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An Alternative to Optimize the Indonesian's Airport Network Design:
An Application of Minimum Spanning Tree (MST) Technique*

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Abstract: Using minimum spanning tree technique (MST), this exploratory research was done to optimize the interrelation and hierarchical network design of Indonesian's airports. This research also identifies the position of the Indonesian's airports regionally based on the ASEAN Open Sky Policy 2015. The secondary data containing distance between airports (both in Indonesia and in ASEAN), flight frequency, and correlation of Gross Domestic Regional Product (GDRP) for each region in Indonesia are used as inputs to form MST networks. The result analysis is done by comparing the MST networks with the existing network in Indonesia. This research found that the existing airport network in Indonesia does not depict the optimal network connecting all airports with the shortest distance and maximizing the correlation of regional economic potential in the country. This research then suggests the optimal networks and identifies the airports and regions as hubs and spokes formed by the networks. Lastly, this research indicates that the Indonesian airports have no strategic position in the ASEAN Open Sky network, but they have an opportunity to get strategic positions if 33 airports in 33 regions in Indonesia are included in the network.

Abstrak: Dengan menggunakan teknik *minimum spanning tree* (MST), penelitian eksploratori ini dilakukan dengan tujuan mengoptimalkan rancangan jaringan interrelasi dan hierarki bandar udara di Indonesia. Penelitian ini juga mengidentifikasi posisi bandar udara-bandar udara di Indonesia dalam kancah regional berdasarkan kebijakan ASEAN Open Sky 2015. Data sekunder berupa jarak antar bandar udara (baik di Indonesia maupun di ASEAN), frekuensi penerbangan, dan korelasi PDRB setiap provinsi di Indonesia digunakan sebagai masukan untuk membentuk jaringan MST. Analisis hasil dilakukan dengan membandingkan bentuk jaringan MST dengan jaringan bandar udara yang selama ini digunakan di Indonesia. Hasil penelitian ini menunjukkan bahwa jaringan bandar udara yang selama ini digunakan di Indone-

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sia belum menggambarkan jaringan yang optimal yang mampu menghubungkan semua bandar udara dengan total jarak terpendek serta memaksimalkan keterkaitan potensi ekonomi setiap provinsi di Indonesia. Penelitian ini kemudian mengusulkan rancangan jaringan yang optimal serta mengidentifikasi bandar udara-bandar udara dan provinsi-provinsi yang menjadi hubs dan spokes dalam jaringan tersebut. Terakhir, hasil penelitian ini menunjukkan bahwa bandar udara-bandar udara di Indonesia kurang mempunyai posisi yang strategis dalam jaringan ASEAN Open Sky, namun berpeluang untuk mendapatkan tempat yang strategis jika 33 bandar udara di 33 provinsi di Indonesia dimasukkan ke dalam jaringan tersebut.

Keywords: airport's network; minimum spanning tree; optimization

Introduction

An airport, as stated in the Decree of Minister of Communications Number KM.11 of 2010 on Order of National Airport Affairs, plays a very critical role as a hub for the network of air transportation. It also becomes a gate for any economic activities, a transshipment point, a support for industries, trading and/or tourism activities, a gateway to open up isolated areas, borderland development, disaster management, and infrastructure for strengthening the archipelago as well as the state sovereignty.

In order to achieve the optimal role, the airports should be connected to each other and form an interrelation network with the hierarchical role, whether as hubs or spokes. This interrelation will be able, not only to accomodate growing demand for flights, but also to maximize the correlation of economic potential of each region in Indonesia. Moreover, the strong interrelation among regions will become a competitive advantage when facing a connectivity issue at regional and international level. This is true because the issue of connectivity[1] development has become an agreement at various upper-level summits such as ASEAN, ASEAN Plus, or East Asia Summit (President of Indonesia Republic 2012). Thus, consolidation and development of the airports in Indonesia must be well prepared as a part of the long-term competitive strategy that will need major investment.

Responding to the more competitive market of the airline industry in Indonesia, the airline companies should be able to optimize their operations activities without sacrificing the criteria of the interrelation and hierarchy among the airports in the country. This can be achieved by optimizing the network design of Indonesian's airports, where the optimal network should not only be seen from the aspect of flight demand, but should also be seen from the total distance to connect all the airports and the correlation of economic potential of each region in Indonesia.

Furthermore, the network design optimization is very important to be considered in facing the flight liberalization under the policy of ASEAN Open Sky 2015. This policy will allow four cities in Indonesia – Jakarta (JKT), Surabaya (SUB), Denpasar (DPS), and Medan (MED) to be involved in it.[2] Hence, certain strategies related to the network design optimization must be considered carefully by the airline industry in Indonesia to compete with other airline industries from the other ASEAN countries.

In the near future, Indonesia is also facing the challenge of ASEAN Economic Community 2015 which makes the economy in the ASEAN area more integrated. Accordingly, the competitive level of a country or a region will significantly determine the level of the economic benefit to be obtained. This then indicates that the higher the competitive level of a country, the more the economic benefit will be obtained. Therefore, optimization of the interrelation and hierarchical network design in Indonesia's airports comes to be a way to improve the competitive level both in domestic areas and ASEAN areas.

[1] Connectivity means an interrelation both among regions and among states in a region. This could be in the form of transportation (land, sea, and air), telecommunication, trade, tourism, and mutual investment.

[2] Based on the research of Forsyth et al. (2004).

Considering all the matters mentioned above, it might be interesting to investigate whether or not the existing airport network in Indonesia has shown an optimal network connecting all airports in the country with the shortest total length and with the maximum correlation of economic potentials of each province in Indonesia. Moreover, it is important to identify the impact of the ASEAN Open Sky policy and the position of Indonesia in the network.

Research Objective

Using the minimum spanning tree (MST) technique, this research is performed purposively to (1) design and (2) analyze the interrelation and hierarchical network that optimally connect all the airports in Indonesia based on flight demands, distance between airports, and the correlation of the local economic potential represented by the correlation of GDRP in each region in Indonesia. In this research, the MST technique is also used to (3) identify the impact of the ASEAN Open Sky policy on the interrelation and hierarchical network based on the distance between the airports in ASEAN and the position of Indonesia in this network.

Literature Review

Optimization (the best achievement) refers to a criterion in selecting an alternative in an economy that consists of minimization and maximization (Chiang and Wainright 2005). Minimization could be referred to as efficiency – a number of inputs used to gain a number of certain outputs (Hill and Jones 2010). Maximization, on the other hand, is called effectiveness – a number of outputs produced by using a number of certain inputs. The concept of transport economics dictates that- economic efficiency could be achieved when the producers are able to use the available resources using the best method (Boyer 1998). Furthermore, Cooley (1946) stated that transportation companies without any efficient management might survive only for certain periods due to their position, financial resources, government support, or right protection. However, the lack of efficiency, sooner or later, will lead to companies being eliminated. Hence, optimization is becoming necessary – one way is by using the transportation network which has been proposed by Russel and Taylor (2006), Render et al. (2006), and Chopra and Meindl (2010).

In the world of aviation, the network, in accordance with the Article 1 sentence 21 of Regulation of Indonesia Republic Number 1 Year 2009 about aviation, refers to several routes of flight that are integrated to be an air transport service. This network will form an interrelation of airports, each of which will have a role in a hierarchy as stated in the Regulation of Minister of Communication Number: KM 11 Year 2010 about the Order of National Airport Affairs. That regulation also stated about the importance of the use of economic potential in consideration of efficiency and effectiveness in the national airport planning system.

Economic potential of a region in Indonesia can be seen from the value of Gross Domestic Regional Product (GDRP) gained by the region. The Central Bureau of Statistics (BPS) of Indonesia (2009) presents a basic concept review of GDRP and shows that there is an income correlation between one region and the others in Indonesia. The correlation, at this point, may describe connectivity between regions. The stronger the correlation of GDRP between two regions is, the stronger the connectivity between two regions will be. This is in line with the research of Miskiewicz and Ausloos (2006) in a global scope correlating the Gross Domestic Product in Top 19 countries in the period of 1953-2003 in which they used the Minimum Length Path (MLP) technique to measure the strongest connectivity between a country and all Top 19 countries in the network.

Not much different, both Minimum Spanning Tree (MST) technique and Minimum Length Path (MLP) technique attempt to optimize the weight to connect all nodes in a network. However, MST sees optimization by assessing the total weight in connecting all nodes in a network. Theoretically, this technique is explained by Render et al. (2012), Jayawant and Glavin (2009), Wiliams (2003), Sedgewick and Wayne (2007), and Sedgewick and Wayne (2011).

Meanwhile, the connectivity issue is critical to be considered both locally and regionally. The local connectivity should be built properly before connecting Indonesia regionally with the countries in Southeast Asia, East Asia, or event Asia Pacific (President of Indonesia Republic 2012). This local connectivity will alleviate the economic transactions and resources movement from one region to another in a more effective and efficient way. Besides that, regionally, this connectivity will support the realisation of the ASEAN community and economic integration in the near future. This connectivity is expected to reduce business transaction cost, time and travel cost, and to connect the "core" and "periphery" in ASEAN (ASEAN Studies Centre 2011).

Furthermore, the connectivity through air is the most developed in the ASEAN countries (ASEAN Studies Centre 2011). Under ASEAN Open Sky Policy 2015, Forsyth et al. (2004) explain that the airline companies should enhance their productivity by reducing costs to gain more profits when competing with other airline companies in ASEAN. This can be done by optimizing the airport's network design in ASEAN. Accordingly, using MST, this research will make significant impacts not only by connecting Indonesian's airports, but also by connecting ASEAN's airports effectively and efficiently.

Research Methods

This research used an exploratory research design supported by a secondary data analysis. It was conducted when the researchers did not know much about the situation or information related to the issue that has been previously addressed in a similar piece of research (Sekaran and Bougie 2010). It is expected from this exploratory research that there will be further research, possibly providing conclusive evidence (Zikmund 2003). One of the techniques that can be applied in an exploratory research according to Cooper and Schindler (2011) is the secondary data analysis. Through this technique, the researchers are allowed to manage and analyze the secondary data from various relevant sources related to the topic of the research.

Procedure in Collecting Data

The first data used in this research were the secondary data in the form of flight frequencies from one airport to the other airports in 33 provinces in Indonesia. The data, subsequently, were used to identify the form of the existing network showing the flight routes used by airlines in Indonesia. The data were obtained by visiting the website of seven airlines providing a service for the scheduled domestic routes in Indonesia.[3] The researchers, at this point, have assumed those seven airlines as the representatives for the domestic flight in Indonesia both in terms of flight frequency and flight scope. To simplify the data collecting process, the researchers used the web site *tiketdomestik.com* that has provided the flight schedules of 4 out of 7 airlines.[4]

The second data in this research were the values of the latitude and longitude of 33 airports in Indonesia as well as the radius earth obtained from the application of *google map*. Those three data were used to determine the distance between an airport and the others in a network. The researchers has limited the number of the airports to 33, each of which represented one province in Indonesia. The selection of those 33 airports was based on the hierarchy of the airports in which the 33 selected airports were the hubs either in primary, secondary, or tertiary level. Those airports include Sultan Iskandar Muda (BTJ), Polonia (MES), Minangkabau (PDG), Sultan Syarif Kasim II (PKU), Sultan Thaha (DJB), S.M. Badaruddin II (PLM), Fatmawati Soekarno (BKS), Radin Inten II (TKG), Depati Amir (PGK), Hang Nadim (BTH), Halim Perdanakusuma (HLP), Husein Sastranegara (BDO), Adi Sumarmo (SOC), Adi Sutjipto (JOG), Juanda (SUB), Soekarno Hatta (CGK), Ngurah Rai (DPS), Supadio (PNK), Tjilik Riwut (PKY), Syamsuddin Noor (BDJ), Sepinggan (BPN), Sam Ratulangi (MDC), Mutiara (PLW), Sultan Hasanuddin (UPG), Wolter Monginsidi (KDI), Djalaluddin (GTO), Tampa Padang (MJU), Lombok Baru (LOP), Eltari (KOE), Pattimura (AMQ), Sultan Babullah (TTE), Rendani (MKW), and Sentani (DJJ).

