

Forecasting the Quality of Port Infrastructure of Asian Port Countries: An Application of the Model GM (1, 1) and Clustering Them Using HCA Algorithm

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ABSTRACT

This study is an endeavor to forecast the quality of port infrastructure of Asian port economies. A sample of 32 economies are selected counting the year from 2015-2019. Data are collected from the Global Competitiveness Report. A data forecasting algorithm, the GM (1, 1) approach, is applied, and finally the economies are clustered with their forecasted values using Hierarchical Cluster Analysis (HCA). The empirical findings demonstrated that there would be change in the quality of port infrastructure. Economies with high quality of port infrastructure will be the best performer, while the others with poor infrastructure will do better in future as well. The modified Grey model showed excellent accuracy and better performance in forecasting the quality of port infrastructure. The forecasting values of each country offer valuable insight to formulate individual policies and strategies. The port facilitators and the decision makers would be able to distinguish the higher and the lower performer from the cluster analysis and focus on the underperformed region undertaking individual measures to improve the quality of their port infrastructure as well. Additionally, it will contribute as a hybrid methodology that the individual country can apply practically in prediction and clustering them to take decision on the quality of port infrastructure for next 5 years. Finally, it will theoretically extend the frontier of knowledge in port infrastructure research.

Keywords: port infrastructure, asian economies, GM (1, 1) model, prediction, hierarchical cluster analysis (HCA)

1. BACKGROUND OF THE STUDY

The quality of port infrastructure is considered to be one of the crucial bottlenecks for global economic circulation (ESCAP, 2020; Hua *et al.*, 2020; Jha & Arao, 2018; Sharapiyeva *et al.*, 2019; Yang *et al.*, 2019). It is well acknowledged that quality of port infrastructure and facilities associated with their operations contribute significantly to the economic growth, accelerate the maritime logistics system, and develop the coastal region (Roh *et al.*, 2016). But ports' infrastructure in Asia and their regional integration have experienced at least a century of crisis from war, technological change, political instability and fragmented infrastructure (Stough, 2005). Now the quality of port infrastructure in Asia needs to be modified for growing interactions among regions. More so on, many Southeast Asian ports are located in strategic geographical position which is influenced by global shipping lines and international trade (Dang & Yeo, 2017). The quality of port infrastructure measured by the World Economic Forum (WEF) is based on port facilities, company size and sector's activities. Ports authorities must have plan, and optimize their future operations and expansion in a sustainable way for future competitiveness (Roh *et al.*, 2016; Stough, 2005). They should have dynamic concept of services (Yang *et al.*, 2019), as the quality of port infrastructure is changing rapidly. The major obstacles in this regard are insufficiency and the complexity of prediction of the future quality of port infrastructure and the lacking of policy formulation (Asian

Development Bank, 2021b). Various empirical models have been developed to calculate the impacts of port infrastructure on economy, trade and transportation. These empirical models are not capable in predicting, and applicable for forecasting the quality of port infrastructure. Yeo *et al.* (2015) used Partial Least Square-SEM in ports' quality research, Dang and Yeo, (2017) utilized Boston Consulting Group (BCG) matrix to analyze competitive strategic position of ports, and both public and private sectors involvement in port development was studied by Galvao *et al.* (2016) applying content analyzing approach. To address and overcome the limitations of prediction, Artificial intelligence (AI), Neural Network (NN) and Grey forecasting model are used frequently. Grey forecasting model draws attention among all for its high accuracy. Many researchers have already applied it successfully in various fields of prediction such as energy use, economic growth, ports performance and cargo throughput of commercial ports. We have utilized GM (1, 1) approach of prediction in this paper as well, and finally applied Hierarchical Cluster Analysis (HCA) to cluster Asian countries using the predicted values. The GM (1, 1) approach, based on Grey System theory, is now a famous and frequently used data forecasting model. The model is used for its reliability and accuracy in predicting small number of samples.

Infrastructure is inseparable from the sustainable and modern port development in Asian (Terada-Hagiwara & Straub, 2010). A close relationship has emerged between infrastructure and economic growth. Development of infrastructure enhances productivity, improves capital efficiency and boosts the accessibility of a region. Port infrastructure is specially contributing to the advancement of coastal economic programs. Development of ports' infrastructure is important both from economic and environmental point of view. Asian port hub will demonstrate a big change in the world economy soon. Some countries such as Bangladesh, China, India and Myanmar (BCIM) will promote Economic zone and trade exchanges in near future, which will make a direct link with Trans-Asian Highway (TAH). So, it is important to harmonize the roles and function of individual port. Port development and the quality of infrastructure play significant role in economic development and regional connectivity in Asia and the Pacific (ESCAP, 2020; Lenz *et al.*, 2018). Though Asian countries are historically exposed to port development and maritime trade, the quality of port infrastructure is still fragmented, and this is largely due to the different level of technical capacity, financial resources, economic development and a lack of effective implementation of policies. Some ports in Asia display high level of technological and operational development, while the others are far away from this. The unevenness of the quality of port infrastructure ultimately reduces the trade benefits of port hub. This is time to predict the quality of port infrastructure in order to let port authorities and managers to observe the future performance and increase the potentiality. Our study is the first and foremost to use Grey prediction to forecast the quality of port infrastructure.

The major port territories in Asia are state owned (ESCAP, 2020), and the infrastructure are featured by capacity constraints, poor logistics performance, intra-port competition, lack of connectivity with hinterlands and low competitiveness (ADB, 2021; ESCAP, 2020; Herrera Dappe

& Suárez-Alemán, 2016; Itf, 2019; Oommen, 2015; Sanaullah, 2003). Ports infrastructure in Asia constitute an important base for costal economics (Dwarakish & Salim, 2015). Asia and the Pacific region countries are seeking to develop mega port-hub due to the increasing demand of national and international seaborne trade (ESCAP, 2020). The higher the throughput of goods, the more infrastructure, provision, and associated services are required. Determining the level of the quality of port infrastructure in Asia, as well as forecasting future performance, is essential to the planning and policymaking. Rehman *et al.* (2020) studied the short-run and long-run impacts of the quality of infrastructure on export and trade deficit in selected Asian countries. The findings suggested that infrastructure positively promotes exports and encourage the future benefits. Infrastructure remained a big hurdle for South Asia to reap potential and develop rapidly. According to Jha and Arao (2018), 40% firms in India, 45% in Pakistan, 60% in Bangladesh and 75% in Nepal are suffering from inadequate infrastructure to grow rapidly. However, Schwab (2017) showed that South Asia has become the world's fastest-growing region, especially India, Bangladesh, and Sri Lanka demonstrated significant improvement in the quality of port infrastructure. Moreover, the efficiency of port infrastructure has a profound impact on bilateral trade as well (Mustafa *et al.*, 2021).

Port infrastructure and maritime transport not only enhance economy but also dominate global trade flows (ESCAP, 2020). Abe and Wilson (2009) examined how port infrastructure affects trade and the role of transport costs in driving exports and imports for East Asia. Sharapiyeva *et al.* (2019) proved the importance of port infrastructure quality and logistics as well efficiency, while Dwarakisha and Salima (2015) reviewed the role and benefits of ports in the development of coastal nation. Song and Panayides (2008) studied the integration and competitiveness of ports in global supply chain perspectives using multiple regressions and the research has emphasized on a positive relation between technology adoption and high quality of the services offered by the ports. Yang *et al.* (2019) evaluated the function and the development directions of Chinese ports. Their study developed a basic framework for Chinese ports function system. Again, the competitiveness and the competitions of major ports in the East Asia are revealed in the study of Kim (2015) and Yap and Lam (2006). Dang and Yeo (2017) analyzed the competitive strategic position of major container ports in the Southeast Asia. The study revealed that effective operations might lead Southeast Asian ports to be dominant in Asia. Song and Geenhuizen (2014) investigated port infrastructure investment and regional economic growth estimating output elasticity of port infrastructure. A positive effect of port infrastructure is found in their analysis. In addition, Song and Geenhuizen's empirical findings also show the effects of investment on regional port infrastructure improvement. The study of Nguyen *et al.* (2016) measured port efficiency by applying DAE. They identified the critical factors that improve the port efficiency and trade competitiveness. Moreover, port regionalization introduced a new phase in port infrastructure development paradigm (Notteboom & Rodrigue, 2005). Asian port harmonization and infrastructure development is very crucial now, as ports' have a direct impact on seaborne trade, and international and domestic freight transportation. Intra-regional trade connection across Asia over the past decades intensified

bilateral trade. Intraregional trade in Central Asia has the highest increase (Asian Development Bank, 2021). Therefore, it is relevant to observe the future quality of port infrastructure and formulate policies. The quality of port infrastructure is defined as the combination of different factors affecting ports' production capacity, throughput and efficiency such as- logistics system, ICT, management practice, port hinterland connectivity, operating procedures, port operating equipment, maritime routes, and the infrastructure elements include port terminals.

