cities formed the center of the international air network in those years because Europe had a larger number of politically and economically stable countries then compared to the other continents, and because it had the geographical advantage of having many metropolitan areas located close to one another. Thus, Europe had more active and freer international exchanges then compared with the other continents. Just certain country or region retains political and economic stability and prosperity, however, does not guarantee active international exchanges or interactions. In this sense, the fact that such world economic centers as New York and Tokyo have a smaller-scale network compared with the other European global cities has many implications. Of course, countries are different in terms of their policies regarding air traffic, their geographic characteristics, and their social, political, and economic backgrounds, but for metropolitan areas to continue to grow in the era of globalization, the international exchange of human resources should be done freely and actively.

Considering this, one should rethink if many countries in Asia or America have the various conditions that are necessary for international socioeconomic activities, such as the issuance of visas and passports, foreign investments, foreign remittances, and international tourism, and if these are as free as those in Europe. Ultimately, the development of international cities in the era of globalization can be continued when these cities are already as developed as the cities in other countries are.

In 2004, 14 cities, including Singapore, Tokyo, Madrid, and Hong Kong, formed class 2. The examination of the connection patterns among the cities included in class 2 revealed that the European cities had weak connections with one another whereas the Pacific coastal cities had relatively highly developed connections with one another. In terms of the connection of the whole global network, the subnetwork composed of the Pacific coastal cities dispersed in Tokyo, Singapore, Hong Kong, Seoul, Bangkok, etc. On the other hand, the connections among the European and Atlantic coastal cities came to be concentrated on some cities, such as London, Paris, and Frankfurt.

When the connection patterns among the cities in class 2 were examined, it was observed that the connections between the *network cities* in 1992 were divided into two groups: the European and Atlantic coastal cities on one hand and the Asian and Pacific coastal cities on the other. In 2004, however, the network among the European cities was substantially reduced, while the connection between the Pacific cities was further strengthened. This tendency was also shown in the connections between the cities in classes 3 and 4, which indicate that the subnetwork in the Pacific coast had been extensively developed since 1992.

In the case of the interaction between the cities of classes 2 and 3, the interaction became more activated in 2004 than 1992, and especially the connection relations between the Asian cities of classes 2 and 3 turned to be stronger. As for the connection pattern of cities of class 4, most of them were forming subnetwork of London in 1992, but in 2004, the subnetwork was reduced, whereas in 2004, the subnetwork composed of Pacific Rim cities came to have more strengthened connection relations.

In 1992, the Asian network was formed around the highest-level center, Tokyo, but in 2004, the Asian network structure was decentralized, and the inter-city interactions therein became more vigorous with the development of Singapore, Seoul, Bangkok, and Hong Kong. Meanwhile, the European network was formed around London, Paris, Frankfurt, and Amsterdam, but compared to 1992, while London’s connection to other cities increased, its connection to the other three cities (Paris, Frankfurt, and Amsterdam) declined. Unlike the Asian network, the European network became more concentrated on the highest-level city therein, which was London. The connection of Paris and Frankfurt to Asian cities, however, even increased.

This suggests that the international air network has simultaneously undergone a dispersion and concentration of its subnetworks. One way of revealing a city's growth mechanism in the era of globalization is to analyze the kind of interaction patterns that each city shows in the international air network, and to examine each city's functional characteristics, rather than to determine whether a city is a global city.

For example, the cities belonging to classes 1 and 2 have something in common: they have a high degree of *international networkability* but are different in terms of connection patterns. In both years (1992 and 2004), all the class 1 cities were connected to the cities in all the continents around the world, but the class 2 cities showed strong interactions only with the other cities in the same continent or with those that were geographically proximate to them. The 1st-class *network cities* undertook inter-regional interactions on a global scale, while the geographic range of the international interactions of the 2nd-class *network cities* was limited to certain continents or regions. This suggests that even those cities with a high *international networkability* in the international air network may have different functions and levels of prestige. Therefore, the *network cities* occupy the central part of the international air network, and the 1st-class *network cities* are connected to the 2nd-class *network cities*, which serve as hubs in each continent, shaping the whole world as one network.

4.2.3 Structural Changes in the International Air Network

Figure 4.5 shows the structural changes that transpired in the international air network between 1992 and 2004, which have been examined in this study since the previous sections. In both years, the structures of the international air network were expressed as a pyramid. The reasons for this are that in terms of the number of cities at each level, the highest level has the smallest number of cities, and that the number of cities increases as the level becomes lower.

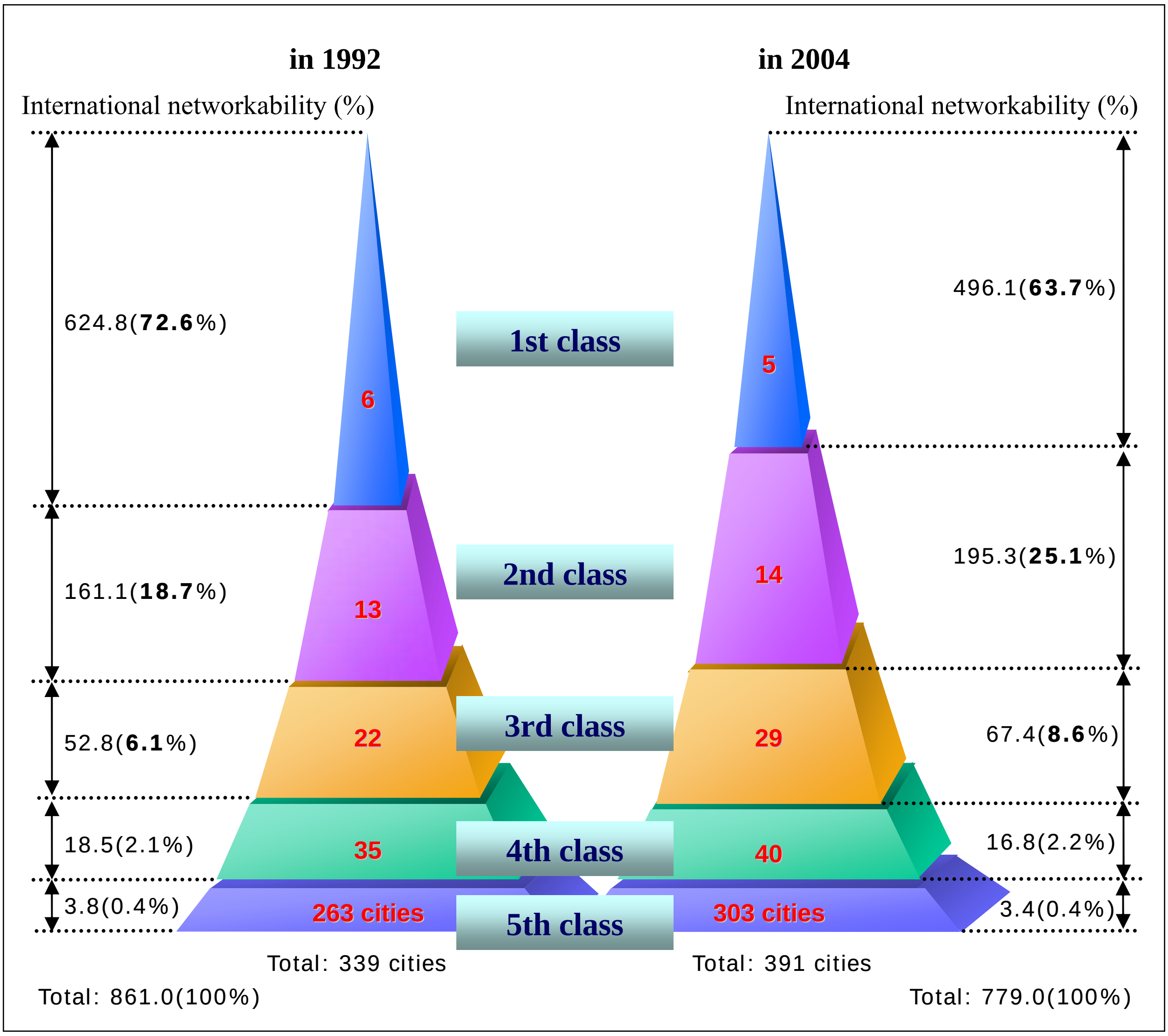

Figure 4.5 Changes in the pyramid structure of the international air network in 1992-2004

The number in the pyramid indicates the number of cities included in the level. The number at the left or right side of each level of the pyramid indicates the total sum of the *international networkability* of the cities on that level, and the number within the parenthesis is the *international networkability* rate of each level, which shows the proportion of the whole network that it occupies. As shown in Figure 4.5, the number of cities increased as the level became lower, whereas each level's *international networkability* increased as the level rapidly rose. It was thus presented in the form of an inverted pyramid.

While the *international networkability* rate of the first class decreased from 72.6% in 1992 to 63.7% in 2004, those of the second and third classes increased. The sum of their *international networkability* rates increased from 24.8% in 1992 to 33.7% in 2004. The decrease rate of 8.9% in class 1 is almost equal to the increase rate in classes 2 and 3. In other words, it can be said that the *international networkability* of the international air network was concentrated on the first class in 1992, whereas it was dispersed into the cities in classes 2 and 3 in 2004.

Of course, there are other physical factors that bring about changes in the international air network. For example, while the number of cities in class 1 decreased in 2004, the numbers of cities in classes 2 and 3 increased. As shown in Table 3.5, however, the *international networkability* of all the cities belonging to class 1 decreased, whereas the *international networkability* of most of the cities belonging to classes 2 and 3 increased. This fact plainly shows that the international interactions among the cities in 1992, which were concentrated on some cities in class 1, gradually dispersed into the cities included in the lower classes, and as a result, the positions of the cities in the lower classes in the 2004 international air network became increasingly important.

Both in 1992 and 2004, class 1 had the same number of *network cities* that class 2 did (19). The *international networkability* rate of these cities, however, decreased from 91.3% in 1992 to 88.8% in 2004. This can also be interpreted in the same context as the phenomenon of the multipolarization of the international air network. The fact, however, that the *international networkability* of the *network cities* represents about 90% of the *international networkability* of all the cities of the world suggests that *network cities* perform pivotal roles as the cores and central stronghold of the international air network.

4.3 The Changes in the Connection System of the International Air Network

In this section, to explicate the changes that have transpired in the very complex multilayered structure of the international air network and to analyze the main connection systems in the whole network, the inter-city distance and positional relation in the network will be examined by supposing that each city's maximum connectivity is the nearest-neighbor distance.

First, of all the air routes that were connected to each city, the air routes with the highest degree of connectivity were selected, and the following is the formula that was used to convert the maximum connectivity (C'_{ij}) of city i to a relative distance (d_{ij}) in the international air network.

$$d_{ij} = \frac{1}{\sqrt{C'_{ij}}} \qquad (4\text{-}1)$$

This means that the higher the connectivity between two cities in the international air network is, the shorter the distance between them, which in turn indicates that the interaction between the two cities is very strong. In this study, to compare the connection systems in 1992 and 2004, the shortest line in the findings was changed to 1, and the relative distances of the other lines were calculated on the basis of the unit drawn from the shortest line.

Unlike geographic locations or distances, the relative distances among cities indicate their relative spatial relationships in the international air network. A relative space can be defined as a relative connection determined by the spatial characteristics of a city, which is described in the network as being composed of the interaction relationships among cities.

The connectivity of the international air routes explained in the previous chapter can be of help in estimating the relative connections among cities. It is difficult, however, to understand the position of an individual interaction relationship between cities in the whole structure of the network, and what functions it carries out or roles it plays. Therefore, in this chapter, the network structure will be analyzed, and the changes that have transpired in it will be examined, by considering the relative distances and location relationships among the cities in the relative space (i.e., the international air network).

Table 4.3 shows the nearest-neighbor distance of the top 25 international air routes in 1992 and 2004. In both years, the Paris-London line was the shortest one, and most cities in Europe and America had the maximum connection when their lines were connected to London. Among the top 25 air routes in both years, 21 were connected to London, which shows London's position as the highest center in the international air network in 1992 and 2004. Other than the London lines, only four lines appeared in the list: the Hong Kong-Tokyo line, the Seoul-Tokyo line, the Bangkok-Hong Kong line, and the Kuala Lumpur-Singapore line. This same tendency appeared in 2004, when 22 of the top 25 air routes were London lines. Other than these lines, only three air routes were left: the Bangkok-Singapore line, the Seoul-Tokyo line, and the Kuala Lumpur-Singapore line.

Based on this calculation, Figures 4.6 and 4.7 show the nearest-neighbor distance of each city, and in the case of the classes of cities and lines, the results of the previously explained hierarchy analysis were used. The cities belonging to class 4 and above, and the lines belonging

Table 4.3 Top 25 international air routes in terms of the nearest-neighbor distance

Rank	1992 International Air Routes		1992 Network Distance	2004 International Air Routes		2004 Network Distance
1	Paris	－London	1.000	Paris	－London	1.000
2	New York	－London	1.731	Amsterdam	－London	1.111
3	Frankfurt	－London	1.774	New York	－London	1.156
4	Amsterdam	－London	1.971	Frankfurt	－London	1.381
5	Tokyo	－London	2.826	Madrid	－London	2.070
6	Zurich	－London	3.255	Singapore	－London	2.354
7	Los Angeles	－London	3.539	Hong Kong	－London	2.600
8	Rome	－London	3.666	Dubai	－London	2.623
9	Brussels	－London	3.779	Los Angeles	－London	2.837
10	Madrid	－London	4.418	Tokyo	－London	2.865
11	Miami	－London	4.424	Barcelona	－London	3.087
12	Hong Kong	－Tokyo	4.437	Toronto	－London	3.290
13	Singapore	－London	4.755	Bangkok	－Singapore	3.305
14	Milan	－London	5.010	Munich	－London	3.334
15	Seoul	－Tokyo	5.405	Chicago	－London	3.378
16	Copenhagen	－London	5.506	Zurich	－London	3.462
17	Vienna	－London	6.244	Copenhagen	－London	3.588
18	Geneva	－London	6.261	Seoul	－Tokyo	3.602
19	Bangkok	－Hong Kong	6.513	Miami	－London	4.150
20	Munich	－London	6.545	Prague	－London	4.665
21	Dublin	－London	7.253	Stockholm	－London	4.717
22	Chicago	－London	7.697	Athens	－London	5.199
23	Kuala Lumpur	－Singapore	7.715	San Francisco	－London	5.269
24	Athens	－London	8.098	Kuala Lumpur	－Singapore	5.334
25	Stockholm	－London	8.299	Vienna	－London	5.652

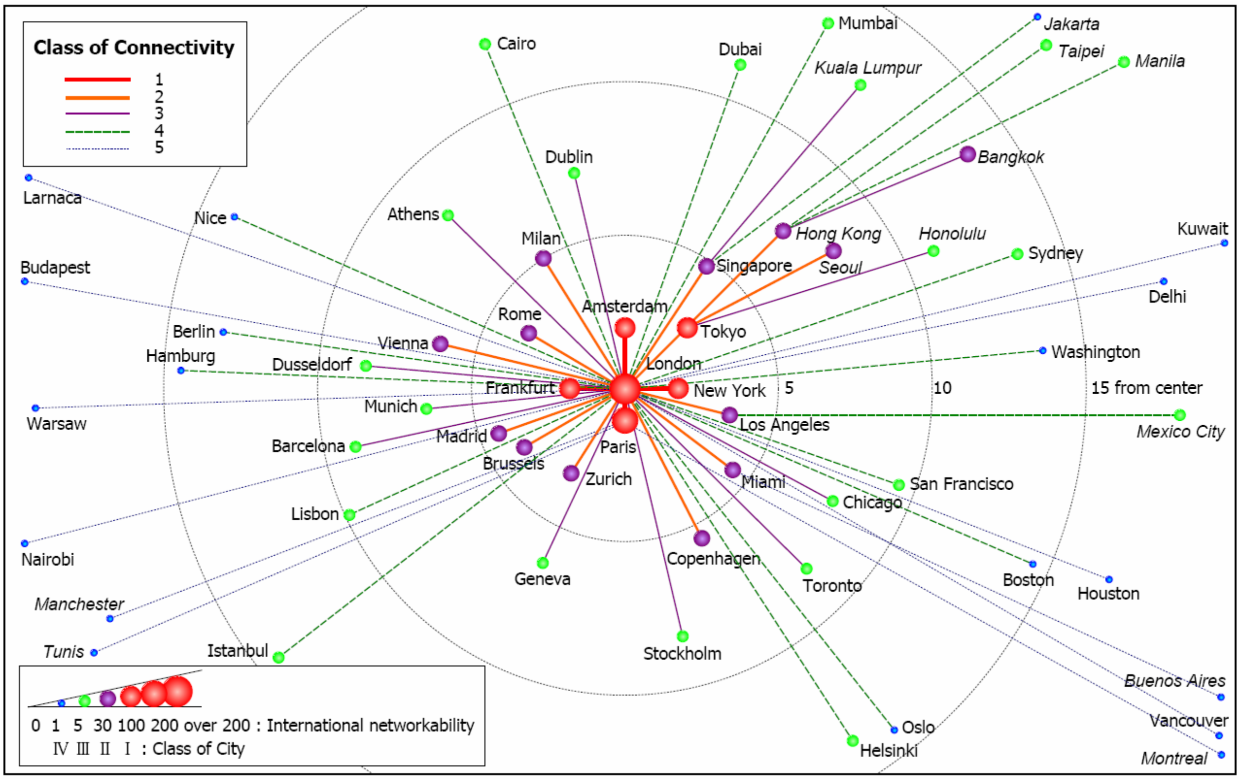

Figure 4.6 The nearest-neighbor distance of the international air network in 1992

* *Note*: The cities in italic were allocated by distance not from center in network but from the lower ranked cities.