In addition, the data of latitude and longitude of 24 airports in 24 cities in ASEAN were needed to determine the distance between one airport and the others as the main points in ASEAN which is mentioned in the research of Forsyth et al. (2004). To measure the distance between the airports, either in Indonesia or in ASEAN, the researchers have applied the great circle distance, which cartographically and mathematically refers to the shortest path that can be flown through between two points in the earth surface assumed to be a totally round in shape (Pearson 2012).[5]

The third data, in turn, were the values of GDRP in each province in Indonesia. Those were the annual data from 2004 to 2010 obtained from the Central Bureau of Statistics (BPS) in Indonesia. The data were used to identify the values of correlation coefficient of GDRP in each province that, afterward, were turned into pseudo distance using the MST technique.

Data Processing

The first data processing was done by inputting the collected data in a 33 x 33 matrix showing the daily flight frequency from one airport to the other airports in 33 provinces in Indonesia (see Table 1). To illustrate, it was

[3] The seven airlines along with the flight code include Garuda Indonesia (GA), Lion Air (JT), Sriwijaya Air (SJ), Batavia Air (Y6), Air Asia (QZ), Merpati Nusantara (MZ), and Citilink (G1).

[4] Information system in the website has been integrated with the information system of airlines: GA, JT, SJ, and Y6.

[5] The measurement of distance among airports using this technique was also used in http://www.aeroplanner.com/calculators/avcalcdist.cfm.

recorded that there were four flights from Sultan Iskandar Muda Airport (BTJ) with the destination of Polonia Airport (MES) or vice versa in one day. The process of inputting the data into the matrix was then repeated for the other airports until Sentani Airport (DJJ). The flight frequency data that have been inputted into the matrix were then used as the input to form the interrelation and hierarchical network used by the airlines as well as the MST network based on the flight frequency in Indonesia.

The second data processing was performed by inputting the data of latitude, longitude, and radius earth[6] into Microsoft Excel formula to obtain the great circle distance between one airport and the other airports in Indonesia. The formula of great circle distance referred to the following one provided by Pearson (2012):

$$d_{xy} = E*((2*ASIN(SQRT((SIN((RADIANS(La_x)RADIANS(La_y))/2)^2) + COS(RADIANS(La_x))*COS(RADIANS(La_y))*(SIN((RADIANS(Lo_x) - RADIANS(Lo_y))/2)^2)))))$$

where,

d_{xy} = distance between airport x and airport y

RE = radius earth

La_x = latitude value of airport x

La_y = latitude value of airport y

Lo_x = longitude value of airport x

Lo_y = longitude value of airport y

Table 1. **Matrix of Flight Frequency**

Flight Frequency per Day (Time)		Flight Frequency per Day (Time)						
		BTJ	**MES**	**PDG**	**PKU**	**DJB**	**...**	**DJJ**
	BTJ	***	**4**	0	0	0	...	0
	MES	**4**	***	**2**	**2**	0	...	0
	PDG	0	**2**	***	0	0	...	0
	PKU	0	**2**	0	***	0	...	0
	DJB	0	0	0	0	***	...	0
	...	...	...	...	...	...	...	...
	DJJ	0	0	0	0	0	...	***

[6] Radius earth used in this research refers to Pearson (2012), that is at 6371,1 km.

Table 2. **Matrix Distance between the Airports in Indonesia**

	Distance between the Airports (km)						
Distance between the Airports (km)	**BTJ**	**MES**	**PDG**	**PKU**	**DJB**	**...**	**DJJ**
BTJ	***	420.987	885.051	873.554	1,211.410	...	5,088.610
MES	420.987	***	516.130	462.346	800.055	...	4,699.870
PDG	885.051	516.130	***	189.680	385.234	...	4,475.620
PKU	873.554	462.346	189.680	***	338.331	...	4,356.270
DJB	1,211.410	800.055	385.234	338.331	***	...	4,098.310
...	...	...	...	...	...	...	...
DJJ	5,088.610	4,699.870	4.475.620	4,356.27	4,098.310	...	***

The distances obtained through the formula were then used as the input in order to form a distance matrix covering the airports in 33 provinces in Indonesia as presented in Table 2. The matrix shows a symmetric distance between one airport and the other airports in which, for instance, the distance between Sultan Iskandar Muda Airport (BTJ) and Polonia Airport (MES) and vice versa was 420.987 km. Meanwhile, the distance between Polonia Airport (MES) and Minangkabau Airport (PDG) and vice versa was 516.130 km. The process of inputting the distance into the matrix was repeated for the other airports until Bandar Udara Sentani Airport (DJJ). The data were then to be the input in forming the MST network based on the distance between the Indonesian's airports. In doing this, the researcher used Operation Research Models and Methods (ORMM), software developed by Jensen (2004). ORMM comprises add-in *combinatoric.xla* and *optimize.xla* that are used to run algorithm in Microsoft Excel. The software alleviated the process of forming MST network by providing the most efficient way to connect all airports in the network.

A similar method was also applied to the matrix of the distance for the airports in ASEAN as presented in Table 3. The matrix also shows the symmetric distance between one airport and the other airports in 24 cities in ASEAN.[7] To illustrate, the distance between Kinabalu City Airport (BKI) and Suvarna Bhumi Airport (BKK) and vice versa was 1,883.900 km. Meanwhile, the distance between Suvarna Bhumi Airport (BKK) and Brunei Airport (BWN) and vice versa was 1,832.850 km. The process of inputting the distance into the matrix was repeated for the

[7] 24 cities along with the flight codes: Kinabalu (BKI), Bangkok (BKK), Bandar Seri Begawan (BWN), Cebu (CEB), Chiang Mai (CNX), Davao (DAV), Denpasar (DPS), Hanoi (HAN), Phuket (HKT), Jakarta (JKT), Kuching (KCH), Kuala Lumpur (KUL), Luang Prabang (LPQ), Mandalay (MDL), Medan (MED), Manila (MNL), Penang (PEN), Phnom Penh (PNH), Siem Reap (REP), Yangon (RGN), Ho Chi Min City (SGN), Singapore (SIN), Surabaya (SUB), and Vientiane (VTE).

other airports until Wattay Airport (VTE). The data were then used as an input to form the network of MST based on the distance between the airports in ASEAN.

The third data processing was conducted by inputting the data of correlation coefficient of GDRP between one province and the other provinces into the 33x33 correlation matrix. The correlation among GDRPs was measured using the correlation coefficient formula of *Pearson's r* as follows:[8]

Table 3. **Matrix of the Distance between the Airports in ASEAN**

		Distance between the Airports (km)						
		BKI	**BKK**	**BWN**	**CEB**	**CNX**	**...**	**VTE**
Distance between the Airports (km)	BKI	***	1,883.900	166.320	992.609	2,337.290	...	1,984.130
	BKK	1,883.900	***	1,832.850	2,544.840	595.523	...	514.971
	BWN	166.320	1,832.850	***	1,156.100	2,315.460	...	1,976.400
	CEB	992.609	2,544.840	1,156.100	***	2,839.890	...	2,450.630
	CNX	2,337.290	595.523	2,315.460	2,839.890	***	...	390.077
	...	...	...	...	...	...	...	...
	VTE	1,984.130	514.971	1,976.400	2,450.630	390.077	...	***

Table 4. **Matrix of Correlation of GDRP among Provinces in Indonesia**[9]

		Correlation Coefficient of GDRP						
		BTJ	**MES**	**PDG**	**PKU**	**DJB**	**...**	**DJJ**
Correlation Coefficient of GDRP	BTJ	1.000	-0.909	-0.914	-0.927	-0.904	...	-0.809
	MES	-0.909	1.00	0.999	0.997	0.999	...	0.629
	PDG	-0.914	0.999	1.00	0.998	0.997	...	0.626
	PKU	-0.927	0.996	0.998	1.000	0.993	...	0.633
	DJB	-0.904	0.999	0.998	0.993	1.000	...	0.644
	...	...	...	...	...	...	...	...
	DJJ	-0.809	0.629	0.626	0.633	0.644	...	

[8] See Lind (2008). Furthermore, to simplify the measurement of correlation between GDRP, the researchers used the formula of correlation (Correl) in *Microsoft Excel*.

[9] Each province in Indonesia was represented by the airport code embedded inside. For instance, BTJ represents the Province of Nangroe Aceh Darussalam, MES representing North Sumatra Province, and so on until DJJ representing Papua Province.

$$r_{xy} = \frac{\Sigma(x - \bar{x})(y - \bar{y})}{(n - 1)s_x s_y}$$

The correlation coefficient indicates the relationship strength and direction of the GDRP of one province and the other provinces. It also indicates the correlation in economic potentials of those provinces. If $x \neq y$, thus $-1 < r_{xy} < 1$, while, if $x = y$, thus $r_{xy} = 1$. Table 4 depicts the example of correlation matrix of GDRP among provinces in Indonesia.

As seen in the Table 4, the correlation coefficient of GDRP of Nangroe Aceh Darussalam Province and GDRP of North Sumatra Province (-0.9092) showed a strong relationship in an opposite direction (negative) between those two provinces. Meanwhile, the correlation coefficient of GDRP of North Sumatra Province and that of West Sumatra Province (0.9997) indicated a strong relationship in the same direction (positive) between them. However, it is found that the relationship between GDRP of Nangroe Aceh Darussalam Province and GDRP of North Sumatra Province was weaker than the relationship between GDRP of North Sumatra and West Sumatra. In turn, this matrix was subsequently read equally until Papua Province.

Once the correlation matrix was formed, the data processing was conducted by changing the correlation coefficient of GDRP among provinces into the following pseudo distance[10] or ultrametricity distance:

$$d_{t,xy} = \sqrt{2(r_{xy} - 1)^2}$$

where,

$d_{t,xy}$ = pseudo distance between GDRP of Provinsi x and GDRP of Province y

r_{xy} = correlation coefficient of GDRP of Province x and GDRP of Province y

Pseudo distance is a distance representing the value of GDRP correlation used to form MST network. Using the formula of the pseudo distance, if $x = y$, thus $d_{t,xy} = 0$. Meanwhile, if $x \neq y$, thus $d_{t,xy} > 0$. In that formula, $d_{t,xy} = d_{t,yx}$ was valid. Thus, the stronger and more positive the correlation of GDRP of those two provinces, the closer their pseudo distance and the more they have to be connected direcly in the MST network. Accordingly, to be optimal, the network should connect all the provinces while minimizing the total pseudo distance between them. The calculated pseudo distance between provinces subsequently was used to be the input to make a matrix as presented in the following Table 5.

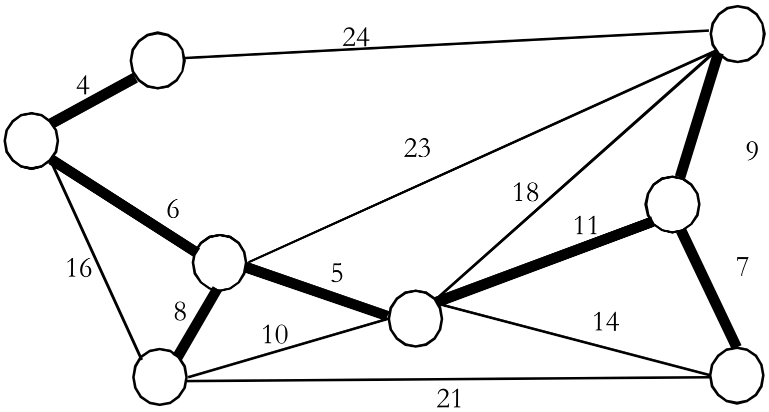
The Table 5 shows that the pseudo distance between Nangroe Aceh Darussalam Province (BTJ) and North Sumatra Province (MES) was 2.7000 given the correlation coeeficient of -0.9092. Meanwhile, the pseudo distance between North Sumatra Province (MES) and North Sumatra Province (PDG) was 0.00046 given the correlation coefficient of 0.99967. This was equally continued until the value of the pseudo distance between one province and the others in Indonesia was found.