However, the quality of port infrastructure is an integral part of world trade. It may endow the economies with benefits lowering the shipment cost, minimizing time and enhancing efficiency between the nations. The existing literature didn't deal with the problem of forecasting the quality of port infrastructure in Asian countries and formulate strategy for future improvement of port infrastructure. This phenomenon created a research gap in the field. The study of Sharapiyeva *et al.* (2019), Nguyen *et al.* (2016), Song and van Geenhuizen (2014), Dwarakisha and Salima (2015) and Yang *et al.* (2019) merely put forward the importance of the quality of port infrastructure, none of them endeavored to observe the prediction in future. Therefore, this study attempts to contribute to the existing literature by forecasting the quality of port infrastructure. It is essential to ensure the quality of port infrastructure and take necessary measures to maintain it for future port economic activities. An accurate prediction can depict the authentic future prospect of Asian ports. This created an urge to undertake this study deploying forecasting approach. Hence, we have applied the model GM (1, 1) in this regard. This will be the first and foremost effort in forecasting the quality of port infrastructure up to 2024. The results will produce a demonstration for each individual port-country predicting future performance, and finally the countries will be clustered into different groups using the predicted values to observe the quality of port infrastructure in next 5 years.

The rest of the paper is organized as follows. In section 2, data sources and details procedure of GM (1, 1) and modified GM (1, 1) is formulated. Being confirm of the validation of the model precision, a Hierarchical Cluster Analysis (HCA) is added to cluster the countries using the forecasted values as well. Results and discussions are presented in section 3; while section 4 ends up with conclusions.

2. DATA SOURCES AND METHODOLOGY

2.1 Data sources

The present study endeavors in forecasting the quality of port infrastructure to formulate the policies to be implemented, and ends up with some recommendations. The study has focused on 31 Asian countries and 1 special administrative region (Hong Kong) (Appendix 1). The sample countries and the region are selected based on data availability and the port facilities in the economies.

The study confessed that some of these economies are transcontinental, but the selection is mainly embedded on the geographical division of Asia rather than the political, diplomatic and/or bilateral relationship. Besides, the score of the quality of port infrastructure of Brunei in 2015 was 0. The selected data on the quality of port infrastructure indicator is one of the components of the Global Competitiveness Index (GCI). The quality of port infrastructure is defined quantitatively and the aggregated score of individual country is prepared adopting sector-weighted averaging. It represents an assessment of the quality of port facilities and the level of performance in a given country based on data from the WEF Executive Opinion Survey, a long-running and extensive survey tapping the opinions of over 14,000 business leaders in 144 countries. It upholds the overall and integrated score of an individual country; it does not stand alone for a specific port of a country. Rather it signifies the combined score of the quality of port infrastructure for all existing ports in a country. The selected data on individual country score published annually by the World Economic Forum (WEF). It classifies the standards of port facilities from underdeveloped to international standards. The score of the quality of port infrastructure is scaled from 1 (underdeveloped) to 7 (extensive and efficient by international standards). The individual responses are aggregated to produce a country score. We used the individual score of each country from 2015-2019 in the study and predicted the score of next 5 years adopting the model GM (1, 1). An illustration of the model is presented in **Figure 1**.

2.2 The model GM (1, 1)

Some econometric methodologies are developed for forecasting the future and the behavior of an uncertainty system. Grey GM (1, 1) forecasting model is the most common and familiar forecasting methodology among them because of its numerous applications (Ding *et al.*, 2018). Professor Deng originally developed Grey system theory in 1982. The term GM (1, 1) indicates one variable and 1st order differential (Dong *et al.*, 2019; Li & Zhang, 2021; Lin *et al.*, 2011). It is a data-driven non-linear intelligent time series forecasting technique at present (Javed *et al.*, 2020; Li & Zhang, 2021) that needs small amount of data to predict the future pattern of unknown scenario (Chiou *et al.*, 2004; Ding *et al.*, 2018; Javed *et al.*, 2020). Grey forecasting model has successfully been used in various fields such as – energy forecasting, financial and economic forecasting, transportation data forecasting and tourism demand forecasting in recent year. The demand of determinations as well as accurate prediction of the quality of port infrastructure has become very significant. Therefore, Grey prediction approach called GM (1, 1) method has been applied in this study for its accuracy and high computational efficiency with small number of samples.

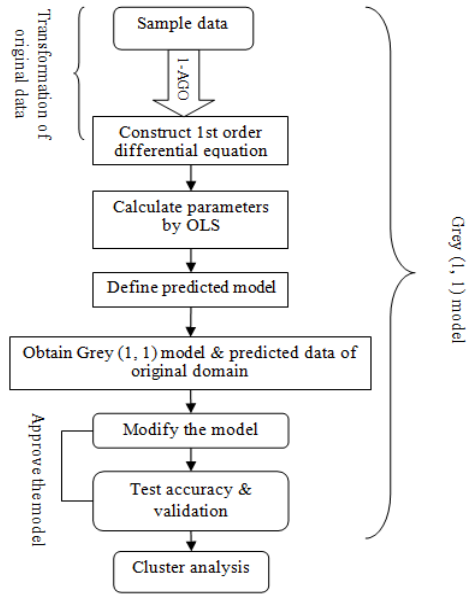


Figure 1. An illustration of Grey model with Hierarchical Cluster Analysis

where,

$$x^{(1)}(1) = x^{(0)}(1) \text{ and } x^{(1)}(k) = \sum_{i=1}^k x^{(0)}(i), \quad k=1, 2, \dots, n. \tag{3}$$

And the sequence mean generated of consecutive neighbors of $X^{(1)}$ is

$$Z^{(1)} = \{z^{(1)}(1), z^{(1)}(2), \dots, z^{(1)}(n)\}, \tag{4}$$

Where $z^{(1)}(k)$ is the mean value of the adjacent data,

$$z^{(1)}(k) = 1/2 \{x^{(1)}(k) + x^{(1)}(k - 1)\}, \quad k=2, 3, \dots, n. \tag{5}$$

$$\text{The equation } x^{(0)}(k) + az^{(1)}(k) = b, \tag{6}$$

is called the basic form of the GM (1, 1) model.

$$\text{The equation } \hat{x}^{(1)}(k + 1) = (x^{(0)}(1) - \frac{b}{a})e^{-ak} + \frac{b}{a}; \quad k=1, 2, \dots, n \tag{7}$$

is called the time response sequence of GM (1, 1). Where $x^{(1)}(k)$ denotes the prediction x at time point k and

the coefficients $[a, b]^T$ can be obtained by the Ordinary Least Square (OLS) method-

$$[a, b^T = (P^T P)^{-1}P^T Y \tag{8}$$

$$\text{In that } Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \dots \\ x^{(0)}(n) \end{bmatrix} \tag{9}$$

$$\text{And } P = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \dots & \dots \\ -z^{(1)}(n) & 1 \end{bmatrix} \tag{10}$$

Where Y is called data series and P is called data matrix, and $[a, b]^T$ is called parameter series. The Inverse AGO

(IAGO) is applied to find the predicted values of the original sequence. By applying the IAGO

$$\hat{x}^{(0)}(k) = \left[x^{(0)}(1) - \frac{b}{a} \right] e^{-a(k-1)}(1 - e^a) \tag{11}$$

GM (1, 1) model works with a minimum of 4 samples (Javed *et al.*, 2020; Wang *et al.*, 2011). It applies the accumulative generation operation (AGO) to the primary data and proceeds to solve the resultant differential equation. Our analysis applied only the data of 5 years of each country to see the quality of port infrastructure. It might help the policy makers to get ready earlier and adopt suitable strategy to increase the efficiency of the quality of port infrastructure.

GM (1, 1) model construction is described below-

Let a non-negative original raw data sequence is

$$X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)\}, \quad n \geq 4 \tag{1}$$

Where n is the amount of data.

An Accumulating Generation Operator (AGO) is used to smooth the randomness of primitive sequence. The AGO converting the original sequence into a monotonically increasing sequence. A new sequence $X^{(1)}$ is generated by AGO as

$$X^{(1)} = \{x^{(1)}(1), x^{(1)}(2) \dots, x^{(1)}(n)\}, \quad n \geq 4 \tag{2}$$

Therefore, the fitted and the predicted sequence is

$$\hat{x}^{(0)} = \hat{x}^{(0)}(1), \hat{x}^{(0)}(2), \dots, \hat{x}^{(0)}(n) \text{ and } \hat{x}^{(0)}(1) = x^{(0)}(1) \tag{12}$$

Where, $\hat{x}^{(0)} = \hat{x}^{(0)}(1), \hat{x}^{(0)}(2), \dots, \hat{x}^{(0)}(n)$ is called the GM (1, 1) fitted sequence,

and $\hat{x}^{(0)}(n + 1), \hat{x}^{(0)}(n + 2), \dots$, is called the GM (1, 1) forecast values.