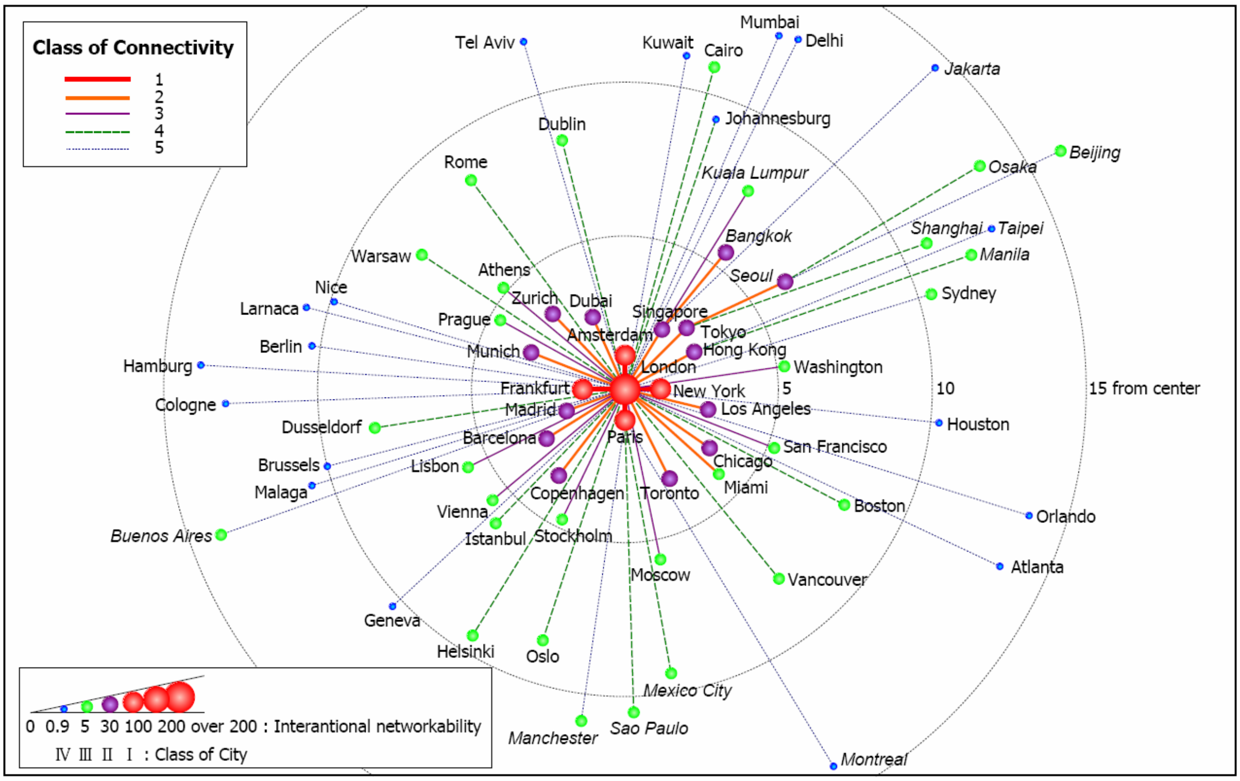

Figure 4.7 The nearest-neighbor distance of the international air network in 2004

* *Note*: The cities in italic were allocated by distance not from center in network but from the lower ranked cities.

to class 5 and above, were shown in diagrams, and the class 1 cities were divided into three levels on the basis of their *international networkability*.

London, which had the highest *international networkability* and routes of the nearest-neighbor distance, was considered the central point, and using the distance from the central point as the standard coordinate, the nearest-neighbor distance to other cities was identified. In the figures, the Asian cities are mostly situated at the top-right side, and the American cities at the bottom-right side. Most of the European cities are situated left of London. This arrangement was done by considering the connection patterns among those cities with their own subconnection systems.

In both years, the central part of the international air network was formed around London through connections to Paris, New York, Amsterdam, and Frankfurt, and most cities were connected to London. The examination of the backgrounds against which London became the center of the international air network revealed that London has five international airports. While the Heathrow and Gatwick airports chiefly provide regular air route services, the Stansted, Luton, and City airports mostly provide chartered-flight services, although they also have regular air route services.

All international airports are located at most within one hour's distance from the center, via the London subway, and serve hub function connecting America with Europe, in the middle (i.e., the trans-Atlantic route and the intra-European system). Major European business centers are located within two hours' distance from London by airplane. London connects 250 cities around the world with one another every day. Moreover, 25 million tourists visit London every year, and among these, 13 million come from abroad (Homepage of the City of London <www.london.gov.uk>, 2006). London possesses international competitiveness as it is the center of the international traffic, thanks to its strategic location.

On the other hand, the Asian cities form a different connection system around such cities as

Tokyo, Singapore, and Hong Kong. In the connection system of the international air network, the connection system of Asian cities has experienced the most dynamic change. In 1992, Tokyo was nearest to the center of the network, but in 2004, it was found that Singapore, Hong Kong, and Dubai were nearer to the center than Tokyo was. Moreover, as shown in Figures 5.2 and 5.3, while three subconnection systems were formed around Tokyo, Singapore, and Hong Kong in 1992, the number increased to four in 2004 as another subconnection system was formed around Seoul. This shows that the connection system of the Asian cities has become stronger.

Aside from London, Paris formed a separate connection system with the other European and American cities, and Miami and Los Angeles in 1992 and Madrid in 2004 formed separate connection systems as well in Figures 5.2 and 5.3. Thus, the cities in Europe, America, and Africa show relatively monotonous connection patterns, focusing on London or Paris, but the Asian cities created a decentralized structure, with the connection systems dispersed to Tokyo, Singapore, Hong Kong, and Seoul.

The aforementioned change in the network structure shows that as the relative distance between cities became shorter in 2004, they focused on the center of the international air network. The variation of the nearest-neighbor distance was substantial, and the city distribution of the same class was irregular, in 1992, but the variation of the nearest-neighbor distance was reduced, and the city groups in the same class were distributed from the center with relative regularity. This suggests that the interactions of various areas became stronger, and not that the international interactions between cities were concentrated on certain areas.

When these results were compared with the findings from the analysis of *international networkability* and connectivity, a decline was shown in the *international networkability* of the 1st-class *network cities*, excluding Amsterdam. Further, among the lines with the nearest-neighbor distance, the connections from Tokyo, Zurich, Rome, Brussels, and Milan to London decreased. This means that the flow of international air routes that used to be concentrated on the conventional hub cities became dispersed due to the emergence of new hub cities and international centers, and that the gap in the *international networkability* among cities decreased.

For example, the average nearest-neighbor distance between cities in 1992 was 10.7, and that in 2004 was 7.4, indicating that the inter-city distance in the network became shorter. In other words, as the interactions between cities around the world became more active, these cities' connections became stronger; and, as the difference in the interactions between cities was reduced, the connection system of the global network became compact.

This illustrates what is called a shrinking world, which Allen and Hamnett (1995) considered one of the characteristics of the era of globalization. According to them, supersonic transport has become widespread by virtue of the developments in science and technology. Accordingly, the world's citizens interact not only with domestic cities but also with the whole world; hence, the term global village. They also argued that not only human and material resources are globally exchanged but information as well, and that this tendency has become increasingly prevalent.

In sum, this section showed that the relative distances between the cities in the international passenger air network have been reduced. This means that the spatial distance between the cities has become easy to overcome, and that the functional interdependency and integration of the cities have increased by leaps and bounds. It also implies that the interconnectivity between regions has expanded.

Chapter Five

Global Networkability and Regional Networkability of Cities in the International Air Network

5.1 The Connection Structure of Subnetworks

The analysis of the international air network structure revealed that the subnetworks were connected around those *network cities* with a high networkability, and that the subnetworks with a high connectivity are forming their own flow patterns, using each continent as a local base. In this section, how the subnetworks of the international air network are formed, and the connection between each subnetwork, will be examined. In other words, whereas in the previous section, how cities are connected in the international air network was analyzed, in this section, an analysis of the connections among subnetworks will be conducted. The purpose for this is to pave the way for an understanding of the structure of the whole network by analyzing the connection patterns that indicate all the elements of the international air network.

Figure 5.1 shows, via a map, the connection patterns of the 2004 international air network that was examined in Figure 4.4. It indicates the *international networkability* of only the cities

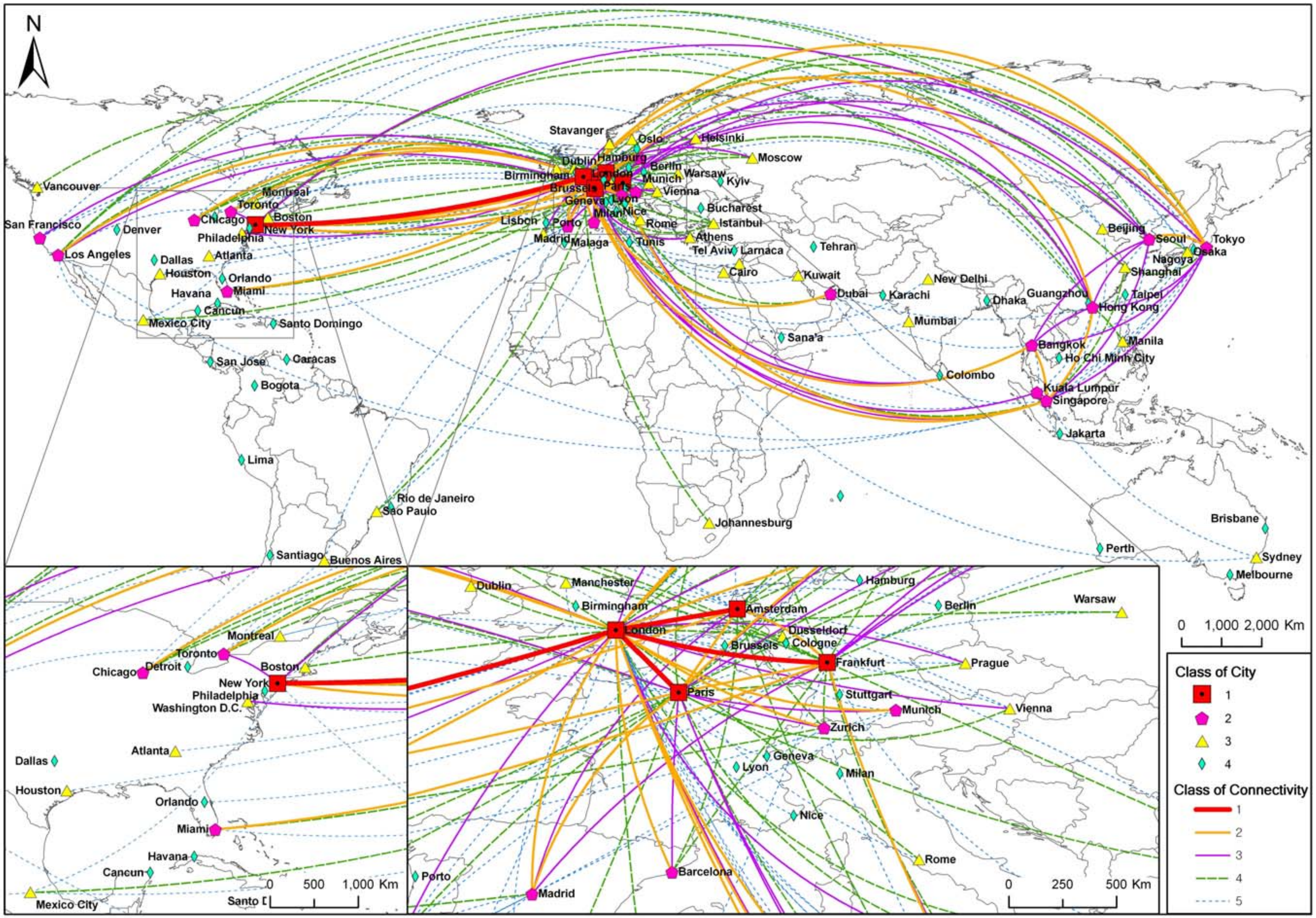

Figure 5.1 The flow pattern of the international air passenger in 2004

belonging to class 4 and higher, and the connectivity of the international air routes, particularly those belonging to class 5 and higher. As demonstrated in the figure, the major connection patterns of the international air network are concentrated on Europe, North America, and East Asia, and the subnetworks are likewise formed around these regions.

The East Asian subnetwork has been shaped around Tokyo, Seoul, Hong Kong, Bangkok, and Singapore. Centering on these cities, it assumes a pattern connected to the cities in other continents. Europe has formed its subnetwork around London, Paris, Frankfurt, and Amsterdam. In the case of America, its connection pattern appears to be different from those of Europe and East Asia. The American subnetwork, which consists only of the cities on the continent, has been weakly formed. North American cities, however, have developed connections with a number of European and East Asian cities. African cities have not formed specific subnetworks, and most of them excluding some cities show remarkably weak connection relations with other African cities which are geographically close to them.

Based on the results of cities' connection pattern analysis in the international air network, the subnetworks that are formed by using each continent as its spatial base classify cities into four regions: Europe, America, Africa, and Asia & Oceania. To pave the way for an understanding of the structure of the whole network, the scopes of the subnetworks were maximized in this study, based on the connections with a high-connectivity city. Besides, the international air routes can be divided into those with an intraregional flow, which connects cities in the same region, and those with an inter-region flow, which connects cities in different regions.

In this study, the international air network was first divided into four regions, and then the connections between these regions were examined. Table 5.1 shows the connectivity among the subnetworks, and the changes that have transpired in it. The 1st-class and 2nd-class *network cities* are separated from the subnetworks. As mentioned above, this was done to determine the kind of connections that these *network cities* have with each subnetwork, as the *international*

Table 5.1 The changes in connectivity between subnetworks in 1992-2004

Subnetwork Connection	Connectivity between Subnetworks		
	1992 (A)	2004 (B)	Change (B−A)
within 1st class *network cities*	223.86	158.12	-65.73
F − S・Europe	74.30	46.17	-28.13
F − S・Asia	27.03	53.60	26.57
F − S・America	18.20	20.32	2.12
F − Europe	29.55	33.70	4.15
F − Asia	9.31	8.48	-0.82
F − America	13.61	15.92	2.31
F − Africa	2.55	1.85	-0.70
within S・Europe	4.30	1.16	-3.14
within S・Asia	6.69	20.50	13.81
within S・America	0.00	0.61	0.61
S・Europe − S・Asia	1.67	1.18	-0.48
S・Europe − S・America	0.50	0.10	-0.39
S・Asia − S・America	1.20	3.60	2.40
S・Europe − Europe	4.29	2.85	-1.44
S・Europe − Asia	0.23	0.11	-0.12
S・Europe − America	0.99	1.19	0.20
S・Europe − Africa	0.36	0.06	-0.31
S・Asia − Europe	0.14	0.70	0.56
S・Asia − Asia	6.72	12.65	5.94
S・Asia − America	0.34	1.18	0.84
S・Asia − Africa	0.02	0.12	0.10
S・America − Europe	0.03	0.09	0.06
S・America − Asia	0.49	0.62	0.13
S・America − America	1.79	1.34	-0.45
S・America − Africa	0.00	0.00	0.00
within Europe	0.50	0.81	0.31
within Asia	0.86	0.79	-0.07
within America	0.57	1.38	0.81
within Africa	0.01	0.00	-0.01
Europe − Asia	0.02	0.13	0.11
Europe − America	0.06	0.04	-0.02
Europe − Africa	0.09	0.04	-0.05
Asia − America	0.07	0.13	0.06
Asia − Africa	0.14	0.03	-0.11
America − Africa	0.00	0.00	0.00

* F: 1st-class *network cities*, S・Europe: 2nd-class *network cities* of Europe
* Asia: other cities in Asia & Oceania except *network cities.*

networkability of the *network cities* in classes 1 and 2 amounts to 90% of the international air network in both years, as shown in Figure 4.5. That is, this means that the flow patterns of these *network cities* can be explained about 90% of international air flow pattern. Therefore, from this chapter, it will be focused on the analyses of flow pattern of *network cities* to examine the structure of the international air network.