[10] Adopted from the research by Setiawan (2011)

Table 4. **Matrix Correlation of GDRP among Provinces in Indonesia**[9]

		Pseudo Distance between Provinces						
		BTJ	**MES**	**PDG**	**PKU**	**DJB**	**...**	**DJJ**
Pseudo Distance between Provinces	BTJ	0	2.7000	2.7069	2.7253	2.6922	...	2.5585
	MES	2.7002	0	0.0005	0.0048	0.0018	...	0.5235
	PDG	2.7069	0.0005	0	0.0027	0.0035	...	0.5287
	PKU	2.7253	0.0048	0.0027	0	0.0099	...	0.5196
	DJB	2.6922	0.0018	0.0035	0.0099	0	...	0.5029
	...	...	...	...	...	...	...	...
	DJJ	2.5585	0.5235	0.5289	0.5196	0.5029	...	0

Figure 1. **Example of MST Network**



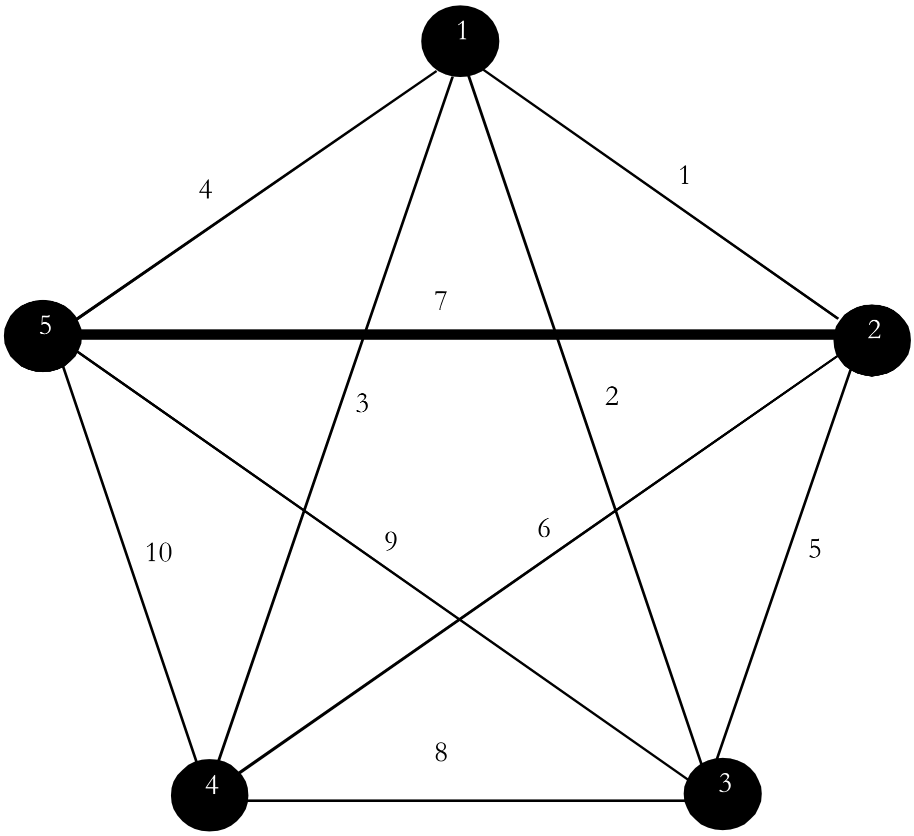
Source: Sedgewick dan Wayne (2007)

Minimum Spanning Tree (MST) Technique

Figure 1 illustrates the application of MST as provided by Sedgewick and Wayne (2007). In this figure, 8 vertices/nodes were given with a variety of cost weights in each arch or edge connecting them. MST, in turn, connected all of those nodes with the lowest total cost. The result of MST is represented in the bold black lines. The most efficient total cost (50) was obtained by summing the cost weights of the MST line.

MST technique is categorized into the symmetric graph theory or commonly called undirected graph in which a weight from the original node to the destination node is equal to a weight from the destination node to the original one. As an illustration, if there are two nodes (*i* and *j*) separated by the distance *d*, the distance from node *i* to node *j* (d_{ij}) is equal to the distance from node *j* to the node *i* (d_{ji}). In the terminology of minimum spanning tree,[11] an undirected graph (*G*) comprises a group of vertices that is notated with *V*(*G*), and a group of vertices connected by edges is notated with *E*(*G*). Each node connected to other nodes in *G* is called connected graph[12]. A graph with the real number (commonly positive) as a weight in each edge, meanwhile, is called the weighted graph. The sample of a connected graph with certain weights is presented in the Figure 2.

Figure 2. **A connected, Weighted Graph**



Source: Jayawant and Glavin (2009)

[11] All terminologies of MST refer to Jayawant and Glavin (2009).

[12] Each graph meant in the text refers to undirected graph.

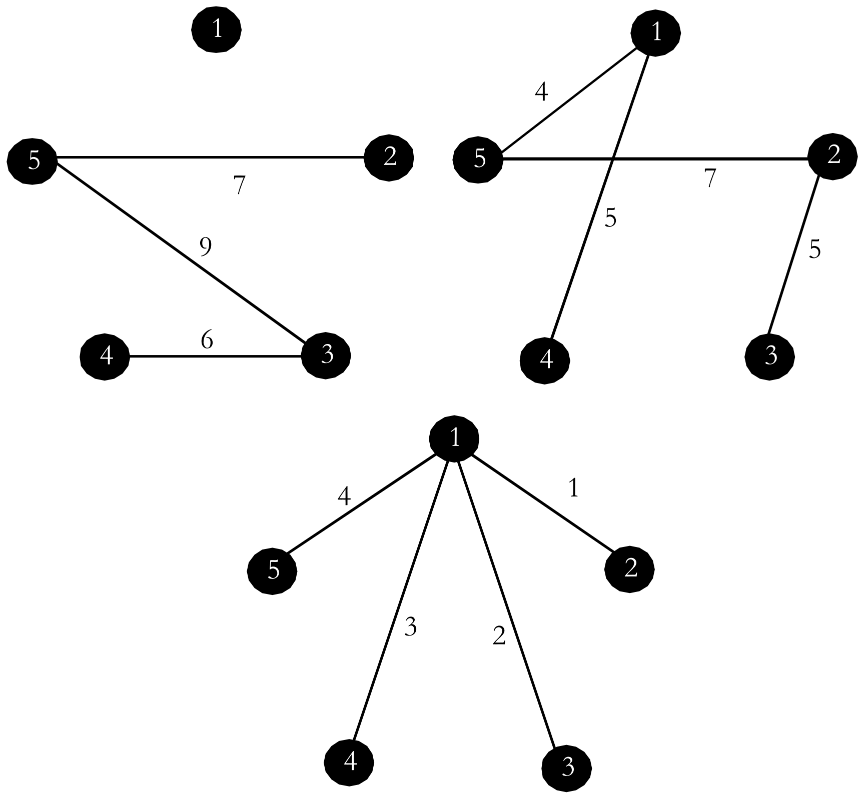
In the graph the vertices are represented by five nodes connected by the edges that, in this case, are presented by the lines connecting each node. The numbers in the lines show the weight of each line connecting two nodes. The weight can be in the form of distance, cost, or others. Also, the graph illustrates the great number of cycles of the lines that connect the nodes inside them as an order of the lines (1,3), (3,4), (4,5), and (5,1) that form one cycle.

Jayawant and Glavin (2009), additionally, illustrate the definition of minimum spanning tree in the graph theory into three: tree, spanning tree, and minimum spanning tree as shown in the Figure 3.

In graph *G*, a tree refers to a connected graph and does not form a cycle. However, the tree does not connect all vertices in this graph either. It is different from the spanning tree in which all vertices in graph *G* are connected by edges with the total weight of 19. Finally, minimum spanning tree (notated with T) connects all vertices in graph *G* with a minimum total weight of 10.

In general, there are two algorithms used to form the MST network, namely Prim algorithm and Kruskal algorithm. Those two algorithms, subsequently, will result in an equal network of MST. In this research, Prim algorithm (greedy algorithm) was used through the following phases (Sedgewick and Wayne 2011):

Figure 3. **In a clockwise manner from the left above, a tree in G, a Spanning Tree in G, a Minimum Spanning Tree G**



Source: Jayawant and Glavin (2009)

1. Selecting the nodes in the network randomly.
2. Adding the lines connecting the nodes to other lines that have the lowest weight.
3. Repeating the second phase in order to connect the nodes that have been connected to other nodes that are not connected yet in the network by prioritizing the lower weights.
4. Repeating those phases until all nodes in the network are connected.

In addition, in order to alleviate the process of measuring and forming the network, the researchers used certain software including *Microsoft Excel, Operation Research Models and Methods* (ORMM),[13] and PAJEK.[14] *Microsoft Excel* and ORMM were used to determine the airports supposed to be connected in order to form the shortest network. PAJEK, meanwhile, was used to describe the network visually. The use of the software referred to the research of Setiawan (2011), that has used MST technique to examine the presence of stock market integration and has used the software to find the least total path distance that connects all the nodes representing stock markets indexes.

Results and Discussion

Principally, the airports in Indonesia have been connected to each other as seen in Figure 4. The network of those airports was obtained based on the presence of the commercial flight from one airport to the others and showed the network of the airports recently used by the airlines in Indonesia.

In that network all airports have been connected to each other – except HLP in which there was no commercial flight from and/or to that airport. In addition, there were three airports functioning as the main and the busiest hubs in the network, namely CGK with 29 spokes, SUB with 17 spokes, and UPG with 16 spokes.[15] The total distance to connect all airports using the network was 84,108.58km.

The MST Network Based on the Flight Frequency

Based on the number of the flight frequencies per day, five airports with the biggest flight services included CGK with 389 flights, SUB with 133 flights, UPG with 78 flights, DPS with 57 flights, and MES with 50 flights.[16] If all airports were connected by maximizing the flight frequencies from one airport to the other airports, the interrelation and hierarchical network would become a form as illustrated in Figure 5. There were two hubs in this network, namely CGK with 26 spokes and UPG with 3 spokes. The total distance to connect all airports with this network was 38,546.830 km, which was 54 percent shorter than the total distance to connect all airports in the network now used in Indonesia.

[13] ORMM is a software developed by Jensen (2004). ORMM comprises add-in combinatoric.xla and optimize.xla that are used to run greedy algorithm in Microsoft Excel.

[14] PAJEK is software developed by Batajelj and Mrvar (2011) in describing certain network.

[15] Basically, all airports not functioning as the hub refer to spoke. However, in this research, the number of spokes was measured based on the absence or present of a direct flight from hub to other airports and vise versa provided by 7 major airlines. The number of the spokes in this research was used as one of indicators to find out the flight concentration directly connected to the hub.

[16] The number of provided flights was measured based on the flight frequencies per day from 7 main airlines as the sample of this research.

Figure 4. **The Interrelation and Hierarchical Network of Airports in Indonesia Based on the Presence the Commercial Flight from One Airport to the Others**

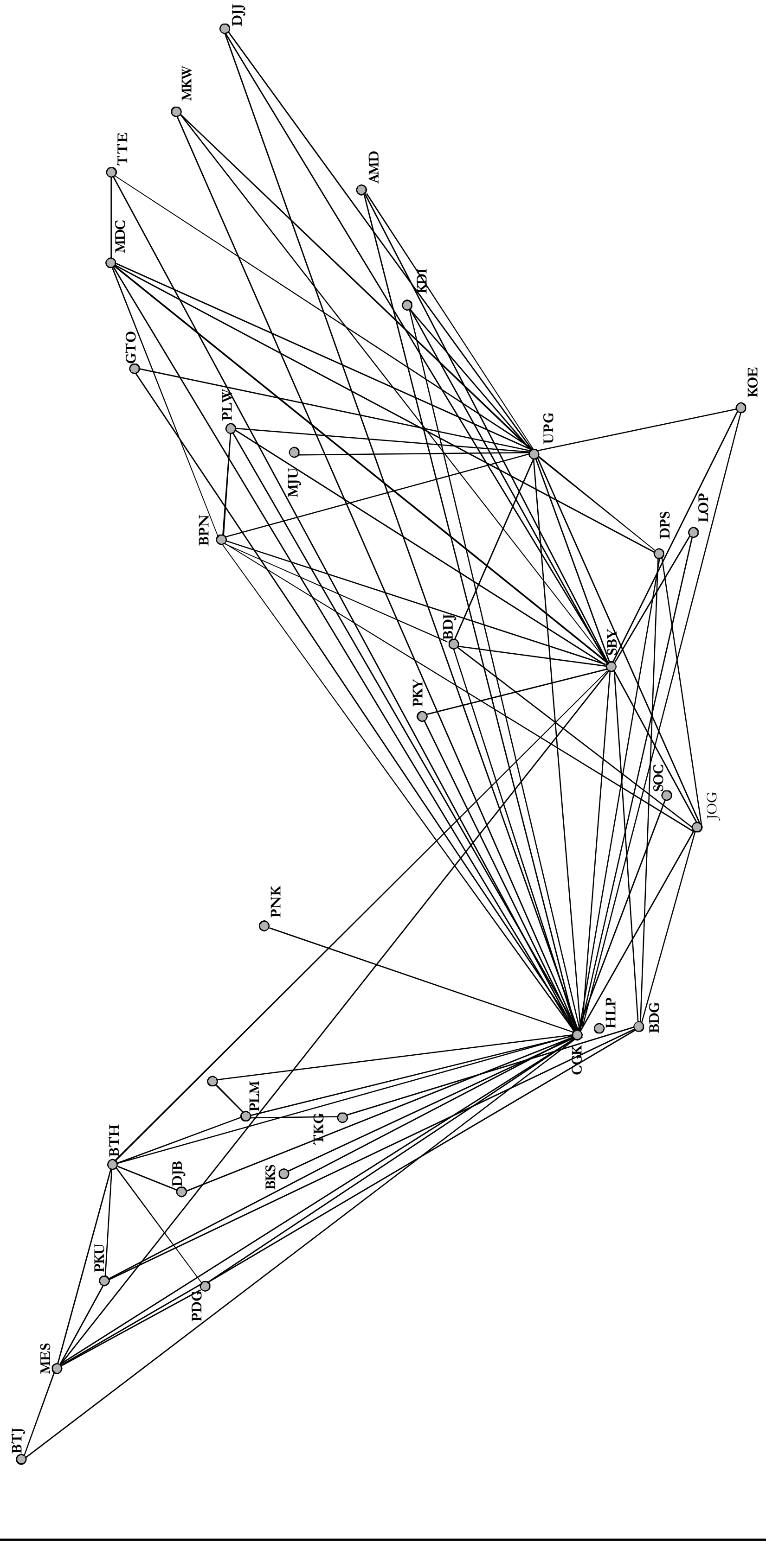


Figure 5. **The MST Network of All Airports in Indonesia by Maximizing the Flight Frequencies from One Airport to the Others**