2.3 Fourier Residual Modification of GM (1, 1)

Furthermore, to improve the accuracy of the forecasting model, the Fourier series has widely and successfully been used in modifying the residuals of the model. The application

of Fourier residual modification increases the prediction capabilities. That’s why, we have used the modified model developed by Nguyen *et al.* (2019a, 2019b). A combination of the procedure of FRMGM (1, 1) is as follows:

Let ε as a residual error series. ε is defined by

$$\varepsilon_0(k) = x_0(k) - \hat{x}_0(k), k = 2, 3, \dots, n \tag{13}$$

The continuous residual series can be modeled using Fourier series as:

$$\hat{\varepsilon}_0(k) = 1/2 a_0 + \sum_{i=1}^z \left(a_i \cos\left(\frac{i2\pi}{T_a} k\right) + b_i \sin\left(\frac{i2\pi}{T_a} k\right) \right) \tag{14}$$

Where, $k= 2, 3, \dots, n$, $T = n-1$, and $z = \left(\frac{n-1}{2}\right) - 1$ is the minimum deployment frequency. Therefore, the residual error can be estimated as

$$\varepsilon = P \times C \tag{15}$$

$$\text{Where } P = \begin{bmatrix} \frac{1}{2} \cos\left(\frac{2\pi \times 1}{T_a} \times 2\right) \sin\left(\frac{2\pi \times 1}{T_a} \times 2\right) \dots \cos\left(\frac{2\pi \times z}{T_a} \times 2\right) \sin\left(\frac{2\pi \times z}{T_a} \times 2\right) \\ \frac{1}{2} \cos\left(\frac{2\pi \times 1}{T_a} \times 3\right) \sin\left(\frac{2\pi \times 1}{T_a} \times 3\right) \dots \cos\left(\frac{2\pi \times z}{T_a} \times 3\right) \sin\left(\frac{2\pi \times z}{T_a} \times 3\right) \\ \dots \dots \dots \\ \frac{1}{2} \cos\left(\frac{2\pi \times 1}{T_a} \times n\right) \sin\left(\frac{2\pi \times 1}{T_a} \times n\right) \dots \cos\left(\frac{2\pi \times z}{T_a} \times n\right) \sin\left(\frac{2\pi \times z}{T_a} \times n\right) \end{bmatrix} \tag{16}$$

$$\text{And } C = [a_0, a_1, b_1, a_2, b_2, \dots, a_z, b_z] \tag{17}$$

OLS method is used to calculate the parameters $a_0, a_1, b_1, a_2, b_2, \dots, a_z, b_z$ by the equation below

$$C = (P^T P)^{-1} P^T [\varepsilon]^T \tag{18}$$

Replacing the parameters estimated in Eq. 18, we get the Eq. 14 as the modified residual series $\hat{\varepsilon}$ as follows:

$$\hat{\varepsilon}_0(k) = 1/2 a_0 + \sum_{i=1}^z \left(a_i \cos\left(\frac{i2\pi}{n-1} k\right) + b_i \sin\left(\frac{i2\pi}{n-1} k\right) \right) \tag{19}$$

From the predicted series \hat{x} and the residual error $\hat{\varepsilon}$, the modeled residual series can be modeled as

$$\varepsilon_0 = [\varepsilon_0(2), \varepsilon_0(3) \dots \varepsilon_0(n)]^T \tag{20}$$

Finally, the original prediction series of FRMGM (1, 1) can be written as

$$\hat{x}_{a0}(k) = \hat{x}_0(k) + \hat{\varepsilon}_0(k), k=2, 3, \dots, n. \tag{21}$$

2.4 Evaluation Precision of GM (1, 1) model

The precision of the proposed GM (1, 1) model needs to be justified. In this section, the capabilities of the predicted model are examined. Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) index are used to evaluate the performance and reliability of forecasting technique. The lower of the values of MAPE is the more accurate of prediction. MAPE% indicates the goodness of

the prediction accuracy. MAE and MAPE are defined according to Eqs. (22) and Eqs. (23)

$$\text{MAE} = \frac{1}{n} \sum_{i=1}^n x^{(0)}(k) - \hat{x}^{(0)}(k) \tag{22}$$

$$\text{MAPE} = \frac{1}{n} \sum_{i=1}^n \left| \frac{x^{(0)}(k) - \hat{x}^{(0)}(k)}{x^{(0)}(k)} \right| \times 100\% \tag{23}$$

Where $x^{(0)}(k)$ is the actual value of k period,

and $\hat{x}^{(0)}(k)$ is the predicted value of k period. The interpretation of MAPE is to judge the accuracy of the prediction in accordance to Lewis scale proposed in 1982. The level of MAPE is categorized into four grades (Lewis, 1982) presented in **Table 1**.

Table 1. grade level of MAPE

MAPE	≤ 1%	1%-5%	5%-10%	> 10%
Grade level	Excellent	Good	Qualified	Not acceptable

Finally, a map using MAPE % and model accuracy is designed to depict the performance of the prediction model shown in **Figure 3**. This will enable the port authorities and managers to get into the validation of the results, and gain insights into the comparison of the economies.

2.5 Hierarchical cluster analysis (HCA)

We will proceed categorizing the port countries in accordance to their forecasting values. The countries will be

clustered deploying Hierarchical Cluster Analysis (HCA). HCA is a multivariate technique for performing data explanatory analysis to cluster them into different group (Hasan & Yan-Chun, 2020; Jiang & Chen, 2009; Mao *et al.*, 2019). The HCA divides and clusters the data matrix into different hierarchies. It finds relative homogeneous clusters based on the similar characteristics (Jiang & Chen, 2009). The HCA consists of building a binary merge tree and the graphical presentation of this binary merge tree is called dendrogram. Visual representation of the dendrogram conveys information of both qualitative and quantitative evaluations of the clusters. Statistical distance is a method used to evaluate the similarity between two data points in HCA (Mao *et al.*, 2019). The distance is called the linkage distance between any two sub-sets (X_iX_j) of X and it is denoted by Δ . Binary merge trees consisted of data, starting from the elements stored at the leaves and proceeds by merging two by two closest sub-sets until it reaches the root of the tree (**Figure 2**).

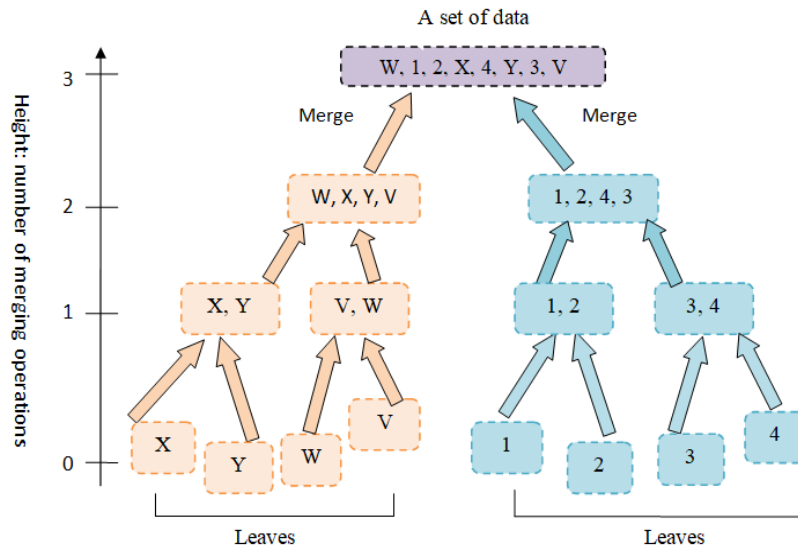


Figure 2. Graphical merge tree of HCA

Let's have N number of data sets of $X = X_1 \dots, X_j \dots, X_n$ with $\Delta(X_iX_j) = d(X_iX_j)$ elementary distance between two clusters. There are many criterions for identifying the distance $d(X_iX_j)$ in HCA. A most frequently used method is Euclidean Distance which can describe the geometric distance between points x and y.

$$d(XY) = \sqrt{(Y_1 - X_1)^2 + (Y_2 - X_2)^2 + \dots + (Y_n - X_n)^2} \tag{24}$$

$$= \sqrt{\sum_{i=1}^n (Y_i - X_i)^2} \tag{25}$$

The average linkage method is chosen to reduce the errors caused by the outliers.

3. RESULTS AND DISCUSSIONS

The prediction results have been presented in this section. It depicts the change that Asian economies will face in future. The algorithm of GM (1, 1) along with a Hierarchical Cluster Analysis (HCA) has been applied to get the authentic situation of the quality of future port infrastructure. The details have been presented dividing the

port countries into different regions to avoid the complexity of understanding. They are geographically categorized as Western Asia, South Asia, Southeast Asia, East Asia and Central Asia. And their quality of port infrastructure varies from region to region. The prediction values of all economies are presented in graph in Appendix 2. The findings show that there will be a great change in the quality of port infrastructure in future.