As aforementioned in previous chapter, the flow patterns of the 1st-class *network cities* are the inter-regional interactions on a global scale, while the geographic range of the international interactions of the 2nd-class *network cities* was limited to certain continents or regions. Also, the 1st-class *network cities* are classified into the same group because they have very strong connections with one another. The 2nd-class *network cities*, on the other hand, are subdivided into the *network cities* in Europe, America, and Asia & Oceania because they have strong connections with the other cities in the same continent where they are located. Therefore, in Table 5.1, each subnetwork in Europe, America, and Asia & Oceania pertains to the cities in the same region other than the *network cities*. After all, the subnetworks include eight networks made up of the 1st-class *network cities*; the 2nd-class *network cities* of Europe, Asia, and America; and the European, Asian, American, and African cities, except the 1st-class and 2nd-class *network cities*.

The connectivity between subnetworks can be calculated by adding up the connectivities between the cities included in each subnetwork. For example, the connectivity of F－S・Europe in 1992, 74.30, as shown in Table 5.1, means the sum of all the air routes' connectivities between the 1st-class *network cities* and the 2nd-class *network cities* of Europe. So, the flow patterns of all cities were analyzed per subnetwork, and then based on this analysis, the connectivity between subnetworks was calculated.

In the connections among the subnetworks in 1992, the subnetwork of the 1st-class *network cities* was 223.86, which was the highest. As shown in Table 5.1, F－S・Europe ranked second

(74.30), followed by F－Europe (29.55), F－S・Asia (27.03), and F－S・America (18.20). Generally speaking, the connections between the 2nd-class *network cities* and the European cities had a high connectivity. In 1992, taking into account the fact that there were many European cities among the 1st-class *network cities*, it can be concluded that Europe was the center of the international air network.

In 2004, the subnetwork of the 1st-class *network cities* had the highest connectivity (158.12). Moreover, F－S・Asia, F－S・Europe, F－Europe, within S・Asia, and F－S・America had high connectivity (53.60, 46.17, 33.70, 20.50, and 20.32, respectively). Compared to 1992, there are remarkable increases in the connectivity related to Asia. The examination of the changes in connectivity described in Table 5.1 revealed that the subnetworks related to Asia, such as F－S・Asia (26.57), within S・Asia (13.81), and S・Asia－Asia (5.94), had the highest increases in connectivity. The positions of Asian cities rose not only in terms of the connection system of the cities examined in the previous section but also in terms of the connection system of the subnetworks.

On the other hand, the connections related to Europe, such as within the 1st-class *network cities* (-65.73), F－S・Europe (-28.13), and within S・Europe (-3.14), showed a large decrease in connectivity. The numerical value of connectivity is a relative value expressing a city's position in the network. Therefore, it is not right to say that a decrease in connectivity necessarily means a similar decrease in the interactions between European cities. It only means that the positions of the European cities that were included in the international air network of 1992 fell relatively sharply in 2004. The biggest reason for this is the fact that the positions of the Asian cities rose by a relatively large margin. The second biggest reason is the fact that the positions of some European cities in the international air network fell by a great margin, as shown in the analyses of *international networkability* and connectivity that were carried out in the previous section.

The connections of the subnetworks related to America show that the connectivity had an overall increase by a small margin, compared to the connectivity in 1992. The connections with America, however, have generally been decreasing, and the connectivity between the subnetworks is so low that it is almost impossible to identify the characteristics of the connection system.

Figures 5.2 and 5.3 show mimetic diagrams illustrating the connections of the aforementioned subnetworks in Table 5.1. The connections between the eight subnetworks are identified. In the figures, the boldface number in the parenthesis refers to the *international networkability* sum of the cities in each subnetwork, and the other number in the parenthesis indicates the connectivity within the network. The thickness of the line indicates the size of the connectivity (there are three classes in all based on this). In the Figures 5.2 and 5.3, the colors of the lines which indicate relationship between subnetworks, and of the figures (i.e., circle and square) standing for each subnetwork mean the degree of connectivity: for example, the lines and figures of red color means the over 10 connectivity, that of blue the 1.0 to 10 connectivity, and that of black the 0.1 to 1.0 connectivity. And, the relations between subnetworks of under 0.1 connectivity were not indicated in the diagram. In figures, the boldface number in the parenthesis is the sum of the *international networkability* of the cities in each subnetwork, and the other number in the parenthesis as well as the number on the connection line refers to the connectivity between the subnetworks.

As mentioned above, both in 1992 and 2004, the 1st-class *network cities* (London, New York, Paris, Frankfurt, and Amsterdam) had very high connectivity, and those of the 2nd-class *network cities* in each continent were comparatively high. Besides, not only the flight's connectivity was much higher than the *international networkability* of the cities in different continents but the *international networkability* of the *network cities* in each group as well. In other words, the four subnetworks composed of these *network cities* formed the center of the

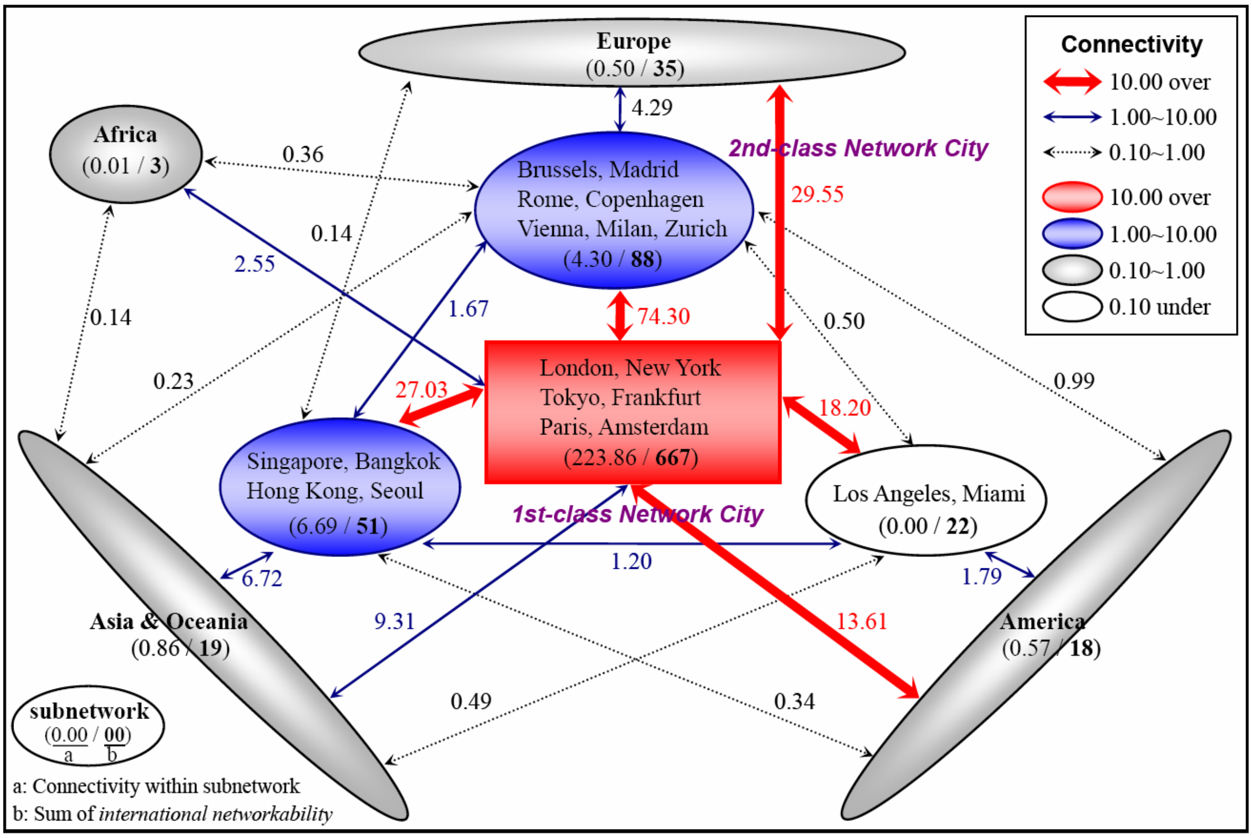

Figure 5.2 The flow pattern of the subnetworks in 1992

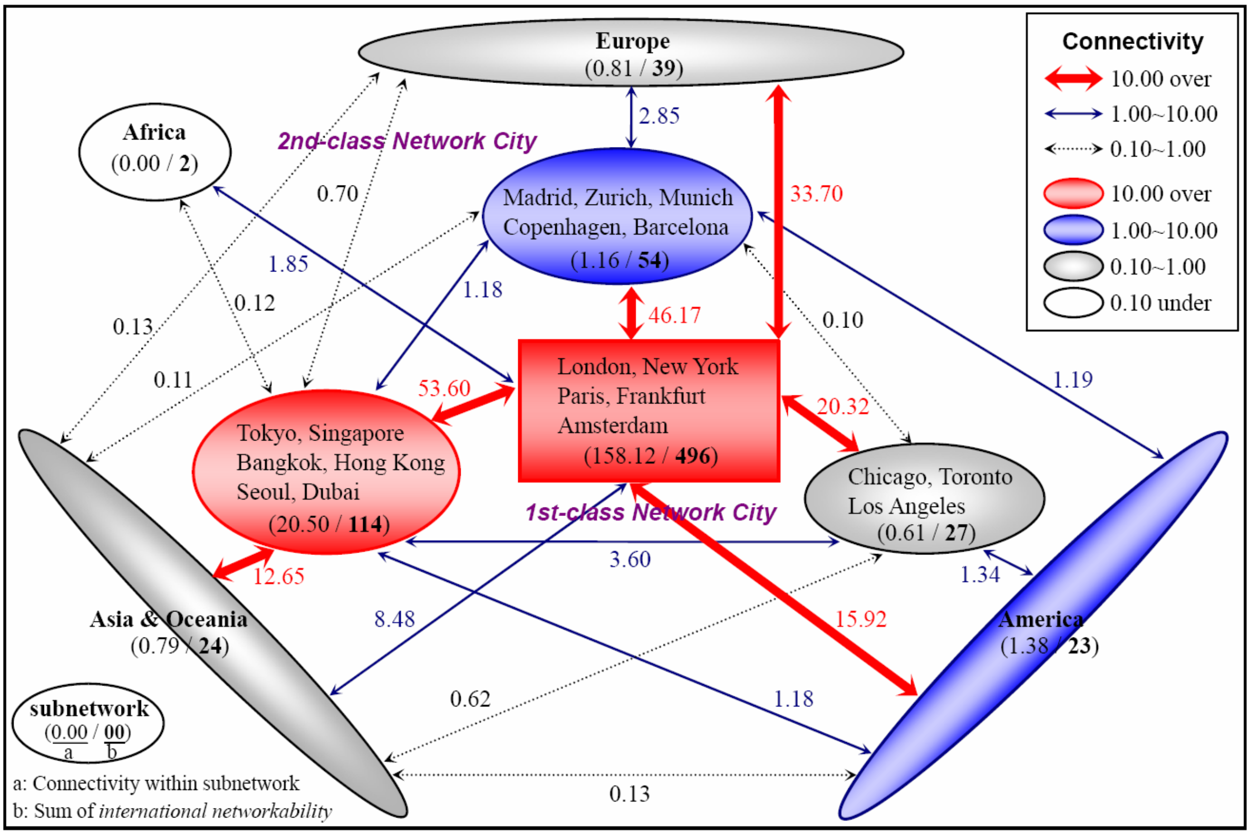

Figure 5.3 The flow pattern of the subnetworks in 2004

international air network, and each continent's subnetwork (made up of cities other these *network cities*) was located at the outer side of the international air network.

The comparison of the two figures revealed that the biggest difference between the two was that the subnetwork of the 2nd-class *network cities* in Asia grew whereas that of the 2nd-class *network cities* in Europe declined. Almost all the connections related to the subnetwork of the 2nd-class *network cities* in Asia increased two times compared to the connectivity in 1992. The number of cities included in this subnetwork also increased from 4 to 6.

On the other hand, almost all the connections related to the subnetwork of the 2nd-class *network cities* in Europe decreased by a great margin compared to the connectivity in 1992. The number of cities included in this subnetwork also decreased from 7 to 5 in 2004. Besides, the *international networkability* of these cities fell from 88 in 1992 to 54 in 2004. These figures conclusively demonstrate the changes that occurred in the connection structure between subnetworks, or the structural changes that occurred in the international air network.

The central axis of the global network is showing a tendency to move from a connection with European cities to a connection with Asian cities. Of course, the center of the international air network is occupied by the 1st-class *network cities*, and all the connections with the subnetworks composed of these *network cities* have high connectivity. The consideration of the changes that have transpired in the connections between subnetworks, however, shows that the positions of the Asian *network cities* are rising sharply.

To sum up, the *network cities* are the core of the international air network, and the 1st-class *network cities* are connected to the 2nd-class *network cities*, which serve as hubs in each continent, putting the whole world together into one network. This international air network creates multilayered networks, and it was shown herein that the international interactions between cities became closer and centered on the *network cities* by 2004. Moreover, the main subnetworks of the international air network are forming flow patterns, using each continent as their local base. While the European subnetwork occupied a very high position in the 1992 international air network, the Asian subnetwork had a very high position in the 2004 international air network.

5.2 The Analyses of Global Networkability and Regional Networkability of Cities

Based on the results mentioned above on the structure of the international air network, connection relations between subnetworks, and flow patterns of *network cities*, in this section, the flow pattern of each city by continent was examined. If the flow pattern of each city, by continent, were to be considered based on the connection structure of these subnetworks, it could be determined which city has a global hub function or whether a city could perform a local hub function limited to a certain continent. Therefore, in this section, the flow pattern of each city will be analyzed, and the functional characteristics of each city in the international air network will be examined.

The *international networkability* of the cities that have thus far been analyzed in this study resulted from the measurement of the position that each city occupies in the international air network, without considering what characterizes the flow pattern of each city. Through an analysis of the flow pattern of each city (by continent) in this section, the differences between the functions of each city in the international air network will be examined. The networkabilities of each city will also be measured by classifying the international air routes of each city into those connected to the other cities in the same continent and those connected to the cities in other continents.

For this purpose, the networkability that is determined in relation to the connections between the other cities in the same continent is regarded as the *regional networkability*, and the networkability that is determined in relation to the connections between cities in other continents is regarded as the *global networkability*. The formulae that were used to measure each networkability are the same as those that were used to measure *international networkability*. That is, the *international networkability* of each city in the international air passenger network can be divided into *regional networkability* and *global networkability* according to its connections, and can be separately explained. In other words, the *international networkability* of a city can be said to be the sum of its *global networkability* and its *regional networkability*.

5.2.1 Cities' Regional Networkability by Continent

Table 5.2 shows cities' *regional networkability* in each continent, in 1992. First, according to the results of the analysis of the *regional networkability*, London had the highest *regional networkability* (187.2) in the international air network. Paris ranked second (126.9), followed by Frankfurt (37.2), Amsterdam (37.2), Zurich (17.4), and Rome (16.9). In other words, in the analysis of the *international networkability* of cities in 1992, the European cities were found to have high numerical values because they very actively interacted with one another within Europe, which was clearly demonstrated in the analysis of *regional networkability*.

Regional networkability means the networkability of each city in its own continent. For example, the *regional networkability* of Paris refers to the networkability of Paris in Europe, and the *regional networkability* of Tokyo indicates the networkability of Tokyo in Asia. As shown in Table 5.2, the *regional networkability* of each continent expresses the connectivity with the cities in that continent. For instance, the fact that New York had a networkability of 56.5 in Europe in 1992, means that the connectivity between New York and the European cities in that year was valued at 56.5.