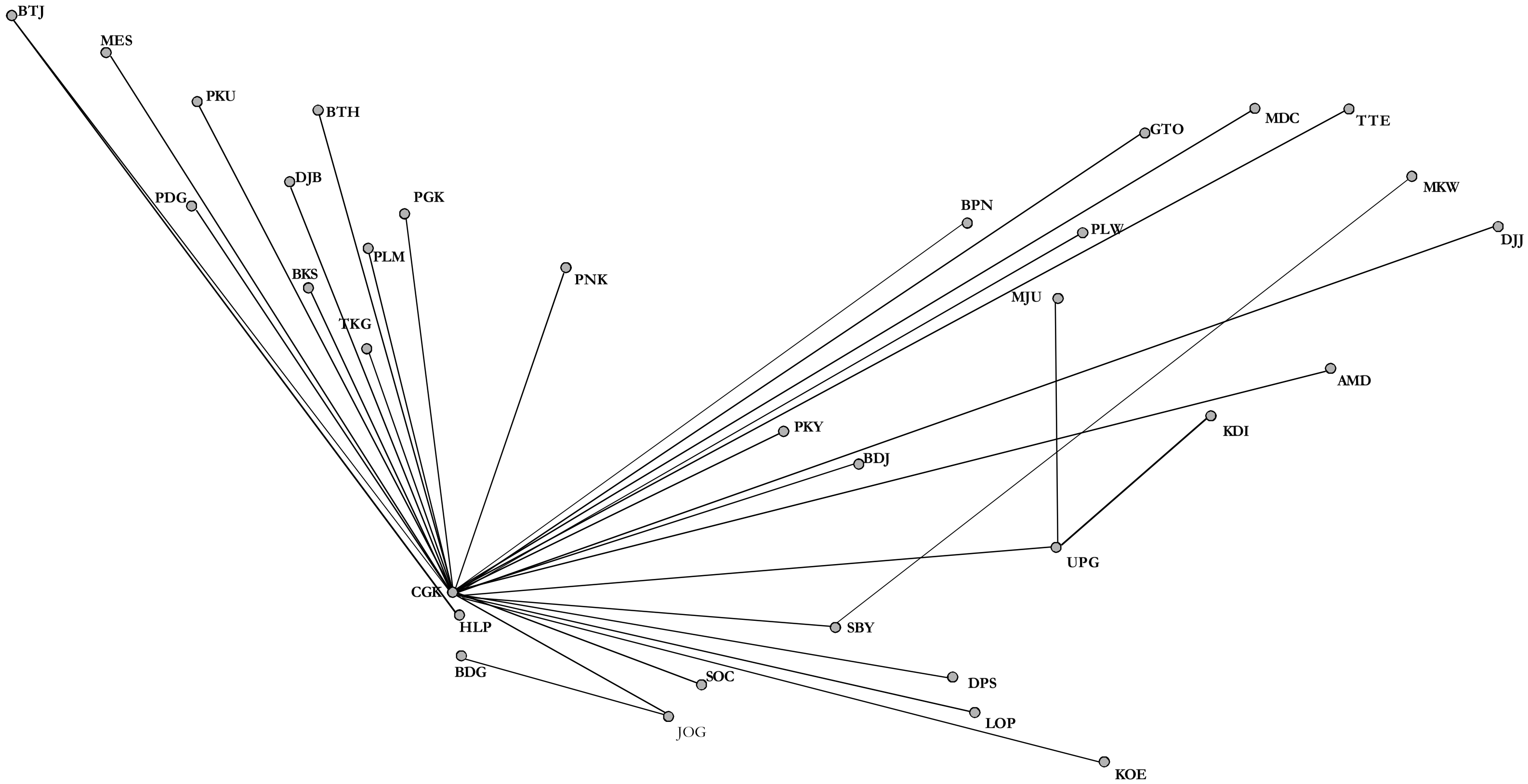


Figure 5 clearly shows that the domestic flights in Indonesia are now concentrated in one airport, namely CGK. With the biggest number of flight frequencies, this airport could function as a distribution center (DC) for the other airports in Indonesia. The network with DC enables the airlines to consolidate the passengers in CGK. Nevertheless, the network with only one DC will increase not only the complexity in coordination but also handling cost. Moreover, the most frequent occurrence in CGK in the air traffic density is the delay for take-off and landing. As a result, it becomes a great loss to the airlines for providing more fuel and brings a detrimental effect on passengers regarding the time they have to spend in the plane. In addition, as a DC, CGK must consider the passengers and the planes capacity under its service that will require a great investment for building and expanding the airport.

The MST Network Based on the Distance between Airports

Figure 6 shows the form of interrelation and hierarchical network of the airports in Indonesia based on the distance between airports. This figure depicts the shortest network of the airports as a result of MST technique. In this network, three airports acted as hub: PLM with 4 spokes, PKU with 3 spokes, SUB with 3 spokes, BDJ with 3 spokes, and MJU with 3 spokes. The total distance to connect all airports using this network was 10,036.600 km, which was 88 percent shorter than the total distance to connect all airports in the network recently used in Indonesia. Unlike the network now used in Indonesia as depicted in Figure 6, the MST network has a spreading hubs with a relatively few spokes in each hub. In this network, SUB was still consistent to be one of the main hubs. Meanwhile, CGK was no longer as the hub with the biggest number of spokes but PLM.

However, the MST network in Figure 6 did not consider any demands or flight frequencies from one airport to the others. As an illustration, by simply considering the distance between the airports, the flight from DJB to CGK must first pass through PLM as a hub. Meanwhile, the flight from SOC with a destination to DPS must pass through SUB as a hub. The flight from BDJ to SUB, however, must be made directly because there was no hub between those two airports. These are done in the purpose of obtaining the shortest total distance in connecting all airports in the network.

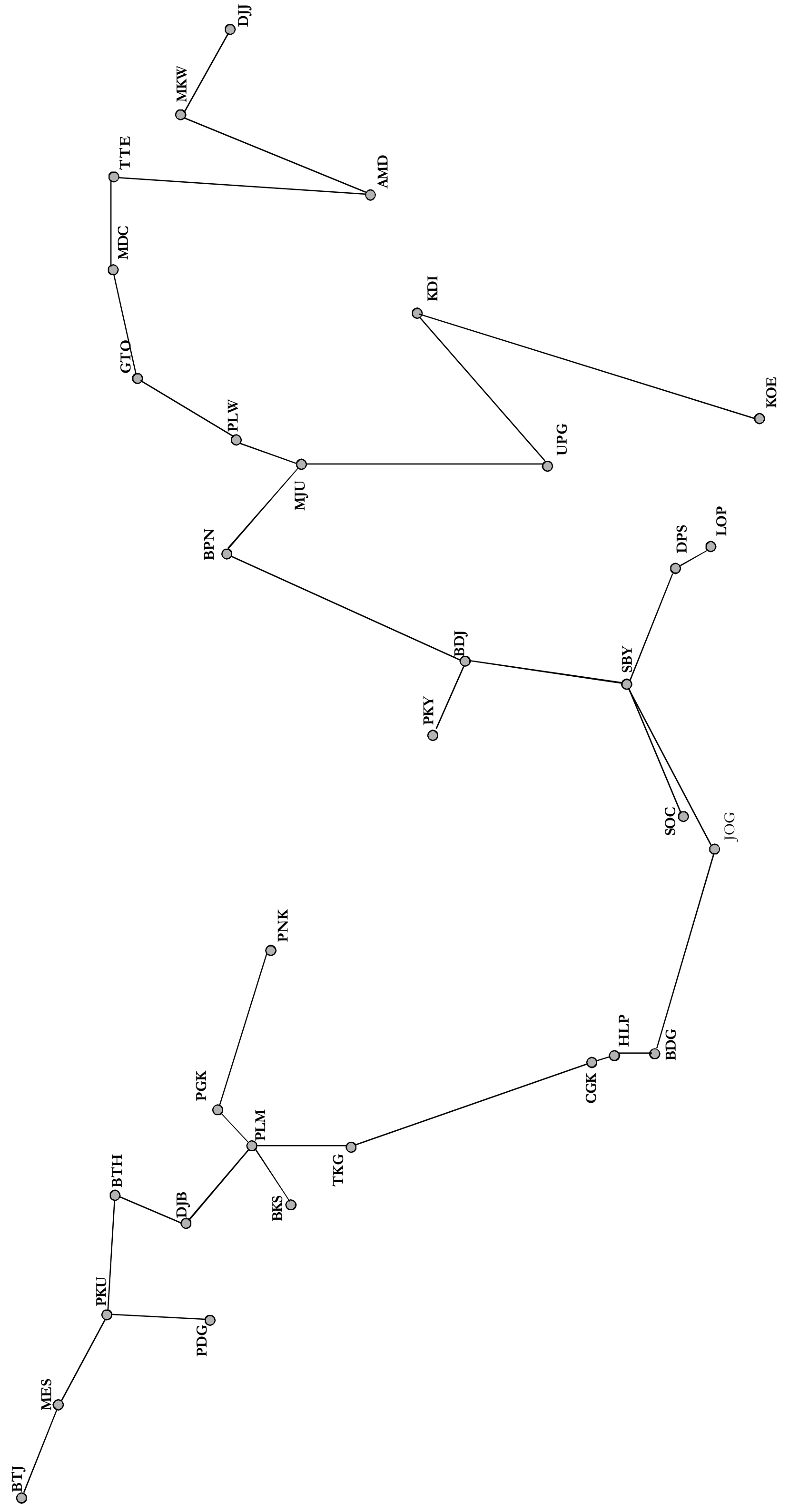
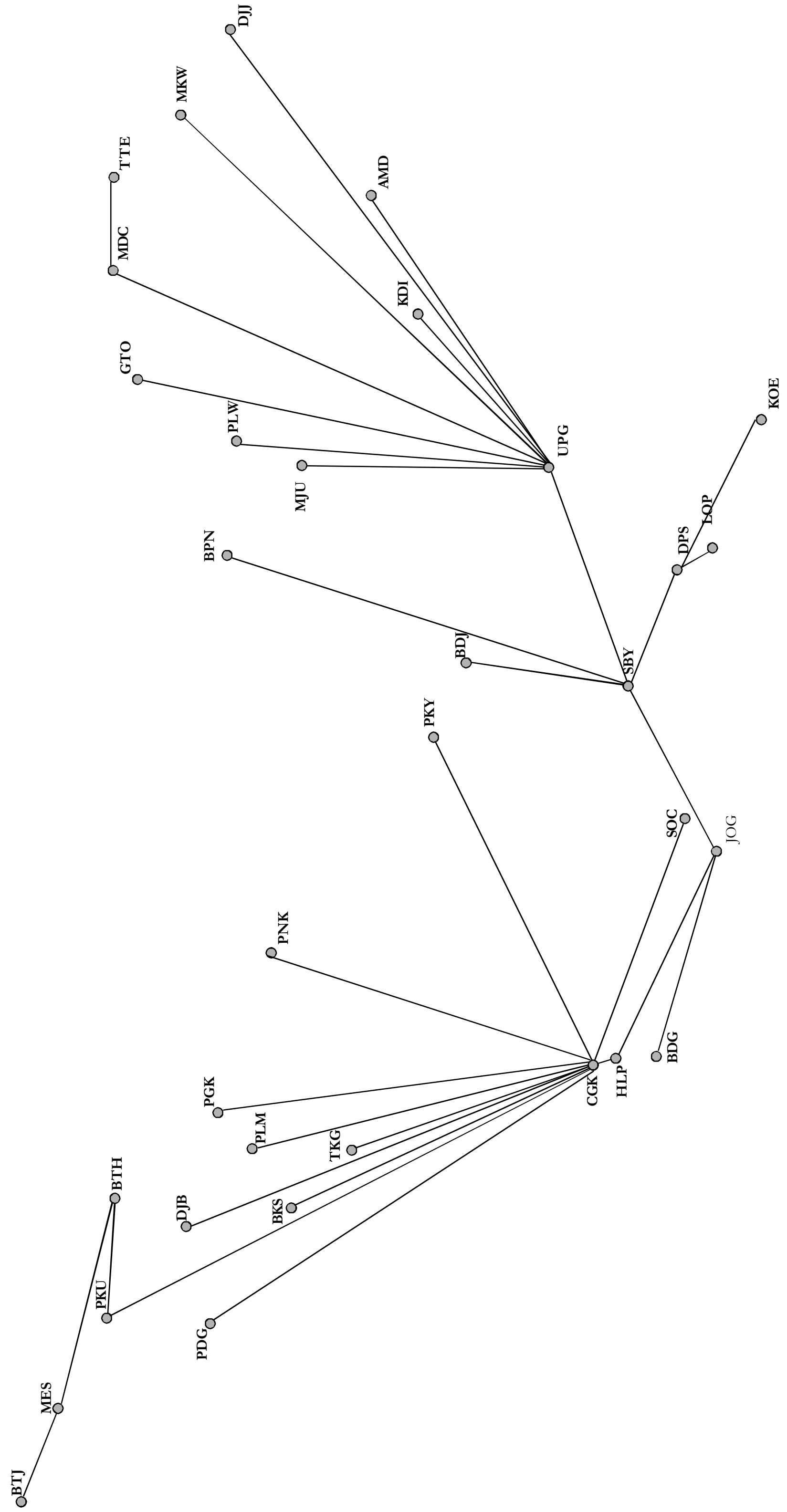