The overall results indicate the well performance of Asian port countries, and the predicted values show a good standard of the quality of port infrastructure will be

maintained in future as well. The predicted values along with the actual values of 13 countries in Western Asia are shown in **Table 2**. It presents a comparative picture of the quality of port infrastructure. The quality of port infrastructure in Western Asia especially in Azerbaijan, Israel, Oman, Qatar, Saudi Arabia and Turkey will be better and better in next five years; while the quality of port infrastructure in Bahrain, Georgia, Kuwait, Jordan and Iran with others will slightly be lower than their actual trend. However, it will decrease in the UAE as well. The competition among the ports in the Caspian Sea and the development programs of Azerbaijan with Poland and Russia to digitize the “Middle Corridor” of port Baku made the universal platform with functional capability of transport and logistics services. Moreover, Azerbaijan’s free trade zone in Baku-Alat port and the multi-modal transportation corridors is playing potential role in integrating the country to the Caspian Sea and vicinity of the Central Asia and Far East: Turkmenistan, Kazakhstan,

Georgia, Turkey, and Pakistan. These may lead the country to be outstanding among the competitors and score better than that of present. Western Asian economies had a gradual recovery in growth from 2018, as the rebalancing of oil markets positively impacted the region’s infrastructure development too. Higher oil price has not only contributed in infrastructure development but also buoyed economic sentiment in the region especially in GCC countries: Bahrain, Kuwait, Qatar, Oman, Saudi Arabia and UAE. Therefore, the quality of port infrastructure improved much and the economies are doing great in the region as well. On the other hand, growth in the energy-importing countries- Jordan and Lebanon, has been mostly subdued partly because of deteriorating terms of trade and transport related infrastructure. Besides, high levels of public debts and geopolitical uncertainty have negatively influenced these countries.

Table 2. Actual values and the forecasted values of Western Asia

Country	Values	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Azerbaijan	Actual	4.26	4.30	4.70	4.90	5.10					
	GM (1, 1)	4.26	4.36	4.61	4.87	5.14	5.42	5.73	6.05	6.38	6.74
	FRMGM (1, 1)	4.26	4.26	4.30	4.90	5.10	5.44	5.66	5.99	6.34	6.73
Bahrain	Actual	5.40	5.10	5.10	4.80	5.10					
	GM (1, 1)	5.40	5.07	5.04	5	4.97	4.94	4.91	4.89	4.86	4.83
	FRMGM (1, 1)	5.40	5.10	5.10	4.80	5.10	4.99	4.94	5	4.86	4.90
Georgia	Actual	3.99	4	4.10	3.80	3.80					
	GM (1, 1)	3.99	4.06	3.96	3.87	3.79	3.70	3.62	3.54	3.46	3.38
	FRMGM (1, 1)	3.99	4	4.10	3.80	3.80	3.73	3.69	3.57	3.50	3.44
Iran	Actual	3.90	3.90	4	3.90	3.70					
	GM (1, 1)	3.90	3.97	3.90	3.83	3.77	3.70	3.64	3.57	3.51	3.45
	FRMGM (1, 1)	3.90	3.90	4	3.90	3.70	4	4.11	3.98	3.67	3.55
Israel	Actual	4.01	4.50	4.70	4.60	4.80					
	GM (1, 1)	4.01	4.53	4.60	4.68	4.77	4.85	4.93	5.02	5.11	5.19
	FRMGM (1, 1)	4.01	4.50	4.70	4.60	4.80	4.88	4.98	5.11	5.23	5.26
Jordan	Actual	4	4.50	4.50	4.20	4.40					
	GM (1, 1)	4	4.49	4.42	4.36	4.30	4.25	4.19	4.13	4.07	4.02
	FRMGM (1, 1)	4	4.50	4.50	4.20	4.40	4.26	4.22	4.18	4.09	4.11
Kuwait	Actual	3.98	4.10	3.80	3.70	3.50					
	GM (1, 1)	3.98	4.06	3.86	3.67	3.49	3.32	3.15	3	2.85	2.71
	FRMGM (1, 1)	3.98	4.10	3.80	3.70	3.50	3.44	3.22	3.14	3.44	3.32
Lebanon	Actual	3.86	3.80	3.50	3.20	3.60					
	GM (1, 1)	3.86	3.66	3.57	3.47	3.38	3.29	3.21	3.12	3.04	2.96
	FRMGM (1, 1)	3.86	3.80	3.50	3.20	3.60	3.32	3.29	3.17	3.12	3.05
Oman	Actual	4.86	4.60	4.60	5.30	5.10					
	GM (1, 1)	4.86	4.57	4.78	5	5.23	5.46	5.71	5.97	6.25	6.53
	FRMGM (1, 1)	4.86	4.60	4.60	5.30	5.10	5.44	5.77	5.96	6.29	6.61
Qatar	Actual	5.60	5.50	5.60	5.30	5.40					
	GM (1, 1)	5.60	5.54	5.47	5.41	5.36	5.30	5.24	5.18	5.12	5.07
	FRMGM (1, 1)	5.60	5.50	5.60	5.30	5.40	5.44	5.26	5.22	5.14	5.09
S. Arabia	Actual	4.84	4.60	4.70	4.60	4.80					
	GM (1, 1)	4.84	4.59	4.64	4.69	4.75	4.80	4.85	4.90	4.95	5.01
	FRMGM (1, 1)	4.84	4.60	4.70	4.60	4.80	4.90	5.02	4.98	4.99	5.12
Turkey	Actual	4.37	4.50	4.50	4.50	4.70					
	GM (1, 1)	4.37	4.45	4.51	4.57	4.64	4.70	4.76	4.83	4.89	4.96
	FRMGM (1, 1)	4.37	4.50	4.50	4.50	4.70	4.71	4.77	4.85	4.88	4.97
UAE	Actual	6.47	6.40	6.20	5.40	5.50					
	GM (1, 1)	6.47	6.41	6.03	5.68	5.35	5.04	4.74	4.47	4.21	3.96
	FRMGM (1, 1)	6.47	6.40	6.20	5.40	5.50	5.12	5.01	4.88	4.32	4.02

Investment pattern in the port sector across South Asia in the past two decades was not uniform. India, Sri Lanka and Pakistan took the lead in South Asia, followed by

Bangladesh (Herrera Dappe & Suárez-Alemán, 2016). Indian latest port sector strategy- Maritime Agenda 2010-2020 and Sagarmala obviously lead the country toward the

development of the quality of port facilities. Again, the leveraging private sector investment for port development, expansion of container capacity, and the ongoing investment are the most dynamic factors of the improvement of Indian ports. That's why; India seems to be the best performer in the quality of port infrastructure among the peers. The prediction of the quality of port infrastructure of South Asia is presented in **Table 3**. Results show that the quality of port infrastructure of India, Pakistan and Sri Lanka will be much better in future than those of they are now; while Bangladesh will maintain the same progress as it is now. It is estimated that more than 80% of global trade by volume (Wignall & Wignall, 2014) and more than 70% by value is facilitated through seaborne shipments (Herrera Dappe & Suárez-Alemán, 2016). According to World Bank Report 2017, improvement of the quality of port infrastructure of South Asia located in Bangladesh, India, Pakistan and Sri Lanka is critical and crucial because port infrastructure is the key bottleneck to the competitiveness of South Asia. Our

prediction indicates the progress of port infrastructure of Pakistan. Major deep seaports such as Karachi Port in Pakistan, which accounts for 60% of its maritime shipments, port of Colombo, and port of Hambantota in Sri Lanka those serving as the South Asia Gateway Terminal, and Chittagong deep seaport in Bangladesh, are South Asia's maritime cluster. Being located in the East-West trade route and neighboring, India, Sri Lanka and Bangladesh will take the geological advantages in South Asia by establishing a key logistics hub and a robust maritime network. Therefore, our prediction creates a clear picture for the decision makers how they will cope with predicted situation. However, Southeast Asia is displaying the utmost consistency in the quality of port infrastructure shown in **Table 4**. Brunei, Indonesia, Philippines, Singapore and Vietnam will do better in the next five years. But the performance of Cambodia and Malaysia will be slower; while Myanmar will come out from its current trend of under performance in the next 5 years.

Table 3. Actual values and the forecasted values of South Asia

Country	Values	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Bangladesh	Actual	3.56	3.50	3.60	3.50	3.50					
	GM (1, 1)	3.56	3.53	3.52	3.52	3.51	3.50	3.49	3.48	3.47	3.46
	FRMGM (1, 1)	3.56	3.50	3.60	3.50	3.50	3.48	3.51	3.50	3.51	3.55
India	Actual	4.21	4.50	4.60	4.60	4.50					
	GM (1, 1)	4.21	4.79	4	4	5	5	4	4	5	6
	FRMGM (1, 1)	4.21	4.50	4.60	4.60	4.50	4.94	4.32	4.10	5.10	5.77
Pakistan	Actual	4.08	3.70	4	4.10	4.10					
	GM (1, 1)	4.08	3.78	3.90	4.03	4.16	4.30	4.44	4.59	4.74	4.89
	FRMGM (1, 1)	4.08	3.70	4	4.10	4.10	4.29	4.46	4.57	4.80	4.93
Sri Lanka	Actual	4.28	4.30	4.50	4.10	4.10					
	GM (1, 1)	4.28	4.39	4.29	4.19	4.10	4	3.91	3.82	3.73	3.65
	FRMGM (1, 1)	4.28	4.30	4.50	4.10	4.10	4.11	4.01	3.86	3.77	3.70