After considering the cities with a high *regional networkability* in each continent in 1992, it

Table 5.2 *Regional networkability* by continent based on the international air flow in 1992

Rank	City	Regional Networkability	City	Networkability in Europe	City	Networkability in America	City	Networkability in Asia & Oceania	City	Networkability in Africa
1	London	187.2	London	187.2	London	46.5	London	20.6	London	1.017
2	Paris	126.9	Paris	126.9	Paris	14.3	Tokyo	15.8	Paris	0.916
3	Frankfurt	52.5	New York	56.5	Frankfurt	10.9	Hong Kong	11.2	Frankfurt	0.402
4	Amsterdam	37.2	Frankfurt	52.5	Tokyo	6.4	Singapore	10.0	Rome	0.244
5	Zurich	17.4	Amsterdam	37.2	Amsterdam	3.8	Paris	8.6	Amsterdam	0.104
6	Rome	16.9	Tokyo	20.2	Rome	2.5	Frankfurt	7.9	New York	0.074
7	Tokyo	15.8	Zurich	17.4	New York	1.6	Bangkok	6.5	Zurich	0.067
8	Hong Kong	11.2	Rome	16.9	Zurich	1.5	Seoul	4.8	Jeddah	0.050
9	Brussels	10.6	Brussels	10.6	Madrid	1.5	Los Angeles	4.0	Kuwait	0.044
10	Madrid	10.5	Madrid	10.5	Mexico city	1.1	New York	3.6	Athens	0.039
11	Singapore	10.0	Los Angeles	10.2	Miami	1.1	Kuala Lumpur	2.1	Tokyo	0.033
12	Milan	9.3	Milan	9.3	Seoul	1.0	Taipei	2.0	Madrid	0.025
13	Copenhagen	6.8	Copenhagen	6.8	Sydney	0.9	Amsterdam	1.7	Dubai	0.024
14	Bangkok	6.5	Singapore	6.7	Toronto	0.8	Manila	1.6	Vienna	0.016
15	Vienna	5.6	Miami	6.3	Washington	0.8	Honolulu	1.4	Geneva	0.015
16	Seoul	4.8	Vienna	5.6	Brussels	0.8	Rome	1.2	Bangkok	0.011
17	Geneva	4.3	Bangkok	4.9	Milan	0.8	Zurich	1.0	Istanbul	0.010
18	Munich	3.8	Geneva	4.3	Los Angeles	0.7	San Francisco	0.8	Munich	0.009
19	Athens	3.4	Munich	3.8	Hong Kong	0.6	Copenhagen	0.8	Barcelona	0.009
20	Stockholm	2.7	Athens	3.4	Buenos Aires	0.4	Jakarta	0.7	Brussels	0.008
21	Barcelona	2.6	Chicago	3.0	Singapore	0.3	Osaka	0.5	Cairo	0.006
22	Lisbon	2.2	Hong Kong	2.8	Vienna	0.3	Sydney	0.5	Singapore	0.006
23	Kuala Lumpur	2.1	Stockholm	2.7	Munich	0.3	Auckland	0.3	Mumbai	0.006
24	Taipei	2.0	Barcelona	2.6	Rio de Janeiro	0.3	Chicago	0.3	Damascus	0.005
25	Dusseldorf	2.0	Toronto	2.2	Caracas	0.2	Dubai	0.3	Karachi	0.005

was confirmed that London and Paris had a very high networkability in Europe in that year, and that New York, Frankfurt, Amsterdam, and Tokyo also had high networkabilities (56.5, 52.5, 37.2, and 20.2, respectively). That is, if only the European networks were to be considered, it would be concluded that London and Paris were forming a polarized system in 1992, and that cities such as New York, Frankfurt, and Amsterdam served as secondary centers in that year. Basically, *Regional networkability* means the networkability of each city in its own continent. The *regional networkability* of Tokyo in the network of Europe, 20.2, however, means that the connection relationship between European cities and Tokyo is 20.2, though the *regional networkability* of Tokyo basically indicates the networkability with Asian cities. In other words, *regional networkability* can be viewed from two points: the viewpoint of each continent and of a city.

In the case of America, it was also London that had the highest networkability in 1992 (46.5). Paris ranked second (14.3), followed by Frankfurt (10.9), Tokyo (6.4), and Amsterdam (3.8). This was because the analysis included only the international air routes in those cities that had a higher networkability; New York, whose networkability was relatively low, was not included in the analysis. Moreover, in America, the international air traffic was dispersed in several cities. As such, there is a strong possibility that the flows from Asia were concentrated around the cities in the west, that those from Latin America were concentrated around the cities in the south, and that those from Europe were concentrated around the cities in the east. On the contrary, in most countries, the international air traffic was concentrated around the capital city or the primary center. Due to the differences between the flow patterns, the networkability of New York in the international air passenger network in 1992 turned out to be lower than what most people think is the position or networkability of New York.

In the case of the networkability in Asia & Oceania in 1992, London had the highest value (20.6). Tokyo ranked second (15.8), followed by Hong Kong (11.2), Singapore (10.0), Paris (8.6), and Frankfurt (7.9). Unlike the 1992 European network, the 1992 Asian network was shaped in the form of a tripolarized system around Tokyo, Hong Kong, and Singapore.

Lastly, in the case of Africa, it was also London that had the highest networkability in 1992 (1.017). Paris ranked second (0.916), followed by Frankfurt (0.404), Rome (0.244), and Amsterdam (0.104). As shown in Table 5.2, among the African cities, only Cairo was ranked in the top 25 cities. It was found out that the connection relationship with African cities are very low, compared to other continents. As examined in the connection structure between subnetworks, these results show that the African cities were not forming particular subnetwork in the international air network.

Both the American and Asian cities have much lower *regional networkabilities* than the European cities. This suggests that the European cities more actively interacted with one another in 1992 in terms of international air routes than the American and Asian cities did. The reason for this is that the *international networkability* of an individual city increases when all the cities constituting the subnetworks on the continental level (not on the individual level) actively interact with one another. As mentioned above, in this study, the *international networkability* of and connectivity between cities are not solely determined by their traffic and centrality but are also affected by the centrality of a connected city. For this reason, when cities in geographically neighboring countries have a low *international networkability*, the positions of these cities in the whole network are found to be low, no matter how much traffic they have with one another. This results from the characteristics of GNA.

Table 5.3 shows cities' *regional networkability* in each continent, in 2004. London had the highest *regional networkability* (138.5) in the international air network. Paris ranked second (72.7), followed by Amsterdam (48.9), Frankfurt (40.8), and Madrid (20.7) in 2004. Of the top 10 cities in terms of *regional networkability*, the European cities ranked from 1 to 5, whereas the Asian cities ranked from 6 to 10. Considering that in 1992, eight of the top 10 cities in terms of

Table 5.3 *Regional networkability* by continent based on the international air flow in 2004

Rank	City	Regional Networkability	City	Networkability in Europe	City	Networkability in America	City	Networkability in Asia & Oceania	City	Networkability in Africa
1	London	138.5	London	138.5	London	52.1	London	32.4	London	0.9297
2	Paris	72.7	Paris	72.7	Paris	14.2	Singapore	13.4	Paris	0.5098
3	Amsterdam	48.9	New York	49.4	Frankfurt	9.1	Frankfurt	11.2	Frankfurt	0.2848
4	Frankfurt	40.8	Amsterdam	48.9	Amsterdam	3.9	Paris	11.0	New York	0.0656
5	Madrid	20.7	Frankfurt	40.8	Tokyo	3.7	Bangkok	10.3	Amsterdam	0.0619
6	Singapore	13.4	Madrid	20.7	New York	2.6	Seoul	9.8	Dubai	0.0587
7	Bangkok	10.3	Singapore	12.9	Toronto	2.3	Hong Kong	9.4	Hong Kong	0.0332
8	Seoul	9.8	Tokyo	10.6	Seoul	2.2	Tokyo	9.2	Singapore	0.0302
9	Hong Kong	9.4	Hong Kong	9.3	Madrid	2.1	New York	4.1	Kuwait	0.0270
10	Tokyo	9.2	Dubai	8.1	Hong Kong	1.6	Los Angeles	3.4	Madrid	0.0266
11	Barcelona	8.1	Barcelona	8.1	Mexico City	1.3	Amsterdam	3.3	Zurich	0.0184
12	Zurich	7.3	Los Angeles	8.0	Los Angeles	1.0	Kuala Lumpur	3.0	Istanbul	0.0176
13	Copenhagen	6.7	Zurich	7.3	Miami	0.9	Osaka	2.0	Athens	0.0115
14	Munich	6.3	Bangkok	6.8	Singapore	0.8	Shanghai	2.0	Barcelona	0.0061
15	Stockholm	3.9	Copenhagen	6.7	Zurich	0.7	Dubai	1.5	Munich	0.0050
16	Moscow	3.4	Munich	6.3	Chicago	0.5	Manila	1.5	Vienna	0.0049
17	Prague	3.3	Toronto	5.7	Sao Paulo	0.5	Beijing	1.2	Moscow	0.0040
18	Lisbon	3.1	Chicago	5.6	Buenos Aires	0.4	San Francisco	0.8	Sao Paulo	0.0034
19	Kuala Lumpur	3.0	Seoul	4.0	Vancouver	0.3	Sydney	0.7	Cairo	0.0011
20	Athens	2.9	Stockholm	3.9	Copenhagen	0.3	Zurich	0.7	Larnaca	0.0011
21	Istanbul	2.9	Miami	3.6	Munich	0.3	Taipei	0.6	Tunis	0.0010
22	Vienna	2.8	Moscow	3.4	Moscow	0.2	Chicago	0.6	Johannesburg	0.0009
23	New York	2.6	Prague	3.3	Osaka	0.2	Vancouver	0.4	Lyon	0.0008
24	Toronto	2.3	Lisbon	3.1	Santiago	0.2	Jakarta	0.4	Sydney	0.0008
25	Osaka	2.0	Athens	2.9	Istanbul	0.2	Moscow	0.3	Mauritius	0.0008

regional networkability were European cities, many changes indeed occurred between 1992 and 2004. It is remarkable that among the Asian cities, Tokyo had the highest networkability in 1992 when its *regional networkability* in the same year was lower than that of Singapore, Bangkok, Seoul, and Hong Kong. This shows that changes in *regional networkability* occurred that were similar to the changes that occurred in *global networkability*.

In terms of the *regional networkability* in each continent in 1992, London had the highest networkability in Europe (138.5). Paris, New York, Amsterdam, Frankfurt, and Madrid also had high networkabilities (72.7, 49.4, 48.9, 40.8, and 20.7, respectively). Along with London, Paris formed a polarized system in the European network in 1992. The networkability of Paris in the network declined sharply, however, in 2004. As mentioned above, the biggest reason for this is that the amount of air passenger flows in the London-Paris line decreased in 2004 because of the inauguration of Eurostar. The same can be said of the *regional networkability* of London.

In America, London had the highest networkability in 1992 (52.1). Paris ranked second (14.2), followed by Frankfurt (9.1), Amsterdam (3.8), Tokyo (3.7), New York (2.6), and Toronto (2.3). Compared to the networkabilities in 1992, in the case of America, no big change happened in the networkabilities of most of the European and Asian cities, and London registered a relatively large increase in *regional networkability*. For the most part, the *regional networkability* of the American cities increased.

Compared to the *regional networkabilities* in 1992 by continent, Asia registered the biggest change in *regional networkabilities* by continent in 2004. London had the highest *regional networkability* in Asia & Oceania (32.4). Singapore ranked second (13.4), followed by Frankfurt (11.2), Paris (11.0), Bangkok (10.3), and Seoul (9.8). Compared to the 1992 networkabilities, what is most remarkable is that the networkability of Tokyo declined in 2004. In 1992, Tokyo had the highest networkability, but it declined in all the networkability items in 2004. In the Asian network, Tokyo had a lower networkability than Singapore, Bangkok, Seoul, and Hong

Kong. In the European network, it ranked lower than Singapore. Among the Asian cities, though, Tokyo had the highest networkability in the American network, but the difference between the networkability of Tokyo and that of Seoul, which ranked second, was reduced from 5.4 in 1992 to 1.5 in 2004. As mentioned above, this can be explained by saying that the networkability of Tokyo relatively decreased as the Asian network became multinucleated because of the developments that took place in Singapore, Seoul, Bangkok, and Hong Kong.

Lastly, in the case of Africa, it was also London that had the highest networkability in 2004 (0.930). Paris ranked second (0.510), followed by Frankfurt (0.285), New York (0.066), and Amsterdam (0.062). As shown in Table 5.3, among the African cities, only Cairo was ranked in the top 25 cities, which is the same result as 1992. And, the African cities were not forming particular subnetwork in the international air network, also in 2004.

The cities with a high *regional networkability* both in 1992 and 2004 were London, Paris, Amsterdam, and Frankfurt. The class with the highest *regional networkability* was that consisting of European cities. This result conclusively demonstrates that the European cities interact more actively with one another than the cities in the other continents do. A previous study on the urban system analyzed the international air routes around the world without considering the geographic characteristics of each continent. It analyzed all the air routes by lumping them together. For example, it ignored the facts that in Europe, there are many countries that have short distances between them, that there are so many islands in Asia, and that there are few countries in North America but that these countries have vast territories. In a word, it disregarded the possible influence of each continent's geographic characteristics on the international air passenger flow.

Pointing out these problems in relation to the existing international air passenger flow data, Derudder *et al.* (2005a) argued that the air passenger flow data of domestic lines should also be analyzed as this was effective in some countries, like the United States, which has a vast territory and whose domestic air routes are considerably developed. It is difficult to do this, however, in those countries with a small territory and other developed means of transportation, such as trains or buses. It is for this reason, therefore, that this study intends to identify the characteristics of each city in the international air network by carrying out an analysis of each city's flow pattern by continent.

For example, as shown in Tables 5.3 and 5.4, the comparison of the results of the analysis of *international networkability* with those of *global networkability* and *regional networkability* revealed that Amsterdam had a higher value than New York in terms of *international networkability* in 2004. But while New York ranked higher than Amsterdam in terms of *global networkability* in the same year, Amsterdam ranked much higher than New York in terms of *regional networkability*. This suggests that although Amsterdam had a higher *international networkability* than New York in the 2004 international air passenger network, the flow pattern of Amsterdam was concentrated on the European cities while that of New York had a global scale.

5.2.2 Global Networkability of Cities

Global networkability shows the connection relationship between the cities in other continents. Table 5.4 shows the *global networkability* of each city in 1992 and 2004. In 1992, London (68.1) and New York (60.2) had the highest values of *global networkability*. Tokyo ranked second (26.6), followed by Paris (23.8), Frankfurt (19.3), and Los Angeles (14.2). To put it in another way, considering only the connection on the wide-area level and not the networkability in the same continent where the network is located, the network on the global level in 1992 can be said to be a polarized system situated around London and New York. It can also be said that Tokyo, Paris, and Frankfurt served as hubs then, a role usually played by secondary centers.

Table 5.4 The top 25 cities in terms of *global networkability* in 1992-2004

Rank	1992		2004		Change in Global Networkability
	City	Global Networkability	City	Global Networkability	
1	London	68.1	London	85.4	17.29
2	New York	60.2	New York	53.6	-6.57
3	Tokyo	26.6	Paris	25.7	1.91
4	Paris	23.8	Frankfurt	20.6	1.34
5	Frankfurt	19.3	Tokyo	14.3	-12.28
6	Los Angeles	14.2	Singapore	13.7	6.66
7	Singapore	7.1	Los Angeles	11.3	-2.86
8	Miami	6.3	Hong Kong	11.0	7.63
9	Amsterdam	5.6	Dubai	8.3	7.31
10	Bangkok	5.1	Amsterdam	7.3	1.70
11	Rome	3.9	Bangkok	6.9	1.84
12	Hong Kong	3.3	Chicago	6.2	2.91
13	Chicago	3.3	Seoul	6.2	3.65
14	Zurich	2.6	Toronto	5.9	3.64
15	Seoul	2.5	Miami	3.6	-2.69
16	Toronto	2.3	San Francisco	3.1	0.85
17	San Francisco	2.2	Madrid	2.2	0.49
18	Cairo	1.9	Washington	2.1	2.09
19	Madrid	1.7	Kuala Lumpur	1.8	1.00
20	Sydney	1.6	Beijing	1.5	1.48
21	Brussels	1.0	Zurich	1.4	-1.19
22	Dubai	1.0	Sao Paulo	1.3	0.89
23	Kuala Lumpur	0.8	Shanghai	1.2	1.21
24	Copenhagen	0.8	Vancouver	1.0	0.63
25	Milan	0.8	Cairo	1.0	-0.87

The results of the analysis of *global networkability* are different from aforementioned those of *international networkability* shown in Table 3.5. In the analysis of the *international networkability* of cities in 1992, in which the differences between the flow patterns of the cities were not considered, London ranked first, followed by Paris, Frankfurt, New York, Amsterdam, and Tokyo. Moreover, there were 15 European cities among the top 25 cities in terms of *international networkability*, which demonstrated that Europe was the center of the international air network in 1992. In the analysis of *global networkability*, however, the number of European cities was reduced to 10, and instead, other cities figured among the top 25 cities. This helps in identifying those cities that function as wide-area hubs in each continent. For example, it was London that had the highest *global networkability* in Europe in 1992. Likewise, New York had the highest *global networkability* in America in that year, Tokyo in Asia, and Cairo in Africa.

