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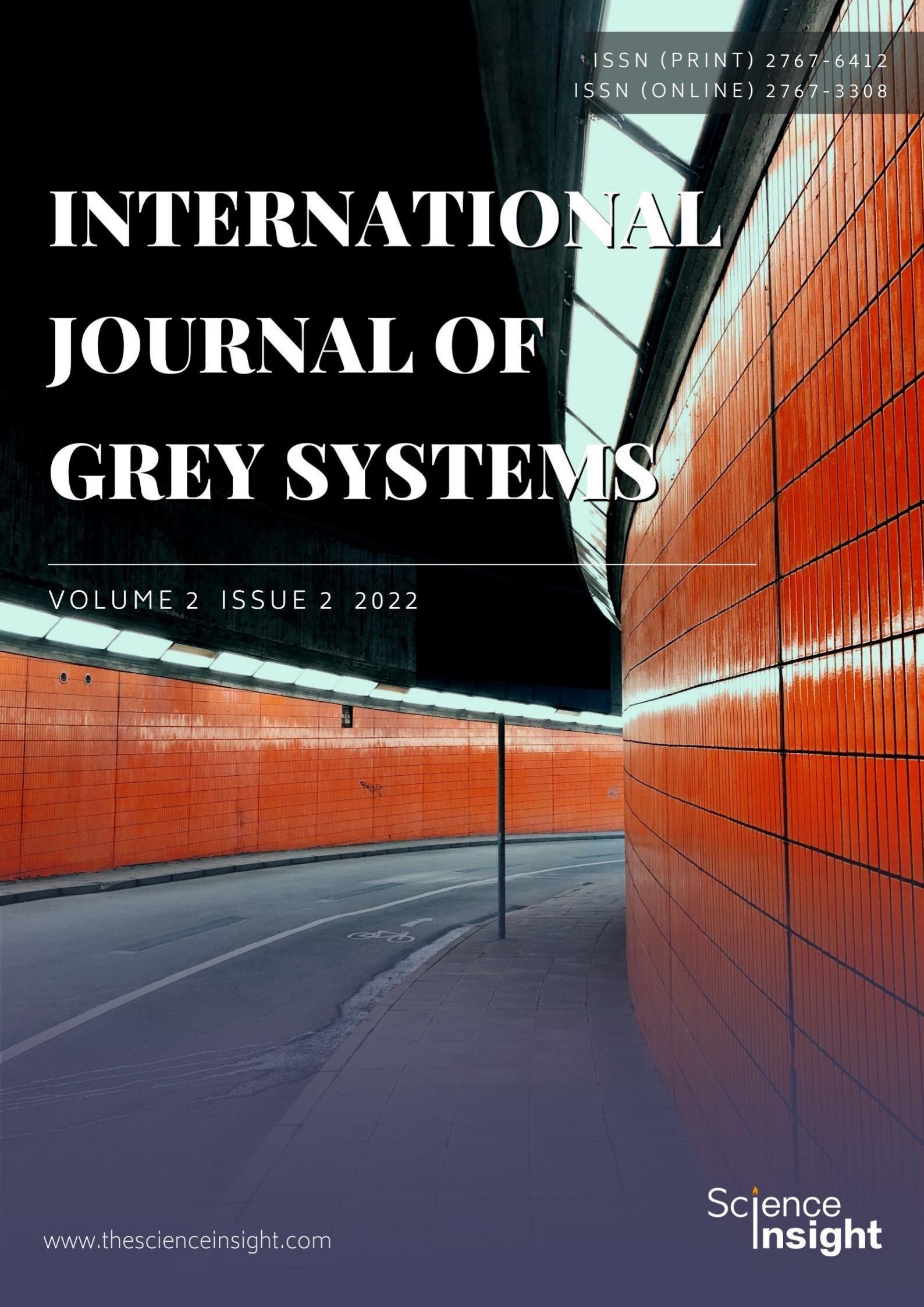

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Statistical and Grey Forecasting of the Inbound Tourism to Malawi

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Abstract: Tourism is one of the fastest growing and complex industries in Malawi. This article is aimed at forecasting the future pattern of the tourism industry in Malawi from the year 2018 to 2028. The study has employed grey forecasting model EGM (1, 1, α, θ) to predict the future pattern of tourism based on the initial data sets sourced from the data base of the World Data over Malawi. The findings of this study showed that the grey forecasting model EGM (1, 1, α, θ) performed well in forecasting the future pattern of tourism by comparing with the linear regression and exponential regression. The forecast has revealed that the tourism industry will grow with an average of 20.84% by the year 2028 based on the current conditions. Following the present findings, the tourism industry should therefore continue improving the current conditions in order to attract more tourists. Furthermore, the industry should continue to supply tourism products and services that can satisfy the increasing demand of the international travel experiences as well as the future growing number such as constructing more standard hotels, proper transportation and communication.

Keywords: Tourism; Grey forecast; Grey system; Grey model; linear regression; Malawi.

1. Introduction

Tourism refers to the temporary movement of people to a particular place either for leisure or work (Bhatia, 1982). Tourism is a significant contributor to the local gross domestic product in many countries (Bunghez, 2015). It generates foreign currency hence aids and supports foreign exchange reserves (Zhang *et al.*, 2021). Tourism also generates job opportunities to the local people of the visited places such as in hotel industries, entertainment, transportation as well as hospitality (Saluja *et al.*, 2022). Furthermore, it also provides an opportunity to the local people of the visited places to generate income through opening up small businesses such as selling of local handicraft items, artifacts to the tourist's also known as private income (Kharipzhanova & Irfan, 2022).

Several techniques have been put in place to develop and promote the tourism industry over the globe. Such techniques include improving hospitality, hotels, transportation as well as planning for the tourists. In addition, a critical analysis in understanding the patterns of tourism in relation to the available conditions is instrumental in improving or maintaining the tourism industry. This includes an assessment of historical as well as future patterns of the tourism (Song *et al.*, 2019; Goh & Law, 2011). In recent years, forecasting of the future tourism pattern has attracted attention

of many practitioners and researchers for the planning purposes. Several forecasting skills have also been developed to generate more accurate and reliable future tourism patterns such as State-Dependent Models (SDMs) (Priestley, 1980; Guan *et al.*, 2022) and Grey Forecast Model (Javed *et al.*, 2020a).

Tourism is mainly focused on visiting places around the world, experience their culture and traditions. Over Malawi, there is limited information about tourism from the pre-independence era, but the industry was recognized in the colonial era. The wildlife, culture and Lake Malawi (the third largest lake in Africa) are the main attractions from both domestic and international arrivals. Before 1995 this industry was presented by the department within the ministry of commerce and industry and in 1995 the ministry responsible for tourism was established. The portfolio of culture, water bodies and wildlife were then later added to the new designed ministry of tourism and culture, responsible for the marketing, development and planning (Bello *et al.*, 2014). Previous studies over Malawi have shown that sustaining the tourism industry is a continuous process and it requires introducing precautions, proper management and planning. This is done with the aim of decreasing the negative impacts and increasing the positive impacts. This includes having a mindset of sustaining nature such as wildlife to stay wildlife because without such proper precautions, nature such as animals is not well taken care of. Furthermore, it keeps the environment clean by making sure the tourists enjoy the good environment (Bello *et al.*, 2018). Most of the international tourists to Malawi come from within the region such as neighboring countries and European countries, for example United Kingdom.

Malawi is one of the countries in southern Africa where tourism industry has played a huge role and is the second largest contributor to the nation's economy (MRA, 2022). On average, the tourism industry provides 24% of the country's gross domestic product (ADB, 2013). However, in 2019 the GDP% dropped to 7.7% signifying high fluctuation of influence of tourism to the country's GDP% (Knoema, 2022a; 2022b). Malawi has several tourist attractions sites such as Lake Malawi, several national parks such as Liwonde national park which tends to be the most leading tourism destination, game reserves and beautiful mountains such as Mulanje Mountain which is the highest mountain in Malawi located to the Southeast of Malawi. Malawi also attracts people for its unique cultural activities such as traditional dances like the gule wamkulu which is translated as "the big dance". There are several tribes with different cultural beliefs, and the major tribe is Chewa. Despite this industry's rapid growth, it has faced challenges such as limited platforms to advertise tourist places abroad. High cost to visit Malawi is another challenge as such it affects the number of tourists visiting the country annually. The country also has no information about the future patterns of tourism hence disrupt future planning purposes regarding the tourism industry. In this study, we utilize the historical data of the inbound tourists to Malawi and use the information to generate the near future forecast for the inbound tourists using the modern Grey forecast models. The findings from this are very crucial for future planning purposes and improve the tourism industry in Malawi.

The rest of the paper is structured as follows: Section 2 presents literature related to the present work, methods and the approach to the present work are highlighted in section 3. Results and discussions are given section 4 while section 5 summarizes the main conclusions drawn from this study.

2. Research design and methodology

2.1 Study area

Malawi (Figure 1) is a landlocked country with a geographical area of 118,484 square km. it shares boarders with Mozambique to the east and southwest, Zambia to the west and Tanzania to the north. Malawi has several tourist attractions while the wildlife and national parks are the most visited areas. The Liwonde national park which covers 548km is the largest and publicly managed by the national parks and wildlife (DNPW). This national park has built one of the top ranger forces and training grounds in the Southern Africa. It has the most advanced technology to protect

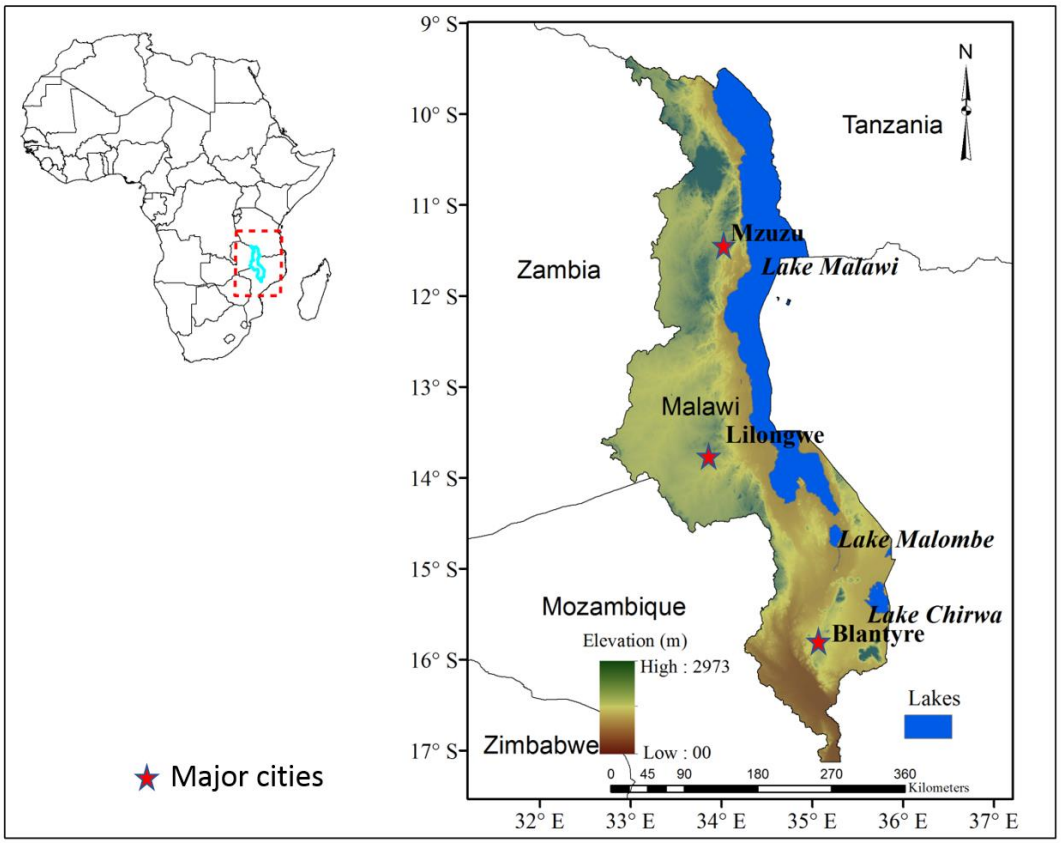

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Figure 1. Geographical location over Southern Africa and map of Malawi

and monitor its wildlife and management activities. Thousands of Malawians live around the Liwonde national park and depend on it as it creates jobs such as generating small businesses to the local people. Apart from the wildlife and national parks, Lake Malawi to the east, attracts many tourists each year.

2.2 Data and software

The study used total annual values of the inbound tourists defined as the total number of tourists that visit Malawi each year. The secondary data was collected from the WorldData (https://www.worlddata.info/africa/malawi/tourism.php). The data from 2010 to 2018 (Table 1) was used to build the model while the forecast horizon was from 2019 to 2028. More information about data collection can be accessed elsewhere. Data analysis including calculations and visualization were carried out using Microsoft Excel, Origin Lab and ArcMap of Geographical Information System (GIS).

2.3 Grey forecasting

Grey forecasting models are important part of the Grey System Theory, founded by Deng (1982). The models have seen their applications in various fields. They are effective for decision making and forecasting as they can be applied on environment where there is data scarcity (Carboni and Russu, 2014; Tian *et al.*, 2021). Furthermore, grey forecasting models have been considered as an interdisciplinary and intelligent techniques for exploring the pattern of variables that follow grey

Table 1. Data collected for the study

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Number of tourists (1000s)	746	767	770	795	819	805	849	837	871

system, or uncertain pattern with partially known information such as inbound of tourists in tourism industry (Javed *et al.*, 2020a; Laksito and Yudiarta, 2021). We therefore observed that the application of grey forecasting model to understand the future pattern of tourism is suitable over Malawi, where data related to tourism is very uncertain and scare.

