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In the memory of Professor Deng Julong (1933 - 2013),

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A New Information Priority Accumulated Grey Model with Hyperbolic Sinusoidal Term and its Application

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Abstract: Compared to fossil fuels, natural gas is cleaner energy, which has developed rapidly in recent years. Studying the urban supply of natural gas has implications for the development of natural gas. In this paper, the new information priority accumulation method is integrated into the grey forecasting model with the hyperbolic sinusoidal driving term, and then the new grey model is used to predict the urban natural gas supply. The system's linear parameters are calculated by the least square estimation method, and the optimal parameter of the new information accumulated priority is determined by the Whale Optimization Algorithm. Finally, the supply of urban gas is forecasted using the proposed model, and comparative analyses with the four other forecasting models are presented.

Keywords: Natural gas; grey forecasting; new information priority accumulation; hyperbolic sinusoidal; optimization algorithm

1. Introduction

Natural gas has become one of the most prevalent forms of energy. Natural gas is widely used in many ways, such as generating electricity, the chemical industry, etc. Because natural gas produces less pollution, is convenient to deliver, and is more affordable than other gases, it is widely applied in our daily lives. Nowadays, natural gas is being delivered to the countryside or distant mountains villages, increasing its consumption year by year. But is the gas supply enough to meet the needs of the urban population? Thus, studying the supply of urban natural gas is of significant importance.

In the 1980s, Deng (1982) proposed the Grey System Theory and opened the door to a new discipline. From then on, the theory has seen application in various fields, especially the energy sector (Wu & Ma, 2019a; 2019b; 2018). Grey forecasting theory is an important branch of it, as it just needs more than four data to make a prediction and obtain acceptable accuracy. In recent years, scholars have proposed a number of models with different structures based on the typical grey prediction model GM (1,1). According to the structure of the GM (1,1) grey model, Cui *et al.* (2013) and Xie *et al.* (2013) introduced a new grey action bt replacing the original grey action b into the grey model to propose continuous grey model NGM (1,1,k) and discrete grey model NDGM

(1,1,*k*). Based on their work, Chen *et al.*(2014) introduced the *bt*+*c* term into the grey model to construct a non-homogeneous grey prediction model called NGM (1,1,*k*,*c*). Recently, Zhang *et al.* (2019) proposed power-driven and incomplete Gamma grey action term into the grey model.. Besides the univariate form, many scholars also research the multivariate grey models, such as the GM (1,N) model (Deng, 2012; Tien, 2005). Ma *et al.* (2014) introduced the nonlinear term into the GM (1,N) model to propose the nonlinear grey Bernoulli GM (1,N) model.

In traditional grey models, the integer order accumulation method is used to the original sequences to obtain a new increasing sequence which is called the first accumulated generating operation (1-AGO). Followed by the idea of the 1-AGO, there are three other ways to deal with original data sequences. Xia *et al.* (2020) combined the new information priority accumulation into the grey model to predict short-term wind turbine capacity. The fractional-order accumulation is introduced into the grey model in 2013 by Wu *et al.* (2013). Ma *et al.* (2019) proposed a new fractional accumulation definition and introduced it into the traditional grey model GM (1,1) to construct the CFGM (1,1).

The detailed algorithm of new information priority accumulation was proposed by Zhou *et al.* (2017). Wu *et al.* (2018) demonstrated that in the new information priority accumulation, the weight of new information should be larger than older information. They pointed out that giving new information more weight would increase the grey model's accuracy. Inspired by the above-mentioned grey models and the advantage of the new information priority accumulation, we propose a new information priority accumulation-based grey forecasting model, abbreviated as NISinHGM (1,1). The current study aims to combine the new information priority accumulation into a grey model with the hyperbolic sinusoidal driving term and then forecast the total urban natural gas supply. The contributions of our paper are summarized as follows. Firstly, we introduce and recall the new information priority accumulation method. Secondly, we use the Whale Optimization Algorithm (WOA) to calculate the parameter, and then a new model, NISinHGM (1,1), is built. The properties of the new model are systematically analyzed. Last but not least, the proposed grey model is applied to the natural gas of urban supply, and the results are compared with the four other grey prediction models.