As shown in Table 5.4, in 2004, London had the highest *global networkability* (85.4). New York, Paris, Frankfurt, Tokyo, and Singapore also had high networkabilities (53.6, 25.7, 20.6, 14.3, and 13.7, respectively). Compared to the networkabilities in 1992, the *global networkability* of London increased by a large margin in 2004, whereas that of New York, whose networkability was high, like London's, in 1992, decreased in 2004. While the European cities in the highest class, including Paris, Frankfurt, and Amsterdam, registered an increase in *global networkability* in 2004, compared to their networkabilities in 1992, Rome, Zurich, Brussels, and Copenhagen registered a decrease in *global networkability* in 2004. The number of European cities included in the top 25 also fell: from 10 in 1992 to 6 in 2004.

The comparison of *global networkability* of each city in 1992 and 2004 showed that London had the largest increase of 17.29. Hong Kong ranked second (7.63), followed by Dubai (7.31), Singapore (6.66), Seoul (3.65), and Toronto (3.64). On the other hand, Tokyo (-12.28) significantly decreased in *global networkability*. New York ranked second (-6.57), followed by Los Angeles (-2.86), Miami (-2.69), and Zurich (-1.19).

The highest-class cities in Asia and America, such as Tokyo or Los Angeles, registered a decrease in *global networkability* in 2004. On the other hand, there was an increase in the networkability of the Asian and American cities included in the second class in terms of *global networkability*, such as Singapore, Hong Kong, Dubai, Seoul, Chicago, Toronto, and San Francisco. All these facts signify that in Europe in 2004, a global-level hub function connecting European cities with cities in the other continents was concentrated around the primary centers, such as London, Paris, and Frankfurt. On the other hand, in the case of Asia and America, a global-level hub function that used to be concentrated on Tokyo, New York, and Los Angeles dispersed in Singapore, Hong Kong, Chicago, and Toronto.

In 1992 and 2004, London had a high networkability in each item. This means that London had strong connections not only with the European cities but also with the cities in every other continent. The fact that London also had a high networkability in Asia and America in 1992 and 2004 basically implies that there is a large traffic volume and a large number of air routes between London and a number of cities in the other continents. It also implies that London has a high accessibility, or that passengers can fly to different cities in different continents via London. Accordingly, these results suggest that London plays the most prominent global hub role in the international air network. Besides London, New York, Paris, Frankfurt, and Tokyo also had very high *global networkabilities* in 1992 and 2004.

In sum, *regional networkability* expresses the connections between the cities in the same continent, and therefore refers to the local hub function in that continent. *Global networkability*, on the other hand, shows the connections between the cities in different continents and therefore pertains to these cities' wide-area hub functions on the global level. For example, the fact that a city has a high *international networkability* but a *global networkability* that is higher than its *regional networkability* means that it performs a strong hub function in a local area. On the contrary, the fact that a city has a very high *global networkability* means that it is functioning as a global hub. Therefore, the difference of these networkabilities of each city can explain the characteristics of each city's flow pattern in the international air network.

Chapter Six

The Characteristics of Network Cities in the Global Network

6.1 The Characteristics of Network Cities in the Socioeconomic Attributes

As mentioned above, the core function of international centers is connectivity with the global economy (the external economy). The external economies of cities moved the economic scale from the level of domestic centers to the level of global centers. It can be said that the international interactions between cities or regions are a necessary factor in this process. Therefore, international air routes and their related facilities, which are not only main infrastructure connecting a city with the external economy but are also outcomes of that connection, can be considered an index that symbolically indicates the position and function of that city in the spatial network of the world. Thus, in this section, the interdependency and causality that exist between networkabilities and socioeconomic attributes were analyzed, using a set of variables that describe the interaction relationships between cities and another set of variables that describe the socioeconomic attributes of cities.

Since World War II, the production of goods in the world has increased, with a recordbreaking growth rate. World trades, however, have rapidly expanded at a rate exceeding this rate of production growth. The advance of internationalization and the enlargement of interactions between cities clearly characterize the contemporary world economy. As the integration of national economies into a world economy increases, the difference between trade and production becomes larger and larger (Dicken, 1998). The growth of world trades involves spatial interactions between regions in whatever form they may take.

The international passenger air traffic can be considered a means and form of these aforementioned spatial interactions. In relation to this view, Ullman (1954) once identified the relationship between traffic and a region, arguing that "the traffic is an indicator of the relationship between regions and is therefore an essential part of geography." He also argued that "the economic relationships or connections between regions are reflected in the characteristics of the traffic facilities or traffic flow." Therefore, the identification of the relationships between regions to examine how a spatial interaction in the international air network (i.e., human transportation by international air traffic) correlates with the socioeconomic attributes of cities can be considered a positive method.

For the purpose of carrying out this correlation analysis, a database separate from the international air passenger flow data that have thus far been used in this study was first constructed in this section. Among the about 400 cities that were examined in the analysis of *international networkability* that was conducted in this study, 24 cities that were selected more than once to comprise the 1st-class and 2nd-class *network cities* in 1992 and 2004 were selected as objects of analysis. In other words, in this chapter, the correlation between networkability, determined on the basis of the spatial interactions between *network cities*, and the socioeconomic attributes of cities will be analyzed.

Tables 6.1 and 6.2 show the networkabilities and socioeconomic indices of the *network cities* in 1992 and 2004, respectively. They are ranked in these tables on the basis of *global*

Table 6.1 The networkabilities and socioeconomic indices of *network cities* in 1992

City	Global Networkability	Regional Networkability	International Networkability	Sales of Industrial Corporation[1]	Capital of Banks[2]	Share Trading[3]	International Meeting[4]	International Air Freight[5]	International Air Mail[5]
London	68.12	187.2**(1)**	255.4**(1)**	410**(2)**	41**(4)**	663**(2)**	191**(2)**	1,034**(5)**	67**(1)**
New York	60.15	1.6	61.8**(4)**	128**(7)**	33**(5)**	2,679**(1)**	68	1,015**(6)**	50**(4)**
Tokyo	26.59	15.8**(7)**	42.4**(6)**	825**(1)**	138**(1)**	477**(3)**	90	1,519**(1)**	66**(2)**
Paris	23.80	126.9**(2)**	150.7**(2)**	213**(3)**	72**(2)**	125**(6)**	355**(1)**	809**(8)**	30**(5)**
Frankfurt	19.26	52.5**(3)**	71.8**(3)**	54	30**(7)**	454**(4)**	40	937**(7)**	62**(3)**
Los Angeles	14.16	0.7	14.9**(10)**	48	0	*NA*	10	494	11
Singapore	7.06	10.0	17.1**(9)**	0	0	19	116**(7)**	1,148**(3)**	14
Miami	6.25	1.1	7.3	0	0	*NA*	20	203	10
Amsterdam	5.61	37.2**(4)**	42.8**(5)**	5	18**(9)**	46	103**(9)**	498	20**(7)**
Bangkok	5.10	6.5	11.6	3	0	72	60	584**(10)**	14
Rome	3.89	16.9**(6)**	20.8**(7)**	108**(8)**	15**(10)**	*NA*	89	26	14
Hong Kong	3.34	11.2**(8)**	14.5	0	0	79**(10)**	108**(8)**	1,341**(2)**	21**(6)**
Chicago	3.29	0.2	3.5	66	0	*NA*	40	484	14
Zurich	2.60	17.4**(5)**	20.0**(8)**	40	20**(8)**	118**(8)**	20	145	18**(9)**
Seoul	2.53	4.8	7.3	139**(5)**	0	116**(9)**	59	1,072**(4)**	14
Toronto	2.31	0.8	3.1	17	13	63	25	112	9
Madrid	1.69	10.5**(10)**	12.2	50	13	*NA*	87	125	12
Brussels	0.97	10.6**(9)**	11.6	35	3	10	164**(3)**	68	13
Dubai	0.97	0.3	1.3	0	0	*NA*	20	117	3
Copenhagen	0.83	6.8	7.7	0	3	22	99**(10)**	79	19
Milan	0.81	9.3	10.1	7	14	28	20	16	6
Vienna	0.40	5.6	6.0	15	0	5	163**(4)**	50	7
Munich	0.28	3.8	4.1	84	11	*NA*	58	26	4
Barcelona	0.09	2.6	2.7	0	0	*NA*	87	34	4

Source: 1. Fortune, 1993, *The Fortune Global 500*: In this study, data by city were indicated based on the addresses of the headquarters of the 500 companies that made it to the list.

2. The Banker, 1993, *The top one thousand world banks*: Data by city were indicated based on the addresses of the headquarters of the top 100 among these 1,000 banks.

3. World Federation of Exchanges, 1992: Total value of share trading includes the domestic & foreign investment funds.

4. Union of International Associations, 1992: The total number of participants should be more than 300, over 40% of which should be foreigners. More than five countries should participate in the meeting, and the meeting should be held for more than three days.

5. ICAO, 1992, *On-Flight Origin and Destination*: These data consisted only of the regular international non-stop flights of each city.

Note: * Unit used in items 1-3: billion US$; unit used in item 5: thou. Ton; *NA*: not available.

** The parenthesized number beside the name of a city indicates the city's place in the world ranking in each item.

Table 6.2 The networkabilities and socioeconomic indices of *network cities* in 2004

City	Global Networkability	Regional Networkability	International Networkability	Sales of Industrial Corporation[1]	Capital of Banks[2]	Share Trading[3]	International Meeting[4]	International Air Freight[5]	International Air Mail[5]
London	85.41	138.5**(1)**	223.9**(1)**	913**(3)**	130**(4)**	5,169**(2)**	131**(8)**	1,776**(5)**	87**(1)**
New York	53.58	2.6	56.1**(5)**	872**(4)**	170**(2)**	20,976**(1)**	94	1,389**(10)**	63**(4)**
Paris	25.71	72.7**(2)**	98.4**(2)**	1,033**(2)**	192**(1)**	1,429**(5)**	221**(1)**	1,101	38**(7)**
Frankfurt	20.60	40.8**(4)**	61.4**(3)**	136	61**(7)**	1,541**(4)**	33	1,684**(7)**	79**(2)**
Tokyo	14.31	9.2**(10)**	23.5**(7)**	1,647**(1)**	147**(3)**	3,218**(3)**	47	2,311**(2)**	74**(3)**
Singapore	13.72	13.4**(6)**	27.1**(6)**	16	7	107	156**(5)**	1,780**(4)**	21
Los Angeles	11.31	1.0	12.3	46	0	*NA*	13	955	39**(6)**
Hong Kong	11.00	9.4**(9)**	20.3**(9)**	17	0	439	58	3,088**(1)**	29**(9)**
Dubai	8.28	1.5	9.8	0	0	*NA*	23	563	7
Amsterdam	7.31	48.9**(3)**	56.2**(4)**	254	56**(8)**	911**(8)**	59	1,421**(9)**	46**(5)**
Bangkok	6.93	10.3**(7)**	17.3**(10)**	16	0	116	69	1,001	15
Chicago	6.20	0.5	6.7	87	0	*NA*	32	974	22
Seoul	6.18	9.8**(8)**	15.9	280**(8)**	8	625	109**(10)**	2,104**(3)**	29**(8)**
Toronto	5.95	2.3	8.3	118	34	651	27	231	17
Miami	3.56	0.9	4.4	0	0	*NA*	25	1,489**(8)**	2
Madrid	2.18	20.7**(5)**	22.9**(8)**	188	14	1,203**(6)**	70	118	14
Zurich	1.41	7.3	8.7	261**(10)**	49**(9)**	792**(10)**	18	247	18
Copenhagen	0.59	6.7	7.3	41	20	100	137**(7)**	94	18
Munich	0.54	6.3	6.8	388**(6)**	34	*NA*	40	143	1
Rome	0.15	1.0	1.1	159	15	*NA*	71	140	10
Barcelona	0.13	8.1	8.2	0	12	*NA*	133**(8)**	52	2
Brussels	0.08	0.6	0.7	143	48**(10)**	59	190**(3)**	580	5
Vienna	0.03	2.8	2.8	0	6	24	219**(2)**	124	8
Milan	0.01	0.1	0.2	38	37	969**(9)**	16	469	17

Source: 1. Fortune, 2005, *The Fortune Global 500*: In this study, data by city were indicated based on the addresses of the headquarters of the 500 companies that made it to the list.
2. The Banker, 2005, *The top one thousand world banks*: Data by city were indicated based on the addresses of the headquarters of the top 100 among these 1,000 banks.
3. World Federation of Exchanges, 2004: Total value of share trading includes the domestic & foreign investment funds.
4. Union of International Associations, 2004: The total number of participants should be more than 300, over 40% of which should be foreigners. More than five countries should participate in the meeting, and the meeting should be held for more than three days.
5. ICAO, 2004, *On-Flight Origin and Destination*: These data consisted only of the regular international non-stop flights of each city.

Note: * Unit used in items 1-3: billion US$; unit used in item 5: thou. Ton; *NA*: not available.
** The parenthesized number beside the name of a city indicates the city's place in the world ranking in each item.

networkability, and the parenthesized number beside the name of a city indicates the rank of that city in the top 10 world ranking. A city's *international networkability*, *global networkability*, and *regional networkability* were selected as the indices of networkability correlation. Six socioeconomic indices were selected: the sales of industrial corporations[4], the capitals of banks[5], share trading[6], the number of international meetings[7], the international air freight traffic, and the international air mail traffic[8].

As regards global cities, Sassen (1994) once defined a global city as a place on which the higher services and telecommunication facilities that are necessary for operating and managing the economic activities of the world are concentrated, and as a place in which the headquarters of multinational corporations could be found. According to Sassen, large major cities in the world have assumed these functions as the international investment and trades therein have increased, and accordingly, the related finance and service activities have come to be required. She also explained that compared to the past, when governments played the leading role in international economic transactions, the role of governments in the international economy has weakened, and instead, professional service corporations and the world market are now organizing and coordinating the operations of the world economy. Through these explanations, she conceptualized a global city. This section intends to examine the socioeconomic characteristics of *network cities* based on this viewpoint.

In the results of the comparison of the *global networkability* and *international networkability* of cities in 1992 shown in Table 6.1, the rankings of cities turned out to be different. For example, in the analysis of *international networkability*, Paris ranked second but had a higher *international networkability* compared to New York and Tokyo. New York and Tokyo, however, ranked higher than Paris in terms of *global networkability* (New York ranked second, and Tokyo third). The European cities (e.g., Amsterdam, Rome, and Zurich) generally fell in the *global networkability* ranking rather than in the *international networkability* ranking, whereas the American and Asian cities rose in the *global networkability* ranking rather than in the *international networkability* ranking. This suggests that *global networkability* can be a more objective standard when it is analyzed only in terms of the flow patterns with the cities in different continents, excluding the backgrounds and characteristics of the international air traffic, which appear to be different in each continent.

In 1992, according to the socioeconomic-attribute ranking by city, Tokyo had industrial corporation sales amounting to US$825 billion, which was the largest. London ranked second (US$410 billion), followed by Paris (US$213 billion), Osaka (US$195 billion), and Seoul (US$139 billion). A city where the headquarters of corporations with the largest sales are located has a great influence on the world economy, through its organized production, sales, and operations network. For this reason, an industrial-corporation sale was selected as a socioeconomic attribute. In 1992, Tokyo and Osaka ranked first and fourth, respectively, which shows the considerable influence of Japan on the business activities in the world economy.

In terms of the capitals of banks in 1992, Tokyo had US$138 billion, which was the largest. Paris ranked second (US$72 billion), followed by Osaka (US$49 billion), London (US$41 billion), New York (US$33 billion), Beijing (US$32 billion), and Frankfurt (US$30 billion). Along with the indices of corporations and of stock exchanges, those of banks were among the economic indices that were used to indicate the standards of a global city in a number of previous studies. These indices of banks help in estimating the degree of influence of banks on the international society, as global finance centers.