The model EGM (1, 1, α, θ) is a generalized form of the classical EGM (1,1) and was proposed by Javed *et al.* (2020b). Let the sequence of actual data expressed as (Javed *et al.*, 2020b):

$$x^{(\alpha)} = \left(x^{(\alpha)}(1), x^{(\alpha)}(2), \dots\ x^{(\alpha)}(n)\right)$$

where, $x^{(\alpha)}(k) = \sum_{i=1}^{k}(\frac{x^{(0)}(i)}{i^{1-\alpha}}), k = 1, 2, \dots, n, \alpha \in (0,1]$.

The adjacent neighbor average sequence of $x^{(1)}$ will be

$$Z^{(1)} = \left(Z^{(1)}(1), Z^{(1)}(2), \dots\ Z^{(1)}(n)\right)$$

where the background value $Z^{(1)}(k) = \theta.x^{(\alpha)}(k) + (1 - \theta).x^{(\alpha)}(k-1), \theta \in (0,1]$. The even form of GM (1,1), a first-order, single-variable grey forecasting model with parameters α and θ, is a continuous-time grey differential equation, defined as

$$\frac{dx^{(1)}(k)}{dk} + ax^{(1)}(k) = b$$

The inverse conformable fractional accumulation is executed through the following formula

$$\hat{x}^{(0)}(k) = k^{1-\alpha}\left(\hat{x}^{(\alpha)}(k) - \hat{x}^{(\alpha)}(k-1)\right), k = 1,2, \dots, n$$

And the time-response function of $x^{(0)}$ is given by

$$\hat{x}^{(0)}(k) = k^{1-\alpha}(1 - e^{a})\left(x^{(0)}(1) - \frac{b}{a}\right)e^{-a(k-1)}, k = 1, 2, \dots, n$$

The values of α and θ are estimated through an optimization technique available in Javed *et al.* (2020b). The EGM (1, 1, α, θ) is advantageous in such a way that it is able to change the parameters of α and θ since the data can have various shapes due to noise. This is different to the general EGM(1,1) because the parameters of the EGM (1, 1, α, θ) are dynamic and changes as the data varies, hence, easy to generate more precise forecast. For further information about the model and its properties, Javed *et al.* (2020b) can be read.

2.4 Statistical forecasting

For comparative analysis purpose, the study applied the linear and exponential regression models, which are popular statistical forecasting techniques. The linear and exponential models are respectively expressed as (Septyari, 2021)

$$y = bx + \varepsilon$$

and

$$y = e^{bx}$$

where y are the forecasted values, b is the constant and ε is residual (noise in the data). The models were run using the built-in functions available in Microsoft Excel.

2.5 Forecast error measurement

Mean Absolute Percentage Error (MAPE) is a popular metric in grey forecasting literature and is frequently used to compare the actual data with the simulation (Javed & Cudjoe, 2022; Wu *et al.*, 2022). For forecast error measurement, Mean Absolute Percentage Error (MAPE) was used as,

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

where, $x(k)$ and $\hat{x}(k)$ are actual and forecasted data, respectively.

3. Results and discussion

The analysis on the performance of the model by comparing with the actual and the regression models is presented in Table 2. The results demonstrated that the EGM (1, 1, α, θ), hereby referred to as EGM, performed better than the regression models. The results from all models are likely to be accurate as the forecast error is less than 5% for all of them, however the EGM reported the lowest value of error.

It can be noted from the results that the mean absolute percentage error (MAPE) between the actual values and the model was 2.37%. The MAPE for the linear regression (LR) was 1.06% and for the exponential regression (ER) was 1.07% respectively in comparison to the actual values. Whereas MAPE between GEM and linear regression was 4.07% while between GEM and exponential regression was 3.23%. The observed MAPE values were generally low (<10%) signifying high accuracy in forecasting values as compared to the regression models and the actual values. The study hence utilized the EGM model to forecast the inbound tourists between the period of 2019 and 2028. The study found that the inbound tourism to Malawi in 2028 would be between 1,011,416 and 1,085,407.

Figure 2 shows the graphical representation of the forecasted values for regression models, EGM model and the actual values. The results have shown the number of tourists increased every year from the year 2010 to the year 2018. With the same precautions, the number is predicted to

Table 2. Forecast for inbound tourists to Malawi

Year	Actual Numbers	EGM (1,1,α,θ)	EGM (1,1)	Linear regression	Exponential regression
2010	746000	746000	746000	748022	749200
2011	767000	774445	764532	762655	762960
2012	770000	792762	778196	777288	776973
2013	795000	810280	792103	791921	791244
2014	819000	827497	806259	806554	805776
2015	805000	844636	820669	821187	820575
2016	849000	861817	835335	835820	835647
2017	837000	879113	850264	850453	850995
2018	871000	896574	865459	865086	866625
2019		914236	880926	879719	882542
2020		932125	896670	894352	898751
2021		950263	912695	908985	915258
2022		968666	929006	923618	932068
2023		987350	945609	938251	949187
2024		1006329	962508	952884	966621
2025		1025613	979710	967517	984374
2026		1045214	997219	982150	1002454
2027		1065142	1015041	996783	1020866
2028		1085407	1033181	1011416	1039615
MAPE (%)		1.04	1.14	1.06	1.07

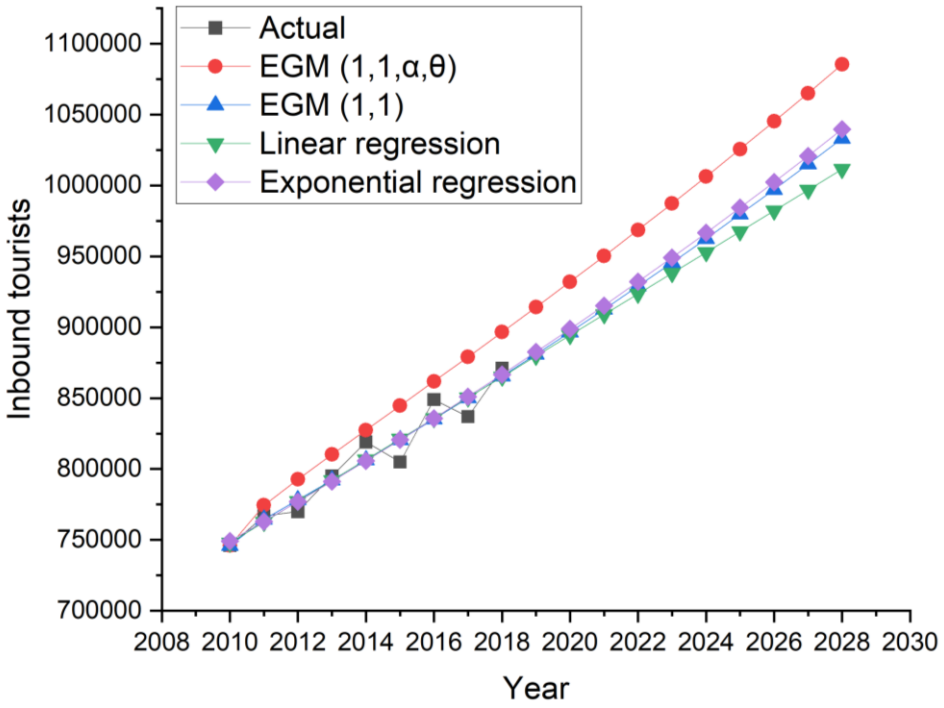

Figure 2. Forecast of inbound tourists to Malawi from grey and statistical methods

continue increasing by an average of 20.84% to the year 2028 as compared to 2010-2018 period. The observed increase in number of tourists implies that the conditions of tourism over Malawi are favorable hence the industry needs to maintain them. In addition, with the observed increasing trend, the country needs to concentrate on building more hotels to accommodate the increasing number of tourists to visit Malawi in the near future. Since tourism is a second major contributor to the total national GDP, the government can therefore take advantage of the increasing tourism industry to boost up national economy through proper management of income generated from tourism industry in the near future.

4. Conclusion and recommendations

The study has analysed future pattern of inbound tourists over Malawi using grey forecasting model. The findings have shown that the grey forecasting model can be reliable and utilized to forecast the future pattern of tourist inbound over Malawi. The results have clearly demonstrated that the tourism will likely increase in the next 6-years. The observed increase in tourist inbound signifies that the country should be more prepared to co contain the increasing number tourists. This may include proper planning such as construct enough and standard hotels to accommodate the tourists. Furthermore, the government should take advantage of the growing industry to boost country's economy through proper management of income generated from the tourism industry.

Below are some recommendations that can help increase the growth rate of tourism industry in the near future over Malawi:

(i) *Encourage operators to have more package trips*. Having package trips and having special offers would increase the marketing of a tourist area because they tend to be more affordable and the travelers do not have a difficult time trying to find a place or tour guide.

(ii) *Develop the tourism brand*. Branding is done to increase awareness and change of the image to meet the value of everyone. This is a very important thing for tourism destinations to do for marketing. It creates an identity for a destination and makes it famous.

(iii) *New attraction ideas*. Waiting for tourists to come does not generate interest. Finding new ways to make the stay of the travelers more comfortable and entertaining would

attract people to an area. This can be done by introducing different leisure activities or introducing a new marketing strategy that would want people to have an experience they would never forget over Malawi.

(iv) *Letting tourist become brand ambassadors.* In the current age social media has become one of the most successful advertising strategies. It is easy to get tourists to become brand ambassadors because most tourists want to share their experience on social media. Therefore, encouraging the travelers to create a personalized hashtag with a good comment review on their social media would get their friends, family members, work colleges and so on to have the interest of visiting the tourist attraction sites over Malawi.

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Impact of COVID-19 on the Big Industrial Enterprises in Hebei, China: Grey Forecast Perspective

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Abstract: To analyze the impact of COVID-19 on the big industry enterprise in Hebei, a province of China, value added of the industrial enterprises 'above designated size' in Hebei Province is predicted by grey forecasting model GM (1,1). The difference between the predicted value and the actual value implied the influence. The study found that the impact of the epidemic is relatively serious in January-February 2020. The industrial value added has a difference of 27.6 billion Yuan. It is recommended that some tax reliefs should be given to the industries above designated size.

Keywords: COVID-19; grey forecast; grey model; industry; Hebei Province.

1. Introduction

The COVID-19 not only came up as a healthcare crisis it also bought havocs on national and regional economies. Caraka *et al.* (2020) studied the impact of the COVID-19 on Indonesian economy. Xu *et al.* (2021) studied its impact on performance of fourteen major Chinese ports. Setyoko and Kurniasih (2022) studied its impact on small and medium enterprises in Indonesia. The problem is today well-known however a major gap in the literature is finding solution. Gu *et al.* (2020) guided the industries in responding to the COVID-19 pandemic-induced disruptions. The role of industrial enterprises above designated size in driving the economy is quite obvious, and local governments attach great importance to these enterprises. An important question in this context is how much influence does the COVID-19 on industries above the designated size? Also, there are different methodologies that can be used in our quest to find answer to this solution however which one should be deemed fit?

Because of the COVID-19 induced-economic disruptions, the influence data of the epidemic on industries are limited. Traditional statistical methods cannot analyze the influence because the distribution of the influence data is unknown. Grey forecasting model can deal with the problem with the limited data (Wu *et al.*, 2022; Tian *et al.*, 2021; Ofosu-Adarkwa *et al.* 2020). Thus, grey forecasting model had been used to analyze the influence of the COVID-19 epidemic on industries (Şahin & Şahin, 2020; Liu *et al.*, 2020). If the COVID-19 epidemic does not have influence on industries, the value added of industries is supposed to continue the trend historically. This trend often follows the grey exponent law (Zeng *et al.*, 2015). Because of the COVID-19 epidemic-induced disruptions, one may argue that the actual data does not follow the grey exponent law. The

difference between the predictive value and the actual data indicates the influence of COVID-19 epidemic on industries. Therefore, there is a need to predict the value added of industries using a suitable grey model while studying the difference between the predictive value and the actual data. With the sudden outbreak of the COVID-19 epidemic in 2020, it has a certain impact on the regional economy and industry (Wu *et al.*, 2021). Also, it's impact on economic development and production activities in Hebei Province was no small. Considering the insignificant amount work on studying the influence of the pandemic on the regional industrial enterprises, the current study will conduct quantitative assessment and analysis of the influence of the COVID-19 epidemic on industries above the designated size in Hebei Province.

The rest of the study is organized as. In the second section, the research methodology is presented. In this section firstly data is presented and then the grey forecasting model GM (1,1) and the assumptions are introduced. In the third section, the forecasting model is applied on real-world data. Firstly, the model GM (1,1) is established. Later, the value added of the Hebei industries is predicted followed by the comparison between actual and predicted values. In the last section, the study has been concluded.

2. Methodology

2.1 Data collection

The data was collected from Hebei Provincial Bureau of Statistics (http://tjj.hebei.gov.cn/). The statistical data of the value added of industries above designated size in Hebei Province from 2016 to 2020 are shown in Table 1.

2.2 Forecasting model and assumption

The current study used the grey forecasting model GM (1,1) for predicting the data. GM (1,1) is the most famous grey forecasting model and it has seen applications in various fields. The complete details of the model can be found in Liu *et al.* (2017). The following assumptions are given: It is assumed that during and after the epidemic of the COVID-19 in Hebei Province, the changes of data are only related to the impact of the COVID-19 epidemic, and the influence of other random factors is not considered.

