MINIMUM SPANNING TREE FOR 29 MOST ACTIVE STOCKS IN BURSA MALAYSIA PRE- AND POST-MCO

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ABSTRACT

On 18 March 2020, the Malaysian government issued the Movement Control Order (MCO) to aid in the fight against the COVID-19. This MCO not only restricts human movement, but it also lowers financial profits for businesses and has a substantial impact on stock returns. The aim of this study is to construct Minimum Spanning Tree (MST) for 29 most active stocks traded in Bursa Malaysia between 2018 to 2021 which is pre- and post-MCO to identify the changes of MST structure for both periods. The daily adjusted closing prices of 29 firms from 2018 to 2021 are chosen to set up the MST. Degree centrality and closeness centrality are studied to identify the important of each stock in the MST. Our MST and centrality measure show that CIMB was the most influential in the Bursa Malaysia for the pre-MCO period (2018-2019) whereas MAYBANK was the most powerful stock in the Bursa Malaysia during the post-MCO period (2020-2021).

Keywords: stock network; minimum spanning tree; degree centrality; closeness centrality

1. Introduction

Financial market is among the most essential commodities for all countries because they significantly impact the country's economy. They can even make the capitalist economy runs efficiently. Darskuviene (2010) states that financial market is a place where exchanging or trading of financial instruments occurs. In addition, financial market also provides three main economic function: liquidity function, price discovery function and reduction of transaction costs function. These functions give an opportunity to the firms and traders to buy and sell various financial instruments and financial securities. In the financial market, there are many trading securities that exist. One of the trading securities that exist in the financial market is stock market. Stock market is one of the world's leading financial markets in today's interconnected world.

According to Khoo (2013), stock market is a public market that occurs for the issuance, purchase, and sale of stocks between brokers and investors that trade on a stock exchange or over-the-counter platform. The stock market is also known as a place where investors can buy and sell their assets. Nevertheless, due to the availability of advanced technologies in the world today, brokers and investors can purchase and sell stocks in a short trading period. The efficient functioning of the stock market is considered crucial to economic development, as it enables companies to access capital from the public quickly. The main objective of the stock market is to give companies with capital that they can utilize to expand their business and offer investors the ability to share in the earnings of publicly listed companies. Every country has its stock market, which is referred to as the stock exchange.

In Malaysia, the stock market is commonly known as Bursa Malaysia. Bursa Malaysia is an exchange holding company that was built in 1976 and listed in 2005. Bursa Malaysia is one of the largest grants in ASEAN, and it is helping more than 900 businesses collect capital through 50 economic activities from various markets. There are eleven main index series under the Malaysian stock market: finance, consumer products, construction, real estate investment trusts (REITs), industrial products, infrastructure project company (IPC), plantation, mining, technology, properties, and trading or services. Thus, the stock market plays a significant role in the Malaysian economy as it can encourage global growth in the availability of funds to support economic development.

Previously, the whole world is shaken by the spread of Coronavirus (COVID-19). COVID-19 has become one of the significant issues to the global economy and financial markets. This is because pandemic COVID-19 has produced a social danger that has disrupted the financial development of firms and Malaysia’s economic growth that has an outstanding impact on financial stability, and diminished global economic growth. Lee et al. (2020) stated this pandemic COVID-19 has affected the stock market in two ways which are firstly this pandemic forced the business and corporate activities to be shut down and secondly the unpredictable of COVID-19 cases has strongly affected investment decisions by investors. This thing drives to triggered higher stock market volatility.

However, the rapid emergence of COVID-19 caused a reaction of Malaysian government issued the Movement Control Order (MCO). The issued of MCO has affect the Malaysia stock market making it more difficult for Malaysian government to develop an effective economic policy response. To deeper research on the situation, this study aims to construct MST during the pre- and post-MCO in order to help the investors and the policymakers in Malaysia make an excellent investment and policy decision. The financial network can be described as a group of items, known as vertices or nodes and connections between the nodes as links or edges. However, there are three key motivations for studying the stock market using financial network. First, financial network of the stock market is popular in analyzing the characteristics or behavior of complex networks (Sun et al., 2015). Second, financial network of the stock market also can improve and optimized investment portfolio (Mandere, 2009). Third, financial network of the stock market is used to predict market movement during the market event, such as the 1987 crash (Onnela et al., 2003).

Furthermore, the stock market is well-known with its complex system. The price fluctuations among the stocks show the complicated relationships that can be represented as a complex network. Then, due to the complexity and complicated of price fluctuations among the stocks in the stock market has encouraged the researchers to construct a financial network of the stock market. Financial networks are a set of methods used to visualize networks, describe specific characteristics of several network structures and build mathematical and statistical models of networks structure and dynamics. This financial network can be used to predict future market portfolios because it helped to obtain more reliable information from the markets. In fact, Chi et al. (2010) states that financial networks give benefit to the investors in representing interactions across financial entities such as regional economies, banks, and businesses; they may also be used to simulate and examine market behavior using market data analysis. This financial network can be better explained using Minimum Spanning Tree (MST).