2. New information priority accumulation method

Definition 1. Let the negative sequence be $X^{(0)}=\left(x^{(0)}(1),x^{(0)}(2),\ldots,x^{(0)}(n)\right)$, the first-order priority accumulation sequence of new information is expressed as

$$x^{(1)}(k)=\sum_{i=1}^{k}\lambda^{k-i}x^{(0)}(i),\lambda\in[0,1], \tag{1}$$

so the first order generation sequence is $X^{(1)}=\left(x^{(1)}(1),x^{(1)}(2),\ldots,x^{(1)}(n)\right)$, which writes in a matrix form as follows

$$\begin{pmatrix} x^{(1)}(1)\\ x^{(1)}(2)\\ x^{(1)}(3)\\ \vdots\\ x^{(1)}(n-2)\\ x^{(1)}(n-1)\\ x^{(1)}(n)\end{pmatrix}=\begin{pmatrix} 1 & 0 & 0 & \cdots & 0 & 0 & 0\\ \lambda & 1 & 0 & \cdots & 0 & 0 & 0\\ \lambda^2 & \lambda & 1 & \cdots & 0 & 0 & 0\\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots\\ \lambda^{n-3} & \lambda^{n-4} & \lambda^{n-5} & \cdots & 1 & 0 & 0\\ \lambda^{n-2} & \lambda^{n-3} & \lambda^{n-4} & \cdots & \lambda & 1 & 0\\ \lambda^{n-1} & \lambda^{n-2} & \lambda^{n-3} & \cdots & \lambda^2 & \lambda & 1\end{pmatrix}\begin{pmatrix} x^{(0)}(1)\\ x^{(0)}(2)\\ x^{(0)}(3)\\ \vdots\\ x^{(0)}(n-2)\\ x^{(0)}(n-1)\\ x^{(0)}(n)\end{pmatrix}.$$

Definition 2. Inverse operation is performed on first-order new information accumulation obtain the values

$$x^{(0)}(k)=x^{(1)}(k)-\lambda x^{(1)}(k-1), \tag{2}$$

which can also be written in matrix form as

$$\begin{pmatrix} x^{(0)}(1) \\ x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n-2) \\ x^{(0)}(n-1) \\ x^{(0)}(n) \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & \cdots & 0 & 0 & 0 \\ -\lambda & 1 & 0 & \cdots & 0 & 0 & 0 \\ 0 & -\lambda & 1 & \cdots & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & 1 & 0 & 0 \\ 0 & 0 & 0 & \cdots & -\lambda & 1 & 0 \\ 0 & 0 & 0 & \cdots & 0 & -\lambda & 1 \end{pmatrix} \begin{pmatrix} x^{(1)}(1) \\ x^{(1)}(2) \\ x^{(1)}(3) \\ \vdots \\ x^{(1)}(n-2) \\ x^{(1)}(n-1) \\ x^{(1)}(n) \end{pmatrix}.$$

The weight of the first-order new information sequence can be adjusted through the parameter λ , making the weight of the new information larger than the old information.

3. The NISinHGM (1,1) model

Definition 3. Based on first-order new information accumulation data sequence, the classical grey prediction model, the ordinary differential equation theory, and the hyperbolic sine function, a new grey prediction model NISinHGM (1,1) is proposed. The whitening equation of the new model is given by

$$\frac{dx^{(1)}(t)}{dt}+ax^{(1)}(t)=b\sinh t+c, \tag{3}$$

where $\sinh t=\dfrac{e^{t}-e^{-t}}{2}$.