2.3 Forecast error measurement

Absolute percentage error (Duan & Nie, 2022) will be used to compare predicted values with the actual values,

Table 1. The value added of industries above designated size in Hebei Province from 2016 to 2020 against twelve months (Unit: 100 million Yuan)

	2016	**2017**	**2018**	**2019**	**2020**
1-2	1641.8	1691.1	1721.5	1843.8	1670.5
3	1067.8	1123.3	1150.3	1283.7	1322.2
4	960.7	1015.5	1069.3	1126.0	1184.5
5	1017.1	1063.9	1100.1	1172.7	1253.6
6	1199.7	1269.3	1315.0	1451.8	1505.5
7	1095.7	1116.5	1137.7	1196.9	1263.9
8	1117.5	1135.4	1176.3	1222.1	1300.4
9	1221.5	1232.5	1327.4	1376.5	1477.0
10	1176.6	1180.1	1300.5	1273.2	1400.5
11	1157.8	1164.7	1271.9	1301.1	1414.3
12	1126.5	1176.1	1271.4	1340.0	1488.8
Total	12782.8	13168.4	13841.3	14587.7	15281.1

$$APE(\%) = \sum_{k=1}^{n} \left| \frac{x(k) - \hat{x}(k)}{x(k)} \right| \times 100$$

where, $x(k)$ and $\hat{x}(k)$ are actual and predicted value, respectively.

3. Results

In this section the grey forecasting model will be built firstly and the results will be analyzed later.

3.1 Establishing the grey model GM(1,1)

(1) Initialize the modeling original sequence:

1162.07, 1197.13, 1258.30, 1326.16

(2) The 1-AGO generation of the original sequence is as follows:

1162.070, 2359.200, 3617.500, 4943.660

(3) The immediate mean generation sequence of 1-AGO generation sequence is as follows:

1760.635, 2988.350, 4280.580

(4) Calculate the grey model development coefficient *a* and the grey action quantity *b*:

a = - 0.05; b = 1106.38

(5) Simulation value and simulation error are as follows:

Serial numbers	Actual data	Analog data	Residual	Relative simulation error
2	1197.13	1196.27	0.86	0.07%
3	1258.30	1259.13	-0.83	0.07%
4	1326.16	1325.30	0.86	0.07%

(6) Calculate the average simulation relative error: 0.07%

(7) Predict the value for the next 1 year: 1394.94.

3.2 Forecasting results of industrial value added

According to the prediction of the grey data model, it can be concluded that the monthly average value of value added of industries above designated size in Hebei Province in 2020 is X_{2020} = 1394.94, and the annual total value is X_{2020} = 11* X_{2020} = 15344.34.

According to the average method of the original data, the monthly ratio is

u = (0.1269, 0.0850, 0.0767, 0.0801, 0.0963, 0.0836, 0.0855, 0.0948, 0.0907, 0.0900, 0.0904)

Therefore, the predicted value added of the industry in 2020 is

Y = u X_{2020} = (1946.5, 1305.0, 1177.1, 1228.5, 1477.4, 1283.0, 1312.5, 1455.4, 1391.2, 1381.3, 1386.6) (100 million Yuan).

3.3 Comparison between predicted value and actual value

Comparison of the predicted value with the actual value is shown in Table 2. According to the prediction results of the model, The Absolute Percentage Error in January-February is the largest, as shown in Table 2. There is a large difference between the predicted value and the actual value in January-February 2020. It can be seen that the impact of the epidemic is relatively serious. Since

Table 2. Comparison between predicted and actual value of industrial growth above designated size in Hebei in 2020 (Unit: 100 million Yuan)

Month	Actual value	Predicted value	Absolute Percentage Error
1-2	1670.5	1946.5	16.52
3	1322.2	1305.0	1.301
4	1184.5	1177.1	0.625
5	1253.6	1228.5	2.002
6	1505.5	1477.4	1.866
7	1263.9	1283.0	1.511
8	1300.4	1312.5	0.930
9	1477.0	1455.4	1.462
10	1400.5	1391.2	0.664
11	1414.3	1381.3	2.333
12	1488.8	1386.6	6.865

March, with the epidemic gradually controlled and the full resumption of production and work, the impact on industries above designated size has been reduced. Compared with tourism and retail industry, the COVID-19 epidemic has little impact on industries above designated size.

4. Conclusion

The study noted a large difference between the predicted and the actual value. It was observed that the impact of the epidemic is relatively serious in January-February 2020. The industrial value added has a difference of 27.6 billion Yuan. Since March, as the epidemic is gradually bought under control and the production and work activities fully resume, the impact of the epidemic on industries above designated size has been reduced. The policy-makers are suggested to bestow tax relief to the industries above designated size to some extent. Analysing the impact of the epidemic on other economic indicators is our future research directions.

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Effects of COVID-19 on Population, Economic Growth, Logistics Performance, and Quality Management in Africa: Grey Relational Analysis

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Abstract: The research aims to examine the emerging repercussions of the COVID-19 pandemic on population, GDP (Gross Domestic Product), logistics performance, and ISO 9001 certification in most effected African countries: South Africa, Morocco, and Tunisia. The innovative Grey Relational Grade (GRG) modelling approach was applied to analyze the interdependent relationship between COVID-19, economic growth, quality and logistics performance. Furthermore, the authors implemented the conservative (maximin) approach to identify which one of the top three most impacted COVID-19 African nations had the least intensifying effects. The data utilized in the research was obtained from several databases and examined in 2021. The results indicate that the pandemic has a tremendous undesirable influence and impact on the population, GDP, logistics performance, as well as ISO 9001 certification in all three considerably impacted African nations. Whereas South Africa was recorded the most affected in terms of the population due to a high number of fatalities. Moreover, the country has demonstrated substantial negative correlations between COVID-19 and logistic performance, whereas Tunisia and Morocco's GDP showed a downward negative trend due mainly to global trade flow constraints. Besides, in all the countries covered in this research, the number of ISO 9001 certificates has declined dramatically. The study outcomes generate much-needed policy recommendations for international organizations, decision makers and world governments to consider implementing immediate reparative interventions and emergent action plans to protect economic systems from further losses, as well as to improve the logistics, economic, and quality performances. This research pursues a multidimensional structure and explores the emerging impacts of the pandemic on economic growth, population, logistical performance as well as the process of quality production.

Keywords: COVID-19; African economy; population; logistics performance; ISO 9001; grey relational analysis.

1. Introduction

The COVID-19 pandemic created two worldwide crises: the health and economic crises. While human health was well affected in many regions of the world, the pandemic caused widespread social and environmental consequences. Various nations are still grappling with changes and problems in dealing with the sickness and the transmission of coronavirus variations in the

aftermath of the COVID-19 pandemic. While the pandemic outbreak has been well controlled ever since March 2020 (as it is in South Africa, Morocco, as well as Tunisia), several measures were implemented to regulate the disease's impacts have been effectively applied, such as lockdowns, sanitary conditions, and protective measures, unified and consolidated care in the preliminary phase of the pandemic, all moreover, South Africa and Morocco are the top two most afflicted COVID-19 African nations, with 2,910,681 (Nkhoma, 2021) and 938,801 cases (Bentaleb, 2021), respectively. Tunisia has had the fewest COVID-19 cases (709,456 cases) (Georank, 2021) to date due to its tiny population. Some businesses are accustomed to a specific level of volatility in their economic atmosphere or market segment or niche; nevertheless, unplanned situations, such as the COVID-19 pandemic, have never been experienced before. Various nations are still dealing with changes and problems in dealing with the sickness and the transmission of coronavirus variations in the post-COVID-19 pandemic era. Despite the fact that the globe is vaccinating at varying rates, coronavirus strains have emerged in Morocco, Tunisia, and South Africa, posing additional challenges. In contrast to the financial crisis of 2008, when monetary injections into banks were adequate, the COVID-19 health crisis had a severe impact on the actual economy. On the supply side, the Tunisian government has imposed total and directed imprisonment. A decline in supply was caused by the stoppage of major country activities, according to the authors. On the other hand, there is a decrease in demand as a result of lower consumption, out, and exports. Furthermore, efforts to contain the virus's spread have resulted in a significant drop in commodities prices. Prices are falling, particularly for energy items and, to a lesser extent, for other commodities.

Regardless of the fact that online organizations and profitability grew fast as a strategy for supporting the marketing of goods and services in various industries, on-demand delivery logistics rose substantially, placing logistics under strain (Luke, 2020). Manufacturing operations were overwhelmed as a result of the pandemic, harming the world economy during the second quarter of 2020. These restrictions highlighted the need for more resilient and imaginative recovery strategies, particularly because logistics networks are critical for constructing an economic comeback. The nutrition and adequate healthcare sectors are the most important in the middle of the COVID-19 outbreak because of the availability of vital products. Any flaws in these two can lead to significant monetary loss, unfulfilled demand, and supply fulfilment. The prior study revealed empirical and theoretical gaps in the literature about the effects of COVID-19 on the waste supply chain and other industrial sectors. Concurrently, additional studies emphasized the importance of exploring eco-innovation techniques in order to overcome the sustainability challenges caused by COVD-19 in Morocco, South Africa, and Tunisia. Companies, employees, and stockholders in all three countries were hit hard by the outbreak. Both supply and demand were influenced in the case of global supply chain activities, resulting in an unprecedented imbalance in commodity and service trade (Babatunde *et al.*, 2020).

More notably, these repercussions are affecting business activities related to certification of sustainability standards, particularly for ISO 9001. Where accrediting agencies monitor administrations and give expert assistance in analyzing risks and emergency plans of businesses to satisfy the accreditation bodies' environmental targets requirements. The epidemic impacted the auditing services mandated by ISO 9001 in 2015, and so they were postponed or done remotely. Auditors engaging in face-to-face audits were also subjected to sanitary and safety requirements, as was the case in numerous other businesses. Auditors evaluate the effectiveness of the management of organizations and communicate the necessary adjustments and actions to ensure that they can continuously offer products and services that are able to satisfy consumer's needs and wants and applicable legislative and regulatory standards, as well as increase customer satisfaction, which includes operations for optimization and guarantee of conformity to customer, statutory, and regulatory.

Given this backdrop, the purpose of this study is to deliver a substantial contribution to the existing scientific literature by first investigating the COVID-19 epidemic outlays on trade flows as well as logistical effectiveness. ISO 9001 certification in the three most affected African countries: South Africa, Tunisia, and Morocco, expanding on previous research that focused on the virus's

implications and evolving a complex conceptual model to supply the void in the existing literature about this matter. Second, analyzing data linked to COVID-19 cases, operational supply chain, and ISO 9001 certifications in 2020; along with the use of the grey relational grade (GRG) models approach a strategy which offers outstanding and accurate alternatives that are consequently recommended for tiny data samples. GRG models ensure the dataset's reliability, even if it contains some uncertainties, and make it easier to identify the essential factors to be examined in relation to the consequences of the COVID-19 pandemic on the global market in terms of the exchange of goods and services, logistic support, and the value of the ISO 9001 certification. And finally, adding brand new information to existing research platforms by envisioning alternatives for African countries to help them out of the crisis and back on track to economic revival and long-term growth.

This paper is structured as follows: the first half discusses the COVID-19 as well as its effects it had on the GDP (Gross Domestic Product) of the three countries, section 2 talks about the logistics' performance during times of crisis; section 3 discusses the value of the ISO 9001 certification and how it could be affected by the pandemic; section 4 would be a set of guidelines that could possibly be used by these countries for a faster and efficient economic recovery.

2. Background

2.1 Covid-19 and population

The World Health Organization (WHO) identified a cluster of unusual cases of pneumonia in Wuhan, China, as Coronavirus disease 2019 (COVID-19) on February 11, 2020. SARS-CoV-2, a new strain and variant of coronaviruses that has 79 percent genetic similarities with SARS-CoV from the 2003 SARS pandemic, was identified as the causal virus (Anand *et al.*, 2020). WHO designated the outbreak a worldwide pandemic on March 11, 2020. COVID-19, a significant pandemic of the 21st century, has caused unparalleled harm to mental health worldwide. While patients and healthcare staff get emotional assistance, the mental health of the broader population must also be addressed. Not only that, but it also affected the lives of families. People lost their jobs, and directly their social status and quality of living shrunk down, affecting not only households, but the economy in general. All non-essential businesses, including restaurants and retail stores, have been shut down, as have all sporting, cultural, and artistic activities. Until further notice, all mosques and other places of worship are shut down. A curfew on public and private transportation is in effect, as well as limitations on intercity movement, and the military is on the streets to protect citizens.

There has been a lockdown strategy used by the governments of three nations, which has limited the mobility of people save for those who work in critical services such as the police and the military. Everyone else must remain inside, except for those who need medical attention, food from supermarkets, or medicine from pharmacies, in rare instances. These outlets must also guarantee that no more than 50 people are at any one moment on the grounds of the establishment. All religious meetings, education, and social-cultural activities have been halted, in response to the social distancing policy. Temporary shelter for the homeless has been set up in a well-spaced manner. However, the lockdown and social distancing policies created serious obstacles. Gender-based violence (GBV) and violence against children are key issues in South Africa. As of April 3, 2020, 8,700 cases of GBV have been documented throughout the lockdown period.