Figure 6. **MST Network by Minimizing the Total Distance to Connect all Airports in Indonesia**

Figure 7. **The MST Network of Airports in Indonesia by Minimizing the Total Distance and by Maximizing the Flight Frequency**



The MST Network by Weighting the Distance and Flight Frequency

Figure 7 presents the interrelation and hierarchical network of airports in Indonesia with an equal weight in distance and flight frequency from one airport to the others (50%: 50%). Five airports that became the hub in that figure included CGK with 11 spokes, UPG with 9 spokes, SUB with 5 spokes, DPS with 3 spokes, and JOG with 3 spokes. Using this network, the flight from JOG to DJJ, as an illustration, must first pass through CGK as the hub. On the other hand, the flight from SUB to DJJ must first pass through UPG as the hub. However, the flight from UPG to SUB must be made directly since there was no hub between these two airports. This was not only to minimize the total distance for connecting all airports but also to maximize the flight frequency from one airport to the other airports. The total distance to connect all airports using this network was 20,097.390 km. As a result, this airport network could result in 76 percent shorter than the total distance to connect all airports using the existing network in Indonesia.

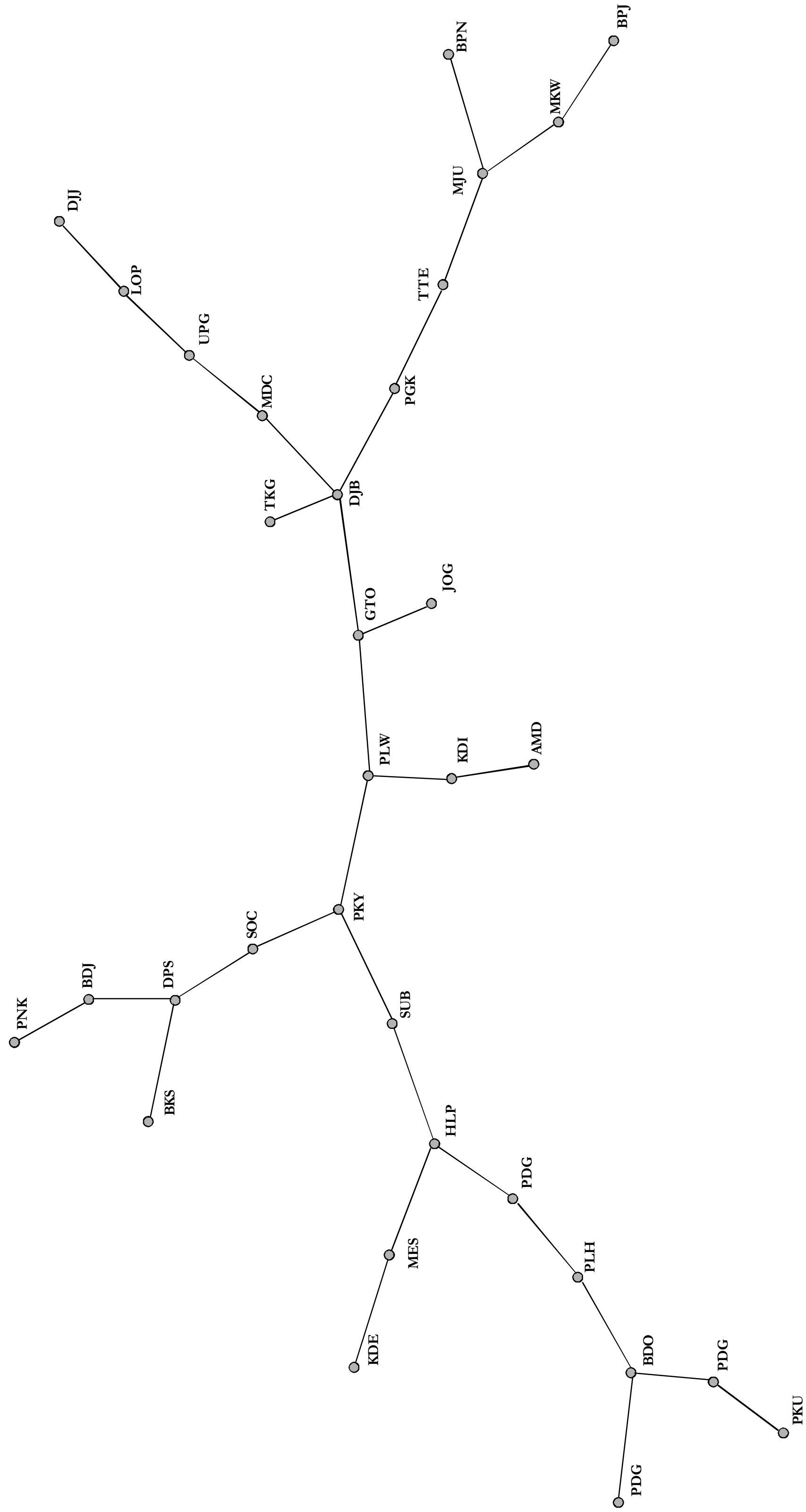
In consideration of the flight frequency from one airport to the others, the form of this airport network was not equal to that of the airport as depicted in Figure 4. However, the main hub formed in this network has been suitable with the main hub in the existing network in Indonesia. In this network, CGK again came to be the hub with the highest number of spokes - followed by UPG and SUB, but the number of spokes to be served were not as many as the spokes served by the airports in the network as in Figure 4.

The MST Network Based on the Correlation of GDRP of each Province in Indonesia

The interrelation and hierarchy of the airports as depicted in Figure 8 below refers to a network of the airports describing a maximal correlation of the economic potential in each province in Indonesia. The form of the network in the figure was simply based on the GDRP correlation of each province without any consideration about the distance between the airports and the flight frequency from one airport to the others. Two airports directly correlated by edge in this network showed that two provinces where those two airports exist had a strong and positive GDRP correlation. In other words, the stronger and more positive the correlation of GDRP between two provinces, the airport located in those two provinces must be directly correlated.

To illustrate, HLP representing Special Capital District (DKI) of Jakarta Province is directly correlated to SUB representing East Java Province, CGK representing Banten Province, and MES representing North Sumatra Province. It means that the correlation of GDRP between DKI Jakarta Province and East Java Province (0.99994), Banten Province (0.99994), and North Sumatra Province (0.99987) is stronger and more positive compared to the correlation of GDRP between DKI Jakarta and other provinces in Indonesia.

Figure 8. **The MST Network of Airports by Maximizing the Economic Potential Based on the Total Correlation of GDRP in Each Province in Indonesia**



For another illustration, SOC that represented Central Java Province was directly correlated to DPS representing Bali Province and PKY representing Central Kalimantan Province. This was due to the correlation of GDRP among Central Java Province and Bali Province (0.99995) and Central Kalimantan Province (0.99998) was stronger and more positive compared to the correlation between GDRP of Central Java Province and other provinces in Indonesia.

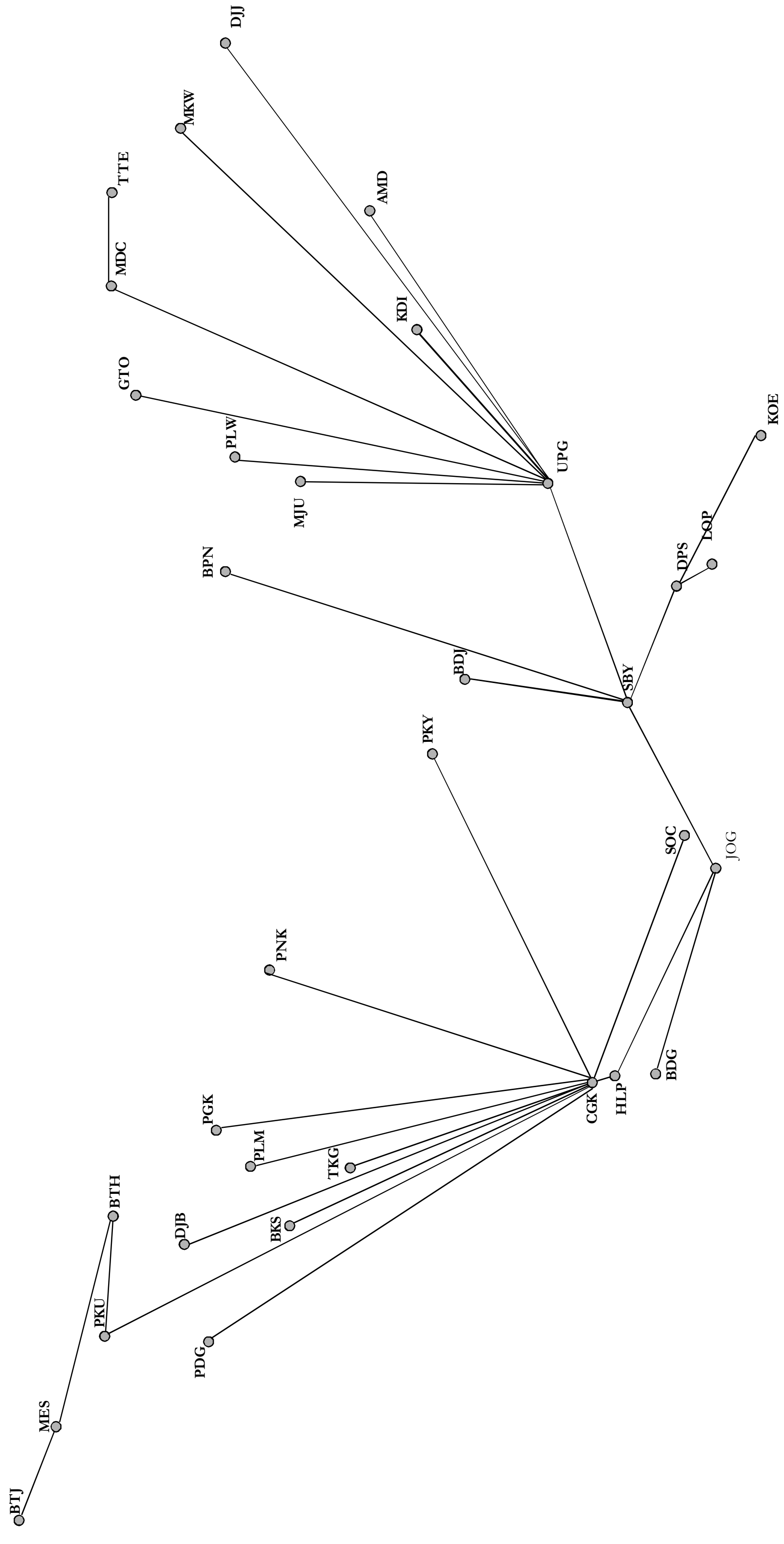
In addition, there were 8 airports in the network that functioned as the hub, namely DJB with 4 spokes, BDO with 3 spokes, HLP with 3 spokes, PKY with 3 spokes, PLW with 3 spokes, GTO with 3 spokes, DPS with 3 spokes, and MJU with 3 spokes. As an illustration of using this network, the flight from SUB to SOC must first pass through PKY as the hub. Meanwhile, the flight from PGK to TTE must be made directly considering that there was no any hub between those two airports. This was done to maximize the connectivity of economic develoment (GDRP correlation) as a base of the conectivity of all airports in this network. It is found that the total distance to connect all airports based on the economic potential of each province in this network was 36,098.440 km. It means that this network of the airports resulted in the total distance of 57 percent shorter that the total distance to connect all airports in the existing network in Indonesia.