MST is a spanning tree whose weight is minimum among all spanning trees graph. A spanning tree of a graph is a subgraph that contains all of the vertices. Many spanning trees can be found in a graph. Assume that each path or edge has a weight, which is a numerical representation of the relationship between two vertices. In order to ensure that the spanning tree is unique, MST present in which the sum of the edge weights is the minimum. MST is importance in due to its applications in the design of computer, communications and transportation networks.

Due to the successful application (Zhang et al. (2020), Esfahanipour and Zamanzadeh (2015), Djauhari and Gan (2014)), financial network has become widely implemented in finance research. There is an increasing number of finance researchers interested in studying the financial network to model the stock market. The justification is that the output of some of these stocks is always correlated, either because of the general trend of the market or because of the cyclicality of the same market segments. One benefit of financial network is that it allows people to understand the entire network through several visualising networks. Thus, this model will be constructed by using 29 most active stocks accumulated from Bursa Malaysia to see the stock market network using the Minimum Spanning Tree approach during pre- and post-MCO by Kruskal's Algorithm.

This paper organized as follows. Section 2 reviews the literature review. Section 2 describes the data and methodology used in this study. Section 4 presents the results and discussion. Lastly, Section 5 discusses the conclusion and future work of the research.

2. Literature Review

This section reviews the literature that is related to the studies of financial network. Various study has been published in the financial network of the stock market. Financial network is widely used in analyzing the relationship between stocks. According to Sun et al. (2015), financial network is known for describing the behaviour or characteristics of complex networks. To use financial network in representing the stock market, various stocks are represented as different vertices. However, describing connections or building edges between different vertices is intuitive, unlike certain physical networks, such as friendship networks, where interactions between different vertices can be precisely specified. In fact, the investigation on the financial network of the stock market has been constructed using various methods. Among the methods are the Winner-take-all proposed by (Chi et al., 2010), the Minimum Spanning Tree (MST) proposed by (Mantegna, 1999) and the planar maximally filtered graph proposed by (Tumminello et al., 2005). Therefore, the comparison of these three methods based on graph centrality identifies that the MST is a feasible alternative to develop the financial network of stock market (Bahaludin et al., 2015).

Furthermore, Mantegna (1999) introduced stock network in econo-physics to investigate the interaction between stocks by using the MST approach. This stock network visualizes the relationship between stocks extracted from MST based on the correlations between stock's price returns. After a decade MST has been introduced by Mantegna (1999), it has become an indispensable tool in econo-physics for filtering crucial information contained in the complicated structure of a correlation matrix across stocks in a specific portfolio. MST is also used in explaining the stock market because complex networks cannot be seen on the stock market since the market is fully connected. Especially in relation to stock markets, MST methodology is used to analyze the interdependence of stock markets and gives a clear visualization of a complex network and market relationship. This network methodology has also been used to analyze a wide variety of economic and financial crises.

MST is a sub-graph containing all the nodes of the network but with fewer edges. Recent research into the history of the MST problem proves that there was a variety of independent discoveries of algorithms and concepts for solving the problem (Aslamet al., 2020). There are different algorithms to extract MST from a network. In the current practice among stock players and researchers, the MST in stock network analysis is often developed from various methods. The most recommended techniques in the literature, namely, Kruskal's algorithm. Kruskal algorithm is the simple method that easy to understand and most likely the best one for solving problems by hand. Kruskal algorithm is a graph theory algorithm that use to finds a minimum spanning tree for a connected weighted graph (Zhang, 2009). This implies it identifies a subset of the edges that creates a tree that contains every vertex and has the minimum total weight of all the edges in the tree. However, a minimum spanning forest is found if the graph is not connected (a minimum spanning tree for each connected component).

The MST approach is widely used in financial networks, especially in the stock market network. For instance, Ibrahim et al. (2018) used MST to build a stock market network between 10 firms from stocks exchanged in Malaysia, Singapore and Indonesia to determine the most influential stocks among Malaysia, Singapore and Indonesia stocks markets, Mahamood et al. (2019) studies the topological structure of shariah-compliant stocks in Malaysia using MST for three different periods in the financial crisis named as pre-crisis, during crisis and post-crisis, Lee and Djauhari (2012),Yee and Salleh (2018) and Bahaludin et al. (2015) carried out studies on the performance of Bursa Malaysia using data from Bursa Malaysia and illustrate it using

MST. Thus, the results for these studies discovered the changes in the topological structure and the network's central hub throughout the period. In addition, as a result, they conclude that their studies can help identify stocks that play significant roles in the Bursa Malaysia and provide platform for the development of investment strategies in Malaysia.