Another challenger has something to do with alcohol. During the lockdown, alcohol sales and use have been banned in order to reduce social aggravation and conflict, particularly among persons in dysfunctional families and crime-ridden neighborhoods. A minister in charge of police in South Africa claimed that despite the unrest generated by the lockdown and limitations on alcohol sales and use, other forms of crime in the country had decreased. A second issue is the lack of clearly defined infrastructure in rural or informal housing, which makes social distancing hard. Remaining outdoors appears healthier than staying indoors for people who live in densely populated areas. As a result, those who live in congested and informal houses find themselves confronted with police

and army patrols imposing to stay at home. Resulting in tensions that rose between the civilian population and the army, which had been used to assist the police in enforcing and making people respect the lockdown. Numerous social media videos, for example, have surfaced showing security forces forcing military-style exercises on citizens who defied the lockdown order.

The optimistic scenario predicts a rise in poverty in Tunisia of 7.3 % points, while the pessimistic one predicts an increase of 11.9 % points. In the first scenario, the poverty rate rises by more than half, while in the second, it almost doubles, reversing the downward trend in poverty that has been occurring over the previous decade. As a result, more individuals will be at risk of being hungry and succumbing to poverty. Under the optimistic scenario, the poverty gap would rise from 3.2 % to 4.4% , and under the pessimistic one, it would rise from 3.2 % to 5 %.

Households in Tunisia's Center West and Southeast areas, which are home to the country's lowest 20% of the population, will be the most severely affected. For the most vulnerable, they are likely to be women who live in big homes, do not have access to healthcare, and work without a contract. Tunisia's unemployment rate is 42 %, while the epidemic has resulted in 53 % of people falling into poverty, and 47 % of the most vulnerable are working without a contract.

2.2 Covid-19 and GDP

After a health disaster in China, COVID-19 swiftly became a worldwide financial crisis. It is clear from our study that COVID-19 is altering nations' long-term macroeconomic and human development trajectories, aggravating already-existing vulnerabilities. For the millions of individuals who have been afflicted and died as a result of the illness, as well as the tens of millions who have been rendered jobless, the spread of COVID-19 has been disastrous. As the virus has spread, governments and civic society have implemented regulations that limit human contact and inhibit its transmission. Many individuals were nonetheless infected by the coronavirus, and fatality cases were reported throughout the world, despite the safety precautions employed. Many nations' price elasticity increased, which had an impact on the long-term viability of the supply chain. The governmental debt-to-GDP ratio in South Africa has steadily increased over the last decade, from 26% in 2008-2009 to 63.5 percent in 2019-2020. As a result, the Covid-19 emergency occurred. As of March 23, 2020, South Africa's president has stated that the country will be under a 21-day lockdown beginning March 26, 2020 and ending April 16, 2020. In order to slow the spread of Covid-19, which has caused devastation over the globe, and to prepare the healthcare system to take in those who are unwell, a lockdown has been implemented.

Structural vulnerabilities in service delivery, such as such as water supply and sanitary processes, housing, medical assistance, and infrastructural facilities, have been brought to light in communities throughout South Africa with the commencement of COVID-19. COVID-19's spread has also revealed the country's inability to manufacture facial masks, protective gloves, and experimental tools, as well as the readiness of its vital providers for a worldwide public health pandemic like COVID-19, such as COVID-19. A complicated and fast-moving crisis like Ebola has highlighted the effectiveness and reactivity of financial components such as credit life insurance plans, unemployment insurance funds, as well as the overall versatility and strength of South Africa's financial system.

COVID–19 crisis has had devastating effects on Morocco's economy, and the country is expected to go into recession in 2020 for the first time in more than two decades. After increasing by 2.5 percent in 2019, real GDP fell by 5.9 percent in 2020. Additionally, a drought in rural areas slashed rural earnings, which in turn lowered domestic demand, making it more difficult to limit the spread of COVID-19. At the end of September 2020, the unemployment rate had risen from 9.2 % to 12.7 %. Morocco's main trading partners (France, Germany, Spain, and Italy) experienced a severe economic downturn, resulting in a 10.1 % decline in international trade during the initial 10 months of 2020. Reduced consumer demand and local output cut imports by 16.6 % during the same time period Remittances, on the other hand, rose by 1.7% in the initial 10 months of 2020. As a result, the existing budget deficit is predicted to rise to 7.6 % in 2020, up from 4.1 % this year.

Through the end of September 2020, tourist arrivals were down by 78%. "Lower tourist profits, combined with dampened domestic market, a reduction in tax receipts at a time when the government was facing significant pandemic related costs and expenses." By 2020, the budget deficit would have roughly quadrupled, from 4.1% to over 8% of GDP. Government debt will increase from 65.8 % of GDP in 2019 to 76.9 % in 2020 as a result of increasing borrowing to cover the deficit. Prior to the epidemic, public debt had already been considerable, particularly due to the government's aggressive infrastructure construction program over the last decade. The low level of inflation is projected to persist. Moroccan authorities increased the range of the dirham's fluctuation on 9 March 2020 to boost the economy's capacity to withstand external shocks and to increase its competitiveness. Telecommunication, financial sectors, agricultural commodities, and chemical products have all been spared the brunt of the economic downturn's impact. Despite reducing its 2.5% reference interest rate by 25 basis points, making it 2% in March 2020 and then another 50 basis points, ending up with a benchmark interest rate of 1.5 %, Bank Al-Maghrib has made very little market interventions in the foreign exchange market. Morocco has secured more than 50 places on the World Bank's Doing Business ranking in the previous decade! Morocco was ranked as the 53rd nation out of 190 other nations in 2020.

The effect of the epidemic on the Tunisian economy became clearer as the year came to a conclusion. Since the start of this crisis, Tunisia's economic growth has been much lower than that of most of its regional rivals. In 2020, the economy will have grown by 8.8% less than it did in 2019. By the conclusion of the first quarter of 2021, the unemployment rate had risen from 15% to 17.8%. Furthermore, it continues to disproportionately afflict women (24,9 percent) and young adults (15-24 percent).

Even though the current account deficit remained significant in 2020, at 6.8% of GDP, imports decreased faster than exports, reducing it (from 8.5% in 2019). By January 2021, the US had $8.3 billion (approximately $26 per person in the US) in foreign currency reserves, compared to $7.4 billion (about $23 per person in the US) at the end of 2019 (equal to 158 days (about 5 months) of import cover). The first quarter of 2021 saw the trade deficit shrink by 10%. Compared to the same time in 2020, exports jumped by 23% and imports rose by 13.7 percent. It dropped from 523 million dinars to 177.5 million dinars in the balance of services, while remittance payments grew by 17 percent to shrink the current account balance by 6.8 percent. Growth in industrial output and exports have contributed to decreased external finance demands and lessening the burden on the country's reserves in the first quarter of this year." However, there is still a major external danger.

2.3 Covid-19 and logistics performance

Many people in Africa are afflicted by natural catastrophes and humanitarian crises, including healthcare and medical emergencies. The worldwide response to West Africa's 2014–2016 Ebola outbreak and the COVID 19 pandemic illustrates the need for efficient and productive logistics and supply chain networks in giving aid to suffering and vulnerable communities.

The subsequent stage of many safety measures to fight COVID-19 spread is the "new normal." It can be defined by e-commerce operations, which involve firms interacting with their consumers via internet technology. E-commerce necessitates tangible distribution, stores, and shipment; therefore, transportation and logistics are highlighted (D'Adamo & Lupi, 2021). It is believed that online sales will continue in the post-COVID-19 age, as customers have shown a good attitude about purchasing online, reinforcing the need for logistical systems. The logistics business will be impacted by the "new normal.". Following the limitation of travel, most of the income for airlines, for example, came from cargo services. To increase efficiency, organizations in the air transportation industry are taking steps slowly but surely to reduce operating costs through business reengineering processes, data science, and business automation. More study is required to comprehend the implications of such acts on company risks (Choi *et al.*, 2021). The transportation industry was hampered due to the constraints imposed by the lockdown measures.

As a result of these constraints, international commerce and fuel usage in logistics have decreased. The lockdowns also impacted transportation freight, which hampered the delivery of commodities. Intermodal transportation of things was suspended in the preliminary stages of the pandemic due to strong lockdown measures in numerous nations but recovered when mobility improved (Zhang *et al.*, 2021). The limits reduced vessel capacity and generated equipment shortages, affecting local and foreign trade. In South Africa, the manufacturing, trading, catering, and accommodation industries, transportation, storage, and communication industries, and mining and quarrying industries all plummeted by 65 to 75%. As a result, transportation and logistics performance suffered. This study provided more evidence that corporations must reform SCs by developing plans with essential partners.

To support Supply chain development, the disruptions produced by the COVID-19 pandemic to transportation and logistics networks necessitate collaborative solutions. In the case of Morocco, reviving shipping and ports might be one approach to restoring pre-pandemic levels. The maritime industry played an essential role in the world trade scene. Because it is the gateway that connects Africa to Europe, it is responsible for linking this country to both local and worldwide markets. Shipping and port traffic and demand decreased as a result of supply/demand contractions. Long-distance trucking experienced a similar drop in shipping. This drop is partly attributable to the fact that many of the vehicles necessary for transporting to various locations are already in low supply, and truck drivers are hesitant to prevent infection.

The COVID-19 pandemic has an impact on the worldwide value chain. Because a global value chain divides the production process among African nations, enterprises specializing in each production sector do not generate a complete product. Even though their production facilities are operating, and borders are reopened to trade, the breakout of COVID-19 triggered the closure of numerous manufacturing units, resulting in a chain reaction in international commerce.

2.4 Covid-19 effects on maintaining ISO 9001

QMS ISO 9001 is one of the tools used to ensure the quality of manufacturing methods. ISO 9001:2015 emphasizes that risk-based thoughts is directed toward the goods and services provided by a specific company in order to ensure the consistency of processes for providing goods and services and meeting the needs of customers (Zimon *et al.*, 2021).

Despite this, companies are struggling hard to maintain the same quality rates that they had before their ISO 9001 certification lapsed during the COVID-19 flu epidemic. The UK Accreditation Service is developing legislation for businesses that were affected by COVID-19 travel requirements and teleworking, as well as methods by which these businesses can interact with accreditation bodies in the specific situation of the disease outbreak.

Among some of the metrics, the use of remote evaluations permits the investigation of documents, even though it does not adequately cover the same objectives as on-site visits. Certified CABs, as well as NABs accreditations, may face problems if they decide to stop supplying some services or even deviate temporarily in order to meet criteria and certification regulations. Members of the European Cooperation for Accreditation, as well as certified administrators of volunteer services, advise on the importance of acting responsibly and transparently when offering services which become subtly different from requirements, as well as not delivering assistance that endangers technical validity (ISO, 2021). Now, regulatory agencies demand emergency plans, which include weather-related events, epidemics, and other human-made concerns.

COVID-19 has emphasized the importance of providing a conducive environment for revising, updating, and testing the aforementioned strategies. When a particular industry necessitates on-site evaluations, the use of information and communication technologies (ICT) to conduct distant evaluations will facilitate the evaluation process. During the flu epidemic, ICT tools enabled numerous operations and grew in popularity as a remedy for several businesses. On-site measures, on the other hand, demand for the employment of preventative measures such as masks, social separation, and quarantine for auditors. Remote auditing is not a novel notion. The ANSI National

Accreditation Board certification processes previously employed distant assessments regularly when evaluating firms with teleworkers or even organizations in the technology industry.

3. Research methodology

The study aims to analyze the prospective effects of COVID-19 on population, GDP, logistics performance, as well as QMS ISO 9001 certifications mainly in the top three affected African countries with high COVID-19 prevalence such as Morocco, Tunisia, and South Africa. To have a clear idea about the quality performance, this study used ISO 9001 Quality Management System which is one of the methods for assuring the quality of manufacturing operations, these certifications emphasize the application of risk-based thinking to a company's goods and services in order to ensure the consistency of procedures and operations for delivering products and services and meeting customers' requirements. The LPI (Logistics Performance Index), which stands for logistics performance index, evaluates the trade supply chain characteristics related to the chosen nations and scores them out of a range of 1 that represents the worst score to 3 which represents the best score. Finally, from March 1 of 2020, up to December 31 of 2020, the total number of COVID-19 cases in the top three African nations was rising exponentially.

In the current study, data analysis involved four phases. In the first stage, data was gathered from several databases for the research from January 1, 2020, to December 31, 2020, and is normalized. In the second step, GRA models are used to investigate the link between COVID-19 instances and population, GDP, Logistics Performance, and ISO 9001. The GRG-based ranking is utilized in the third step, which uses the weights/scores yielded in the second stage, and is allocated alternatives, after specifying the decision criteria. The conservative model then goes through the analytical findings to identify the most optimal solution (the variable or combination of variables), which demonstrates how African nations were affected by the pandemic. In Figure 1, we present the framework of the study.