In terms of the share trading in 2004, New York had the largest amount (US$2,679 billion). London ranked second (US$663 billion), followed by Tokyo (US$477 billion), Frankfurt (US$454 billion), and Taipei (US$250 billion). The activities of multinational corporations presuppose the free international flow of capitals. The flow of capitals by share trading and the subsequent growth of the capital market serve as primary factors for the continuous growth of a region in the world economy network. Therefore, the degree of influence of the capital market on the world economy, as a global finance center, can be determined based on its size.

It should be noted that Tokyo's capital market, located in Japan, the second world economic power, has a relatively small size because the corporations therein raise their capitals using different methods. In the United States, the capital (stocks and shares) market is overwhelmingly important; in Japan, however, bank loans are relatively much more important. Accordingly, the sizes of banks should also be considered. It can thus be said that, on the contrary, the capitals of banks in New York are relatively smaller than those in Tokyo.

In terms of the number of international meetings in 1992, Paris had 355, the largest number. London ranked second (191), followed by Brussels (164), Vienna (163), Geneva (145), and Berlin (117). One of the characteristics of the present era of globalization is that international collaborations are active in various spheres, such as in politics, the economy, the society, and culture. The holding of various kinds of international meetings that are necessary for various organizations to work and to collaborate among themselves can be considered one of the main standards of *network cities*, in which international interactions are active.

In addition, the convention industry is being paid increasing attention to these days. This industry provides exclusive convention facilities, such as large conference halls with simultaneous-interpretation equipment, banquet halls, and exhibition halls, and attracts large-scale international meetings and exhibitions. It accompanies the growth of related industries, including the hotel, air, shipping, distribution, and food & beverage industries, which contributes to the economic development of the host place and its surrounding areas. In a word, it is a futuristic higher-value-added business.

In terms of the international air freight traffic in 1992, Tokyo conveyed the largest amount (1,519 thou. ton). Hong Kong ranked second (1,341 thou. ton), followed by Singapore (1,148 thou. ton), Seoul (1,072 thou. ton), and London (1,034 thou. ton). This shows that Asian cities convey large air freight traffic. In terms of international air mail traffic, London conveyed 67 thou. ton of air freight, which was the largest amount conveyed. Tokyo ranked second (66 thou. ton), followed by Frankfurt (62 thou. ton), New York (50 thou. ton), and Paris (30 thou. ton). International air mail traffic is a good standard by which a city with a hub function can be picked out. In the present era of globalization, international transport traffic, such as freight, mail, and passengers, can be a good variable to use in measuring the degree of international interactions of each city.

In the results of the comparison of the *global networkability* and *international networkability* of cities in 2004 shown in Table 6.2, a difference can be seen between the two rankings of cities. As in 1992, European cities like Amsterdam, Madrid, and Zurich generally fell in the *global networkability* ranking rather than in the *international networkability* ranking. On the other hand, American and Asian cities rose in the *global networkability* ranking rather than in the *international networkability* ranking.

In the ranking of cities by socioeconomic attributes in 2004, Tokyo ranked the highest, registering industrial-corporation sales of US$1,647 billion. Paris ranked second (US$1,033 billion), followed by London (US$913 billion), New York (US$872 billion), and Beijing (US$395 billion). In terms of capitals of banks, Paris ranked the highest (US$192 billion). New York ranked second (US$170 billion), followed by Tokyo (US$147 billion), London (US$130 billion), and Beijing (US$95 billion). This demonstrates that many changes occurred in the 2004 ranking, compared to the 1992 ranking. In terms of share trading, New York recorded US$20,976 billion, which was decisively the largest amount of shares traded. London ranked second (US$5,169 billion), followed by Tokyo (US$3,218 billion), Frankfurt (US$1,541 billion), and Paris (US$1,429 billion).

In terms of the number of international meetings in 2004, 294 meetings were held in Paris, which was the largest number of international meetings held in a city. Vienna ranked second

(245), followed by Brussels (189), Singapore (177), Barcelona (162), and Geneva (161). These results show that, as in 1992, a large number of international meetings were held in European cities in 2004. In terms of the international air freight traffic in 2004, Hong Kong recorded 3,088 thou. ton, the largest amount. Tokyo ranked second (2,311 thou. ton), followed by Seoul (2,104 thou. ton), Singapore (1,780 thou. ton), and London (1,776 thou. ton). This demonstrates that the Asian cities had a large amount of air freight in 2004. In terms of the international air mail traffic in 2004, London had the largest amount (87 thou. ton). Frankfurt ranked second (79 thou. ton), followed by Tokyo (74 thou. ton), New York (63 thou. ton), and Amsterdam (46 thou. ton).

6.2 Canonical Correlation Analysis between Networkability and Socioeconomic Attributes of the Network Cities

Based on the database containing the aforementioned data, canonical correlation analysis was conducted in this section, using SPSS, to determine the correlation between the three coefficients of *international networkability*, *global networkability*, and *regional networkability*, measured by the flow pattern of international air passengers, and the socioeconomic attributes of cities. Canonical correlation analysis is a method of seeking the linear combination called canonical coefficient or canonical vector using the correlations between the variables in a set of more than two variables, and then inferring the canonical correlation coefficient between the canonical coefficients. It is an analysis technique that is used to determine the correlations of a set of variables based on its canonical coefficient (Murayama, 1990).

As shown in Table 6.3, in the canonical correlation analysis of individual variables conducted in 1992, *global networkability* was found to have a high correlation with international

Table 6.3 Correlations between networkabilities and socioeconomic attributes in 1992-2004

Sets of Variables	1992			2004		
	Global networkability	Regional networkability	International networkability	Global networkability	Regional networkability	International networkability
Industrial-corporation sales	0.550	0.404	0.482	0.561	0.446	0.520
Capital of banks	0.501	0.405	0.468	0.660	0.541	0.623
Share trading	0.775	0.125	0.339	0.646	0.127	0.347
International meeting	0.307	0.667	0.607	0.174	0.297	0.265
International air freight	0.554	0.331	0.427	0.416	0.285	0.356
International air mail	0.814	0.597	0.713	0.764	0.625	0.720

air mail traffic (0.81) and share trading (0.78). It also had a slightly high correlation with international air freight traffic (0.55), industrial-corporation sales (0.55), and capitals of banks (0.50). *Regional networkability* had a relatively high positive (+) correlation with the number of international meetings (0.67) and international air mail traffic (0.60). *International networkability* also had a high positive correlation with international air mail traffic (0.71) and the number of international meetings (0.61).

In other words, in 1992, *regional networkability* and *international networkability* had similar patterns of correlation to socioeconomic attributes, but *global networkability* had a different pattern of correlation thereto. The index of international air mail traffic had a high correlation with all the three indices of networkability indicating the international air passenger flow pattern of cities. On the other hand, international air freight traffic had a slightly high correlation only with *global networkability*. This suggests that passenger, mail, and freight traffic had different flow patterns, although the international air traffic was used in each case. Especially, the international air freight flow[9] is closely connected with the industrial structure of the corresponding area. When freight is transported by international air traffic, it consists mostly of lightweight and higher-value-added goods due to the expensive freight charges. Accordingly, those Asian countries that produce many goods related to the IT industry currently have large international air freight traffics (Lee, 2004).

As shown in Table 6.3, the 2004 canonical correlation analysis produced similar results. In the canonical correlation analysis of individual variables in 2004, *global networkability* was found to have a high correlation with international air mail traffic (0.76), capitals of banks (0.66), share trading (0.65), and industrial-corporation sales (0.56). *Regional networkability* had a relatively high positive (+) correlation with international air mail traffic (0.63) and capitals of banks (0.54), while *international networkability* had a high positive correlation with international air mail traffic (0.72), capitals of banks (0.62), and industrial-corporation sales (0.52).

The biggest difference, however, between the 1992 and 2004 results is that there was a change in 2004 in the correlation not only between the networkability variables and capitals of banks but also between the networkability variables and the number of international meetings. In 1992, the number of international meetings had a high correlation with both *regional networkability* and *international networkability*, whereas in 2004, it had a low correlation with all the networkability variables. On the contrary, capitals of banks had a slightly high correlation with *global networkability* in 1992, whereas it had a high correlation with all the networkability variables in 2004.

In short, each networkability index referring to the flow of people had a high correlation not only with indices like capitals of banks, industrial-corporation sales, and share trading, which indicate the flow of capital, but also with the index of international air mail traffic, which expresses the flow of information. This clearly demonstrates that the *network cities* not only perform a hub function in the international air passenger network but also serve as global centers of capital and information on the basis of their *international networkability*.

As shown in Table 6.4, because three variables were included in the set of networkability variables, finally, three canonical vectors were calculated both in 1992 and 2004. The canonical vector III, however, was not significant at the significance level of 0.05 both in 1992 and in 2004. Therefore, the canonical vectors I and II are considered significant in this study, both of which were significant at the significance level of 0.01.

As shown in Table 6.4, in terms of the canonical vector I in 1992, *global networkability* (0.821) was selected from among the networkability variables, and share trading (0.954) and international air mail traffic (0.639) from among the urban-attribute variables, as principal factors of interaction. Based on this, it can be said that the larger the share trading and the international air mail traffic are, the higher the *global networkability* is.

In terms of the canonical vector II, both the networkability and the urban-attribute

Table 6.4 Canonical correlation analysis between urban networkabilities and socioeconomic attributes in 1992 and 2004

Sets of Variables		Canonical Vectors in 1992			Canonical Vectors in 2004		
		I	II	III	I	II	III
Network-abilities	Global networkability	0.821	-0.566	-0.221	-0.671	-0.708	-0.221
	Regional networkability	0.107	-0.989	-0.317	-0.033	-0.948	-0.317
	International networkability	0.340	-0.935	-0.297	-0.295	-0.908	-0.297
Socio-economic Attributes	Industrial-corporation sales	0.431	-0.414	0.467	-0.387	-0.650	0.467
	Capital of banks	0.364	-0.426	0.209	-0.439	-0.721	0.209
	Share trading	0.954	-0.033	-0.032	-0.951	-0.121	-0.032
	International meeting	-0.099	-0.801	-0.378	0.077	-0.314	-0.378
	International air freight	0.496	-0.337	0.426	-0.345	-0.435	0.426
	International air mail	0.639	-0.615	0.011	-0.521	-0.789	0.011
Canonical Correlations		0.972*	0.868**	0.217	0.898*	0.818**	0.467
Chi-Square Tests		77.881	26.006	0.865	53.848	24.327	4.431
Degree of Freedom		18	10	4	18	10	4

* The canonical vector I was significant at the significance level of 0.01.

** The canonical vector II was significant at the significance level of 0.05.

coefficients produced negative correlation. Among the networkability variables, *regional networkability* (-0.989) and *international networkability* (-0.935) had a very high loading. The number of international meetings (-0.801) and international air mail traffic (-0.615) were selected from among the urban-attribute variables as principal factors of interaction. Therefore, conversely speaking, the larger the number of international meetings held in a city is and the more international air mail a city has, the higher its *regional networkability* and *international networkability*. In terms of the canonical vector II, a correlation was shown between *global networkability* and the number of international meetings and international air mail traffic.

In terms of the canonical vector I in 2004, all the coefficients, except the number of international meetings, had a negative causality. *Global networkability* (-0.671) was selected from among the networkability coefficients, and share trading (-0.951) from among the urban-attribute coefficients, as principal factors of interaction. It turned out that, in addition to share trading, international air mail traffic and capitals of banks also had a correlation with *global networkability*. Especially, based on the results obtained in 2004, it can be said that the greater the amount of shares traded is, the higher the *global networkability*. This suggests that a city's wide-area *networkability* on the global level has a close correlation with the flow of capitals therein.

On the other hand, in terms of the canonical vector II in 2004, as in 1992, both the networkability and the urban-attribute coefficients produced a negative causality. Among the networkability coefficients, *regional networkability* (-0.948) and *international networkability* (-0.908) had a relatively high loading. Among the urban-attribute coefficients, international air mail traffic (-0.789), capitals of banks (-0.721), and industrial-corporation sales (-0.650) were selected as principal factors of interaction. It can thus be said that the higher the *regional networkability* and *international networkability* of a city is, the greater its economic activities and the information regarding its banks and industrial corporations are. These characteristics of the canonical vector II also had a high correlation with *global networkability*.

In a word, *global networkability* had a comparatively high loading in every vector both in 1992 and 2004. This suggests that *global networkability* has a higher correlation with urban socioeconomic attributes than *regional networkability* or *international networkability* has. It can also be said that the correlation between global or *regional networkability* and urban socioeconomic attributes is determined by the degree of *global networkability* or *regional networkability*. This is based on the fact that all the 24 *network cities* that were selected as analysis objects in this section basically have the highest degree of *international networkability* in the world.

Based on the aforementioned analysis results, Figures 6.1 and 6.2 show the canonical vector between the networkability and the socioeconomic attributes of the *network cities*. In terms of the canonical vector I in 1992, it was shown that the greater the amounts of shares traded and of international air mail are, the higher the *global networkability*. As shown in Figure 6.1, the cities with this attribute are New York, London, and Tokyo, which are located far away from the origin. Generally speaking, the world's top three capital markets are New York, London, and Tokyo. This suggests that share trading and international air mail traffic have a high correlation with *global networkability*. Besides these, cities such as Frankfurt and Seoul have relatively high characteristics in the canonical vector I.

In terms of the canonical vector II, it was shown that the greater the number of international meetings that are held in a city, and the greater the international air mail traffic is, the higher the *regional networkability* and the *international networkability*. In terms of the canonical vector II, as shown in Figure 6.1, London, Paris, Frankfurt, and Amsterdam are located farthest away from the origin. This shows that *regional networkability* and *international networkability* have a high correlation with the number of international meetings held in a city and international air mail traffic. Cities such as Rome, Hong Kong, Brussels, Copenhagen, Vienna and others have

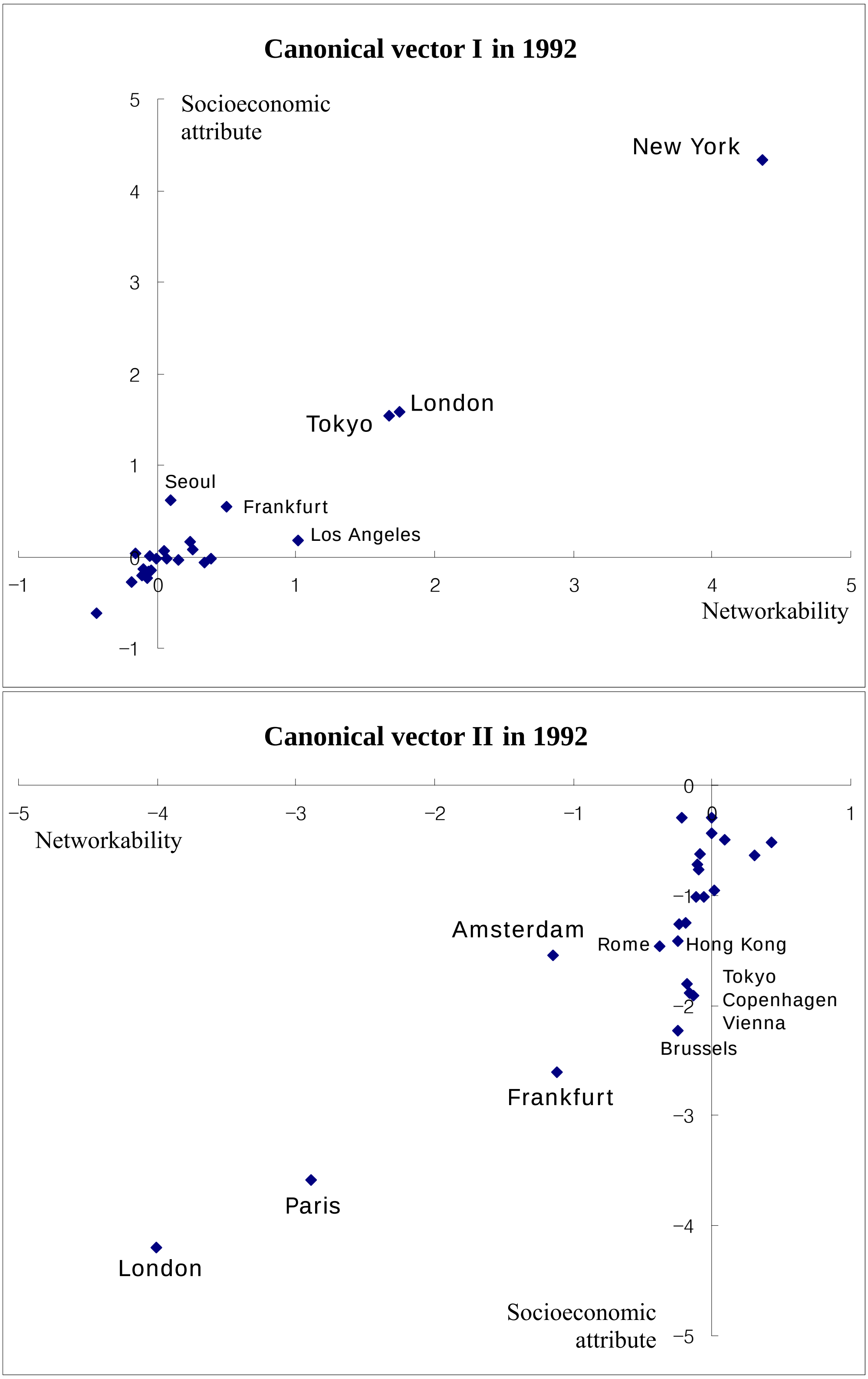

Figure 6.1 Canonical vectors between networkabilities and socioeconomic attributes in 1992

relatively high correlation in the canonical vector II.