Southeast Asia's infrastructure is emerging as a major beneficiary of Belt and Road infrastructure investment. And the region is likely to experience a reform in port and logistics infrastructure development (Oxford, 2017). Based on favorable demographics, strong natural resources, and strategic geographical location of the Southeast Asia (Dang & Yeo, 2017), the countries are attracting a high proportion of China's OFDI outflows, nearly one-third of which goes directly towards infrastructure development. The improvements in the quality of port infrastructure and the hinterland links are seen as the central gravity to reduce logistics costs and increasing the global competitiveness of the economies such as- Indonesia, Philippines, Myanmar, Vietnam and Cambodia, where ports and hinterland links suffer from congestion, poor productivity and inefficiency. To remain Southeast Asian economy competitive, most of the countries in the region are planning to improve roads,

railways, ports and airports. Singapore's plan to build new port terminal at Tuas in the Southwest of the city-state, Malaysian expansion of port Klang, and Indonesian and the Philippines' heavy investment will definitely help to catch up their wealthier neighbors' maritime infrastructure. Their plan to develop the port and seaborne trade links between the Eastern islands of Indonesia and the Philippines. These lead the countries to maintain a steady and continuous progress in the quality of port infrastructure. As a result, the quality of port infrastructure in these two economies will be outstanding in the near future. Southeast Asia has a lot of works regarding the port infrastructure development to be done. Above all, port operators in Southeast Asia need to think about the strategies and identify their competitors in order to retain and improve ports' infrastructure quality in the region (Dang & Yeo, 2017).

Table 4. Actual values and the forecasted values of Southeast Asia

Country	Values	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Brunei	Actual	0	3.70	3.90	4.10	4.10					
	GM (1, 1)	0	3.74	3.87	4.01	4.15	4.30	4.46	4.62	4.78	4.95
	FRMGM (1, 1)	0	3.70	3.90	4.10	4.10	4.44	4.88	5.13	5.11	4.98

Table 4. Actual values and the forecasted values of Southeast Asia (Con't)

Country	Values	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Cambodia	Actual	3.71	3.90	3.10	3.60	3.60					
	GM (1, 1)	3.71	3.61	3.57	3.53	3.48	3.44	3.40	3.36	3.32	3.28
	FRMGM (1, 1)	3.71	3.90	3.10	3.60	3.60	3.55	3.59	3.33	3.39	3.21
Indonesia	Actual	3.81	3.90	4	4.20	4.50					
	GM (1, 1)	3.81	3.85	4.04	4.24	4.45	4.67	4.49	5.15	5.41	5.56
	FRMGM (1, 1)	3.81	3.90	4	4.20	4.50	4.67	4.55	5.15	5.44	5.55
Malaysia	Actual	5.57	5.40	5.40	5.30	5.20					
	GM (1, 1)	5.57	5.42	5.35	5.28	5.22	5.15	5.08	5.01	4.95	4.88
	FRMGM (1, 1)	5.57	5.40	5.40	5.30	5.20	4.99	5.12	5.08	4.99	4.77
Myanmar	Actual	2.6	2.6	0	2.6	0					
	GM (1, 1)	2.6	2.14	1.43	0.96	0.64	0.43	0.29	0.19	0.13	0.08
	FRMGM (1, 1)	2.6	2.6	0	2.6	0	0.66	1.12	1.01	0.77	1.23
Philippines	Actual	3.22	2.90	2.90	3.60	3.70					
	GM (1, 1)	3.22	2.82	3.10	3.41	3.75	4.12	4.53	4.98	5.48	6.03
	FRMGM (1, 1)	3.22	2.90	2.90	3.60	3.70	4.16	4.55	4.99	5.55	6
Singapore	Actual	6.66	6.70	6.70	6.40	6.50					
	GM (1, 1)	6.66	6.71	6.61	6.52	6.44	6.35	6.26	6.18	6.09	6.01
	FRMGM (1, 1)	6.66	6.70	6.70	6.40	6.50	6.33	6.30	6.22	6.08	6.18
Thailand	Actual	4.49	4.20	4.30	4.10	4.10					
	GM (1, 1)	4.49	4.24	4.19	4.14	4.10	4.05	4	3.95	3.90	3.86
	FRMGM (1, 1)	4.49	4.20	4.30	4.10	4.10	4.28	4.09	4.10	4.13	3.98
Vietnam	Actual	3.91	3.80	3.70	3.80	3.80					
	GM (1, 1)	3.91	3.75	3.76	3.78	3.79	3.80	3.81	3.82	3.83	3.84
	FRMGM (1, 1)	3.91	3.80	3.70	3.80	3.80	4.01	4.13	3.99	3.88	4.01

The quality of port infrastructure especially in East Asia as well as in Central Asia is satisfactory too (Table 5, Table 6). The quality of port infrastructure in Japan, South Korea and Hong Kong is excellent and the predicted values also show there will be an increasing of the quality of port infrastructure in future. Although the performance quality of Chinese port will be little bit lower than the present trend, ports in East Asian region have experienced a sharp increase of trade volume and served internal competition for hub ports in the region (Kim, 2015). This is because of some major phenomenon, and the long history of East Asian strong maritime industry is another explanation (Kim, 2015). At the beginning of the century, East Asian ports occupied a place among the top 10 ports countries in the world for their modern technology, trade and transport related infrastructure, comprehensive cost minimization, operation capacity, efficiency and better services, geographical location and quality infrastructure. So, the quality of port infrastructure in East Asia is getting better and better. Chinese dramatic growth of economy and trade; export-driven economic policies of the countries in the region including China, Japan, Korea and Hong Kong attributed the region to be dynamic in the quality of infrastructure (Kim, 2015; Yap & Lam, 2006). The forecasting results from 2020-2024 in Table 5 revealed that intra-port competition of the quality of port infrastructure in Asia will be intensified in the future as the

center of gravity. The gradual shift towards East Asia and the central gravity will give rise to the emergence of new transshipment and gateway hub ports. However, the quality of port infrastructure in Central Asia- Kyrgyzstan and Tajikistan is getting well too. Although they are performing, the region will require a/an managerial, regulatory, institutional mechanism and a good governance reform in future to get the quality of port infrastructure (Sanauallah, 2003). The vulnerability, political and economic instability, fragmented infrastructure in Central Asia concerns about the stable performance of ports' quality; while shippers face difficulties in conducting commercial transactions, especially for international shipments (Itf, 2019). So, sufficient institutional capacity will be necessary to increase the quality of infrastructure in Central Asia (Itf, 2019) especially in Tajikistan. Central Asia is a part of the global transport network, and the poor transport infrastructure in the region implies not only longer and less-reliable travel times, but also increased vehicle maintenance costs. That's why, both public-private and regional organization like the Central Asia Regional Economic Co-operation (CAREC) should come in front line to promote international standards in the quality of port infrastructure, improve port's connectivity with its hinterland and align logistics planning with needs (Asian Development Bank, 2021).

Table 5. Actual values and the forecasted values of East Asia

Country	Values	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
China	Actual	4.55	4.60	4.60	4.50	4.50					
	GM (1, 1)	4.55	4.61	4.56	4.52	4.49	4.45	4.41	4.37	4.33	4.29
	FRMGM (1, 1)	4.55	4.60	4.60	4.50	4.50	4.49	4.50	4.35	4.48	4.33
Japan	Actual	5.40	5.30	5.30	5.60	5.80					
	GM (1, 1)	5.40	5.23	5.40	5.58	5.77	5.96	6.16	6.37	6.58	6.80
	FRMGM (1, 1)	5.40	5.30	5.30	5.60	5.80	6	6.12	6.38	6.55	6.86
South Korea	Actual	5.23	5.20	5.20	5.40	5.50					
	GM (1, 1)	5.23	5.16	5.26	5.37	5.49	5.60	5.72	5.84	5.96	5.09
	FRMGM (1, 1)	5.23	5.20	5.20	5.40	5.50	5.62	5.77	5.88	5.94	6.01
Hong Kong*	Actual	6.45	6.40	6.50	6.20	6.30					
	GM (1, 1)	6.45	6.44	6.37	6.31	6.26	6.20	6.14	6.08	6.02	5.97
	FRMGM (1, 1)	6.45	6.40	6.50	6.20	6.30	6.22	6.18	6.12	6.08	6

*special administrative region

Table 6. Actual values and the forecasted values of Central Asia

Country	Values	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Kyrgyzstan	Actual	1.5	1.5	1.4	1.4	1.5					
	GM (1, 1)	1.5	1.44	1.45	1.45	1.45	1	2	1	2	1
	FRMGM (1, 1)	1.5	1.5	1.4	1.4	1.5	1.1	1.98	1.4	1.88	1.67
Tajikistan	Actual	4.03	2	2	1	1					
	GM (1, 1)	4.03	2.12	1.63	1.26	0.97	0.74	0.57	0.44	0.34	0.26
	FRMGM (1, 1)	4.03	2	2	1	1	1.04	0.96	0.67	0.45	0.39