Theorem 1. The time response function of the grey model NISinHGM (1,1) is

$$\begin{aligned}\hat{x}^{(1)}(k)=&\frac{b}{2(a+1)}\left(e^{k}-e^{-a(k-1)+1}\right)-\frac{b}{2(a-1)}\left(e^{-k}-e^{-a(k-1)-1}\right)\\&+\left(x^{(0)}(1)-\frac{c}{a}\right)e^{-a(k-1)}+\frac{c}{a},\left(k=1,2,\ldots\right),\end{aligned} \tag{4}$$

and the restored value of $\hat{x}^{(0)}(k)$ is

$$\begin{aligned}\hat{x}^{(0)}(k)=&\frac{be^{k\text{-}1}}{2(a+1)}\left(e-\lambda\right)-\frac{be^{-k+1}}{2(a-1)}\left(e^{-1}-\lambda\right)+\frac{c}{a}\left(1-\lambda\right)\\&+\left(e^{-a}-\lambda\right)e^{-a(k-2)}\left(-\frac{be}{2(a+1)}+\frac{be^{-1}}{2(a-1)}+x^{(0)}(1)-\frac{c}{a}\right)\left(e^{-a}-\lambda\right)e^{-a(k-2)},\\&\left(k=1,2,\ldots\right),\end{aligned} \tag{5}$$

with $\lambda \in [0,1]$.

Proof 1. Transforming the homogeneous equation of Eq. (3) into

$$\frac{dx^{(1)}(t)}{dt} = -ax^{(1)}(t). \tag{6}$$

By using the constant variation method, we calculate the first-order differential equation

$$x^{(1)}(t) = u(t)e^{-at}. \tag{7}$$

Substituting the expression of $x^{(1)}(t)$ into the original Eq. (3), one obtains

$$u'(t) = (b\sinh t + c) \times e^{at}. \tag{8}$$

Integrating $u^{'}(t)$ on the left and the right sides, one can obtain

$$u(t) = \frac{b}{2(a+1)}\left[e^{(a+1)t} - e^{a+1}\right] - \frac{b}{2(a-1)}\left[e^{(a-1)t} - e^{a-1}\right] + \frac{c}{a}\left(e^{at} - e^{a}\right) + x^{(1)}(1)e^{a}. \tag{9}$$

Substituting $u(t)$ into Eq. (7) will produce

$$\begin{aligned} x^{(1)}(t) = u(t)e^{-at} &= \frac{b}{2(a+1)}\left[e^{t} - e^{-a(t-1)+1}\right] - \frac{b}{2(a-1)} \\ &\times\left[e^{-t} - e^{-a(t-1)-1}\right] + \left(x^{(0)}(1) - \frac{c}{a}\right)e^{-a(t-1)} + \frac{c}{a}. \end{aligned} \tag{10}$$

Let $t = k$ and one can directly calculate the time response function

$$\begin{aligned} \hat{x}^{(1)}(k) &= \frac{b}{2(a+1)}\left(e^{k} - e^{-a(k-1)+1}\right) - \frac{b}{2(a-1)}\left(e^{-k} - e^{-a(k-1)-1}\right) \\ &+ \left(x^{(0)}(1) - \frac{c}{a}\right)e^{-a(k-1)} + \frac{c}{a}, (k = 1, 2, \ldots), \end{aligned}$$

Moreover, the restored values of $\hat{x}^{(0)}(k)$ can be obtained with the expression of $\hat{x}^{(1)}(k)$ and the inverse new information priority accumulation

$$\begin{aligned} \hat{x}^{(0)}(k) &= \frac{be^{k-1}}{2(a+1)}(e - \lambda) - \frac{be^{-k+1}}{2(a-1)}\left(e^{-1} - \lambda\right) + \frac{c}{a}(1 - \lambda) \\ &+ \left(e^{-a} - \lambda\right)e^{-a(k-2)}\left(-\frac{be}{2(a+1)} + \frac{be^{-1}}{2(a-1)} + x^{(0)}(1) - \frac{c}{a}\right)\left(e^{-a} - \lambda\right)e^{-a(k-2)}, \\ &(k = 1, 2, \ldots), \end{aligned}$$