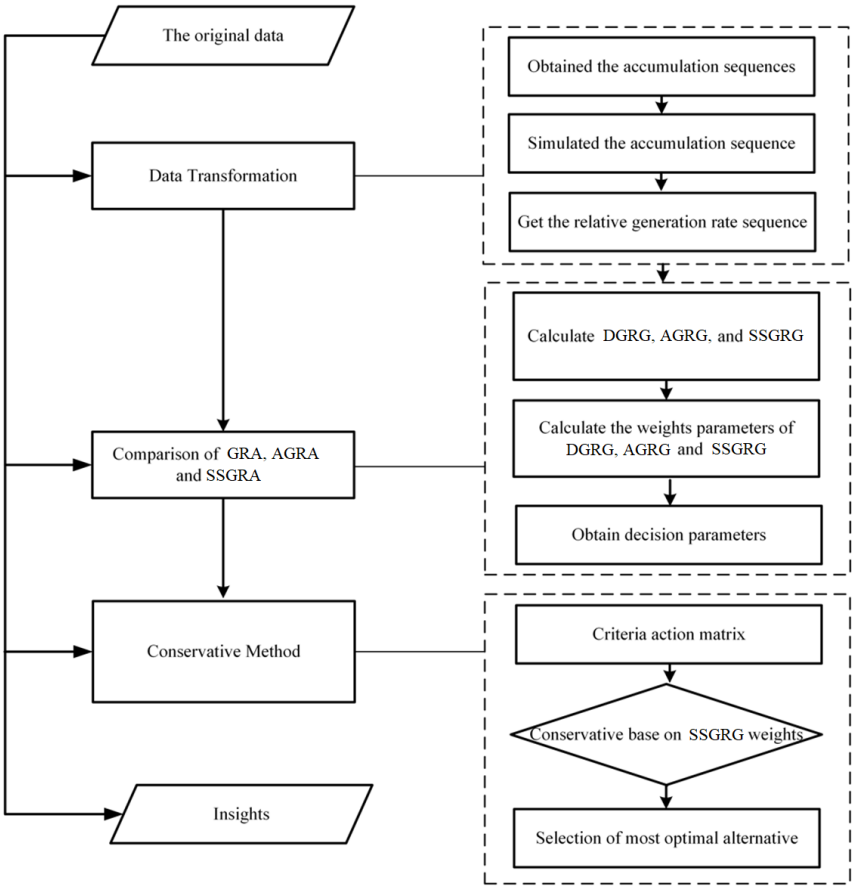

Figure 1. Schematic framework of the study (Adapted from Ikram *et al.*, 2021)

3.1 Data Collection

To conduct this research, a set of secondary data was used to draw conclusions and comparisons. The data related to population and GDP was obtained from the website of World Bank (www.worldbank.org). Moreover, the data related to Logistic Performance and ISO 9001 was collected from the website of Global Innovation Index (https://www.globalinnovationindex.org). While procedures differ depending on the field, the focus on ensuring accurate and honest collecting remains constant. The variables, units and time scale of the data involved in the current study is shown in Table 1. The statistics reported in the current study mostly came from published reports such as ADB (2021), NICD (2021), dailymorocco.com, Gerorank (2021), World Bank (2022), among others.

3.2 Grey Relational Analysis

Professor Julong Deng created the grey system theory in 1982 (Ju-Long, 1982). His GRA model is an important components of the grey system theory. The Grey Relational Analysis (GRA) models have gained a lot of attention in the last two decades. Management, engineering, economics, and medicine are just a few of the disciplines where GRG models are used (Xu & Li, 2018). GRA have become a popular choice since they outperform other techniques in a variety of ways. GRA is capable of handling limited data collection as well as grey values and delivering optimal results (Ikram *et al.*, 2021; Liu *et al.*, 2017). The GRA models outperform other techniques when it comes to dealing with data problems, such as missing values or inaccurate data sources (Ikram et., 2019b). It also maximizes the efficiency of the limited dataset (Rehman *et al.*, 2020). GRA models, give stronger foundations for understanding the conceptual model's complexity (Dai *et al.*, 2014). Recently, many scholars have used the GRA models in different industries. Tsoy (2022) used the GRA for evaluating the expectations of the Russian citizens from increasing gas exports to Europe. Ivanova (2022) used it to evaluate risks to food supply chains. Kharipzhanova and Irfan (2022) used it to evaluate the barriers to tourism in Gilgit Baltistan. Sheikh *et al.* (2019) used the GRA models to analyse the key factors influencing process quality during construction projects in Pakistan. A detailed discussion on the GRA models can be found in Liu *et al.* (2017). The three important GRA models are defined below (Javed & Liu, 2018).

3.2.1 Deng's Grey Relational Analysis: Let $X_0 = \big(x_0(1), x_0(2), \dots, x_0(n)\big)$is the reference data sequence and $X_k = \big(x_k(1), x_k(2), \dots, x_k(n)\big)$ is the alternative data sequence then the Deng's Grey Relational Grade (DGRG) between the two data sets is given by (Javed *et al.*, 2022),

$$\Gamma_{0k} = \sum_{j=1}^{n} w(j) \times \gamma_{0k}(j) \tag{1}$$

Table 1. The variables, units and time scale of the data

Code	Variables	Units	Time scale	Source of data
X_0	COVID-19 cases	Total number of COVID cases	January 2020 to Dec 2021	WHO (2022)
X_1	Population	Number of people	2020-2021	World Bank (2022)
X_2	GDP	Per Capita	2020-2021	World Bank (2022)
X_3	Logistic performance	Performance measurement based on Logistics Performance Index (LPI) by using scale of 1 (worst) to 5 (best)	2020-2021	Global Innovation Index (2022)
X_4	ISO 9001 certifications	ISO 9001:2015 sets out the criteria for a quality management system	2020-2021	Global Innovation Index (2022)

where,

$$\gamma_{0k}(j) = \frac{\Delta_{min} + \xi * \Delta_{max}}{|\Delta_{0k}(j)| + \xi * \Delta_{max}}, k = 1,2, \dots, m \quad (2)$$

$$|\Delta_{0k}(j)| = |x_0(j) - x_k(j)| \quad (3)$$

$$\Delta_{min} = min_k\, min_j |x_0(j) - x_k(j)| \quad (4)$$

$$\Delta_{max} = max_k\, max_j |x_0(j) - x_k(j)| \quad (5)$$

Here, ξ represents the Distinguishing Coefficient, m denotes the total number of comparative data sequences, and n denotes the total number of data points in each data sequence. In the current study, $\xi = 0.5$ and $w(j)$ was replaced by $\frac{1}{n}$ since all data values were equally weighted.

3.2.2 Absolute Grey Relational Analysis: Let $X_0 = \big(x_0(1), x_0(2), \dots, x_0(n)\big)$ is the reference data sequence and $X_k = \big(x_k(1), x_k(2), \dots, x_k(n)\big)$ is the alternative data sequence, and their zero-point starting images are $X_0^0 = \big(x_0^0(1), x_0^0(2), \dots, x_0^0(n)\big)$ and $X_k^0 = \big(x_k^0(1), x_k^0(2), \dots, x_k^0(n)\big)$, then Absolute Grey Relational Grade (AGRG) is given by (Javed & Liu, 2019),

$$\varepsilon_{0k} = \frac{1 + |s_0| + |s_k|}{1 + |s_0| + |s_k| + |s_0 - s_k|} \quad (6)$$

where,

$$|s_0| = \left| \sum_{j=2}^{n-1} x_0^0(j) + \frac{1}{2} x_0^0(n) \right| \quad (7)$$

$$|s_k| = \left| \sum_{j=2}^{n-1} x_k^0(j) + \frac{1}{2} x_k^0(n) \right| \quad (8)$$

$$|s_0 - s_k| = \left| \sum_{k=2}^{n-1} (x_0^0(j) - x_k^0(j)) + \frac{1}{2} (x_0^0(n) - x_k^0(n)) \right| \quad (9)$$

3.2.3 Second Synthetic Grey Relational Analysis: Let $X_0 = \big(x_0(1), x_0(2), \dots, x_0(n)\big)$ is the reference data sequence and $X_k = \big(x_k(1), x_k(2), \dots, x_k(n)\big)$ is the alternative data sequence. Let Γ_{0k} denotes Deng's Grey Relational Grade, and ε_{0k} denotes Absolute Grey Relational Grade, then the Second Synthetic Grey Relational Grade (SSGRG) is their weighted mean and is given by (Javed & Liu, 2018),

$$\varrho_{0k} = \theta * \varepsilon_{0k} + (1 - \theta) * \Gamma_{0k} \quad (10)$$

where, θ is a coefficient whose value ranges between 0 and 1. Generally, its value is taken as 0.5.

4. Results and discussion

The links between COVID-19, population, GDP (current value in USD), logistics performance, as well as QMS ISO 9001 certification in the three highly affected African nations, namely South Africa, Morocco, and Tunisia, are investigated using GRG models. GRA models are a superior

strategy since they confront endogeneity concerns as well as grey values while offering the optimum answer. Tables 2 to 5 display the analytical outcomes for DGRG, AGRG and SSGRG.

Using GRA models, we may evaluate and investigate the relation between COVID-19, population, GDP, logistics performance, as well as QMS ISO 9001 certifications in the highly impacted African countries in 2020. DGRG, AGRG and SSGRG exhibit the relationship between these components. The AGRG model rates the strength of linkages on a scale of 0 to 1, with 0 representing the weakest links and values closer to 1 representing the strongest. In this study, a higher score value indicates that COVID-19 has a strong intensifying impact. The DGRG model uses a scale of 0.5 to 1, with 0.5 representing a moderate effect and 1 indicating a high influence among study variables. SSGRG, on the other hand, represents the sum of AGRG and DGRG, indicating both association and implications. Figure 2 evaluates COVID-19, population, GDP, logistical performance, and QMS (ISO 9001 certifications).

As seen in Table 2, the Grey Relational Analyses scores for COVID-19, as well as population are measured for the top three highly affected African countries. According to the AGRG data, South Africa had the highest rating of 0.9297, meaning that COVID-19 had a deleterious influence on the South African population in the year of 2020. Followed by Tunisia with an absolute GRG score of 0. 9286. While Morocco has scored the lowest absolute GRG with a value of 0.7536. Referring to the DGRG, Morocco and Tunisia received the highest-ranking scores of 0.8119 and 0.7474, respectively, succeeded by South Africa with the lowest score of 0.7017 suggesting that these three countries' population has been severely affected owing to the effect of COVID-19 confirmed cases of contamination and mortality. The SSGRG model, on the other hand, has revealed a quite similar ordering trend between population and the viruse's number of cases with Tunisia scoring the highest value of 0.8186, the main difference in this model if that South Africa scored the second value, respectively, while Morocco came last with the lowest score of 0.7811.

The association between COVID-19 cases and GDP in the top afflicted African countries is explored in Table 3. With a weight score of 0.9096, Tunisia's GDP received the highest position in the AGRG, meaning that COVID-19 will have a negative influence on Tunisia's GDP in 2020. With association values of 0.8581 and 0.8336 respectively, Morocco and South Africa are rated second and last, respectively. As shown by DGRG findings, Tunisia as well as South Africa received the highest values of 0.7466 and 0.7456, respectively, implying that the effect of COVID-19 number of instances has reduced drastically the GDP of these three countries. The worldwide COVID-19 pandemic, the consequent production as well as the global trade flow limitations, resulted in a drop in South Africa's commerce in March 2020. In the top-three most afflicted African nations, the SSGRG model revealed the similar ordering trend between the number of cases and GDP. Morocco and Tunisia got heights scores of 0.8993 and 0.8377, respectively, followed by South Africa with the lowest score of 0.7708.

Table 4 displays the Grey Relational Assessment scores for COVID-19, as well as the logistical performance. The AGRG demonstrates that the coronavirus pandemic has had a negative and long-term impact on the logistical systems of South Africa, Morocco, and Tunisia, which are ranked first and second in Africa, respectively. In fact, South Africa has the greatest AGRG of "0.8662." The other two nations recorded "0.5933" for Morocco and "0.5540" for Tunisia. Lockdown and

Table 2. Grey Relational Assessment for COVID-19 and Population

	AGRG	DGRG	SSGRG
South Africa	0.92970405	0.70175754	0.79516658
Morocco	0.75359648	0.81198711	0.78118801
Tunisia	0.92869504	0.74744010	0.81865925

Table 3. Grey Relational Assessment for COVID-19 and GDP (Current US$)

	AGRG	DGRG	SSGRG
South Africa	0.83360368	0.74560464	0.77084981
Morocco	0.85818835	0.71297424	0.89931074
Tunisia	0.90966922	0.74662434	0.83773708

Table 4. Grey Relational Assessment for COVID-19 and Logistics Performance

	AGRG	DGRG	SSGRG
South Africa	0.85521072	0.70985376	0.79419744
Morocco	0.59336256	0.61416531	0.60538044
Tunisia	0.55403712	0.70960923	0.61070994

Table 5. Grey Relational Assessment for COVID-19 and ISO 9001 certification

	AGRG	DGRG	SSGRG
South Africa	0.60802434	0.70985376	0.69137806
Morocco	0.59336256	0.76900923	0.65512594
Tunisia	0.55403712	0.84094164	0.79716963

safety measures have had a substantial impact on industrial and logistical activities, which have a direct impact on product demand and supply. As a result of the logistics industry's interconnectedness, operations were weak or non-existent (Singh *et al.*, 2021; Miceli *et al.*, 2021). According to the SSGRG model, South Africa suffered the most damage of the three countries, reporting an SSGRG of "0.7941," which is higher than the "0.6107" and "0.6053" achieved by Tunisia and Morocco, respectively.

Quality standards, taking in this case ISO 9001 certifications, necessitate adjustments in habits, methods, as well as the responsibilities of management and workers in order to completely overhaul an organization (Ikram *et al.*, 2019a). Due to travel constraints and social hurdles, the development of COVID-19 hinders the successful and lasting of ISO 9001. We looked at how unplanned events like COVID-19 might hinder QMS implementation and how firms can keep their production processes operating while meeting quality standards in this study. Table 4 shows the COVID-ISO 9001 relationship in the top three most affected African nations. For all of the nations included in this analysis, the number of ISO 9001 certificates is on the decline. South Africa came in top in the row, with an AGRG score of 0.6080, followed by Morocco with a score of 0.5933 and Tunisia with a score of 0.5540, respectively.