Recently, Liu et al. (2020) studied the relationship between Malaysian stock market returns and variables linked to the COVID-19, while Lee et al. (2020) and Topcu and Gulal (2020) figured out the performance of stocks market during COVID-19 in 21 leading stock market indices in major affected countries, shows that negative effect of the pandemic on developing financial markets has steadily declined and has started to slow. However, it is found difficult for investors and policymakers to see the visualization of the complex relationship of the stocks traded in the stock market in the previous studies. Thus, to improve this we propose a study to construct a Minimum Spanning Tree during pre and post-MCO that consist of 29 most active stocks listed in Bursa Malaysia based on market capitalization from 1st January 2018 to 31st December 2021. This study uses Minimum Spanning Tree Approach by Kruskal's Algorithm, which produces the best result in discovering which stock is the most dominant and influential stocks to the other stocks. Furthermore, we also used the centrality measures to determine the importance of each stock.

3. Materials and Methods

This section describes the research methodology used to construct the MST, which we are going to use the daily adjusted closing price as the data. Then, from the data, we calculate the log returns, correlation matrix, and distance metric. After that, we construct the MST by applying the Kruskal Algorithm. Lastly, we present the hypothetical illustration of constructing MST using five stocks.

3.1. *Data*

The daily adjusted closing prices for 29 most active stocks accumulated from Bursa Malaysia are used. This data is extracted from Yahoo! Finance. Analysis is divided into two periods namely pre-MCO (2018-2019) and post-MCO (2020-2021). The list of 29 most active stocks and their corresponding codes and sectors is presented in the Appendix.

3.2. *Minimum Spanning Tree*

MST minimize the complexity of correlation networks, which involve the following steps:

1. Log returns

To define the synchronization of the stocks, we calculate logarithm of daily stock returns in a given period, $r_i(t)$:

$$r_i(t) = \ln P_i(t+1) - \ln P_i(t), \tag{1}$$

where $P_i(t)$ is the adjusted closing stock price of a company i, for $i = 1,2,\dots,N$.

2. Correlation matrix

Using the logarithm of daily stock returns, we compute the correlation coefficient between stock i and j using Pearson's correlation coefficient as follows:

$$\rho_{ij} = \frac{\langle r_i r_j\rangle - \langle r_i\rangle\langle r_j\rangle}{\sqrt{(\langle r_i{}^2\rangle - \langle r_i\rangle^2) - (\langle r_j{}^2\rangle - \langle r_j\rangle^2)}}, \tag{2}$$

where $\langle r_i\rangle$ is the average of $r_i(t)$ for all t, such that:

$$\rho_{ij} = \begin{cases} 1 & completely\ correlated \\ 0 & uncorrelated \\ -1 & inversely\ correlated \end{cases}.$$

3. Distance metric

Then, we compute the matrix distance by transforming the correlation coefficient ρ_{ij} into distance equation as follows:

$$d_{ij} = \sqrt{2(1-\rho_{ij})}, \quad (3)$$

where d_{ij} is the distance between for each pair of stock i and stock j.

4. Kruskal algorithm

The MST is constructed using Kruskal's algorithm based on matrix distance. The procedure of Kruskal algorithm is the Kruskal algorithm determines the edges to be selected and added, while adding the weight to the tree. This algorithm finds an edge with the least possible weight to connect 2 different trees. In this thesis, the first path of the tree is the shortest distance followed by the next short distance, while avoiding the formation of loops between each node.

3.3. *Centrality Measures*

For further analysis of the MST, centrality measures are implemented to determine the importance of each stock in the MST. This study uses two types of centrality measures to assess the relative value of degree and closeness centrality for each stock in the network. These measures are obtained based on MST.

1. Degree centrality

Degree centrality is implemented to define the most influential stocks, indicating how many connections a stock i has to other stocks. Freeman (1978) stated that degree centrality is the number of edges joined to a vertex. Generally, in terms of degree centrality, the most influential stock is stock with the greater number of edges joined to it. The degree centrality of a stock i is defined:

$$C_D(i) = \frac{\sum_{j=1}^{N} A_{ij}}{N-1}, \quad (4)$$

where A_{ij} is the element of the i-th row and j-th colum of the adjacency matrix. If the i-th and j-th stocks are linked, $A_{ij} = 1$, otherwise $A_{ij} = 0$. However, the higher the value of the $C_D(i)$, the greater the number of other stocks directly affected by the stock i.

2. Closeness centrality

According to Freeman (1978), closeness centrality measures the shortest average distance which is from stock i to stock j. Centrality of closeness denotes how quickly data is spread to all other stocks in the MST. The closeness centrality of a stock i is computed in:

$$C_C(i) = \left[\sum_{j=1}^{N} d_G(i,j)\right]^{-1}, \quad (5)$$

where $d_G(i,j)$ is the shortest path from stock i to j. In this method, the average number of shortest paths between i and all other stocks can be obtained from $C_C(i)$.

3.4. *Hypothetical Illustration*

This section shows the manual calculation of the MST for five stocks with eight trading days. Firstly, we collected the data on the daily adjusted closing price of stocks from AXIATA, CIMB, DIALOG, DIGI, and GENTING from 2 January 2018 to 11 January 2018. Table 1 presents the daily adjusted closing price for all chosen five stocks in eight trading days, and Table 2 documents the rate of returns computed using Eq. (1).