Theorem 2. The system's linear parameters in the newly proposed grey prediction model NISinHGM (1,1) can be expressed as

$$(a, b, c)^{T} = \left(B^{T}B\right)^{-1}\left(B^{T}Y\right), \tag{11}$$

where

$$B=\begin{pmatrix}-z^{(1)}(2) & \cosh 2-\cosh 1 & 1\\ -z^{(1)}(3) & \cosh 3-\cosh 2 & 1\\ \vdots & \vdots & \vdots\\ -z^{(1)}(r) & \cosh r-\cosh(r-1) & 1\end{pmatrix},\ Y=\begin{pmatrix}x^{(1)}(2)-x^{(1)}(1)\\ x^{(1)}(3)-x^{(1)}(2)\\ \vdots\\ x^{(1)}(r)-x^{(1)}(r-1)\end{pmatrix}.$$

Proof 2. Integrating the whitening equation (3) and organizing it, we obtain

$$\int_{k-1}^{k} dx^{(1)}(t)+a\int_{k-1}^{k} x^{(1)}(t)\,dt=b\int_{k-1}^{k}\sinh t\,dt+\int_{k-1}^{k} c\,dt. \tag{12}$$

By applying the trapezoid formula $\int_{k-1}^{k} x^{(1)}(t)\,dt=\frac{x^{(1)}(k)+x^{(1)}(k-1)}{2}=z^{(1)}(k)$, one gets

$$x^{(1)}(k)-x^{(0)}(k)=-az^{(1)}(k)+b\left[\cosh k-\cosh(k-1)\right]+c\left(k=2,3,\ldots r\right), \tag{13}$$

Writing in matrix form, it becomes

$$\begin{pmatrix}x^{(1)}(2)-x^{(1)}(1)\\ x^{(1)}(3)-x^{(1)}(2)\\ \vdots\\ x^{(1)}(r)-x^{(1)}(r-1)\end{pmatrix}=\begin{pmatrix}-z^{(1)}(2) & \cosh 2-\cosh 1 & 1\\ -z^{(1)}(3) & \cosh 3-\cosh 2 & 1\\ \vdots & \vdots & \vdots\\ -z^{(1)}(r) & \cosh r-\cosh(r-1) & 1\end{pmatrix}\begin{pmatrix}a\\ b\\ c\end{pmatrix}.$$

And then, the expression of system parameters of the new model is computed by

$$\left(a,b,c\right)^{T}=\left(B^{T}B\right)^{-1}\left(B^{T}Y\right).$$

4. Estimating the parameter λ through Whale Optimization Algorithm

From the previous discussion, the parameter λ cannot be directly computed, and the parameter's function is adjusting the weight of information. Thus, the purpose of this section is to find out the values of the parameter λ.

4.1 Building the optimization problem

The parameter λ not only affects the first-order generation sequence but also plays a crucial role in obtaining the best accuracy from the grey prediction model. Thus, we construct an optimization problem with constrained conditions and search for optimal value. In such a problem, the minimum MAPE is used to be the optimal model where the λ parameter is the decision variable. The corresponding objective function is given below.

$$\min_{\lambda} MAPE=\frac{1}{n}\sum_{k=1}^{n}\left|\frac{\hat{x}^{(0)}(k)-x^{(0)}(k)}{x^{(0)}(k)}\right|\times 100\%,\left(0\le\lambda\le 1\right),$$