Table 7. Evaluation precision of GM (1, 1) and FRMGM (1, 1) model

Region	Country	Grey GM (1, 1) model				FRMGM (1, 1) model			
		MAE	MAPE %	Prediction accuracy %	Performance	MAE	MAPE %	Prediction accuracy %	Performance
Western Asia	Azerbaijan	0.044	0.94	99.06	Excellent	0.00	0.00	100	Excellent
	Bahrain	0.084	1.7	98.3	Good	0.00	0.00	100	Excellent
	Georgia	0.056	1.40	98.6	Good	0.00	0.00	100	Excellent
	Iran	0.062	1.5	98.5	Good	0.00	0.00	100	Excellent
	Israel	0.048	1.03	98.97	Good	0.00	0.00	100	Excellent
	Jordan	0.07	1.6	98.4	Good	0.00	0.00	100	Excellent
	Kuwait	0.028	0.73	99.27	Excellent	0.00	0.00	100	Excellent
	Lebanon	0.14	4	96	Good	0.00	0.00	100	Excellent
	Oman	0.128	2.5	97.5	Good	0.00	0.00	100	Excellent
	Qatar	0.064	1.17	98.83	Good	0.00	0.00	100	Excellent
	S. Arabia	0.042	0.89	99.11	Excellent	0.00	0.00	100	Excellent
	Turkey	0.038	0.83	99.17	Excellent	0.00	0.00	100	Excellent
UAE	0.122	2.16	97.84	Good	0.00	0.00	100	Excellent	
Southeast Asia	Brunei	0.042	1.05	98.95	Good	0.00	0.00	100	Excellent
	Cambodia	0.19	5.5	94.5	Qualified	0.00	0.00	100	Excellent
	Indonesia	0.036	0.86	99.14	Excellent	0.00	0.00	100	Excellent
	Malaysia	0.022	0.41	99.59	Excellent	0.00	0.00	100	Excellent
	Myanmar	0.64	16	84	Not applicable	0.00	0.00	100	Excellent
	Philippines	0.10	3.23	96.77	Good	0.00	0.00	100	Excellent
	Singapore	0.056	0.85	99.15	Excellent	0.00	0.00	100	Excellent
	Thailand	0.038	0.89	99.11	Excellent	0.00	0.00	100	Excellent
Vietnam	0.028	0.74	99.24	Excellent	0.00	0.00	100	Excellent	
South Asia	Bangladesh	0.028	0.78	99.22	Excellent	0.00	0.00	100	Excellent
	India	0.39	8.70	91.30	Qualified	0.00	0.00	100	Excellent
	Pakistan	0.062	1.50	98.50	Good	0.00	0.00	100	Excellent
	S. Lanka	0.078	1.7	98.30	Good	0.00	0.00	100	Excellent
East Asia	China	0.016	0.35	99.65	Excellent	0.00	0.00	100	Excellent
	Japan	0.044	0.81	99.19	Excellent	0.00	0.00	100	Excellent
	S. Korea	0.028	0.53	99.47	Excellent	0.00	0.00	100	Excellent
	H. Kong	0.064	1	99	Excellent	0.00	0.00	100	Excellent

Table 7. Evaluation precision of GM (1, 1) and FRMGM (1, 1) model (Con't)

Region	Country	Grey GM (1, 1) model				FRMGM (1, 1) model			
		MAE	MAPE %	Prediction accuracy %	Performance	MAE	MAPE %	Prediction accuracy %	Performance
Central	Kyrgyzstan	0.042	2.89	97.11	Good	0.00	0.00	100	Excellent
Asia	Tajikistan	0.156	10.7	89.3	Not applicable	0.00	0.00	100	Excellent
AMAPE % = 2.4, Prediction accuracy = 97.6, Performance = Good						AMAPE % = 0.0, Prediction accuracy = 100, Performance=Excellent			

The individual country MAPE %, prediction accuracy % as well as the performance of the model is shown in **Table 7**. The performance is defined on the basis of Lewis (1982) scale of MAPE % (**Table 1**) and prediction accuracy % (**Table 7**) of each individual country. The prediction performance is excellent when MAPE % is 1 or less than 1, good when it is 1-5, and acceptable when it is 5-10. The overall results incurred from Grey method have satisfied the validation and the precision of the model. The Average Mean Absolute Percentage Error (AMAPE) is the average of MAPE %, which is 2.4%, indicates 97.6% accuracy of the model. The GM (1, 1) confirms that the quality of port infrastructure of the countries is well predicted. Since the MAPE % of Myanmar and Tajikistan is greater than 10, and the accuracy is less than 90 in case of GM (1, 1) approach, the prediction accuracy for them is not up to the accepted level. These are indicated marking as black and blue point in

Figure 3(a). The Grey prediction results are further improved applying Fourier Residual Modification following Nguyen *et al.* (2019a, 2019b). The prediction accuracy of FRMGM (1, 1) is shown in **Table 7** as well. The AMAPE of FRMGM (1, 1) model is 0.00 indicating the 100% accuracy of the prediction. A comparison of the prediction performance of both for the GM (1, 1) and FRMGM (1, 1) model is shown in graphical presentation in **Figure 3(a) and 3(b)** respectively. **Figures 3(a) and 3(b)** will help better understanding of the performance accuracy and comparison of the two different approaches. It is noticeable from the two graphs that FRMGM (1, 1) model presents more accurate and better prediction than that of GM (1, 1) in this case. More so on, the graphs of actual and forecasted results are presented in **Appendix 2**. They will present comparative scenery of the quality of port infrastructure of Asia.

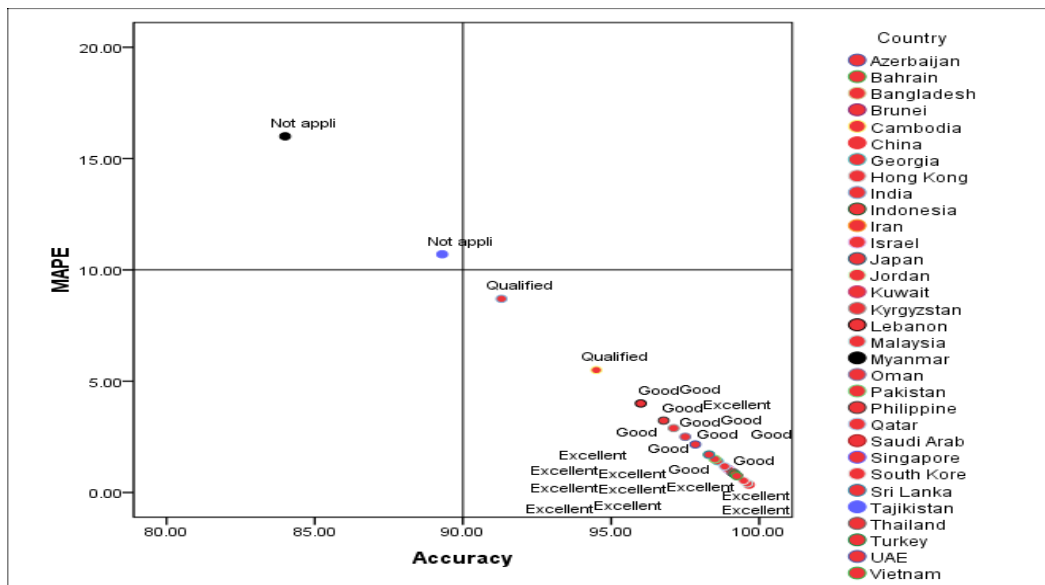


Figure 3(a). Performance map of the model GM (1, 1)

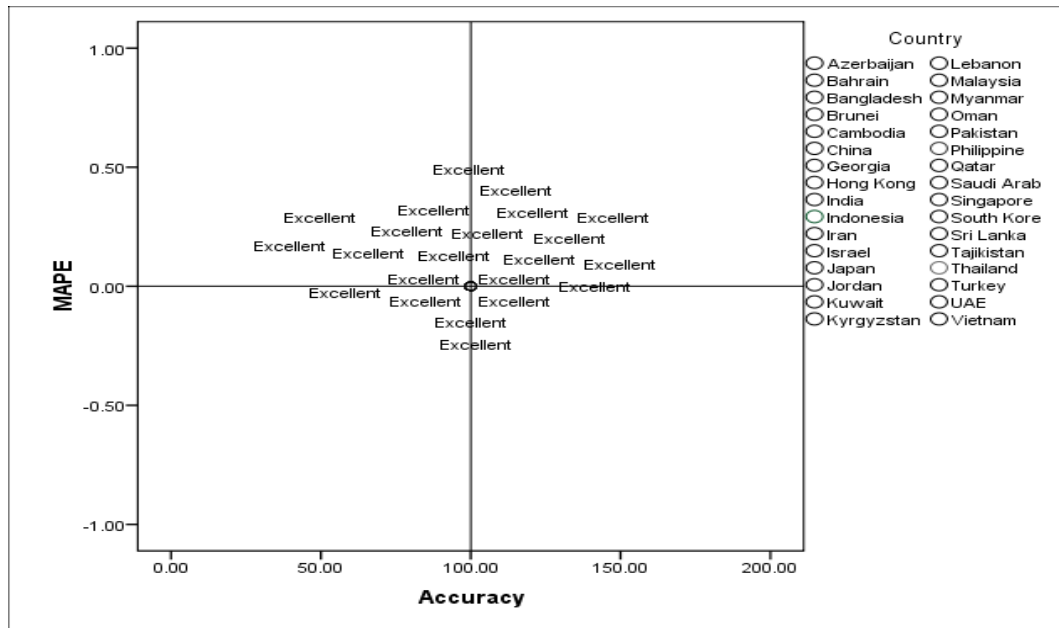


Figure 3(b). Performance map of the FRMGM (1, 1)

Since the prediction precision of modified model shows better accuracy, the actual values and the predicted values derived from it have been used in Hierarchical Cluster Analysis (HCA) to cluster the countries according to the level of their performance. Diagram of actual values and the predicted values is shown in Figure 4a and Figure 4b respectively. The cluster dendrograms of the actual and prediction values presents a clear overview of the change in the quality of port infrastructure in Asia. The economies are grouped into different clusters in accordance to their quality of port infrastructure- countries with best quality in 1st cluster, countries with middle quality in 2nd cluster and the countries of underperformance in 3rd cluster; while the others are in 4th.