Table 1. A sample of adjusted closing price for 8 trading days.

Day	AXIATA	CIMB	DIALOG	DIGI	GENTING
0	5.00862	5.59314	2.39940	4.10073	8.12242
1	5.03649	5.61896	2.39940	4.09234	8.17477
2	5.07366	5.63616	2.44739	4.10911	8.25328
3	5.28739	5.76524	2.57216	4.10073	8.39288
4	5.27810	5.86849	2.61055	4.08396	8.28818
5	5.23164	5.80826	2.59135	4.06718	8.16604
6	5.22234	5.79966	2.59135	4.02525	8.20094
7	5.17588	5.80826	2.56256	3.94140	8.00900

Table 2. Rate for returns for a sample of adjusted closing price.

Day	AXIATA	CIMB	DIALOG	DIGI	GENTING
1	0.00555	0.00460	0.00000	-0.00205	0.00642
2	0.00735	0.00306	0.01980	0.00409	0.00956
3	0.04126	0.02264	0.04972	-0.00204	0.01677
4	-0.00176	0.01775	0.01481	-0.00410	-0.01255
5	-0.00884	-0.01032	-0.00738	-0.00412	-0.01485
6	-0.00178	-0.00148	0.00000	-0.01036	0.00426
7	-0.00894	0.00148	-0.01117	-0.02105	-0.02368

Then, using Eq. (2), we compute the correlation coefficients. Table 3 documents the values for each component in Eq. (2), while Table 4 documents the correlation matrix between each stock.

Table 3. Rate for returns for a sample of adjusted closing price.

i	j	$\langle r_i \rangle$	$\langle r_j \rangle$	$\langle r_i r_j \rangle$	$\langle r_i^2 \rangle$	$\langle r_j^2 \rangle$	$\langle r_i \rangle^2$	$\langle r_j \rangle^2$
AXIATA	AXIATA	0.00469	0.00469	0.00028	0.00028	0.00028	0.00002	0.00002
AXIATA	CIMB	0.00469	0.00539	0.00015	0.00028	0.00014	0.00002	0.00003
AXIATA	DIALOG	0.00469	0.00940	0.00033	0.00028	0.00047	0.00002	0.00009
AXIATA	DIGI	0.00469	-0.00566	0.00003	0.00028	0.00009	0.00002	0.00003
AXIATA	GENTING	0.00469	-0.00201	0.00017	0.00028	0.00020	0.00002	0.00000
CIMB	AXIATA	0.00539	0.00469	0.00015	0.00014	0.00028	0.00003	0.00002
CIMB	CIMB	0.00539	0.00539	0.00014	0.00014	0.00014	0.00003	0.00003
CIMB	DIALOG	0.00539	0.00940	0.00022	0.00014	0.00047	0.00003	0.00009
CIMB	DIGI	0.00539	-0.00566	-0.00001	0.00014	0.00009	0.00003	0.00003
CIMB	GENTING	0.00539	-0.00201	0.00005	0.00014	0.00020	0.00003	0.00000
DIALOG	AXIATA	0.00940	0.00469	0.00033	0.00047	0.00028	0.00009	0.00002
DIALOG	CIMB	0.00940	0.00539	0.00022	0.00047	0.00014	0.00009	0.00003
DIALOG	DIALOG	0.00940	0.00940	0.00047	0.00047	0.00047	0.00009	0.00009
DIALOG	DIGI	0.00940	-0.00566	0.00003	0.00047	0.00009	0.00009	0.00003
DIALOG	GENTING	0.00940	-0.00201	0.00017	0.00047	0.00020	0.00009	0.00000
DIGI	AXIATA	-0.00566	0.00469	0.00003	0.00009	0.00028	0.00003	0.00002
DIGI	CIMB	-0.00566	0.00539	-0.00001	0.00009	0.00014	0.00003	0.00003
DIGI	DIALOG	-0.00566	0.00940	0.00003	0.00009	0.00047	0.00003	0.00009
DIGI	DIGI	-0.00566	-0.00566	0.00009	0.00009	0.00009	0.00003	0.00003
DIGI	GENTING	-0.00566	-0.00201	0.00008	0.00009	0.00020	0.00003	0.00000
GENTING	AXIATA	-0.00201	0.00469	0.00017	0.00020	0.00028	0.00000	0.00002
GENTING	CIMB	-0.00201	0.00539	0.00005	0.00020	0.00014	0.00000	0.00003
GENTING	DIALOG	-0.00201	0.00940	0.00017	0.00020	0.00047	0.00000	0.00009
GENTING	DIGI	-0.00201	-0.00566	0.00008	0.00020	0.00009	0.00000	0.00003

GENTING	GENTING	-0.00201	-0.00201	0.00020	0.00020	0.00020	0.00000	0.00000

Table 4. Correlation matrix for a sample of adjusted closing price

	AXIATA	CIMB	DIALOG	DIGI	GENTING
AXIATA	1.00000	0.72841	0.92987	0.44538	0.78618
CIMB	0.72841	1.00000	0.81107	0.22898	0.39773
DIALOG	0.92987	0.81107	1.00000	0.55165	0.71296
DIGI	0.44539	0.22898	0.55165	1.00000	0.66615
GENTING	0.78618	0.39773	0.71296	0.66615	1.00000

The distance metric of size 5x5 is then computed using Eq. (3) as tabulated in Table 5.