Table 5 delivers an identical raking sequence outcomes for COVID-19 in relation with QMS ISO 9001 certifications in the three most impacted African nations, as shown by DGRG and

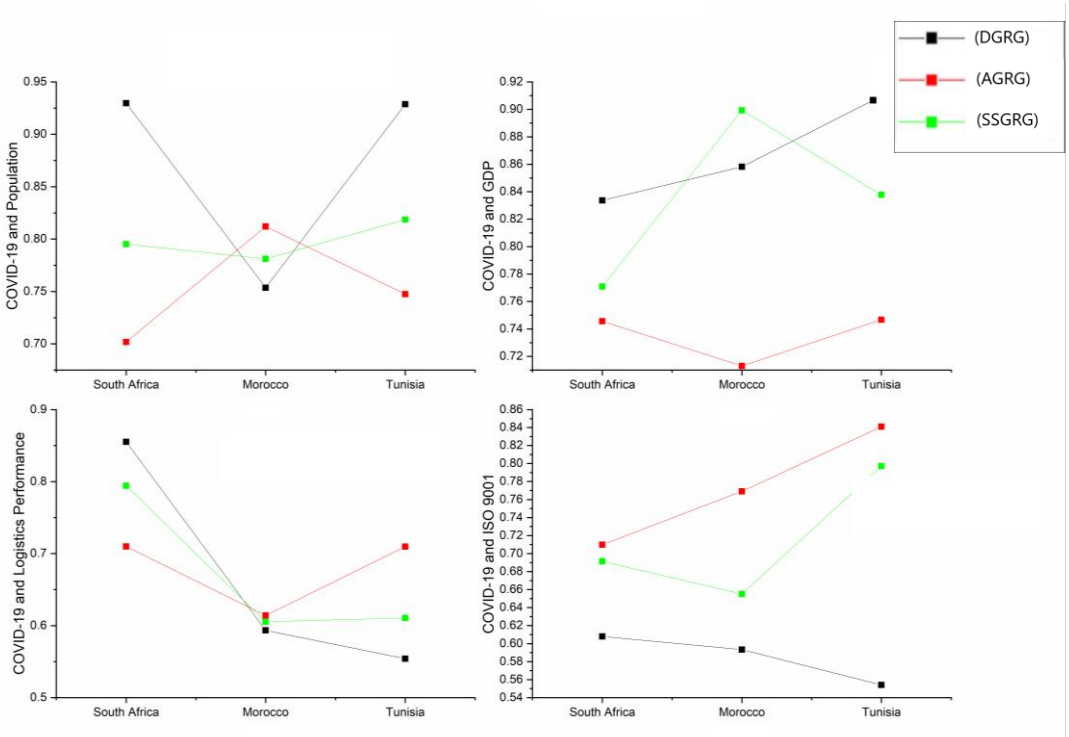

Figure 2. GRG based evaluation of COVID-19 population, economic growth, logistic performance, and quality management

SSGRG. South Africa scored the highest values of 0.8494 and 0.9110 and has the most influenced and unfavorable link between pandemic outbreak and ISO 9001 certifications. In terms of the QMS ISO 9001 certification procedure, Morocco is the second most affected, followed by Tunisia, which was the most affected nation during the pandemic crisis. Furthermore, the position of the top three highly affected African countries changes in DGRG and SSGRG models. As in DGRG, Tunisia is ranked first, while Morocco and South Africa are ranked second and last, respectively. Table 5 displays the results of the correlation between COVID-19 and ISO 9001 certification.

As an overall analysis of this research, Tunisia, like Morocco, exhibited a substantial negative relationship between COVID-19 and the GDP of these countries. Whereas, among all the top three highly affected African countries, South Africa exhibited a substantial negative relationship between COVID-19 and population along with the logistic performance of this country.

Following the calculation of weighted values and scores, the top three African nations may be ranked based on population, GDP, logistics performance, and ISO 9001 certifications. Furthermore, based on the GRA models, the upcoming phase of this process analyses which country has the least amplified impact of COVID-19 on its population, economic growth, logistics performance, and quality management system requirements. To do so, we established the assessment and decision parameters, which detailed description is outlined in Table 6. Here, m = 4, n = 3, outcome = $v(a_i, S_j)$, whereas i = 1, 2, 3, 4 and j = 1, 2, 3. Let a_1, a_2, a_3 and a_4 show the SSGRG of population, GDP, logistics performance, and ISO 9001 certifications in the top three highly affected COVID-19 African nations is presented in Table 6.

Table 7 shows the decision parameters. Table 8 shows the SSGRG, which explains the relationships between the study elements in order to organize the variables and conclude the criteria answer. The influence of COVID-19 on population, GDP, logistic performance, and ISO 9001 certifications in South Africa, Morocco, and Tunisia is then evaluated using a decision-making model, as shown in Table 7.

Finally, based on SSGRG results, we used the conservative (MiniMax and MiniMin) model (Javed & Liu, 2018; Ikram *et al.*, 2019a; 2019b) to determine which nation(s) have the least (or highest) intensifying impacted among all of the top three affected COVID-19 African countries, as shown in Table 8. In this study, we emphasize decreasing the better criterion, with the minimal value of V obtained from the SSGRG matrix model for each nation. The MiniMax model yields,

$$\min a_i \{\max S_j \ v(a_i, S_j)\} = \max a_i \begin{Bmatrix} 0.8187 \\ 0.8993 \\ 0.7942 \\ 0.7972 \end{Bmatrix} = 0.7942 \text{ (South Africa)}$$

The results indicate that the overall grey relation between the factors is strongest for South Africa, i.e., the grey relation between the COVID-19 and other factors is generally strongest for it.

Table 6. Grey Assessment Ranking of highly effected COVID-19 African countries

Variables	Grey Relational Model	Ranking
Population	AGRG	South Africa > Tunisia > Morocco
	DGRG	Morocco > Tunisia > South Africa
	SSGRG	Tunisia > South Africa > Morocco
GDP	AGRG	Tunisia > Morocco > South Africa
	DGRG	Tunisia > South Africa > Morocco
	SSGRG	Morocco > Tunisia > South Africa
Logistics Performance	AGRG	South Africa > Morocco > Tunisia
	DGRG	South Africa > Tunisia > Morocco
	SSGRG	South Africa > Tunisia > Morocco
ISO 9001	AGRG	South Africa > Morocco > Tunisia
	DGRG	Tunisia > Morocco > South Africa
	SSGRG	Tunisia > South Africa > Morocco

Table 7. The decision parameters

Goal	Measuring Grey Relation (Association) between Population, GDP (Current $) , logistic performance, ISO 9001 within highly effected COVID-19 African Countries
State of Nature (S_j); $j = 1,2,\dots,n$	South Africa (S_1) Morocco (S_2) Tunisia (S_3)
Alternative Actions (a_i); $i = 1,2,\dots,m$	Grey Relation was superior between COVID-19 cases and Population (a_1) Grey Relation was superior between COVID-19 cases and GDP (a_2) Grey Relation was superior between COVID-19 cases and logistic performance(a_3) Grey Relation was superior between COVID-19 cases and ISO 9001 certification (a_4)

Table 8. The criteria-actions matrix based on the SSGRG values

	S_1	S_2	S_3
a_1	0.7952	0.7812	0.8187
a_2	0.7708	0.8993	0.8377
a_3	0.7942	0.6054	0.6107
a_4	0.6914	0.6551	0.7972

The MiniMin model yields,

$$\min a_i \{\min S_j \ v(a_i, S_j)\} = \min a_i \begin{Bmatrix} 0.7812 \\ 0.7709 \\ 0.6054 \\ 0.6551 \end{Bmatrix} = 0.6054 \text{ (Morocco)}$$

The results indicate that the overall grey relation between the factors is weakest for Morocco, i.e., the grey relation between the COVID-19 and other factors is generally weakest for it. Thus, Morocco's system is more resilient, while that of Tunisia lies between the two countries.

This paper examines the impact of COVID-19 on population, GDP, logistics performance, and ISO 9001 quality management systems in a multi-framework for the most COVID-19 afflicted top three African nations. Individual independent factors have been investigated for their possible impact on dependent variables in the study.

5. Conclusion and implications

Using unique advanced mathematical modelling, particularly the GRA technique, this research examines the impacts of COVID-19 on population, GDP, logistics performance, and ISO 9001 certifications in the three heavily affected African nations (South Africa, Morocco, and Tunisia). To focus on the extent to which COVID-19 has altered the economic system of these countries we employed AGRG, DGRG, and SSGRG to investigate the possible link between various metrics.

The following is a summary of our findings. First, regardless of whether the metric is used to quantify the severity of COVID-19, we have observed that during a pandemic epidemic, COVID-19 has a severe negative impact on the population, GDP, logistics performance, and ISO 9001 certifications in all three heavily afflicted nations.

During the COVID-19 disease transmission, all the designated nations' logistical activities were shut down, resulting in thousands of transactions being abandoned or delayed, resulting in large losses and detrimental consequences on economic growth. COVID-19 caused negative economic development in all three nations. This finding shows that the disruption of logistics activity caused by COVID 19 has a detrimental impact on the logistics employment market. Organizational sustainability goals are also jeopardized as a result of the COVID-19 epidemic. ISO 9001, one of the most effective instruments for guiding quality system management, has been severely harmed. The certifying body failed to follow up on the COVID-19 surveillance audits, affecting the firms' environmental performance and quality requirements throughout manufacturing operations.

This study implies some theoretical as well as practical implications. This is the first research of its kind in Morocco, establishing a framework and analyzing the escalating impacts of COVID-19 on population, GDP, logistic performance, and ISO 9001 certification. Until now, studies have confined their research to GDP, but no one has addressed the population, logistic performance, and ISO 9001 certification in connection to the current scenario. This study addresses a void in the literature by analyzing the impacts of COVID-19 on the population, GDP, logistic performance, and ISO 9001 certification in connection to the COVID-19 scenario utilizing GRG models in the top 3 top affected African countries. The technique used (AGRG, DGRG, and SSGRG) proved useful for studying nations classed as developing economies in order to encourage growth. We advise using such methodologies to analyze other developing economies and compare the outcomes to our findings.

There are several policy considerations that leaders, international agencies, and countries should consider while developing an emergency strategy to protect economies from further damage and enhance logistics and quality performance during the COVID-19 pandemic.

These policy points are presented as follows: One of the primary goals of government is to keep the pandemic under control, and various nations are focusing their efforts on this goal in unusual ways. These measures will enable a quicker return to normalcy, as well as assistance for national governments' recovery strategies. It is also possible to ease the procedure of certification so that commercial activities are not affected beyond the remote audit. One option is to extend certification renewals for organizations that currently have them until the conclusion of the pandemic emergency. They should also take into consideration the lack of reserves they can eventually face, especially after the lockdown because of the extremely limited trade countries are open to. To avoid that, some agreement among other nations should be made to secure a smooth and satisfying consumer experience for the citizens and avoid any uncontrollable inflation that could damage the country heavily in the future.

This study does have some limitations. We only listed three of Africa's most impacted countries and conducted a comparison based on population, GDP, logistic performance, and ISO 9001 certification. Since data was only available until 2021, data from the entire year (2020-2021) was utilized in this analysis. To explore the escalating impacts of COVID-19 on population, economic growth, logistic performance, as well as the ISO 9001 certification, we employed GRG models such as Absolute GRG, Deng's GRG, and the Second Synthetic GRG model.

Future studies may be undertaken on many countries, such as those in the Arab world. Furthermore, in the future, a comparison investigation between industrialized and developing nations might be undertaken to evaluate how the countries faced the COVID-19 epidemic. Also, the impacts of COVID-19 on other criteria such as social certification, health and safety certification, renewable energy generation, and access to power may be explored using various techniques of analysis.

Data availability

Data will be made available on a reasonable request to the corresponding author.

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Evaluation of Chinese Cloth Suppliers using Dynamic Grey Relational Analysis

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Abstract: The clothing industry is one of the world's most important and innovative industries. Furthermore, it is a major industry in developing economies such as China and India. With the global economic turmoil and environmental problems expanding, it is extremely important to choose suppliers who offer the highest level of customer satisfaction while taking environmental concerns into account. The study aims to evaluate wholesale clothing suppliers of a Chinese import/export company using the Dynamic Grey Relational Analysis (DGRA) model. The results are validated through comparative analyses with the Ordinal Priority Approach (OPA) and TOPSIS models. The results show that the DGRA is a reliable approach to supplier selection in apparel industry.

Keywords: Apparel industry; grey relational analysis; grey system; grey model; supplier selection.

1. Introduction

Supply chain disruptions continue to affect most industries, even nearly three years after the initial challenges of the COVID-19 pandemic. One industry that has been particularly affected is apparel. Buyers are finding fewer choices at physical stores while delivery times for online purchases are getting longer. Meanwhile, suppliers and retailers are also struggle to keep inventory levels high, sometimes not receiving major designs until much later in the season than expected (Dashoush, 2021). One way to deal with these problem sis revisiting the existing supplier selection practices and sourcing strategies. Literature has long acknowledged the importance of performance aspects and evaluation in supply chain management (Estampe *et al.*, 2013; Melnyk *et al.*, 2014). Thus, selecting the appropriate suppliers is critical to the procurement procedure and it is a significant opportunity for businesses to lower costs across their entire supply chain. The rise of new challenges (e.g. political conflicts, wars, and epidemics) has all disrupted supply chains (SCs) in incredible ways, demanding better decisions from businesses throughout all industries. On the other hand, Supply chains were indeed advancing as new issues and opportunities arose (Cebekhulu & Ozor, 2022). In essence, adaptability and flexibility are essential for surviving in the market.