In fact, by simply considering the total correlation of GDRP, it is found that the form of the network was different from the network now used in Indonesia. This network has a more widespread hub and if compared to the network as presented in Figure 4, it is found that only DPS that still acted as one of the main hubs in this network. In addition, CGK was no longer the hub with the most number of spokes but DJB that, in turn, led DJB to be the busiest hub in this network.

The MST Network with the Weighting of the Distance, Flight Frequency, and Pseudo Distance

Figure 9 presents the form of the interrelation and hierarchical network of Indonesia's airports with a distribution of the equal weight (33,33% : 33,33% : 33,33%) between the airports in distance, flight frequency, and pseudo distance, respectively. Broadly, the form of this network was unequal to the form of a network that simply considered with the correlation of GDRP in the total manner as in Figure 8 but had a similarity with the form of the network with the weighting of distance and flight frequency as in Figure 7. Thus, this indicates that the pseudo distance processed from the correlation of GDRP in each province in Indonesia did not result in a significant effect on the form of the airports in Indonesia. Though the weight for the pseudo distance was calculated to be 50 percent thus making it weightier than the distance and flight frequency (25% : 25% : 50%), the form of the airport network in Indonesia remained the same as in Figure 7 (see Figure 10). Thus, the total distance to connect all airports using this network was able to reach 20,097.390 km. The network of the airports, in addition, resulted in the total distance of 76 percent shorter than the total distance to connect all airports in a network now in use in Indonesia.

Figure 9. **The MST Network of Indonesian's Airports with the Weighting of the Distance (33,33%), Flight Frequency (33,33%), and Pseudo Distance (33,33%)**



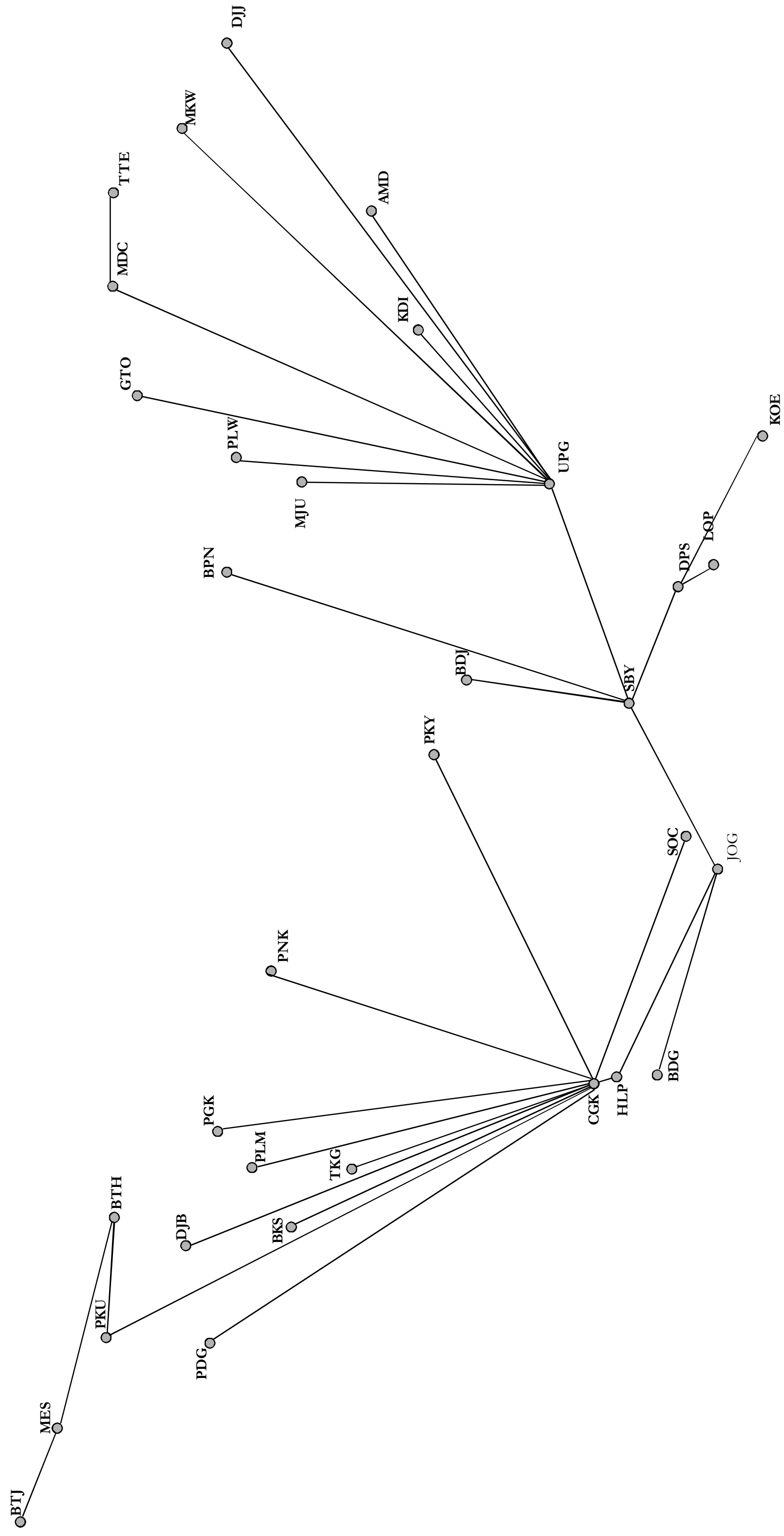


Figure 10. **The MST Network of Indonesian's Airports with the Weighting of the Distance (25%), Flight Frequency (25%), and Pseudo Distance (50%)**

Meanwhile, Figure 1 presents the network of the airport in Indonesia by providing the weight to the distance between the airports (50%) greater than the weight for the flight frequency (25%) and pseudo distance (25%). In common, the form of this network is not far different from another form of the network as depicted in Figure 9. However, there were 6 airports in this network that function as the hub: CGK with 9 spokes, UPG with 7 spokes, SUB with 4 spokes, BTH with 4 spokes, JOG with 3 spokes, and DPS with 3 spokes.

To exemplify this, the flight from PKU to CGK, using this network, could not be made directly but must first pass through BTH as the hub. Meanwhile, the flight from BTH to PLM must be made directly without passing through CGK that previously acts as the hub for those two airports (see Figure 9). The total distance to connect all the airports in the network was 15,541.700 km. This airport network resulted in the total distance of 82 percent - shorter than the total distance to connect all airports in the network now used in Indonesia.

Moreover, this network had the hub more widespread compared to the network as depicted in Figure 9. This form of the network was also different from the form of the existing network used in Indonesia. However, similar to the network as depicted in Figure 4, CGK in this network came to be the hub with the most number of spokes, followed by UPG and SUB. Nevertheless, the number of the spokes provided by CGK, UPG and SUB in this network was not as many as the spokes provided in the network as in Figure 4 and Figure 9.

Furthermore, Figure 12 presents a network of Indonesia's airports in which the flight frequency from one airport to other airports was provided with the larger weight (50%) compared to the weight for the distance between the airports (25%) and pseudo distance (25%). In this network, there were three airports functioning as the hub, namely CGK with 15 spokes, UPG with 9 spokes, and SUB with 6 spokes. Through this network, the flight from CGK to SUB, for instance, must be made directly without passing through JOG that previously acted as the hub for both two airports. While, the flight from JOG to SUB could not be made directly but must first pass through CGK as the hub. It, as a result, made the total distance to connect all airports in the network was 22,098.100 km. This airport network, in turn, resulted in a total distance of 74 percent shorter than the total distance to connect all airports in the network used in Indonesia recently.

Furthermore, this network had a more concentrated hub compared to the network as depicted in Figure 9. Two main hubs in this network, e.g. CGK and SUB, in addition, had more spokes than the spokes in the network as shown in Figure 9. The establishement of CGK, UPG, and SUB as the hubs in this network had been suitable with the network as shown in Figure 4 in which those three airports acted as the busiest airports in this network.