Table 5. Distance matrix for a sample of adjusted closing price

	AXIATA	CIMB	DIALOG	DIGI	GENTING
AXIATA	0.00000	0.73701	0.37451	1.05320	0.65395
CIMB	0.73701	0.00000	0.61470	1.24179	1.09752
DIALOG	0.37451	0.61470	0.00000	0.94695	0.75768
DIGI	1.05320	1.24179	0.94695	0.00000	0.81713
GENTING	0.65395	1.09752	0.75768	0.81713	0.00000

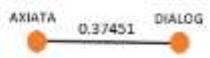
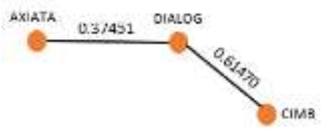
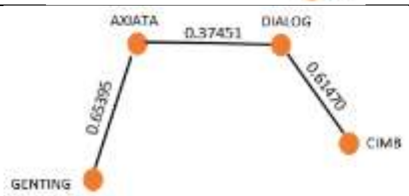
Now we construct the minimum spanning tree (MST) of undirected edge weighted. The distance of the stocks is sorted from the lowest to the highest distance as shown in Table 6.

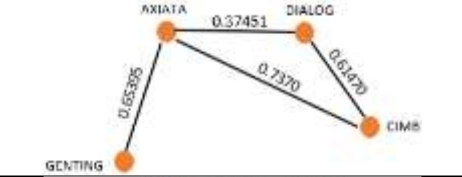
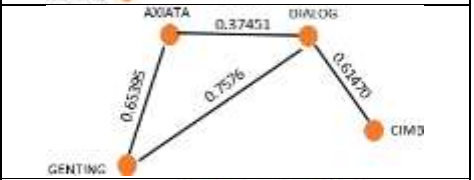
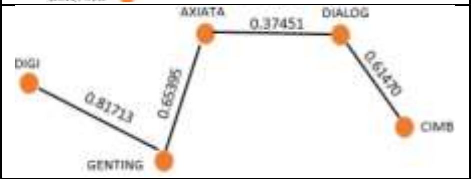
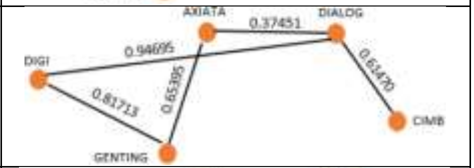
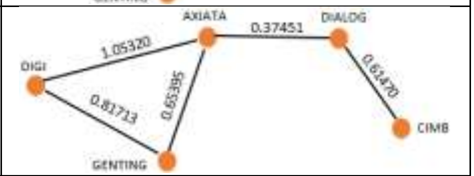
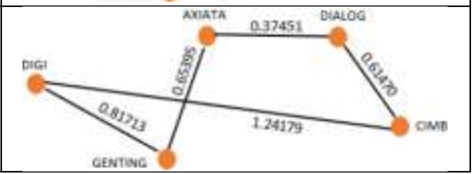
Table 6. Rank of distances between stocks

	AXIATA	CIMB	DIALOG	DIGI	GENTING
AXIATA	0.00000	0.73701	0.37451	1.05320	0.65395
CIMB	0.73701	0.00000	0.61470	1.24179	1.09752
DIALOG	0.37451	0.61470	0.00000	0.94695	0.75768
DIGI	1.05320	1.24179	0.94695	0.00000	0.81713
GENTING	0.65395	1.09752	0.75768	0.81713	0.00000

Starting from the lowest distance we construct the MST by observing if forms a loop it will be removed. Table 7 illustrates the steps to construct the MST as shown in Figure 1.

Table 7. Steps to construct MST for 5 stocks

No.	Step	Visualization
1	Distance from AXIATA to DIALOG no loop	
2	Distance from CIMB to DIALOG no loop	
3	Distance from AXIATA to GENTING no loop	

4	Distance from AXIATA to CIMB has loop. Remove edges AXIATA to CIMB	
5	Distance from DIALOG to GENTING has loop. Remove edges DIALOG to GENTING	
6	Distance from DIGI to GENTING no loop	
7	Distance from DIALOG to DIGI has loop. Remove edges DIALOG to DIGI	
8	Distance from AXIATA to DIGI have loop. Remove edges AXIATA to DIGI	
9	Distance from CIMB to GENTING have loop. Remove edges CIMB to GENTING	
10	Distance from CIMB to DIGI have loop. Remove edges CIMB to DIGI	