In today's competitive environment, effective and efficient supply chains are becoming increasingly important for gaining a competitive advantage. In this regard, "Sustainable Development" has gained more prominence internationally in previous decades. The World Commission on Environment and Development (WCED, 1987) simply defined "Sustainable

Development" as "having effective for satisfying the needs of today's individuals without having a major impact on the resources required for the next generation". To reach this, the notion of Green Supply Chain Management (GSCM) was first reported in the literature in the nineties, when the rivalry was on the rise (Zhu & Sarkis, 2006). GSCM is described as adopting sustainable or incorporating environmental concerns into supply chain activities starting from product layout and ending with product recyclability, and it has the potency to lessen the environmental impact of industrial production while sustaining high quality, actual cost, durability, performance, and energy efficiency (Srivastava, 2007; Bah & Tulkinov, 2022).

Classically, the supplier selection has played an important role in supply chains, as it adds value to higher product quality and satisfaction of customers (Gonzalez *et al.* 2004). In traditional supply chains, the process of supplier selection has evolved into a vital part of Global Sustainable Supply Chain Management (GSCM). Furthermore, with emerging advancements, sustainability development, and GSCM, it has been more difficult and complicated. Therefore, establishing a model for deciding green suppliers is essential to guarantee supply chain sustainability (Amindoust *et al.*, 2012). Dheeraj and Vishal (1992) argued that GSCM equals Green manufacturing/materials management + Green purchasing + Green Distribution/marketing + Reverse logistics.

Green supplier selection, in contrast, is viewed as an interesting example of sustainability principles in today's society. Green supplier evaluation is a significant step toward more sustainable network systems. It is critical for a sustainable supply chain to integrate environmental factors into traditional supplier evaluation methods and procedures (Rostamzadeh *et al.*, 2015; Darnall *et al.*, 2008). As new insights into the interactions between business and the environment emerge, there is a growing focus on how to incorporate sustainability performance into business processes and a broader supply chain (Davis-Sramek *et al.*, 2020; Srivastava, 2007). In literature several methods have been used to solve supplier selection problems. An overview of them is presented in Table 1, while the last row shows the contribution of the current study.

The current study used the Dynamic Grey Relational Analysis (DGRA) to evaluate cloths suppliers against multiple criteria. In section 2 criteria are defined. Section 3 discusses the methodology, including data collection strategies, criteria weighting and the DGRA model. Section 4 contains the results and discussion. The comparative analyses with the Ordinal Priority Approach (OPA), and the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) model is also presented. In the final section, some concluding remarks are made.

Table 1. Literature on supplier selection in clothing/textile/apparel/garment industry

Year	Market/Country	Method for ranking suppliers	Literature
2007	Garment vendors in Turkey and Egypt	AHP	Koprulu and Albayrakoglu (2007)
2010	Apparel Industry	AHP	Chan and Chan (2010)
2009	Apparel manufacturing Firm	AHP	Marufuzzaman *et al.* (2009)
2011	Taiwanese textile industry	TOPSIS	Chen (2011)
2015	Indian textile and clothes company	TOPSIS	Jia *et al.* (2015)
	Textile company Istanbul, Turkey	Fuzzy AHP, linear goal programming	Sivrikaya *et al.* (2015)
	Textile industry between China & India	AHP and TOPSIS	Sasi and Digalwar (2015)
2019	High-functionality textile industry	AHP and Fuzzy AHP	Mondragon *et al.* (2019)
	Garment industry of Vietnam	TOPSIS	Wang *et al.* (2019)
2020	Textile company in Turkey	Intuitionistic fuzzy TOPSIS	Nakiboglu and Bulgurcu (2021)
2021	Apparel and textile in Vietnam	Fuzzy AHP and Fuzzy TOPSIS	Wang *et al.* (2021)
2022	Chinese cloths import/export industry	Dynamic GRA, OPA, and TOPSIS	The current study

2. Supplier selection criteria

Selecting relevant criteria to use in evaluating potential suppliers is crucial for the procurement manager. Based on the literature (Ulutaş *et al.* 2019), a list of important criteria was created to evaluate suppliers in the clothing industry (see, Table 2). The final set of criterion are detailed as follows:

2.1 Technological capability

The technological capability has been seen as a significant player in the economic progress of a nation since the advance of manufacture relies on the ability to launch new items and it is also an indication of whether the company can keep up with the changing in the market (for instance, high demand, green products, new design, resilient products, etc.). Given the capability of a firm to implement any applicable practical utility, including the capability to form innovative goods, operations, and high-tech knowledge in order to reach upper levels of operational effectiveness (Tsai, 2004). Literature (Reed & Walsh, 2002; Tsai, 2004; Ulutaş *et al.*, 2019) regarded technological capability to be critically important for supplier selection in the aerospace, electronics, and textile industries.

The technological ability of the manufacturer is vital in bringing innovation to clothing and the process of cloth manufacturing. Through decent technological capability, the manufacturers can create a smart business that gathers both efficiency and effectiveness. As a result, the business will only employ resources that are necessary for production, limiting risks and extravagance (Wang *et al.*, 2006; Bergek *et al.*, 2008; Song *et al.*, 2008; Santos-Vijande *et al.*, 2012; García *et al.*, 2012). In addition, there is a clear correlation between technological capability, and business performance for small and medium-sized enterprises (Salisu & Bakar, 2019). Moreover, the well-built technological capabilities of the company are a notable factor for innovation in the area of management (Ercan, 2019). Guerra and Camargo (2016) argued that excellent technological capabilities possibly would create competitive advantages in the international market for the firm. In spite of everything, business owners should spend both money and effort to strengthen their technological capacity in order to secure their future in the marketplace.

2.2 Cost

Cost is the most favored economic characteristic used in supplier selection, it signifies the value given to take possession of (goods, services, raw materials, etc.), achieve, produce, or sustain anything. The importance of cost is demonstrated by their inclusion in nearly every supplier selection research, and failure to perform well on these criteria (cost, quality, and delivery) influences deeply supplier selection (Javed *et al.*, 2022; Jia *et al.*, 2015).

The cost influences the consumer segments that opt to purchase the product, as well as impacts the customer's expectations. Ohno (1988) said the only thing we are doing is observing the timeline, then removing the non-value-added wastes, and as a result shortening that timeline production. Because in the end, the firm's objective is looking to increase its profits, and this requires an understanding from the suppliers of the best cost afforded by buyers and consumers. Companies

Table 2. Supplier selection criteria (Ulutaş *et al.* 2019)

Dimension	Criteria
Economic	Technological Capability Cost Defective rate Late Delivery rate Technical assistance
Environment	Pollution control Environmental management Green transportation Green warehousing

can also decrease the cost by adopting new managerial approaches like kaizen, six sigma, Kanban, etc. and the best example is Japanese firms.

2.3 Defective rate

The defective rate is expressed as the sum of defective products detected divided by the total of units tested. The term defect rate refers to the proportion of damaged parts in comparison to the number of units produced. It is an indication of the quality of the production. A high defect rate influences negatively production costs as well as might perhaps result in a process shortage. Moreover, it might increase the storage rate in manufacturing (Yang *et al.*, 2015). All waste sources must be identified and eliminated because defectives are a form of production waste (Ohno, 1988). Sarkar (2019) argued that to reduce defective items the entire manufacturing system must be checked and verified.

Tracking the defective rate allows businesses to assess the overall quality of each product and the manufacturing process. Recognizing the above assessment enables the firm to recognize where defects are happening and, potentially, assist in the development of solutions or service quality. This concept is applicable to a wide range of industries and businesses. A software developer, for example, may use defect rate to determine what percentage of their lines of code are incorrect, while a call center may calculate how many calls fail to meet quality standards. All produced items should be categorized into good and defective products because defective items have a negative impact on economic ordering quantity (EOQ) (Salameh & Jaber, 2000; Wahab & Jaber, 2010).

2.4 Late delivery rate

The late delivery rate refers to the ratio of seller-fulfilled orders that are ship confirmed after the estimated ship date divided by those fulfilled during the relevant timeframe. Delivery timeliness has huge importance in measuring the performance of suppliers (Simpson *et al.*, 2002). Additionally, delivery timeliness influences severely supplier selection (Javed *et al.*, 2022).

Logistics and supply chain management can be time-consuming and overwhelming business endeavors. As a result, late delivery comes at a high cost to the business, as evidenced by lowering customer loyalty, higher customer acquisition costs, and declined customer lifetime value. Bushuev (2018) emphasized that higher levels of delivery uncertainty may make a buyer unwilling to agree to contract terms with the supplier. That is why the suppliers should indeed look for creative ways to provide higher levels of delivery service even with super low inventory levels.

2.5 Technical assistance

Technical assistance refers to a supplier's capacity to provide specialized assistance to the firm with a development necessity. Out of all the service components discussed in the study, technical assistance was an attribute that appeared on more than 20% of the assessments (Simpson *et al.*, 2002). The more the firm is advanced in technology capabilities the more technical assistance provides and verse versa.

Technical assistance was among the strategies used by companies to accomplish significant economic and environmental gains by collaborating with their supplier partners (Kim & Rhee, 2012). In today's digital age, businesses are defined by their technological capabilities. A firm can be brought to a halt without the assistance and knowledge of a tech team. In other words, technical support ensures that the firm's technology remains productive and therefore achieves maximum advantages (cost saving, enhanced performance, higher product quality, and service quality).

2.6 Pollution control

Organizations and governments all around the globe are attempting to lower their environmental impact by implementing a sustainable supply chain. Pollution control refers to any sort of practice adopted by the firm to minimize, mitigate, or avoid pollution at its source before it is created. Developing guidelines to help to prevent environmental harm (see Rabbani *et al.*, 2019;

Amindoust, 2018; Amindoust *et al.*, 2012). A successful pollution prevention initiative entails meeting a group of qualified individuals, reporting how the business processes actually work and then delving into where setbacks happen and how much it actually costs. Only then can workers and staff work harmoniously to minimize or avoid shortfalls that cost you money and have detrimental effects on the environment. Consequently, training could be more crucial in boosting a company's adoption of environmental policies (Efobi *et al.*, 2019).

The impact is apparent in the performance of small businesses, which gain social acceptance. The said acceptance level will boost sales volume and performance. In addition, by implementing pollution control, the company will avoid government financial penalties and harassment from public agencies responsible for enforcing environmental protection regulations, as well as other environmental organizations (Efobi *et al.*, 2019). Clearly, businesses that aim to flourish in the global market should not continue ignoring environmental problems.

2.7 Environmental Management

People are becoming more conscious of the deep ties that exist between the economy and the environment. As a result, several nations have enacted environmental legislation and regulations to regulate the use of potentially harmful goods, processes, and wastes (Lee *et al.*, 2009). The EU requires importers to adhere to environmental rules and acquire more environmentally friendly equipment (Lee *et al.*, 2009). Collaboration on environmental concerns with suppliers was connected to improvements in three conventional aspects of manufacturing performance - quality, delivery on time, and flexibility - as well as environmental performance (Vachon & Klassen, 2008). Moreover, the Supplier's environmental performance must be defined under four types of indicators (wastewater, air emissions, solid wastes, and energy consumption) (Noci, 1997). Handfield *et al.* (2002) argued that buyers requisite to buy products and services from suppliers who can provide them at the lowest possible cost and with the highest possible quality, and with the shortest delivery dates while also managing their activities related to environmental responsibility.

The economy's prosperity is highly reliant on the well-being of the environment and society (Mahmoudi *et al.*, 2021). As a result, managers and policymakers should indeed take into account the combination of environmental practices with economic objectives.

2.8 Green transportation

Sustainable logistics development prompts activities that achieve maximum economic and social benefits while limiting negative environmental impacts (Abbasi & Nilsson, 2016). Green transportation is defined as any method of transportation used by suppliers that are powered by [an alternative power source], [Alternative fuel]. The environmental impact can be direct, considering that the products purchased generate waste during storage, transportation, processing, usage, or disposal (Handfield *et al.*, 2002). According to Salimifard *et al.* (2012), the transportation industry is directly responsible for 23% of emissions of CO2. Moreover, a further 40% increase in CO2 emissions is predicted between 2007 and 2030, threatening global health (Rostamzadeh *et al.*, 2015). Therefore, serious efforts should be made to reduce or eliminate CO2 emissions through the adoption of green transportation.

Logistics includes transportation, which can be employed in a range of ways. The main modes of transportation are by road, rail, sea, and air (Gurel *et al.*, 2015). Govindan *et al.* (2019) emphasized that green and energy-efficient transportation practices could well assist in minimizing the negative influence on the environment while also enhancing the usage of resources efficiently, herewith improving the environmental image of both suppliers and customers. Additionally, the most frequent initiatives to boost the effectiveness and efficiency of internal logistical resources concerned the mode of transportation and the energy consumption of vehicles (Abbasi & Nilsson, 2016).

2.9 Green warehousing

Developing solutions to minimize energy consumption, employ sustainable energy sources and materials, and reduce non-recyclable trash generated during warehouse operations. In order to mend supply chain sustainability, Wang *et al.* (2015) emphasize the importance of recycling facilities in supporting green warehousing. Furthermore, green warehousing might well reduce the expense of pollution control by generating no waste or emitting neither emissions, which may lead to enhanced economic performance and might even save companies from financial penalties for environmental violations (Agyabeng-Mensah *et al.*, 2020). According to Torabizadeh *et al.* (2020) green warehousing seems to have an advantageous effect on company performance.