In terms of the canonical vector I in 2004, it was shown that the greater the amount of shares trading is, the higher the *global networkability*. As shown in Figure 6.2, New York and London are located farthest away from the origin in the third quadrant. In addition, the canonical vector I was shown relatively high correlation between the *global networkability* and attributes such as international air mail traffic and capitals of banks, besides share trading. Cities such as Tokyo, Los Angeles, and Hong Kong have relatively high correlation.

It was thus shown that in terms of the canonical vector II in 2004, the greater the international air mail traffic, capitals of banks, and industrial-corporation sales are, the higher the *regional networkability* and *international networkability*. In Figure 6.2, London, Paris, Frankfurt, Tokyo, and Amsterdam are located farthest away from the origin, while in 1992, Tokyo was included in the canonical vector I, along with New York and London, and was included in the canonical vector II in 2004. In addition, cities that have relatively high canonical vector II are Brussels, Singapore, Copenhagen, Seoul, Hong Kong, Zurich, and Madrid.

Thus, London had a high coefficient in all the canonical correlation analyses that were conducted in this study. This suggests not only that London, being the highest center of international air traffic in the world, performs a hub function in terms of air traffic in the whole world, but also that it serves as the highest center in the world economy network. For example, London's money market, called City of London, constitutes one of the two axes in the world economy network, the other one being New York's Wall Street. Worthy of being regarded as the hub of the world's money market, London, the center of world finance, has 561 foreign banks, making it the city with the largest number of foreign banks in the whole world. The banks in London guarantee fast transactions and safety in foreign-exchange dealings.

Based on the 2004 data, London has foreign-exchange dealings of US$4,640 million a day, which amounts to 32% of the world market and is larger than the sum of New York's and

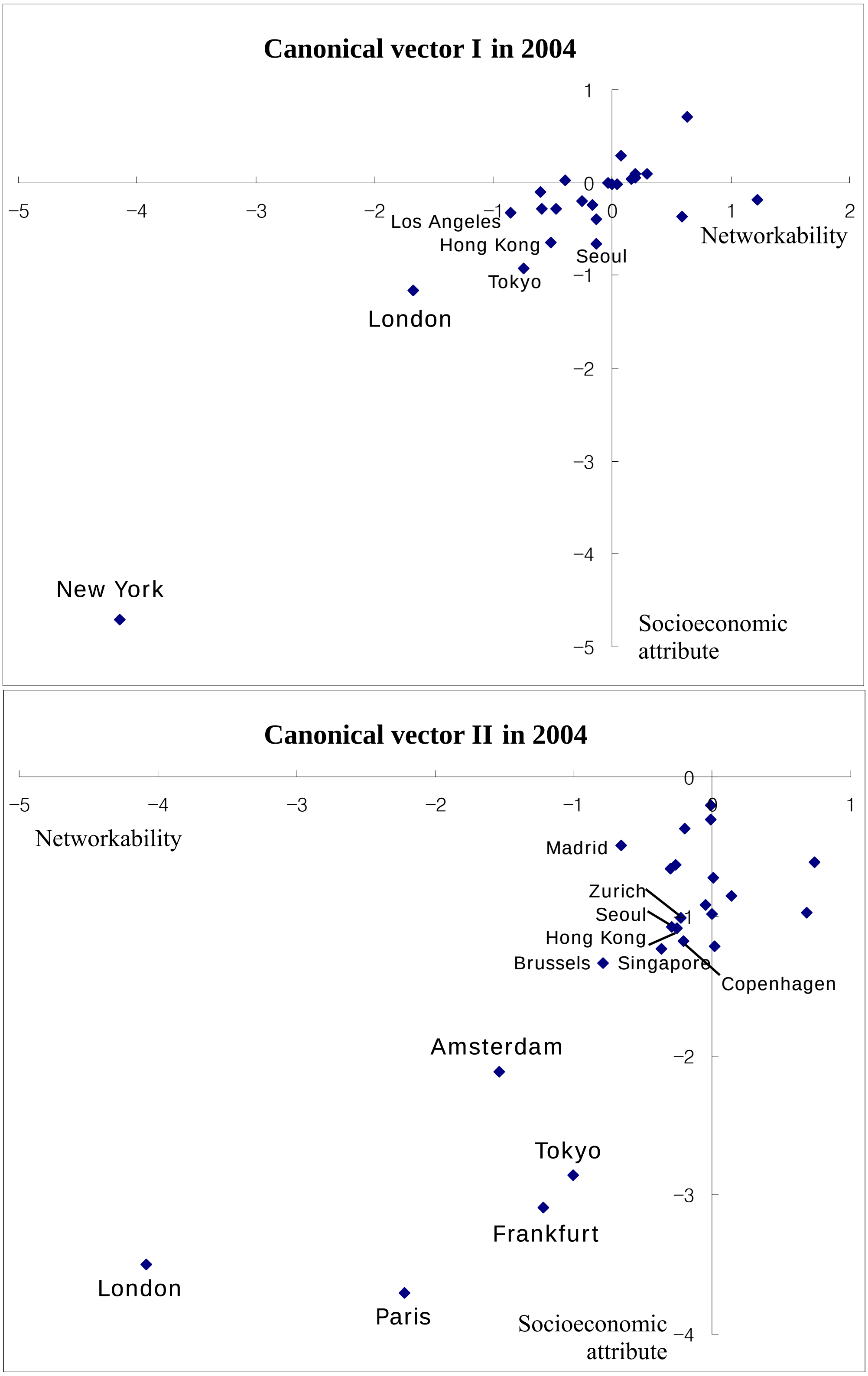

Figure 6.2 Canonical vectors between networkabilities and socioeconomic attributes in 2004

Tokyo's foreign-exchange dealings per day. Fifty-six percent of the world's bonds and 76% of Euro bonds are exchanged in London. As such, London can boast the largest scale of foreign-exchange dealings in the whole world. There are 53 American and Canadian banks, and 50 Japanese banks, in London, which are two or three times larger than the numbers of such banks in Frankfurt or Paris (KOTRA, 2005; UBIN, 2005).

Although the London money market has refused to use Euro as currency, it has a solid position as one of the world's top three money markets, along with New York and Tokyo. A considerable number of finance experts argue, however, that London is the center of world finance in the true sense of the term because New York and Tokyo are respectively founded on the U.S.'s and Japan's economic power, whereas London has spontaneous international exchanges of capitals, including foreign exchanges.

In addition, 24% of the headquarters of large European corporations are located in London, and 60% of the Fortune Global 500 built representative offices in the city. In addition, the headquarters of 118 of the European 500 corporations are located in London, and 87% of the 185 UN member-countries have opened embassies or trade offices therein (UBIN, 2005). Lastly, London serves not only as the center of global business and of world finance but also as the global center in various other areas, such as politics, culture, education, media, fashion, sports, and the arts.

London's *international networkability* is thus considered a main factor influencing its establishment and maintenance of its position in the world economy network. *Network cities* like New York, Tokyo, Paris, and Frankfurt also occupy some of the highest positions in the world economy network, thus proving that a city's position in the world economy network is closely related to the city's *international networkability*.

When the transition of changes in each city's networkability indices and socioeconomic indices is compared, it is possible to see that the spatial interaction between cities in the international air network is closely related with the cities' socioeconomic attributes. When the previously examined indices of city's networkabilities shown in Chapters 3 and 5 and socioeconomic indices of a city as shown in Tables 6.1 and 6.2 are compared, cities with decreased networkability such as *global networkability*, *regional networkability*, and *international networkability* tend to fall behind in the city rank in terms of the indices such as traffic of international air mail & freight, capital of banks, share trading and industrial-corporation sales as well.

For example, Amsterdam and Madrid experienced significant increase in the three networkability indices in 2004 compared to 1992, and the cities' rank increased in most of the socioeconomic indices. Meanwhile, Rome and Zurich experienced significant decrease in the networkability in terms of all networkability indices in 2004, and cities' rank in socioeconomic indices decreased as well. In Asia too, all the networkability indices of Tokyo decreased significantly, and the rank of socioeconomic indices decreased for the most part as well, which shows that its position in the world declined. However, all the networkability indices of other Asian *network cities*, especially Singapore and Seoul increased significantly, and most of the socioeconomic indices increased when it comes to their position in the world. As mentioned above, this may be so because the Asian network structure became the multipolarization due to the growth of Singapore, Seoul, Bangkok and Hong Kong in 2004 compared to 1992. Likewise, networkability of Tokyo decreased relatively. That is to say, the results of spatial interaction analysis back up the changes in the socioeconomic attributes of cities.

Accordingly, this study showed that the networkability of the network cities is high, which does not merely mean that the traffic volume or the accessibility is high. Instead, this can be understood as showing the cities' high position and central function within the spatial network of the world. In other words, increase in the *international networkability* of the cities in the international air network is an important factor that enables cities to grow into the international center in the era of globalization, and also an outcome at the same time.

In sum, in analyzing the international air network structure, this study estimated the *international networkability* of each city based on the air traffic in cities and the number of international air routes therein. *International networkability* is the quantitative measurement of the spatial interaction relationships in the whole network without considering the characteristics of each city's flow pattern. Based on this, the multilayered structure of the international air network and the connection patterns of its subnetworks were identified in this study. Furthermore, the fact that subnetworks form a network was confirmed, using each continent as its local base.

In Chapter 5, each city's flow pattern was analyzed by continent, based on the connection structures of subnetworks. The cities with a high networkability turned out to be different in each continent, and certain cities have a high networkability only in certain continents. On the contrary, London, Paris, New York, Frankfurt, and Tokyo have a high networkability in every continent, and their *global networkability* is also high. The correlation analysis of networkability and of the socioeconomic attributes of these cities confirmed that cities with a high networkability serve as centers on the regional or global level.

Figures 6.3 and 6.4 show the results of the analysis of the global network structure and of *international networkability* in the form of a mimetic diagram. In both 1992 and 2004, the global network was formed into a multilayered network around *network cities*. In Chapter 4, it was defined the 1st-class and 2nd-class *network city* based on the cities' networkability and spatial interaction pattern. When these *network cities* are synthetically examined by combining with the results of the canonical correlation analysis between the socioeconomic attributes and the flow patterns by continent of each city analyzed in Chapters 5 and 6, *network cities* which have the highest level of *global networkability*, enjoy highest position in the world economy, as well as experience very powerful correlation with the socioeconomic attributes, can be referred to as *global network city*. In other words, the *global network cities* that have the most influence in the

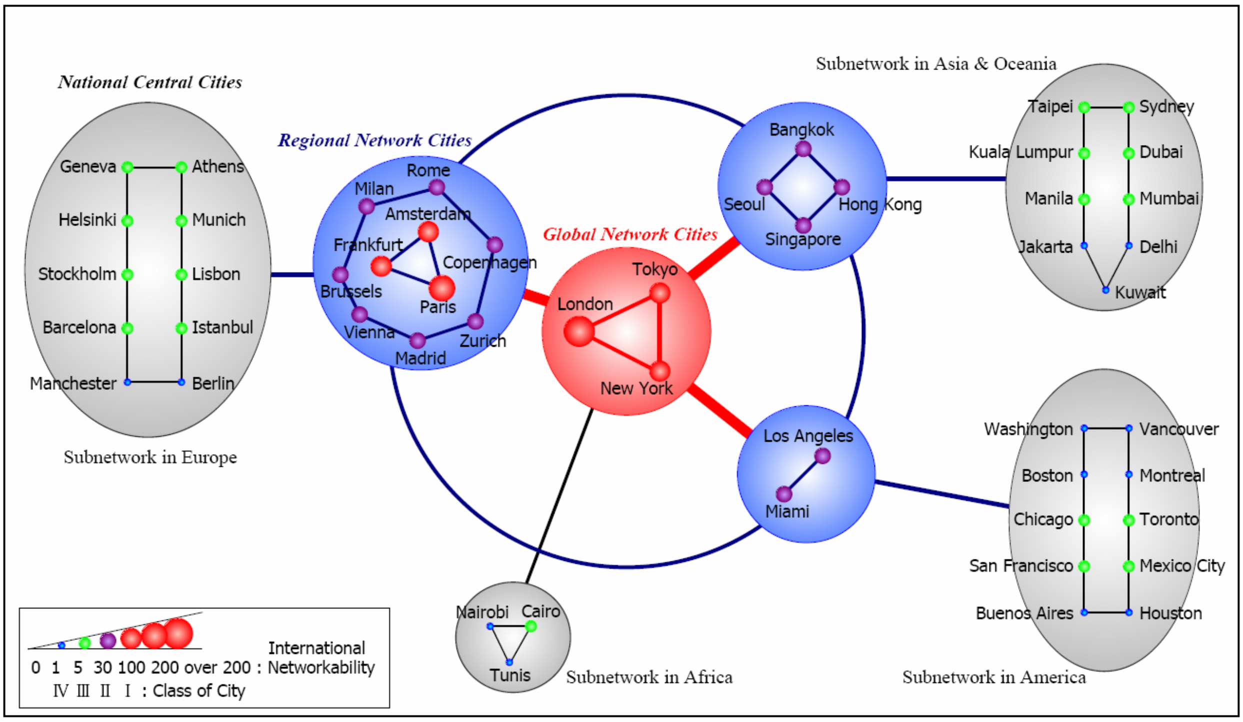

Figure 6.3 The connection structure of the global network in 1992

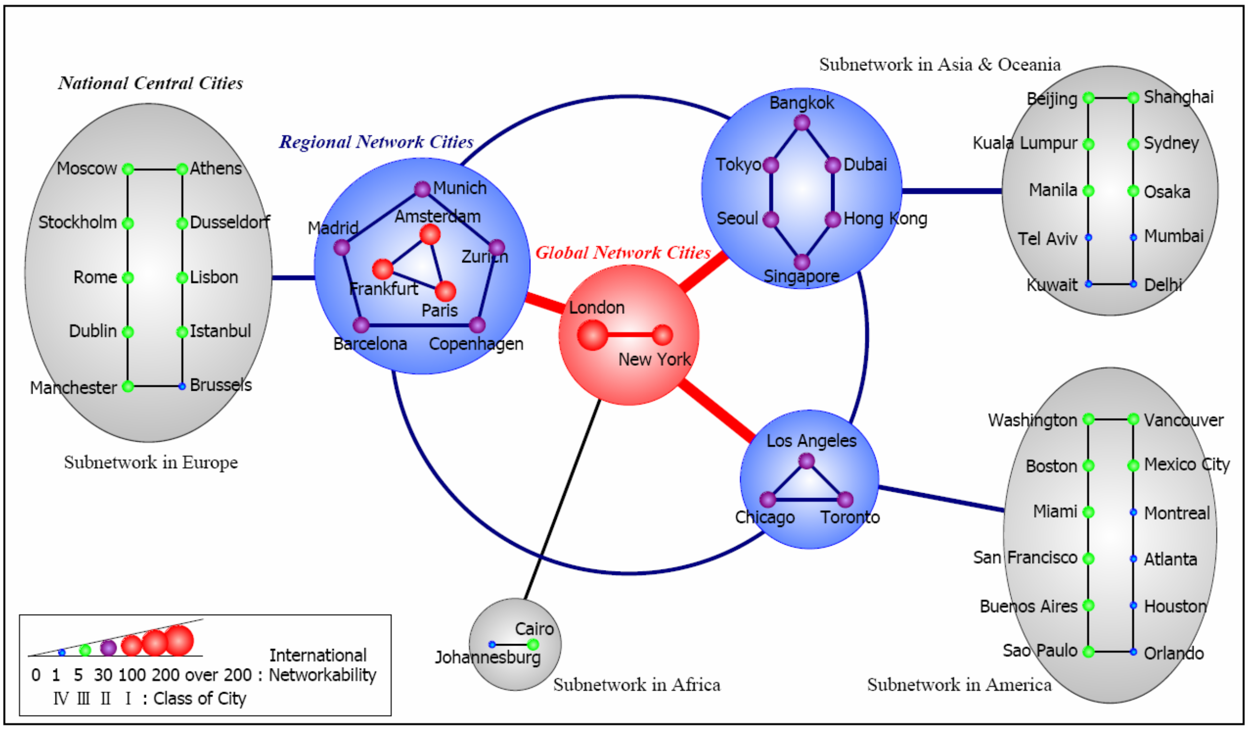

Figure 6.4 The connection structure of the global network in 2004

world economy engage in the spatial interaction of the global level while enjoying their position as the foremost core of the global network.