$$
s.t.\begin{cases}
(a,b,c)^T = \left(B^T B\right)^{-1}\left(B^T Y\right) \\
B = \begin{pmatrix} -z^{(1)}(2) & \cosh 2 - \cosh 1 & 1 \\ -z^{(1)}(3) & \cosh 3 - \cosh 2 & 1 \\ \vdots & \vdots & \vdots \\ -z^{(1)}(n) & \cosh r - \cosh(n-1) & 1 \end{pmatrix} Y = \begin{pmatrix} x^{(1)}(2) - x^{(1)}(1) \\ x^{(1)}(3) - x^{(1)}(2) \\ \vdots \\ x^{(1)}(n) - x^{(1)}(n-1) \end{pmatrix}. \\
\hat{x}^{(1)}(k) = \frac{b}{2(a+1)}\left(e^{k} - e^{-a(k-1)+1}\right) - \frac{b}{2(a-1)}\left(e^{-k} - e^{-a(k-1)-1}\right) \\
\qquad + \left(x^{(0)}(1) - \frac{c}{a}\right)e^{-a(k-1)} + \frac{c}{a} \\
\hat{x}^{(0)}(k) = x^{(1)}(k) - \lambda x^{(1)}(k-1)\left(k = 2,3,\ldots,n\right)
\end{cases} \tag{14}
$$

4.2 Whale Optimization Algorithm

It's hard to calculate the parameter λ directly from Eq. (14) as the problem is nonlinear. For the parameter λ , it requires an optimization algorithm to compute it, while making full use of the new information. This paper uses the Whale Optimization Algorithm (WOA), developed by Mirijalili and Lewis (2016), to compute the parameter λ . The WOA is an intelligent nature-inspired optimization method and is inspired by the behavior of whales hunting their prey. The WOA mainly simulates three kinds of behavior during whale hunting with high accuracy.

(1) *Constriction Containment Strategy*

Humpback whales can recognize prey and surround it, so the constriction containment strategy about the optimal position is for prey, and the humpback whales move towards the optimal position. The whole process can be expressed by the following equation:

$$\vec{D} = \left|2\vec{r}\cdot\vec{P}(t) - \vec{P}(t)\right|. \tag{15}$$

$$\vec{C} = 2f(t)\cdot\vec{r} - f(t). \tag{16}$$

$$f(i) = 2 - 2i/T. \tag{17}$$

$$\vec{P}(i+1) = \vec{P}^{*} - \vec{C}\cdot\vec{D}. \tag{18}$$

where $\vec{P}(i)$ represents the current position of the humpback whale, $\vec{P}^{*}(i)$ represents the optimal location of the population, $\vec{r}$ represents the random number on the interval $[0,1]$, and T represents the maximum number of iterations.

(2) *Spiral Search*

Whales hunt their food in an upward spiral, and humpback whales spiral simultaneously as they surround their prey. According to the process, the data model can be constructed as follows:

$$
\vec{P}(i+1) = \begin{cases} \vec{P}^{*}(i) - \left(2f(i)\cdot\vec{r} - f(i)\cdot\vec{D}\right), & if\ \ \xi < 0.5 \\ \left|\vec{P}^{*}(i) - \vec{P}(i)\right|\cdot e^{\beta l}\cdot\cos(2\pi l) + \vec{P}^{*}(i), & if\ \ \xi > 0.5 \end{cases} \tag{19}
$$

where l represents the random number on the interval $[-1,1]$, β is the constant that determines the shape of the spiral motion, and ξ indicates the probability of choosing enveloping contraction behavior and spiral motion.

(3) *Random Walk Hunting*

Humpbacks can also randomly search for food, randomly searching each other based on where the whales are. The data model can be constructed as follows:

$$\vec{P}(i+1) = \vec{P_r} - \vec{C} \cdot \left| 2\vec{r} \cdot \vec{P_r}(i) - \vec{P_r}(i) \right| \tag{20}$$

where $\vec{P_r}$ represents the location of a randomly selected individual whale in a pod $\left|\vec{C}\right| < 1$, whales update their location in a random walk feeding mode.

The WOA can be used to estimate the desired parameter's value. The pseudocode of the whale optimization algorithm has been described in detail by Zhang (2019a; 2019b). In the current study, we slightly modified Zhang's code in light of our needs, and the resultant pseudocode of the WOA is presented below:

The Whale Optimization Algorithm:

Input: The raw data $X^{(0)}$, lower and upper bound of λ.