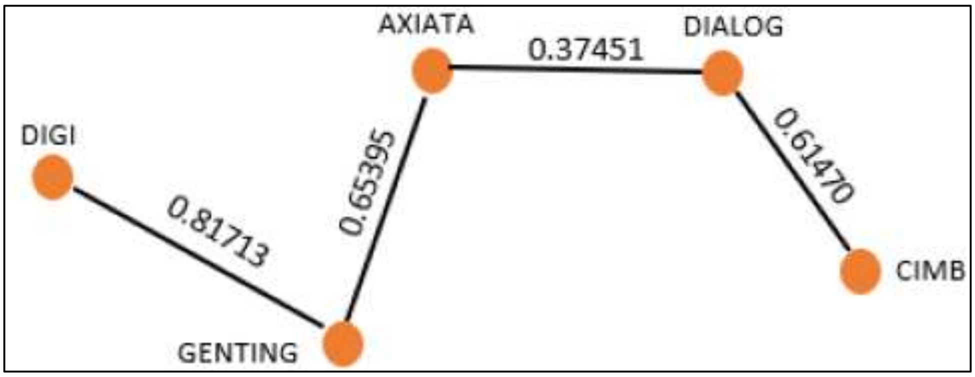


Figure 1. The MST for the chosen 5 stocks.

4. Results and Discussion

This chapter present the visualization of MST for 29 most active stocks traded in Bursa Malaysia for the two period which are pre-MCO (2018-2019) and post-MCO (2020-2021). The

visualization of MST can help in analyzing the movement of 29 most active stocks in Bursa Malaysia. Then we are going to present the results obtained from the centrality measure that consists of degree centrality and closeness
centrality into the table and discuss which stocks is the most influential stock in the MST.

4.1. *Minimum Spanning Tree*

Figure 2 illustrate the transformation of MST pre-MCO period (2018-2019). From Figure 2, there were seven main clusters in the MST. It started with CIMB as the most influential stock, which is the number of the link is six and followed by HLFG forming five linked stocks. Next, the third and fourth clusters are IOICORP and MAYBANK, with four links connected to each of them. Lastly, the following clusters are AXIATA, DIALOG, and GENTING, which share the same number of three links.

Next, Figure 3 illustrate the transformation of MST post-MCO period (2020-2021). From Figure 3, there are six main clusters in the MST which MAYBANK is the most prominent stock with seven stocks linked to it. Then, the second cluster is IOICORP, with the number of links four. Lastly, the next clusters are CIMB, HAPSENG, HLBANK, and PUBLICBANK have three stocks linked to it, respectively.

As we can see, in pre-MCO CIMB have greater number of stocks linked to it but in post-MCO the number of stocks linked to CIMB decreased. This shown that the issued of MCO had a significant impact on CIMB. Besides, in post-MCO the number of stocks linked to MAYBANK increase from four in pre-MCO to seven. The number of clusters in MST post-MCO is fewer compared to MST pre-MCO. This indicates that the stocks during the MCO had less linkages with other stocks compared to pre-MCO.

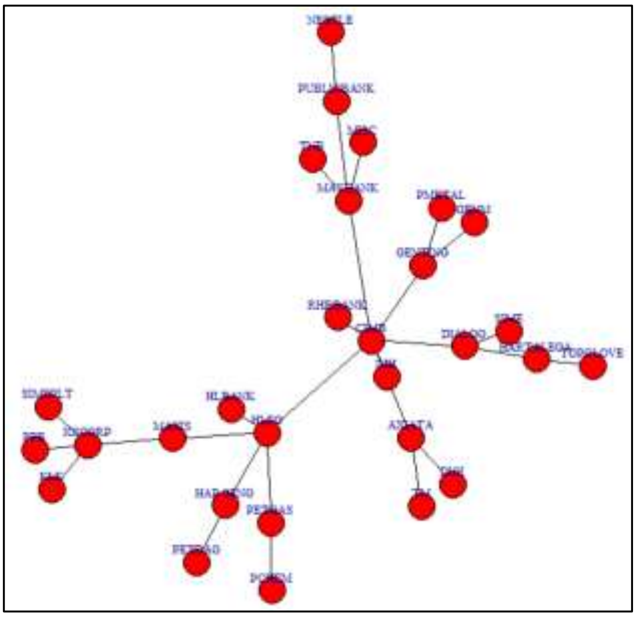


Figure 2. The MST for pre-MCO (2018-2019)

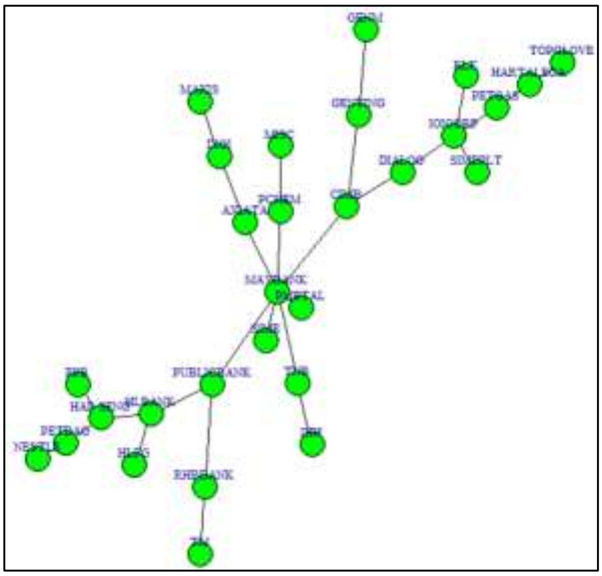


Figure 3. The MST for post-MCO (2020-2021)