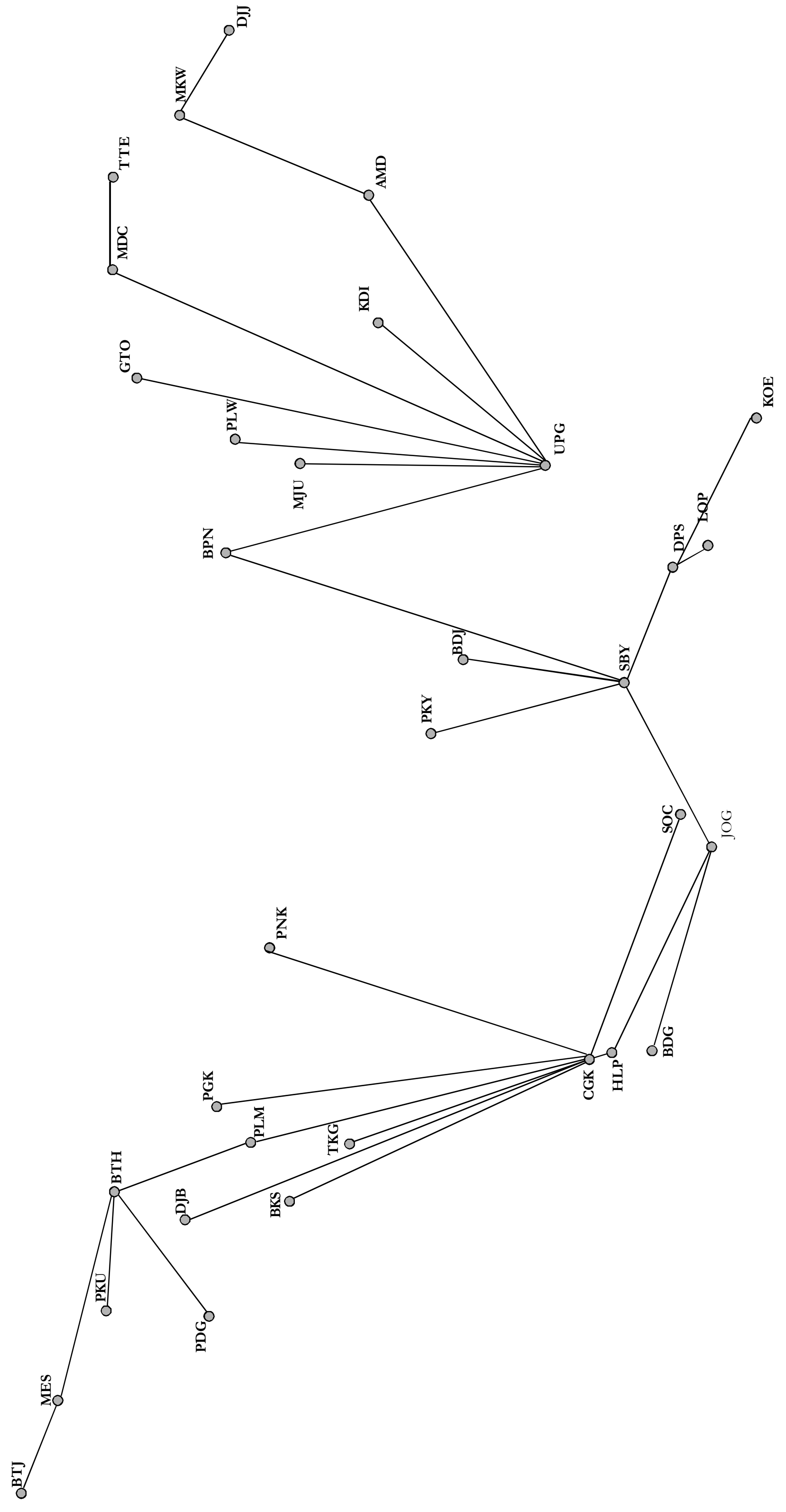
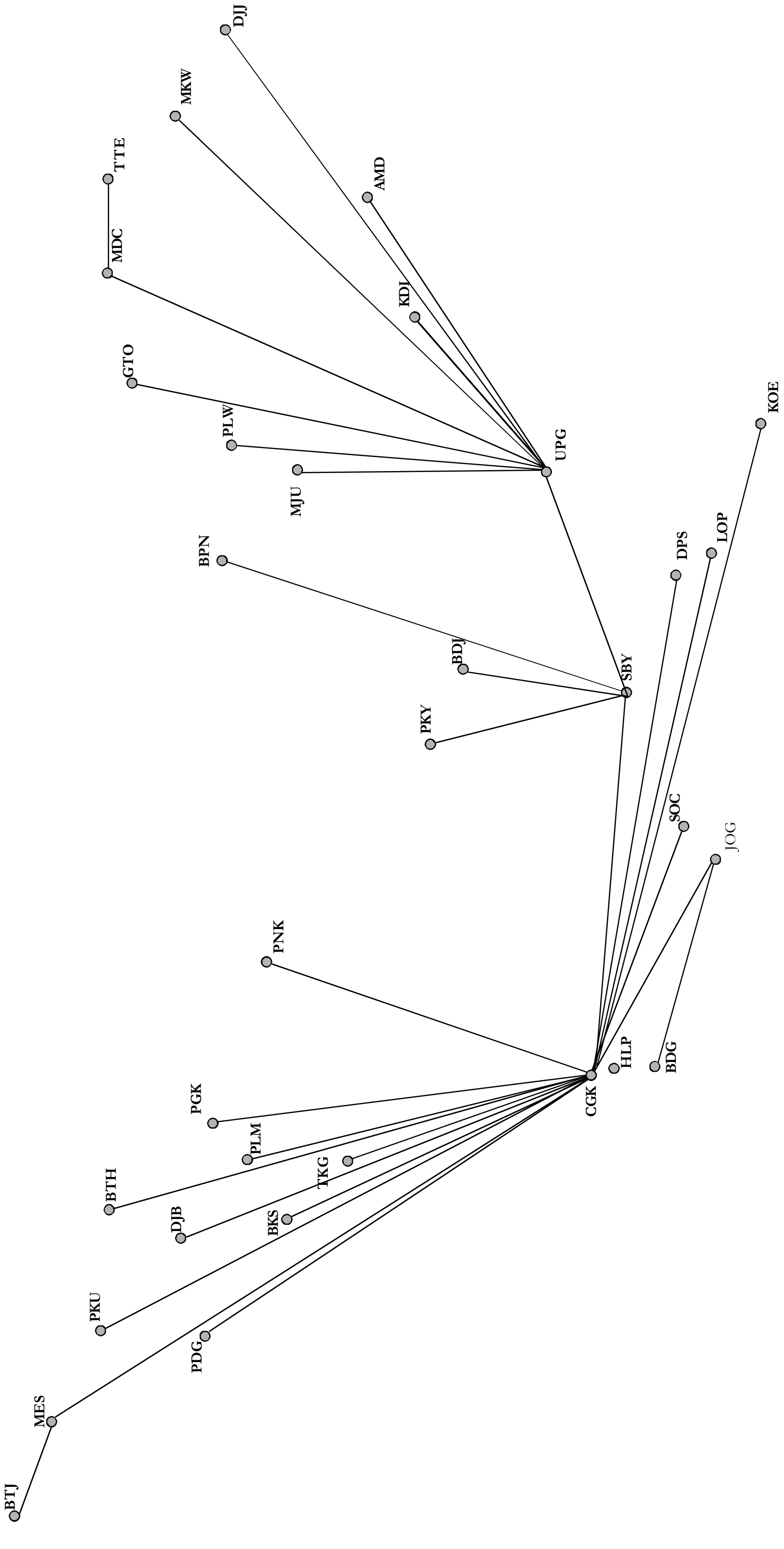


Figure 11. **The MST Network of Indonesian's Airports with the Weighting of the Distance (50%), Flight Frequency (25%), and Pseudo Distance (25%)**

Figure 12. **The MST Network of Indonesia's Airports by Providing Weight for Distance (25%), Flight Frequency (50%), and Pseudo Distance (25%)**



The MST Network of Airports in ASEAN

Given the policy of ASEAN Open Sky, four airports in four cities in Indonesia, namely Soekarno-Hatta Airport representing Jakarta (JKT), Juanda Airport representing Surabaya (SUB), Ngurah Rai Airport representing Denpasar (DPS), and Polonia Airport representing Medan (MED) have been used as the main airports that provide a service for flights with a number of destinations in ASEAN countries. For this, the flights from Indonesia with city destinations in ASEAN and vice versa must pass through one of those four airports. In other words, those four airports have been the hubs for the airports in Indonesia that must be passed through as the gates for the destinations in ASEAN.

Figure 13 presents the interrelation and hierarchical network of the airports in ASEAN based on the distance between one airport and other airports. This network referred to the network with the shortest total distance in connecting all airports in ASEAN (10,405.400 km). In this network, six airports acted as the hub; those are CNX with 3 spokes, LPQ with 3 spokes, BKK with 3 spokes, PEN with 3 spokes, SIN with 3 spokes, and CEB with 3 spokes.

In this network, four cities in Indonesia, JKT, SUB, DPS, and MED, did not have any role as the hubs in ASEAN regions. In fact, those four airports were connected by SIN. It means that the flight from MED to JKT, SUB and DPS, for instance, must first pass through SIN as the hub. Therefore, SIN became a strategic place to consolidate the passengers in those routes. Sub regionally, the airports in Indonesia, additionally, are closer to Singapore, Malaysia, Thailand, and Brunei Darussalam (SMTB + Indonesia). For this reason, by considering the shortest distance to connect all airports in ASEAN Open Sky, the sub regional classification by Forsyth et al. (2004), including Vietnam-Indonesia-Philippine and Brunei (VIP+B) is not suitable with the result of this research.

Meanwhile, Figure 14 presents an optimal form of network based on the distance between airports if 33 airports in 33 provinces in Indonesia were put into the network of ASEAN Open Sky. Through this network, the total distance to connect 33 airports in Indonesia and 22 airports in ASEAN was 17,199.100 km. Eventhough the hub in that network was dominated by other cities in ASEAN, several airports in Indonesia also played an essential role as the hub. MDC in this network importantly was to connect MNL, CEB, and DAV to SUB. In addition, PLM also played a significant role by connecting SIN to JKT, KCH, BWN and BKI. Thus, the position of Indonesia in this network was quite strategic. Moreover, Indonesia in this network was getting closer to Phillipine through MDC - thus making the sub-regional group to be SMTBP + Indonesia.

Figure 13. **The MST Network of Airports in the Policy of ASEAN Open Sky by Minimizing the Total Distance to Connect All Airports in ASEAN.**

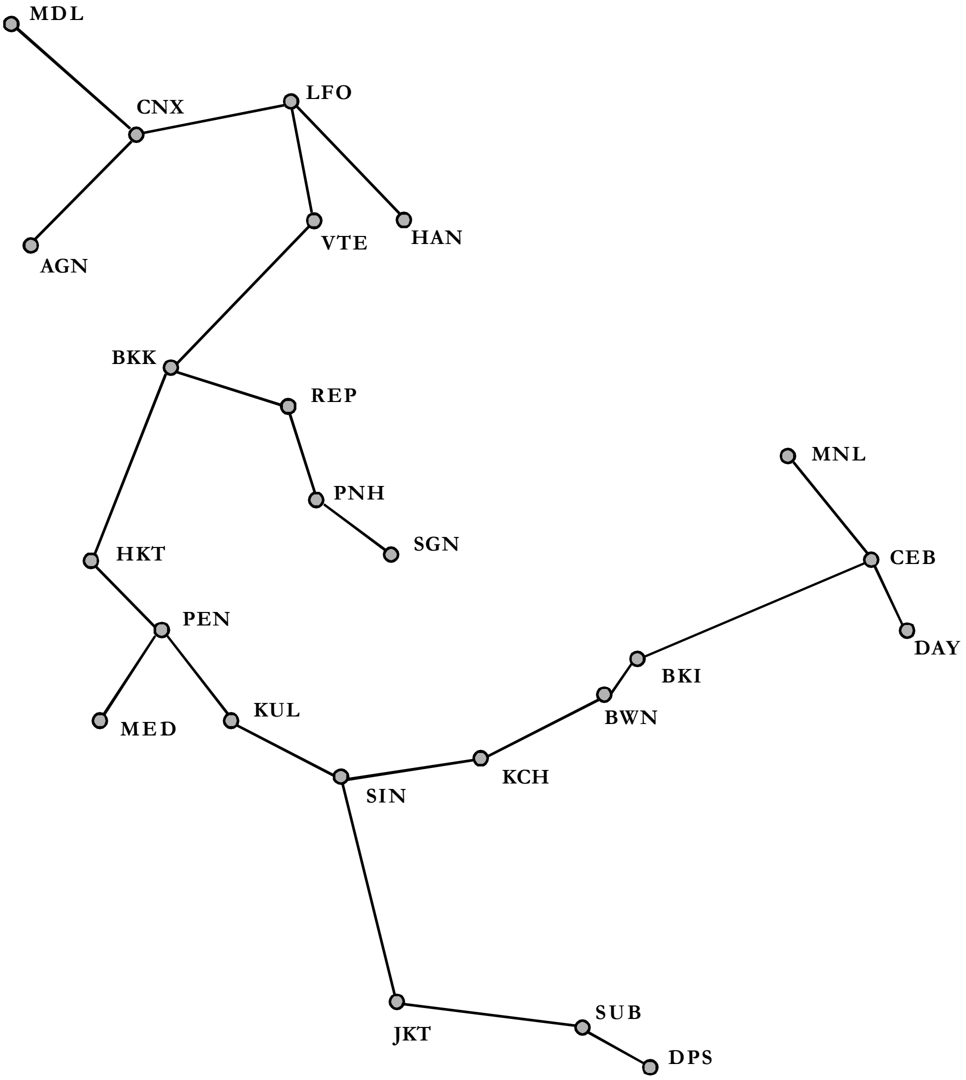
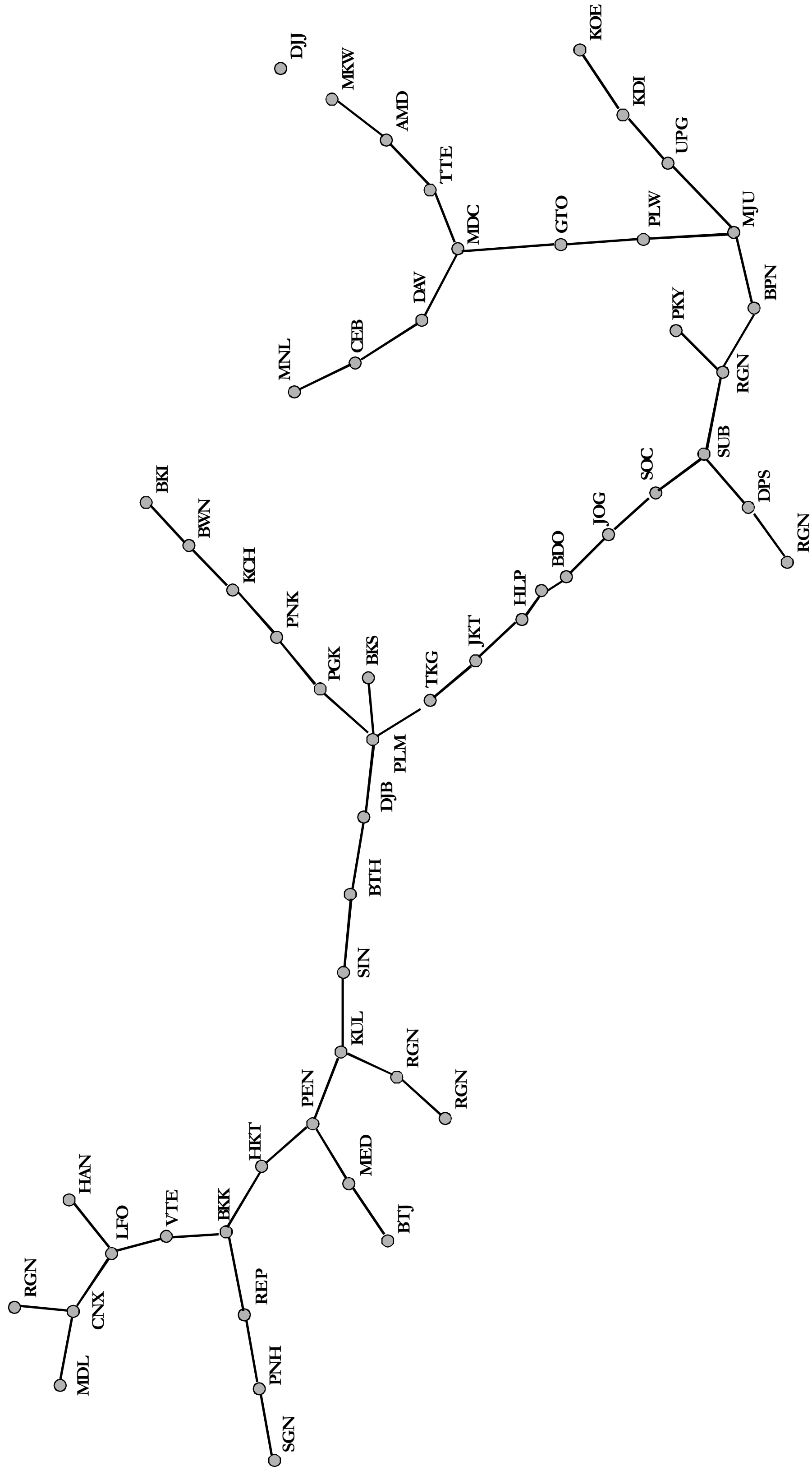