Output: The optimal value of the nonlinear parameter λ.

(1) Initialize the maximum number of iterations T and the number of humpback whales;

(2) Initialize the locations $\vec{P}$ of the humpback population;

(3) Compute the fitness of each humpback by equation

$$\min_{\lambda} MAPE = \frac{1}{n}\sum_{k=1}^{n}\left|\frac{\hat{x}^{(0)}(k) - x^{(0)}(k)}{x^{(0)}(k)}\right| \times 100\%, (0 \le \lambda \le 1);$$

(4) Determine the best candidate $\vec{P}^*$ based on fitness of each whale agent;

(5) **for** $k = 1; k < T; k = k+1$ **do**

(6) **for** each humpback whale **do**

(7) Update the parameters r, p, l, β;

(8) if $\xi < 0.5$ **then**

(9) if $\left|\vec{C}\right| < 1$ **then**

(10) Update the location of each humpback by equation (19)

(11) **else**

(12) Determine $\vec{P_r}$ by randomly choosing a whale;

(13) Update the location of each humpback by equation (20)

(14) **end**

(15) **else**

(16) Update the location of each humpback by equation (19)

(17) **end**

(18) Compute the fitness of each humpback by equation

$$\min_{\lambda} MAPE = \frac{1}{n}\sum_{k=1}^{n}\left|\frac{\hat{x}^{(0)}(k) - x^{(0)}(k)}{x^{(0)}(k)}\right| \times 100\%, (0 \le \lambda \le 1)$$

(19) **end**

(20) Update $\vec{P}^*$ if a better solution exists;

(21) **end**

(22) return the optimum value $\vec{P}^*$;

In general, the whale optimization algorithm is simple, easy to operate, and fewer parameters are regulated during algorithm operation. But the whale optimization algorithm also has some defects, such as slow convergence, late stagnation of convergence tends to fall into local optimal solution, and so on. The whale optimization algorithm is evolving.

5. Application

In this section, the NISinHGM (1,1) is utilized to forecast the urban natural gas supply in China. By comparing to GM (1,1), DGM (1,1), NGM (1,1,*k*) and NGM (1,1,*k*,*c*), the feasibility of the new grey model NISinHGM (1,1) is verified. The data from the year 2006 to 2019 was collected from the National Bureau of Statistics of China. In this application, the data from 2006 to 2016 are used to build the grey models, and 2017 to 2019 are used to validate the accuracy of different grey models. The raw data is shown in Table 1.

In the grey prediction model, errors are often calculated to verify the feasibility of the model. In the current study, Absolute Percentage Error (APE) and Mean Absolute Percentage Error (MAPE) are used to evaluate the accuracy of the five forecasting models. The formulas of APE and MAPE are respectively given by:

$$APE(k)=\left|\frac{\hat{x}^{(0)}(k)-x^{(0)}(k)}{x^{(0)}(k)}\right|\times 100\%,(k=2,3,\ldots)$$

$$MAPE=\frac{1}{n}\sum_{k=1}^{n}\left|\frac{\hat{x}^{(0)}(k)-x^{(0)}(k)}{x^{(0)}(k)}\right|\times 100\%,(k=2,3,\ldots)$$

Now let's see the step-by-step execution of the new model NISinHGM (1,1).

Regard raw data from 2006 to 2016 will serve as the original sequence given by

$X^{(0)}$=(244.77, 308.64, 368.04, 405.10, 487.58, 678.80, 795.04, 900.99, 964.38, 1040.79, 1171.72).

By using the WOA algorithm, we calculated λ =0.002231296, so the first order priority accumulation sequence is computed

$X^{(1)}$=(244.77, 309.19, 368.73, 405.92, 488.49, 679.89, 796.56, 902.77, 966.39, 1042.95, 1174.05).