As shown in Figure 6.3, in 1992, London, New York and Tokyo were considered *global network cities*. On the other hand, Paris, Frankfurt and Amsterdam, which were classified as 1st-class *network city* in the Chapter 4 were excluded from the rank of *global network cities* since their *regional networkability* experience greater correlation with the socioeconomic attributes more so that the *global networkability*. In Figure 6.4, networkability of Tokyo declined significantly in 2004, and its position in the world economy decreased significantly compared to 1992. Thus, in 2004, Tokyo was excluded from the rank of *global network city*, and only London and New York were selected as *global network city*. Moreover, as shown in Figures 6.3 and 6.4, *global network cities* belong to the highest class of the global network, and the network that these *global network cities* comprise can be considered a *global main-network*.

Meanwhile, the rest of the *network cities* among the 1st-class and 2nd-class *network cities* in 1992 and 2004 except for the *global network cities*, are classified as *regional network city*. The *regional network city* is characterized by the following; active spatial interaction with the cities of continent that is geographically close, and *regional networkability* experience higher correlation with the socioeconomic attributes more so than *global networkability*.

That is, *regional network cities* have a stronger function as centers on the continental or local level than on the global level. Moreover, they experience lower position and has lower influence in the world economy compared to the *global network cities*. However, they correspond to relatively higher level in the world. As shown on Figures 6.3 and 6.4, in both years, Paris, Frankfurt, Singapore, Los Angeles, Hong Kong, Amsterdam, Bangkok, Seoul, and Madrid were selected as *regional network cities*. Miami, Rome, Brussels, Milan, and Vienna that were selected as *regional network cities* in 1992 were excluded from the list in 2004. Dubai, Chicago, Toronto, Munich, and Barcelona were added onto the *regional network city* list in 2004.

Accordingly, the network that these *regional network cities* comprise can be called a *regional subnetwork*.

The cities that are among the lower-class *network cities* can be classified into *national central cities* based on their *international networkability*. These cities correspond to classes 3 of the global network analyzed in Chapter 4. Furthermore, the connection patterns between the subnetworks in each class also helped in the examination of the spatial structure of the global network.

The global network structure was examined in this study using the concept of a multilayered network, and the differentiated functions and different interaction patterns of the cities in the international air network were analyzed. The spatial changes in the global network in 1992 and 2004 caused by both the horizontal and the vertical movements of the cities in the multilayered network structure of the international air network in those years were also examined herein.

Chapter Seven

Conclusion

This study aims to analyze the structural changes of the international air network in 1992 and 2004, and to examine the functional characteristics of the upper cities in the global network. For this purpose, the GNA model, a revision of the *social network analysis* model, was devised for use in the analysis of the *international networkability* of cities and the connectivity of the international air routes by analyzing the inter-city spatial interactions. Based on these results, the multilayered structure of the international air network was analyzed, and the functional characteristics of cities with a high *international networkability* were examined. Moreover, based on the results of structure analyses of the international air network, the *global networkability* and *regional networkability* of each city will be measured by classifying the international air routes of each city into those connected to the other cities in the same region and those connected to the cities in other regions. Lastly, using the results of the GNA that was conducted in this study, the correlation between networkabilities and the socioeconomic attributes of those cities with a high *international networkability*, and the characteristics of the cities that perform central functions in the global network, were examined.

As a result, London, Paris, Frankfurt, Amsterdam, and New York were the top-ranked *network cities* in both years. Tokyo was included in class 1 in 1992 but not in 2004. Rome, Zurich, Singapore, Los Angeles, Hong Kong, and other cities were identified as the 2nd-class *network cities* in 1992, while Singapore, Tokyo, Madrid, Hong Kong, Bangkok, and other cities were identified as the 2nd-class *network cities* in 2004. The *network cities* were selected based on the size of their *international networkability* and the geographic range of their main connections. By examining their connections in the international air network, it was possible to explain these cities' functional differences.

The *network city* is the mutual arena in the global flows, such as the flow of people, capital, goods, information, and knowledge, and it could be a metropolitan area that activates the international connection between regions with highly developed infrastructure (e.g., transportation and communication). The center of the global network is occupied by the *network cities*, and the 1st-class *network cities* are connected to the 2nd-class *network cities* that perform the role of hubs in each continent, putting the whole world together in one network. This global network creates multilayered networks, and it was shown herein that the international interactions between cities became closer through the years, centering on the *network cities* by 2004.

The international air network can be largely divided into the Pacific Rim and the Atlantic Rim. In the case of the Pacific Rim, especially Asia, the single-center system centered on Tokyo was turned into a multi-center system with the development of Singapore, Seoul, Hong Kong, and Bangkok, and the cities' interactions also became closer than before. In the Atlantic Rim, which includes Europe and America, the network was formed around London, Paris, New York, Frankfurt, and Amsterdam, and the concentration on London became stronger in 2004. In the same year, the interactions between the cities in Europe and Asia became stronger, and a network was formed in the Middle East, with Dubai as the center. Meanwhile, it was observed that the cities in Africa and South America had a weaker network system in 2004, which was based on the local regions in the international air network than on the other continents.

The analysis of the nearest-neighbor distance between the cities revealed that in both 1992 and 2004, the center of the international air network was formed by Paris, New York, Amsterdam, and Frankfurt around London, and most of the cities were connected to London. The Asian cities, however, formed a different connection system around such cities as Tokyo, Singapore, and Hong Kong. In the connection system of the international air network, the Asian cities showed dynamic changes in their connection patterns. In 1992, Tokyo was the closest city to the center of the network, whereas in 2004, Singapore, Hong Kong, and Dubai were closer to the center of the network than Tokyo was. There were three subnetwork systems that were formed around Tokyo, Singapore, and Hong Kong in 1992. In 2004, however, as another subnetwork was formed around Seoul, the number of Asian subnetworks increased to four. In addition, it was found that the relative distances between cities were reduced. This implies that as the spatial interactions between the cities all over the world became more active, their connections became stronger, and that as the differences between inter-city interactions decreased, the connection system of the international air network became compact.

The analysis of the connection patterns of the subnetworks of the international air network proved that the main subnetworks are forming their flow patterns by using each continent as their local base. The international air network can be classified into the 1st-class *network cities*; the European, Asian, and American 2nd-class *network cities*; and eight subnetworks composed of other European, Asian, American, and African cities, with the exception of these *network cities*. The 1st-class *network cities* are located at the center of the international air network, and these cities have a high connectivity with the other cities comprising their respective subnetworks and with those comprising other subnetworks. The biggest change in the connection patterns of the subnetworks was that the subnetwork consisting of the 2nd-class Asian *network cities* had grown, whereas the subnetwork of the 2nd-class European *network cities* had declined. In other words, it was found that the central axis of the global network has a tendency to move from connections with the European cities to connections with the Asian cities, which means that the positions of the Asian *network cities* in the international air network have risen.

On the basis of flow patterns, those *network cities* with a high *international networkability* were divided into those cities with a high *global networkability* and those with a high *regional networkability*. *Regional networkability* expresses a city's connections with the other cities in the continent where it is located; it therefore points to the role of a local hub in the continent. On the other hand, *global networkability* indicates a city's connections with the cities in other continents; it therefore points to the role of a wide-area hub on the global level. In 1992 and 2004, London had the highest *global networkability* among all the cities in the international air network, which suggests that its role as a global hub was most prominent. It was also observed that New York, Paris, Frankfurt, and Tokyo had very high *global networkabilities*. Compared to the results of the 1992 analysis, the *global networkability* of the European cities belonging to the highest class (e.g., London, Paris, Frankfurt, and Amsterdam) had increased, whereas those of Rome, Zurich, Brussels, and Copenhagen had decreased. In the case of Asia and America, the hub function on the global level, which was concentrated on Tokyo, New York, and Los Angeles, was dispersed in Singapore, Hong Kong, Chicago, and Toronto.

The cities that were found to have a high *regional networkability* in 1992 and 2004 were London, Paris, Amsterdam, and Frankfurt, and the class with the highest *regional networkability* was found to be composed of European cities. The Asian cities had a remarkable rise in *regional networkability*. In 1992, among the Asian cities, Tokyo had the highest networkability, whereas in 2004, Singapore, Bangkok, Seoul, and Hong Kong had higher *regional networkability* compared to Tokyo. London, New York, Paris, Frankfurt, and Tokyo had high networkabilities in every continent, while Amsterdam, Madrid, and Bangkok had high networkabilities only in certain continents. These results suggest that differentiated functions and different interaction patterns exist in the international air network.

Canonical correlation analysis was conducted in this study, in which the correlations between a set of variables pertaining to networkability indices that indicate the international interactions between cities, and a set of variables pertaining to the socioeconomic attributes of cities, were analyzed. As a result, it was found that *global networkability* and *regional networkability* have different correlations with the socioeconomic attributes of cities. In 1992, Tokyo had a high *global networkability*, indicating that *global networkability* has a high correlation with share trading and international air mail traffic. On the other hand, the high *regional networkability* and *international networkability* of London, Paris, Frankfurt, and Amsterdam in 1992 were closely related to the number of international meetings that were held in these cities, and with the international air mail traffic in these cities, in 1992.

In 2004, the high *global networkability* of New York and London had a high correlation with the amount of shares that were traded in these cities in that year, and the high *regional networkability* and *international networkability* of London, Paris, Frankfurt, Tokyo, and Amsterdam in the same year were closely related to their international air mail traffic, bank capitals, and industrial-corporation sales. These results imply that an organic network was formed, based on the functional differentiations and complementarities between the cities in the global network. It was also observed that the centers in the international air network not only had a large amount of air traffic but also functioned as the center of the world economic system. As such, it can be concluded that a strong *international networkability* means a strong centripetal force.

In sum, this research analyzed the *international networkability* of about 400 cities in the world by using the international air passenger flow to understand the growth mechanism of the cities in the era of globalization. Towards this end, the global network structure formed by the spatial interaction between cities and the changes were defined, and the interaction patterns of the cities in the international air network were examined. Moreover, this research examined how the spatial interaction of the *network cities* that correspond to the upper class of the global network is related to the socioeconomic attributes of cities. In other words, this research conducted the network analysis to indicate the quantitative methodology for measuring the networkability of cities and interaction between cities, and defined the significance of *international networkability* in the growth and decline of the international center by analyzing the spatial interaction of cities and correlation between socioeconomic attributes.

As a result, it was possible to see that the *global network cities* such as London, New York and Tokyo acted as the foremost core of the world economy in addition to playing the role of the center in the international air network in 1992. However, Tokyo's *international networkability* declined in 2004, and its position in the world economy decreased along with it. Change in the socioeconomic attributes following the change in the *international networkability* of the city was evident in the cases of other cities such as Amsterdam, Madrid, Seoul and Singapore. Moreover, unlike other continents, Asia manifested the decline of Tokyo and the growth of Singapore, Seoul, Bangkok and Hong Kong which shows the trend in which the core of the Asian sub network structure is becoming increasingly diverse.

Meanwhile, *regional network cities* such as Paris, Frankfurt, Singapore, Los Angeles, Hong Kong, Amsterdam, Bangkok, Seoul, and Madrid are the cities that are considered sub class of the *global network cities*. They play greater central role at the respective regions or continent level instead of playing central role at the global level enjoy very high position in the world economy and play central role based on the powerful interaction with the cities that are geographically close to them. Through the change in the networkability of the *regional network cities* such as Miami, Rome, Brussels, Dubai, Chicago, and Toronto in 1992 and 2004, it is possible to see that the expansion and decline in the spatial interaction of the cities are accompanied by the change in their position in the world economy. Accordingly, very dynamic spatial interaction is what grows these *network cities*. Moreover, the *international networkability* in the global network is a very important index that manifests the position and influence of cities in the world economy network.

Thus, by analyzing the international interactions of each city in the era of globalization, the spatial structure of the world could be identified, and the mechanism of the continuous growth of each city could be examined. To scientifically explain and analyze the increase in international interchanges and the subsequent intensification of spatial interactions in the world, the subsequent study should involve a comprehensive macro analysis. Accordingly, this study did not stop at uniformly quantifying the networkability of cities based on their international air passenger flow; rather, it arranged the cities in a hierarchy. It also examined the different functions of cities based on their flow patterns. The results of this positive analysis demonstrate that, for a city to continue to grow in the era of globalization, international interactions between regions should be required, and that these international interactions will continue when complementary interrelationships and not domination-subordination relationships are formed.

The contemporary world is symbolically described by the convergence of time and space, made possible by the development of scientific technology, and by the increase in the international exchanges due to the expansion of the global economy. The research on the inter-regional interactions on the global level based on the globalization theory provides a paradigm for understanding the contemporary world and for explaining the evolution of contemporary cities. To continue this process, new perspectives and analysis methods should be proposed. This study is significant as an empirical study on the international air network as it combines the global-city theory based on the analysis of hierarchy, and the network theory, which focuses on the analysis of the interactions between cities.

Notes

1. In the 1991 and 1992 data, the OD matrices were created with the volume of passenger flows from the "On-Flight Origin and Destination" of the ICAO; and, the 2004 and 2005 data uses the international air passenger flows between cities from the secure site (http://icaosec.icao.int) of the ICAO.

2. *Prestige centrality* is generally called *Bonacich power centrality,* and its equation is:

$$C_i(\alpha, \beta) = \sum_{j}^{n} (\alpha + \beta C_j) R_{ij} \, ,$$

where

α is a constant to standardize an exponent of centrality;

β is the degree of interaction;

C_j is the centrality of node j; and

R_{ij} is the flow volume between i and j.

3. The equation of *Degree centrality* (C_i) is as follows:

$$C_i = \frac{t}{g-1} \, ,$$

where

g is the total number of nodes.

t is the number of nodes directly connected to node i.

4. Fortune ranked the companies all over the world on the basis of the size of their sales, and it came up with a list that it called the *Fortune Global 500.* Data by city were indicated based on the addresses of the headquarters of the 500 companies that made it to the list.

5. Based on the scale of capitals of banks, *Banker* ranked the banks all over the world and came up with a list that it called the *Top One Thousand World Banks.* Data by city were indicated based on the addresses of the headquarters of the top 100 among these 1,000 banks.

6. Total value of share trading includes the domestic & foreign investment funds (*Source*: World Federation of Exchanges).

7. Union of International Associations (UIA) defines a *meeting* as an international one, which can be included in the convention industry only when it meets the following regulations: "The total number of participants should be more than 300, over 40% of which should be foreigners. More than five countries should participate in the meeting, and the meeting should be held for more than three days."

8. The international air freight traffic and the international air mail traffic had been drawn from ICAO's *On-Flight Origin and Destination* data. Their data consisted only of the regular international non-stop flights of each city.

9. See the following article to find out the details about the differences between the flow pattern of international air freight and that of international air passengers:

   Lee, H.S., 2003, Changes of global urban system reflected in international air passenger flow data's 1992-2001, *Journal of the Korean Urban Geographical Society* 6 (2), 103-117.

   Lee, H.S., 2004, *Changes of global urban system reflected in international air OD data's 1992-2001*, Korea Univ., M.A. dissertation.

   Nam, Y.W. and Lee, H.S., 2004, Changes of global urban system reflected in air freight flows, *Korea Planners Association* 39 (1), 129-143.

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