4.2. *Degree Centrality*

The position of a stock in the MST has its own characteristics and reflects its relationship with other stocks. To provide a more detailed interpretation about the structural position of the stocks in Figure 2 and Figure 3, we calculate the centrality measures that consists of degree centrality and closeness centrality.

Table 8 shows degree centrality value for the period pre-MCO. According to the degree centrality measure, Table 8 shows that CIMB has the highest degree values pre-MCO periods, which are 0.2500 and followed by HLFG in the second place with the degree value of 0.1786. IOICORP and MAYBANK are in third and fourth place, with the same degree centrality value of 0.1429. Then, the fifth and sixth places are AXIATA and DIALOG have the same degree centrality value, which is 0.1071.

Next, Table 8 portrays degree centrality value for the period post-MCO. Table 8 shows that MAYBANK has increased its degree value from 0.1429 pre-MCO period to 0.2500 post-MCO period, which put MAYBANK in the highest place of degree centrality in post-MCO period. Unfortunately, during post-MCO period, CIMB decreases to third place, which the degree value is 0.1071. This has caused IOICORP to be in the second place even though the degree centrality value for IOICORP 0.1429 did not change in pre- and post-MCO. We can compute that CIMB was affected by the MCO. HAPSENG, HL BANK, and PUBLICBANK were in the fourth, fifth, and sixth places, respectively, sharing the same degree centrality value of 0.1071.

Besides, as observed in Table 8 and Table 9, there are no consistent stocks listed as top six in the degree centrality value in pre- and post-MCO except for CIMB, MAYBANK, and IOICORP. This indicates that the MST was restructured to acclimate the post-MCO period. Further, Table 8 exposes that the financial service sector was higher influential sector in pre- and post-MCO period. This can be seen as Table 8 displays that the financial service sector played an important role since three out of top six stocks with highest degree centrality belong to the financial service sector. Post-MCO, the financial service sectors were also influential in post-MCO period since four out of top six stocks with highest degree centrality belong to the financial service sector, and the rest belong to the plantation sector and industrial product and service. Thus, this shows that these sectors have many stocks linked to them, making them the most influential stocks across all periods.

Table 8. Degree centrality values pre- and post-MCO

No.	Stock	Sector	Pre-MCO (2018-2019)	Post-MCO (2020-2021)
1	CIMB	Financial Service	0.2500	0.1071
2	HLFG	Financial Service	0.1786	0.0357
3	IOICORP	Plantation	0.1429	0.1429
4	MAYBANK	Financial Service	0.1429	0.2500
5	AXIATA	Telecommunications and Media	0.1071	0.0714
6	DIALOG	Energy	0.1071	0.0714
7	GENTING	Consumer Products and Services	0.1071	0.0714
8	HAPSENG	Industrial Products and Services	0.0714	0.1071
9	HARTALEGA	Health Care	0.0714	0.0714
10	MAXIS	Telecommunications and Media	0.0714	0.0357
11	PETGAS	Utilities	0.0714	0.0714
12	PUBLICBANK	Financial Service	0.0714	0.1071
13	DIGI	Telecommunications and Media	0.0357	0.0714
14	GENM	Consumer Products and Services	0.0357	0.0357
15	HLBANK	Financial Service	0.0357	0.1071
16	IHH	Health Care	0.0357	0.0357
17	KLK	Plantation	0.0357	0.0357
18	MISC	Transportation and Logistics	0.0357	0.0357
19	NESTLE	Consumer Products and Services	0.0357	0.0357
20	PCHEM	Industrial Products and Services	0.0357	0.0714
21	PETDAG	Consumer Products and Services	0.0357	0.0714
22	PPB	Consumer Products and Services	0.0357	0.0357
23	PMETAL	Industrial Products and Services	0.0357	0.0357
24	RHBBANK	Financial Service	0.0357	0.0714
25	SIME	Consumer Products and Services	0.0357	0.0357
26	SIMEPLT	Plantation	0.0357	0.0357
27	TM	Telecommunications and Media	0.0357	0.0357
28	TNB	Utilities	0.0357	0.0714

29	TOPGLOVE	Health Care	0.0357	0.0357

4.3. *Closeness Centrality*

The closeness centrality value for the period pre-MCO has been computed in Table 9. From Table 9, analysis reveals that CIMB continues to be the top value in closeness centrality in pre-MCO period with a value of 0.4065, and HLFG come after CIMB with the closeness centrality value of 0.3648. Thus, the greater value of closeness centrality of CIMB indicates that CIMB significantly affects the performance of other stocks traded in Bursa Malaysia. Then, the third place in the top six of closeness centrality measure is MAYBANK with the value of 0.3167, and the fourth place is DIALOG with 0.2981 of closeness. Lastly, fifth and sixth place is AXIATA and GENTING with the value of closeness centrality 0.2970 and 0.2915.