Furthermore, we make a comparison between the original sequence and first-order priority accumulation sequence, which are shown in the following Figure 1. According to the trapezoid formula, we can calculate the background sequence value

Table 1. Urban Natural Gas Supply (100 million cubic meters)

Year	Raw Data
2006	244.77
2007	308.64
2008	368.04
2009	405.10
2010	487.58
2011	678.80
2012	795.04
2013	900.99
2014	964.38
2015	1040.79
2016	1171.72
2017	1263.75
2018	1443.95
2019	1608.56

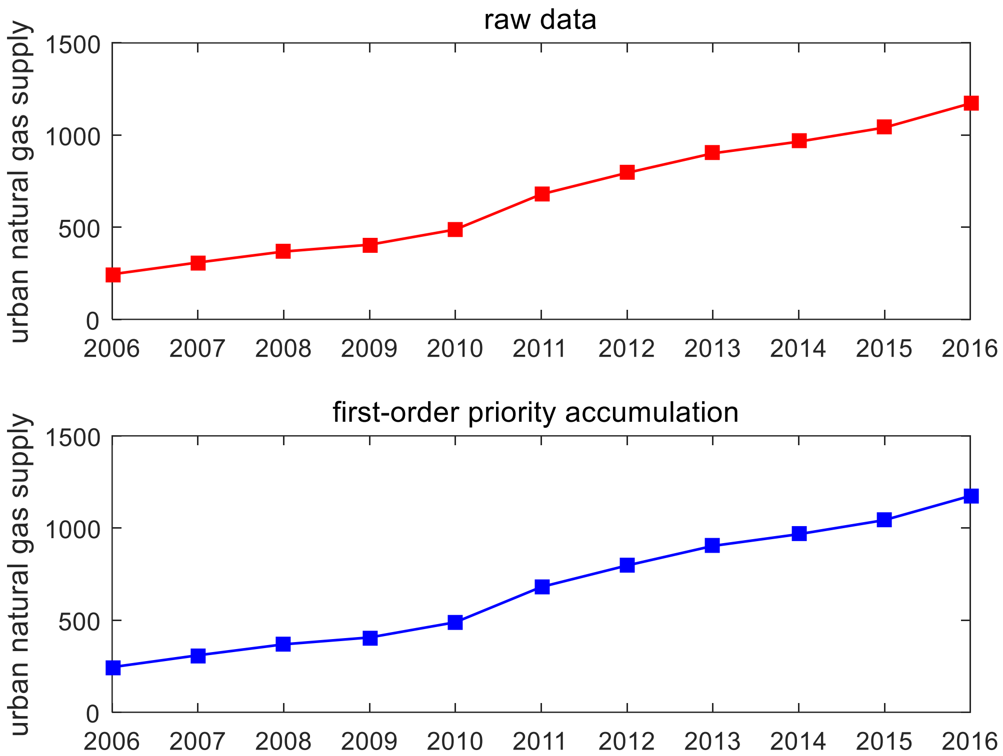

Figure 1. Comparison between raw data and first-order priority accumulation

$Z^{(1)}$=(276.98, 338.96, 387.33, 447.20, 584.19, 738.22, 849.66, 934.58, 1004.67, 1108.50).

Then, according to *Theorem 2*, B and Y could be computed as following

$$B=\begin{pmatrix} -276.98 & 2.22 & 1 \\ -338.96 & 6.31 & 1 \\ -387.33 & 17.24 & 1 \\ -447.20 & 46.90 & 1 \\ -584.19 & 127.50 & 1 \\ -738.22 & 346.60 & 1 \\ -849.66 & 942.16 & 1 \\ -934.58 & 2561.06 & 1 \\ -1004.67 & 6961.69 & 1 \\ -1108.50 & 18923.84 & 1 \end{pmatrix},\ Y=\begin{pmatrix} 63.87 \\ 59.40 \\ 37.06 \\ 82.48 \\ 191.22 \\ 116.24 \\ 105.95 \\ 63.39 \\ 76.41 \\ 130.93 \end{pmatrix}.$$