Figure 14. **The MST Network of Airports in the Policy of ASEAN Open Sky by Minimizing the Total Distance to Connect All Airports in ASEAN**



Conclusion and Managerial Implications

By comparing the optimal network based on the MST technique with the network now used in Indonesia, the researchers, in turn, come to the conclusions consisting of several points. *Firstly*, the interrelation and hierarchical network of airports recently used in Indonesia does not completely reflect the airport network with the shortest total distance that could be obtained if only the distance of the airports in Indonesia was considered to form the network in which PLM, PKU, SUB, BDJ, and MJU had acted as the hubs. The network of the airports that has been formed, by considering the aspect of flight frequency from one airport to another and by providing the equal weight to distance, will produce the total distance of 76 percent shorter that the total distance to connect all airports in the existing network used in Indonesia. In this case, CGK, UPG, and SUB become the main hubs in this network. The equal result will be obtained if the aspect of GDRP correlation in each province in Indonesia is considered with the equal weight in the distance and in flight frequency in which the network refers to the optimal network in this research.

Another point is that the interrelation and hierarchical network of the airports recently used in Indonesia has not maximally reflected the correlation of economic potential of each province in Indonesia. If mixed with the aspect of the distance between airports and the flight frequency from one airport to the others with an equal weight, the correlation of economic potential measured with the correlation of GDRP of each province in this research does not have a significant impact on the total distance and the form of the optimal airport network in Indonesia. This might have happened because of the very small differences between GDRP correlations of provinces in Indonesia.

The third one, given the policy of ASEAN Open Sky, based on the distance between the airports, Indonesia still lacks a strategic role in the airport network in ASEAN. In the network involving 24 airports in ASEAN with the minimization of the total distance to connect all airports, there is no airport in Indonesia acting as the hub. In fact, the airports in Indonesia are connected by airports of other countries in ASEAN. The efficient position of Indonesia in the network based on the distance is merely as the spoke. This leads to the limited scope of service of those four Indonesian's airports in ASEAN. Moreover, the position of Indonesia is closer to Singapore, Malaysia, Thailand, and Brunei Darussalam instead of Vietnam and Philippine. Conversely, if 33 airports in 33 provinces in Indonesia are becoming part of the ASEAN Open Sky network, Indonesia will have a strategic role as having hubs that connect Indonesia to Singapore, Malaysia, Thailand, Brunei Darussalam, and Philippine.

Thus, the managerial implications that this research can contribure are as follows: Firstly, in order to further develop the airports in Indonesia, it is suggested for the airport managers consider the airports acting as hubs in each optimal network. In addition, if three important aspects, namely distance between the airports, flight frequency, and the correlation of economic potential in each province in Indonesia, are carefully considered in forming an optimal network, equal weight should be applied to each of those three aspects. Moreover, the airport managers should consider the development of Soekarno-Hatta Airport (CGK), Hassanuddin Airport (UPG) and Juanda Airport (SUB) as the main hubs of the network. However, the main concern should be focused on CGK and UPG since those two airports are the hubs with the widest service scope. It is important to anticipate the growing demand in the airline industry in the future.

Secondly, to connect all provinces in Indonesia and to maximize the correlation of economic potential of each province, the government should consider the aspect of distance between the airports and flight frequency in 33 provinces in Indonesia. Thirdly, in facing the ASEAN Open Sky policy, the airport managers should consider the four airports that are supposed to join the ASEAN Open Sky network (i.e. JKT, SUB, DPS, and MED). In addition, the managers should prepare the development of Sam Ratulangi Airport (MDC) and S.M. Badaruddin II Airport (PLM) to be the hubs if there is an opportunity for 33 airports in 33 provinces in Indonesia to join the ASEAN Open Sky network. Furthermore, to be efficient, the airlines in Indonesia should consider Changi Airport (SIN) and Penang Airport (PEN) as the hubs in consolidating the passengers from and to the countries in ASEAN regions. In turn, if 33 airports in 33 provinces in Indonesia have an opportunity to join the ASEAN Open Sky network in the future, the airlines in Indonesia should consider Sam Ratulangi Airport (MDC) and S.M. Badaruddin II Airport (PLM) to be the hubs to consolidate the passengers.

Thirdly, the optimization of the airport network will be very important in the future. This research can be an alternative for airlines to make decisions related to cost reduction, route design, passenger consolidation, and the like. Moreover, the optimal network will enhance economic transactions among connected regions so that this research can also be an alternative for the Indonesian Government to make decisions related to what regions should be connected direcly and indirectly according to their GDRP correlation and some regulations to be made in facing flight liberalization both locally and regionally.

Furthermore, in the field of airport economics, airport systems and neworks can achieve economies of scale if they are managed carefully (ACI Policy and Recommended Practices Handbook 2009). The optimal network will enhance the value transfering process from one airport or region to the other airports or regions. Consequently, it will form a value network in which economic and other benefits are exchanged. The economic contribution and connectivity issue can lead this research to the issue of networked economy, which also includes information, communication, and technology issues. This may be an interresting subject to be examined by future researchers concerning the network study, particularly using the MST as an Operations Research tool.

Finally, the researchers realize that there are some limitations in this research. The optimal network should not be seen partially. The MST technique was used to form an optimal network that should be seen as a whole. Thus, changing the connected nodes (airports) in the optimal network will significantly changes the total weight of the network to be unefficient network design. Moreover, this research uses only secondary data. Thus, further research is required as conclusive evidence. In this case, the next researchers can confirm the result of the research using the primary data, such as confirming the feasibility of the airports in Indonesia to be the hubs in an optimal network or conducting the further researches related to the impact of three essential aspects to form an optimal network: distance between the airports, flight frequency from one airport to the others, and the correlation of economic potential of each province in Indonesia. Another limitation is that this research does not consider the goverment and airport operators view points. Thus, further research regarding those things needs to be done to confirm the results of this research.

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APPENDIXES

Appendix 1. **List and Value of Latitude and Longtitude of Airports in Indonesia**

Province	Airport	Code	Latitude	Longtitude
Aceh	Sultan Iskandar Muda	BTJ	5.518616	95.421729
North Sumatra	Polonia	MES	3.567766	98.676764
West Sumatra	Minangkabau	PDG	-0.786064	100.286529
Riau	Sultan Syarif Kasim II	PKU	0.464749	101.446407
Jambi	Sultan Thaha	DJB	-1.638542	103.645234
South Sumatra	S.M. Badaruddin II	PLM	-2.900133	104.698629
Bengkulu	Fatmawati Soekarno	BKS	-3.862199	102.337124
Lampung	Radin Inten II (Branti)	TKG	-5.242333	105.177863
Bangka Belitung Islands	Depati Amir	PGK	-2.162511	106.138058
Riau Islands	Hang Nadim	BTH	1.125704	104.111742
Special Capital District Jakarta	Halim Perdanakusuma	HLP	-6.265518	106.892381
West Java	Husein Sastranegara	BDO	-6.899757	107.577181
Central Java	Adi Sumarmo	SOC	-7.515922	110.756929
Special District Yogyakarta	Adi Sutjipto	JOG	-7.788150	110.431834
East Java	Juanda	SUB	-7.380683	112.787704
Banten	Soekarno-Hatta	CGK	-6.126218	106.657333
Bali	Ngurah Rai	DPS	-8.656299	115.222104
West Kalimantan	Supadio	PNK	-0.147784	109.403878
Central Kalimantan	Tjilik Riwut	PKY	-2.226746	113.943965
South Kalimantan	Syamsuddin Noor	BDJ	-3.442334	114.761188
East Kalimantan	Sepinggan	BPN	-1.267444	116.893759
North Sulawesi	Sam Ratulangi	MDC	1.549248	124.926277
Central Sulawesi	Mutiara	PLW	-0.918778	119.909456
South Sulawesi	Sultan Hasanuddin	UPG	-5.061684	119.553952
South-East Sulawesi	Wolter Monginsidi	KDI	-4.078166	122.416853
Gorontalo	Djalaluddin	GTO	0.638996	122.850718
West Sulawesi	Tampa Padang	MJU	-2.683373	118.899693
West Nusa Tenggara	Lombok Baru	LOP	-8.560652	116.086428
East Nusa Tenggara	Eltari	KOE	-10.171407	123.670757
Maluku	Pattimura	AMQ	-3.705043	128.088892
North Maluku	Sultan Babullah	TTE	0.833644	127.386975
West Papua	Rendani	MKW	-0.892346	134.048810
Papua	Sentani	DJJ	-2.576755	140.515945

Appendix 2. **List and Values of Latitude and Longtitude of the Airports in ASEAN Countries**

Countries	Cities	Airports	Latitude	Longtitude
Malaysia	Kota Kinabalu	Kota Kinabalu	5.937625	116.051495
Thailand	Bangkok	Suvarna Bhumi Int Airport	13.693858	100.751295
Brunei	Bandar Seri Begawan	Brunei	4.947644	114.925175
Philippine	Cebu	Mactan Int Airport	10.326921	123.905546
Thailand	Chiang Mai	Chiang Mai	18.76693	98.962862
Philippine	Davao	Fransisco Bangoy Int Airport	7.125379	125.645392
Indonesia	Denpassar	Bali	-8.656299	115.222104
Vietnam	Hanoi	San Bay Quoc	21.219821	105.803998
Thailand	Phuket	Phuket	8.11285	98.313897
Indonesia	Jakarta	Soekarno Hatta	-6.126218	106.657333
Malaysia	Kuching	Kuching	1.484812	110.34642
Malaysia	Kuala Lumpur	Kuala Lumpur	2.756419	101.701541
Laos	Luang Prabang	Luang Prabang	19.898471	102.16228
Myanmar	Mandalay	Mandalay Chanmyathazi	21.941453	96.089673
Indonesia	Medan	Polonia	3.567766	98.676764
Philippine	Manila	Ninoy Aquino	14.509394	121.018767
Malaysia	Penang	Penang	5.297545	100.275292
Kamboja	Phnom Penh	Phnom Penh	11.546635	104.847836
Cambodia	Siem Reap	Siem Reap	13.410994	103.812532
Myanmar	Yangon	Yangon	16.909355	96.134992
Vietnam	Ho Chi Min City	Tan Son Nhat	10.827911	106.649237
Singapore	Singapore	Changi	1.358272	103.910576
Indonesia	Surabaya	Juanda	-7.380683	112.787704
Laos	Vientiane	Wattay	17.98355	102.566078