In recent times, more businesses have recognized the importance of green warehousing in terms of cost and energy savings. However, the initial cost and time investment required to transform to this type of warehousing frightens many businesses (Rostamzadeh *et al.*, 2015; Dheeraj & Vishal, 1992). Even though the advantages of green warehousing on economic growth would appear indefinable or far away. However, implementing energy-saving strategies, such as shifting lighting systems to minimize electricity usage, does have a beneficial economic impact. Long-term benefits include reduced risks from climate change, energy shocks, and water shortages.

3. Research methodology

3.1 Data collection and analysis

Data from suppliers were gathered from the boss of a small import-export company founded in 2013 that trades clothing and furniture to countries in the Middle East, where customers are difficult to satisfy due to high living standards. The company is based in Yiwu, China, and their suppliers are from different parts of China. The suppliers of clothes were evaluated using a 9-point Likert scale. After asking the person to rank the criteria in order of importance to his business, we asked him how satisfied he is with the performance of these suppliers on these nine criteria. Nonetheless, the respondent did not give any supplier the highest rating.

The current study evaluated six suppliers using the Dynamic GRA against nine criteria. The Rank Reciprocal (RR) method was used to determine the weights of the criteria. For comparative analyses, TOPSIS and OPA were applied. For TOPSIS as well, the criteria weights were estimated through the RR method. The Dynamic GRA and TOPSIS were executed in MS Excel, while the OPA was executed in Amin Mahmoudi's OPA Solver. The algorithms of the OPA and TOPSIS can be found in Mahmoudi and Javed (2022) and Hwang and Yoon (1981), respectively.

3.2 Criteria weight estimation

The weights of the nine attributes for both Dynamic GRA and TOPSIS were calculated using the Rank Reciprocal (RR) method. The Rank Reciprocal (RR) weights are estimated through the following formula (Stillwell, 1981).

$$\mathrm{W_j} = \frac{\frac{1}{R_j}}{\sum_{j=1}^{n}\left(\frac{1}{R_j}\right)} \tag{1}$$

where, $\mathrm{W_j}$ is the normalized weight of the jth criterion, R_j is the rank for the jth criterion, and n is the number of criteria.

3.3 Dynamic grey relational analysis

The Grey System Theory (GST) is an emerging methodology that was proposed by Julong Deng in the 1980s (Mahmoudi *et al.*, 2021). Since then, the model has been applied in numerous fields and has gained recognition as a leading theory of uncertainty analysis and managing systems with imperfectly known information. For instance, Abifarin *et al.* (2021) used the GRA for optimization

of engineering parameters. Tsoy (2022) used it to identify the key expectations of Russians from the increased supplies of Russian natural gas to Europe. Ivanova (2022) used the GRA to identify the main factors affecting the food safety of the Russian supply chain. Kharipzhanova and Irfan (2022) used the GRA to identify and evaluate multiple barriers to the development of GB's travel & tourism industry in Pakistan. Oyedeji *et al.* (2022) used the GRA for optimization of the mechanical properties of palm oil processing plant in Nigeria.

The Grey Relational Analysis (GRA) is a measure of correlation that becomes more evident in multiple criteria decision-making (MCDM), clustering of data, and optimization (e.g., in mechanical engineering) and it is an important part of the Grey systems theory (GST). Deng's GRA is the most influential form of the GRA and has become an influential multiple attribute decision-making method along with the Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS). However, the method has certain shortcomings, e.g., the value of its distinguishing coefficient is chosen subjectively and normalization of input data is mandatory. In 2022, Javed *et al.* (2022) overcome these shortcomings by proposing the Dynamic GRA model.

The Grey Relational Grade (GRG) (Γ_{0k}) is:

$$\Gamma_{0k} = \sum_{j=1}^{n} w(j) \times \gamma_{0k}(j) \tag{2}$$

where, the Grey Relational Coefficient (GRC) ($\gamma_{0k}(j)$) is:

$$\gamma_{0k}(j) = \frac{\Delta_{min} + \xi(j)\Delta_{max}}{|\Delta_{0k}(j)| + \xi(j)\Delta_{max}}, k = 1,2,\ldots.m \tag{3}$$

Here,

$$|\Delta_{0k}(j)| = |x_0(j) - x_k(j)| \tag{4}$$

$$\Delta_{min} = min_k min_j |x_0(j) - x_k(j)| \tag{5}$$

$$\Delta_{max} = max_k max_j |x_0(j) - x_k(j)| \tag{6}$$

$$\xi(j) = \{\xi(1), \xi(2), \ldots, \xi(n)\}, \xi(j) \in (0,1] \tag{7}$$

In the Dynamic GRA, $\xi(j)$ is the vector of the Dynamic Distinguishing Coefficients. The method to estimate this vector is available in Javed *et al.* (2022).

4. Results and discussion

For clarity, the suppliers are labelled as follows: first supplier (S1), second supplier (S2), third supplier (S3), fourth supplier (S4), fifth supplier (S5), and sixth supplier (S6). The same person was requested to assess the suppliers based on the following nine criteria: Cost (C1), Technological Capability (C2), Late Delivery Rate (C3), Defective Rate (C4), Pollution Control (C5), Environmental Management (C6), Technical Assistance (C7), Green Warehousing (C8), and Green Transportation (C9). Thus, C1, C2, C3, C4, and C7 considered as economic dimensions, while C5, C6, C8 and C9 as environmental dimensions (see, Table 2).

The environmental performance of businesses has gotten a lot of care in latest years from government entities, scholars, and environmentally responsible citizens. As a result, industry decision-makers are becoming more mindful of the impact of businesses on the environment. Therefore, green supply chain systems are now becoming extremely relevant. The current study used the Dynamic GRA for the evaluation of six suppliers against nine criteria. The original data is shown in Table 3, while the Grey Relational Coefficients and the Grey Relational Grades are shown in Tables 4 and 5, respectively. For the comparative analyses, the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) and the Ordinal Priority Approach (OPA) have been used. To estimate the weights of the criteria for both the Dynamic GRA and TOPSIS, Stillwell's Rank Reciprocal (RR) method was used, and then both the Dynamic GRA and TOPSIS

Table 3. Input data

	C1	C2	C3	C4	C5	C6	C7	C8	C9
Priority	1st	1st	2nd	3rd	4th	4th	5th	5th	6th
S1	8	6	8	8	5	4	4	2	4
S2	8	7	7	8	5	4	5	2	6
S3	7	6	7	7	5	4	4	2	5
S4	8	6	5	6	4	3	4	2	4
S5	6	8	8	8	5	4	5	3	4
S6	6	8	7	8	4	3	6	4	5

Table 4. Criteria weights, dynamic grey relational coefficients and distinguishing coefficients

	C1	C2	C3	C4	C5	C6	C7	C8	C9
W	0.256	0.256	0.128	0.085	0.064	0.064	0.051	0.051	0.043
S1	1.00	1.00	1.00	0.54	1.00	0.57	1.00	0.57	0.60
S2	1.00	1.00	0.67	0.70	1.00	0.73	1.00	1.00	0.60
S3	0.63	0.50	0.67	0.54	1.00	0.57	1.00	0.73	0.60
S4	1.00	0.33	0.40	0.54	0.40	0.57	0.40	0.57	0.60
S5	0.45	1.00	1.00	1.00	1.00	0.73	1.00	0.57	0.75
S6	0.45	1.00	0.67	1.00	0.40	1.00	0.40	0.73	1.00
$\xi(j)$	0.56	0.78	0.67	0.33	0.22	0.22	0.89	1.00	0.89

Table 5. Dynamic grey relational grade and ranking

	GRG	Rank
S1	0.894	2
S2	0.897	1
S3	0.635	5
S4	0.577	6
S5	0.810	3
S6	0.734	4

were executed on MS Excel. While the OPA was performed through Amin Mahmoudi's OPA Solver.

According to the Dynamic GRA's findings, the second supplier (S2) is the best, while the fourth supplier (S4) is by far the worst (Table 5; Figure 1). As a result, the decision-makers of this Chinese company should sustain a fairly close connection with the suppliers (S2) and (S1) and minimize the risks associated with the supplier (S4) because it may lead to lost profits or even the ruination of the company's reputation. According to the study, suppliers (S2) and (S1) are the most trustable suppliers who could deliver supplies with much less environmental effects while achieving economic advantages. On the other hand, the remaining suppliers are not as reliable. As a result, the manager should observe closely their performance and take into account whether requesting them to enhance their performance in the above criteria (Table 2) within a specific timespan or ending their partnership.

The results show that the second supplier (S2) is best among all six cloth suppliers, and the Cost (C1), and Technological Capability (C2) are the two criteria with highest importance for the buyer. For comparative analysis the OPA (Mahmoudi & Javed, 2022) and the TOPSIS (Hwang & Yoon, 1981) methods were applied. The TOPSIS and OPA results confirmed the earlier Dynamic GRA outcomes that the second supplier (S2) is the most reliable among the six suppliers, whereas, the fourth supplier (S4) is the least reliable (Table 6). The reason of the superior performance of S2 can be attributed to its relatively better performance on most of the criteria (economic and environmental dimensions).

The procurement manager at the Chinese company realizes the essential benefits of implementing a green supplier selection for the well-being of their long-term business goals. It does provide the Chinese company as well as other businesses in the same industry with a complete picture of the most significant factors to seriously consider in supplier selection. Thus, this study might very well help tremendously the less-performing suppliers in enhancing their strategies and

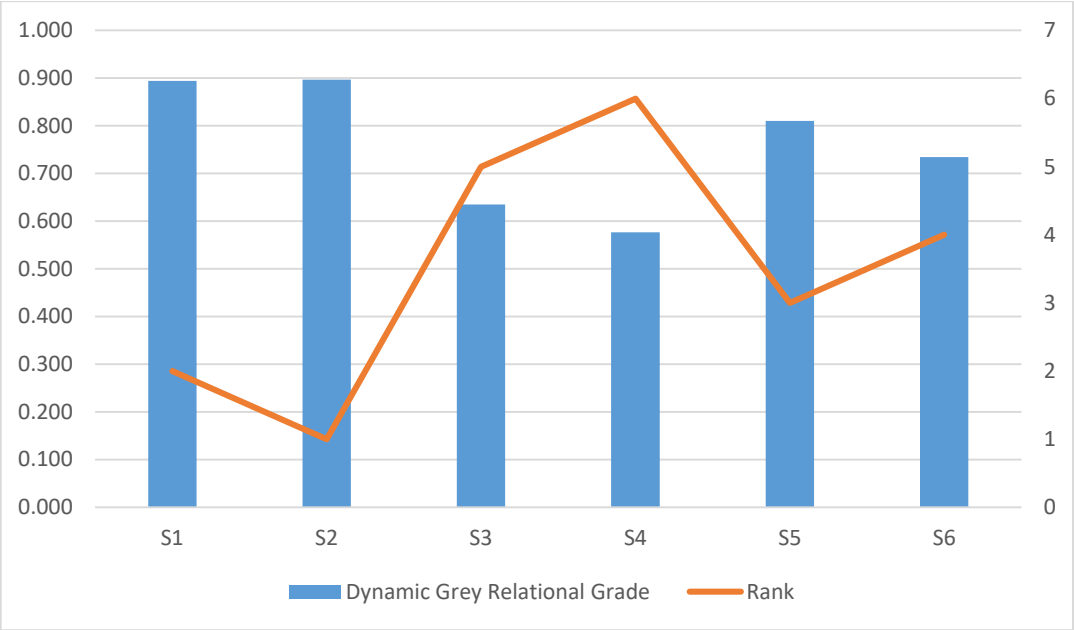

Figure 1. The Dynamic Grey Relational Grade-based ranking of the suppliers

adopting new policies that go along with the customers and environmental goals as well as with the economic competitive advantages.

The selection of suppliers can be overwhelming and tiring. Especially, if the manager needs to choose between a dozens of suppliers with different performance levels (and with a lack of information). However, when applying MCDM models would make it easier for decision-makers in various industries. Also, choosing the right MCDM model is another headache. Thus, scholars and researchers have to double their effort to simplify or update the models to make them easier for real-life managers.

5. Conclusion and implications

At the present time, achieving sustainable development through the incorporation of environmental, economic, and social performance is indeed a business's biggest challenge. Thus, supplier selection (SS) is the process of choosing suppliers who consider economic goals besides sustainability goals. Therefore, the goal of this study was to advocate using The Dynamic GRA to solve Green SS issues and to make better decisions when choosing between suppliers. The OPA and TOPSIS models confirmed the accuracy of the results produced through the Dynamic GRA. Six suppliers and nine criteria were used in this study. The findings demonstrated that the cost and technological capabilities criteria are important criteria for the companies importing cloths/ garments from China and exporting to Middle East.

According to our findings, companies must take serious measures to deal with impending environmental issues and continually evaluate the sustainability and social performance of their supply chain partners. In addition, business owners should create strong relationships with their suppliers and implement creative plans to transform them from mere financial records to an essential part of their businesses. It is impossible to overstate the importance of choosing green

Table 6. Comparison between the Dynamic GRA, the TOPSIS, and the OPA

	Dynamic GRA	TOPSIS	OPA
S1	2	2	2
S2	1	1	1
S3	5	5	5
S4	6	6	6
S5	3	3	3
S6	4	4	4

suppliers in order to achieve Sustainable Development Goals (SDGs). If businesses continue to ignore environmental issues (pollution and climate change, etc.) it will be harder to mitigate their negative effects on the environment in the future.

Supplier selection is indeed an essential step in all domains. Therefore, managers should focus more on how and why they choose one supplier over another. According to our research, ignoring the green criterion when evaluating/selecting suppliers can result in financial losses and possibly destroy the business' reputation. Moreover, firms should prioritize long-term goals over immediate (short-term) economic benefits. All business owners are responsible for reducing the negative impact on the environment.

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