The UAE, Hong Kong and Singapore are in 1st cluster, Bahrain, Qatar, Malaysia, South Korea, Oman, S. Arab, Israel, Azerbaijan, India, China and Japan are in 2nd cluster, Tajikistan, Myanmar and Kyrgyzstan are in 3rd cluster, while the rest are in the 4th cluster shown Figure 4a. The prediction shows that Azerbaijan S. Korea, Japan, and Oman will be included in the 1st cluster for better improvement the quality of the port infrastructure in future (Figure 4b); while the UAE will move to the 2nd cluster in future for the deterioration of port infrastructure. After all, the dendrogram of HCA depicted Western Asia, East Asia, and Singapore as the dominating part of the regional gravity of the quality of port infrastructure.

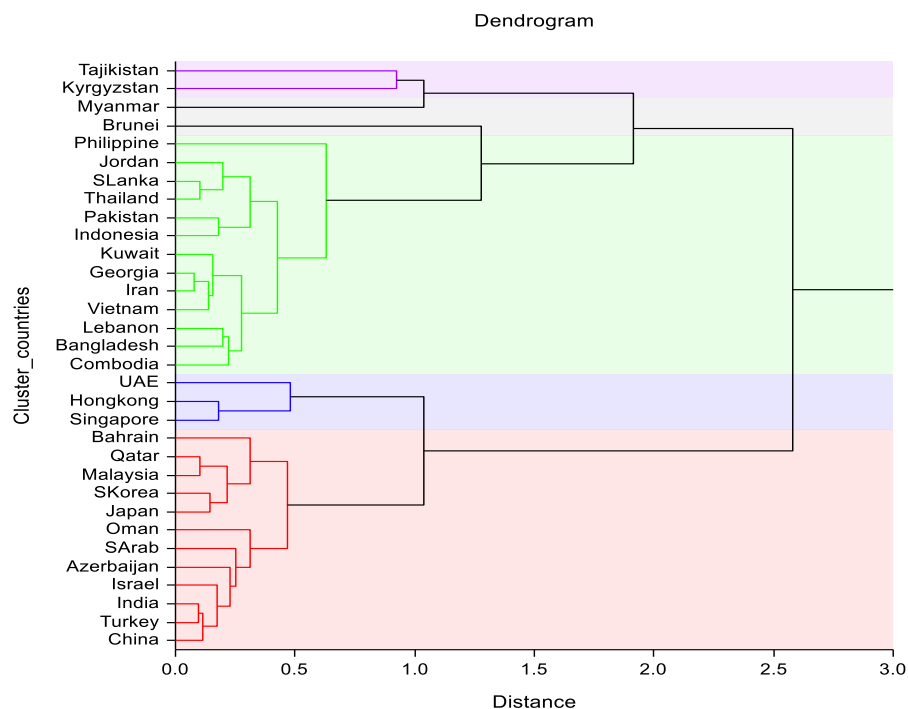


Figure 4a. Actual clusters of the quality of port infrastructure of the economies

The forecasting results, the performance map, and the dendrograms of HCA will work as the visual presentation for the decision makers. Asian policy makers must encourage regional investments and bilateral agreements; prioritize on operational facilities and digitalization, strategize in regional port development projects, and increase the terminal capacity. Since the emergence of South Asia as a growing maritime economic center is an opportune time, Asia needs to materialize its vision of becoming a regional transshipment and maritime hub. Decision makers must ensure a robust maritime network with regionalization to invest in port infrastructure development and formulate policy framework. Countries in tertiary level and those are comparatively less efficient specially, Georgia, Iran, Kuwait, Bangladesh, Cambodia, Myanmar, Vietnam, Kyrgyzstan and Tajikistan must improve container handling facilities in terminals, identify and encourage building new ports, finally develop hinterland connection in the near future. Since efficient port infrastructure services lower maritime transaction costs, raise value added (Brooks, 2008), Asian emerging

economies need to focus on solving chronic port congestion, slow turnaround of vessels, poor connectivity of demand region and shipments are to be transshipped through gateway ports in other countries (Oommen, 2015). Countries with lower quality of port infrastructure may develop regional port hub, infrastructure development bank, reform logistics systems, and improve regional cooperation on cross-border issues and challenges (ADB, 2021). Again, development of microeconomic variables, hinterland connection, port cybersecurity and digital maritime network in Western Asian, South Asian, and Southeast Asian must be ensured. Finally, port countries, along with the decision makers must observe the prediction of the future quality, and formulate institutional, infrastructural and operational regulations hereafter along with capable and skilled manpower. According to the ADB report 2021 on ports and logistics scoping, a bunch of recommendations are prescribed in concluding section.

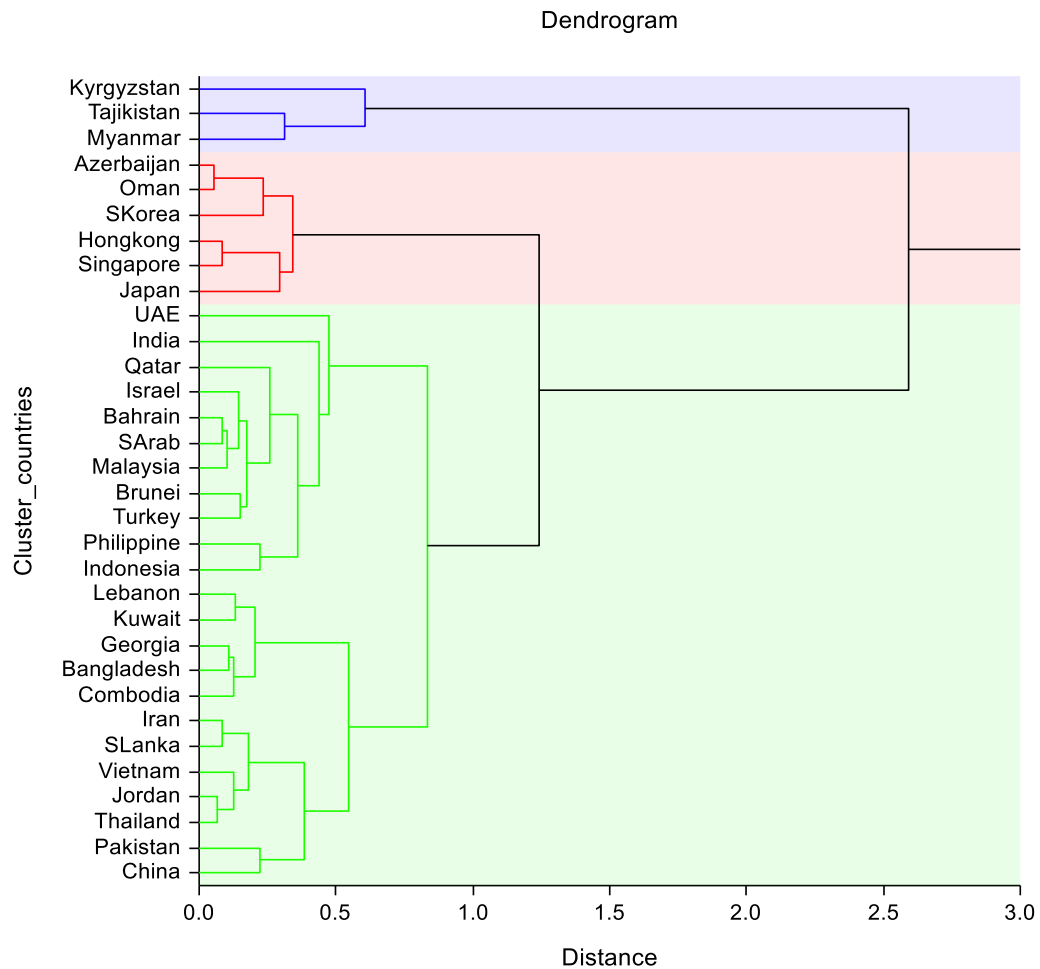


Figure 4b. Prediction Clusters of the quality of port infrastructure of the economies

The contributions of this study are many folds. First of all, the findings of modified FRMGM (1, 1) model and the graphical presentation of the forecasted values will contribute to the existing literature showing the hierarchies of the quality of the port infrastructure in Asia. Secondly, the port facilitators and the decision makers would be able to

distinguish the higher and the lower performer from the cluster analysis. Consequently, they would be able to focus on the underperformed region. Furthermore, the study found the model suitable to forecast the quality of port infrastructure of Asia update to 2024. It will further serve as a hybrid methodological approach that the policymakers and

the individual researcher can apply in forecasting the data of a region or a group, and cluster them according to their hierarchies. The merit of this study not only has a practical contribution but also has a methodological way to contribute to the literature. Thirdly, the individual forecasting values of each country will help the port authorities to formulate future policies and strategies regarding the development of the quality of port infrastructure. Asian economies would be able to undertake individual measures to improve their port infrastructure as well. On the other hand, the study will theoretically extend the frontier of knowledge in port infrastructure research, and the port authorities can apply the knowledge in the development of the quality of Asian port infrastructure.