During post-MCO period, in Table 4.4, CIMB was replaced by MAYBANK with a value of 0.3956. Remarkably, MAYBANK climbs from third place in pre-MCO period to first place in post-MCO period. This has led CIMB to be in second place with a 0.3622 closeness centrality value. Next, PUBLICKBANK and HLBANK are in third and fourth place post-MCO period with the value of closeness centrality 0.3542 and 0.3011. DIALOG decreased a little bit during the post-MCO period with a value of 0.2998, causing it to be in fifth place, as displayed in Table 4.11. The last place in the top six highest closeness centrality value in post-MCO is TNB, with a closeness centrality value of 0.2961.

Furthermore, CIMB, MAYBANK, and DIALOG remained in the top six highest closeness centrality value lists for all periods. This result discloses that all other stocks were closely connected to CIMB, MAYBANK, and DIALOG across all periods. Hence, this investigation also reveals that the financial service sector was the most influential in pre- and post-MCO period.

Table 9. Closeness centrality values pre- and post-MCO

No.	Stock	Sector	Pre-MCO (2018-2019)	Post-MCO (2020-2021)
1	CIMB	Financial Service	0.4065	0.3622
2	HLFG	Financial Service	0.3648	0.2360
3	IOICORP	Plantation	0.2261	0.2509
4	MAYBANK	Financial Service	0.3167	0.3956
5	AXIATA	Telecommunications and Media	0.2970	0.2934
6	DIALOG	Energy	0.2981	0.2998
7	GENTING	Consumer Products and Services	0.2915	0.2866
8	HAPSENG	Industrial Products and Services	0.2681	0.2458
9	HARTALEGA	Health Care	0.2246	0.1641
10	MAXIS	Telecommunications and Media	0.2829	0.1857
11	PETGAS	Utilities	0.2631	0.2038
12	PUBLICBANK	Financial Service	0.2379	0.3542
13	DIGI	Telecommunications and Media	0.2276	0.2283

14	GENM	Consumer Products and Services	0.2315	0.2457
15	HLBANK	Financial Service	0.2648	0.3011
16	IHH	Health Care	0.2758	0.2214
17	KLK	Plantation	0.1787	0.2038
18	MISC	Transportation and Logistics	0.2313	0.2224
19	NESTLE	Consumer Products and Services	0.1849	0.1626
20	PCHEM	Industrial Products and Services	0.1993	0.2906
21	PETDAG	Consumer Products and Services	0.2043	0.1968
22	PPB	Consumer Products and Services	0.1799	0.1956
23	PMETAL	Industrial Products and Services	0.2181	0.2869
24	RHBBANK	Financial Service	0.2803	0.2839
25	SIME	Consumer Products and Services	0.2205	0.2762
26	SIMEPLT	Plantation	0.1796	0.2020
27	TM	Telecommunications and Media	0.2246	0.2157
28	TNB	Utilities	0.2320	0.2961
29	TOPGLOVE	Health Care	0.1824	0.1470

5. Conclusion

Throughout this research, MST for the 29 most active stocks traded in Bursa Malaysia has been constructed to analysis the MST pre-MCO (2018-2019) and post-MCO (2020-2021). Using two centrality measures: degree centrality and closeness centrality, this study intends to analysis the topological structure of the 29 most active stocks traded in Bursa Malaysia. Thus, identify the most influential stocks in each period.

From the MST, there were seven main clusters in pre-MCO period and six main clusters in post-MCO period. However, CIMB was the most important stock in pre-MCO period, with six connected links while, MAYBANK was the most important stock in post-MCO period having seven links connected to it. Hence, we can conclude that the financial service sector was important sector in pre- and post-MCO period.

In addition, based on the centrality measure, it is shown that CIMB recorded the highest value for degree centrality, and closeness centrality measures in pre-MCO period while MAYBANK recorded the highest value for degree centrality and closeness centrality measures in post-MCO period. Thus, this indicates CIMB is a dominant stock during pre-MCO, and MAYBANK is a dominant stock during post-MCO that plays a significant part in affecting other stocks used in this research.

Therefore, MST can be used by the investors to carry out the relation between stocks and their impact on other stocks. Lastly, this finding will benefit the investors interested in investing in the stocks listed, hence identifying which sectors and stocks they should invest in.

In this research, we focus on constructing MST in pre- and post-MCO using a Kruskal algorithm. We also calculate the centrality measure that consist of degree and closeness centrality to get the hidden information in MST. In fact, there are still a lot of possibilities worthy of exploration in the future. In the future, we can study the MST using directed weighted graph and see the topology structure.

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