In the context of high competition among Asian ports, port performers and the managers need to focus on the continuous improvement of their port infrastructure. The major obstacle on this way to introduce new direction is the unpredictable quality of the port infrastructure. Port management authorities need to get on a criterion to take decision regarding the quality of port infrastructure. The results of our study will mend this inconsistency specifying the best, middle and the lower performer. Individual forecasting results will stage different scenario of individual country. Asian ports managers will get new idea what to do and where the importance should give. Each individual result demonstrates the future performance of the quality of port infrastructure. Individual researcher and the port managers may consider the result as the benchmark to see the ports performance up to 2024. Furthermore, the study can be taken as example to see the regional performance of other parts of the world as well.

4. CONCLUSIONS

Forecasting methodology and related applications to predict the quality of port infrastructure are gradually receiving attention. These approaches can have a great contribution in taking decisions based on time series to predict possible future situations as well as orienting development in future. The result of this study will serve as a landmark in forecasting the quality of port infrastructure. The modified FRMGM (1, 1) model built here depicted a change in the performance that will be seen in future. Some economies might be able to upgrade their port infrastructure; while some others will face difficulties to retain on the same position. Western Asian countries will see a great change in the infrastructure in future for the stable politics, and their suitable environment will attract more investment in infrastructure. More so on, FDI both from private and public sectors in the underdeveloped countries will hasten the progress as well. India, Pakistan and Myanmar will also be outstanding, while Central Asia will face crisis in building port infrastructure. Predicting the quality of the port infrastructure is of great importance both for local and national economy to formulate the port development strategies. It will help port manager for making decision in formulating policies for regional development as well. Besides, it will have practical implications for country, region and continent in or out of Asia and related policy makers. Policy makers and port authorities can apply the methodology to get the condition of regional port development in advance.

However, critical geographical location and the lack of accurate prediction have limited the development of the quality of port infrastructure in Asia. These have created vague ideas of undertaking proper measurements by the policy makers. Therefore, it's rather important to develop a methodology to estimate the port infrastructure quality. Accurate and reliable prediction is major concern for the authorities. This led us to adopt Forecasting Method and recommend the policies to be implemented. Based on the forecasting analysis and in accordance with Asian Development Bank report 2021, the study comes with some institutional, infrastructural, and operational formulations and recommendations for the development of the quality of port infrastructure. The countries need an optimized methodology to forecast the quality of port infrastructure more accurately and cluster them to find out the underperformer to give more importance to them. Ports' connectivity with hinterland must be increased and there must have a reformation in Asian roads & railway logistics sectors aiming to connect to Asian Highway. Furthermore, promotion of international standards in logistics infrastructure, develop cross border connection among nations, and building regional port hub are essential. However, the quality of regulations, management and operational efficiency with port digitalization are necessary as well.

More so on, the study has limitations as well. This could create more scope of future research. First, the study only has built an accurate forecasting model for combined economies. Further study might be conducted on an individual country to improve the model accuracy using Grey optimization of background value. Again, the study didn't formulate any strategies to improve the quality of port infrastructure. Therefore, future research may be conducted on how to improve the quality of port infrastructure, and recommend the policies to be implemented.

AUTHORS' CONTRIBUTIONS

Mohammad Kamrul HASAN: Conceptualization, Data collection, Design, Methodology, Software use, Writing- Original draft preparation, Interpretation & Visualization; **Chen YAN-CHUN:** Investigation, Supervision, Fund collection, Reviewing, Editing & Validation; **Shengyong YAO:** Reviewing, Editing; **Arifa Parvin KEMI:** Reviewing, Editing.

CONFLICT OF INTERESTS

On behalf of all authors, the corresponding author declares that there is no conflict of interest.

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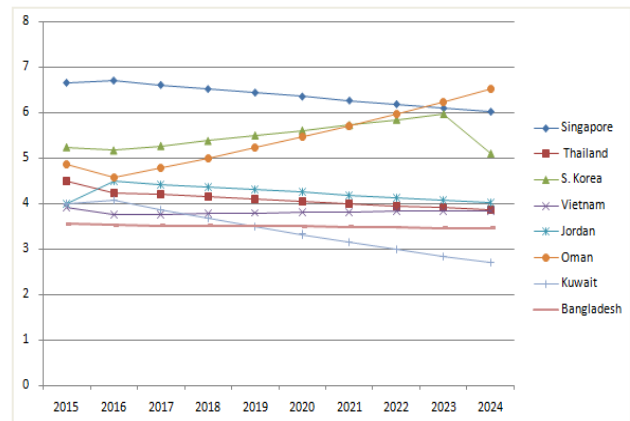
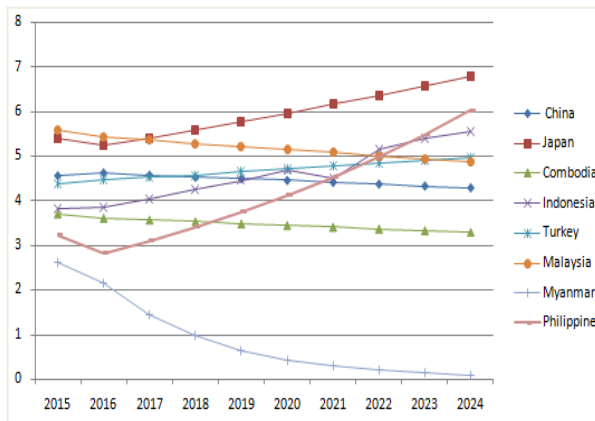
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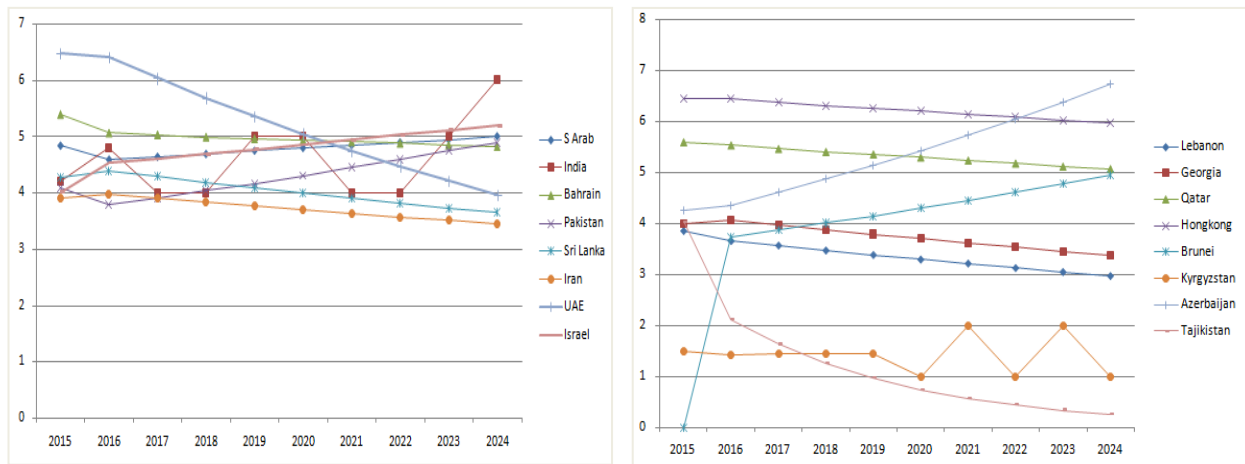
APPENDIX 1. LIST OF ASIAN PORT COUNTRIES

Azerbaijan	China	India	Japan	Lebanon	Philippine	Singapore	Thailand
Bangladesh	Cambodia	Indonesia	Jordan	Malaysia	Pakistan	S. Korea	Turkey
Bahrain	Georgia	Iran	Kuwait	Myanmar	Qatar	Sri Lanka	UAE
Brunei	Hong Kong*	Israel	Kyrgyzstan	Oman	S. Arab	Tajikistan	Vietnam

*special administrative region

APPENDIX 2. PREDICTED VALUES OF THE QUALITY OF PORT INFRASTRUCTURE OF 32 ECONOMIES





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