Further, the value of the parameter a, b, c can be calculated by the formula

$$(a,b,c)^T=\left(B^TB\right)^{-1}\left(B^TY\right)$$

where

$$\begin{pmatrix} a \\ b \\ c \end{pmatrix}=\begin{pmatrix} -0.0481 \\ 3.2324 \\ 60.5031 \end{pmatrix}.$$

Table 2. Comparison of the four model expressions

GM (1,1)	$\frac{dx^{(1)}(t)}{dt}$-0.1379$x^{(1)}(t)=302.0795$
DGM (1,1)	$x^{(1)}(k)=(1.1481)^{k-1}x^{(0)}(1)+48.05061\left[1-(1.1481)^{k-1}\right]$
NGM (1,1,*k*)	$\frac{dx^{(1)}(t)}{dt}+\ 0.0214x^{(1)}(t)=118.7708t$
NGM (1,1,*k*,*c*)	$\frac{dx^{(1)}(t)}{dt}-$-0.0182$x^{(1)}(t)=87.8866t+86.7243$

Then the expression of the NISinHGM (1,1) is built

$$\frac{dx^{(1)}(t)}{dt}-0.0481x^{(1)}(t)=3.2324\sinh t+60.5031. \tag{21}$$

In the same way, we can compute the expressions for the other models where the expressions are concluded in the following Table 2. The entire modeling process of this application is provided in the following flowchart (see Figure 2). The results, along with the forecasting errors, obtained by the five models are shown in Tables 3, 4 and 5, and Figures 3, 4 and 5, respectively.

Later, the urban supply of natural gas is predicted by five models, which are the GM (1,1) model, the DGM (1,1) model, the NGM (1,1,*k*) model, the NGM (1,1,*k*,*c*) model, and the NISinHGM (1,1) model. According to Figure 3, we see that the NISinHGM (1,1) model predicts China's urban natural gas supply from 2006 to 2019, which most closely matches the image of the raw data. From the tables, it is clear that the forecast error of the new grey model NISinHGM (1,1) is lower than the other four models. The simulation errors and forecast errors of NISinHGM (1,1) only are 6.34% and 2.10%, respectively. But the other four models' errors are a little high, especially the simulation error of NGM (1,1,*k*) model is 11.32%, and the forecast error of DGM (1,1) model is 15.09% as high as possible. The GM (1,1) forecast error is also a little high, which is 14.62%. The tables and the figures confirm that the new grey model NISinHGM (1,1) forecasting urban natural gas is more accurate than other grey models. Then after verifying the accuracy, we use the grey model to forecast urban natural gas supply in the next several years from 2020 to 2023, and the detailed forecast data is listed in Table 5.

According to the prediction data for 2020 to 2023, the urban natural gas supply is increasing year by year. As we know, natural gas produces less pollution and is economical energy; thus, an increase in its demand is very likely. Also, the natural gas is delivered to some distant mountains, showing its outreach and exceeding demand in the population as remote as possible. Thus, the prediction of increasing urban natural gas supply is logical. It is argued that the increase in the urban natural gas supply is due to a significant increase in natural gas consumption in the power generation, residential, transportation, and chemical industries. To meet the demand for natural gas in various fields, the governments and policy-decision makers should try to produce natural gas, and increase the natural gas supply to the city as much as possible.

5. Conclusion

The study proposes a new grey forecasting model NISinHGM (1,1) to forecast the urban natural gas supply. A new information priority accumulation method has been integrated into the grey model with hyperbolic sine driving term. Firstly, we use the Whale Optimization Algorithm to search for an important parameter generated in the new information priority accumulation method. Then we make use of grey prediction theory and ordinary differential equation theory to determine the model. In the end, we verify the validity of the proposed grey model by forecasting urban natural gas supply. Comparative analysis with four models revealed the superiority of the proposed model, which revealed better forecast accuracy.

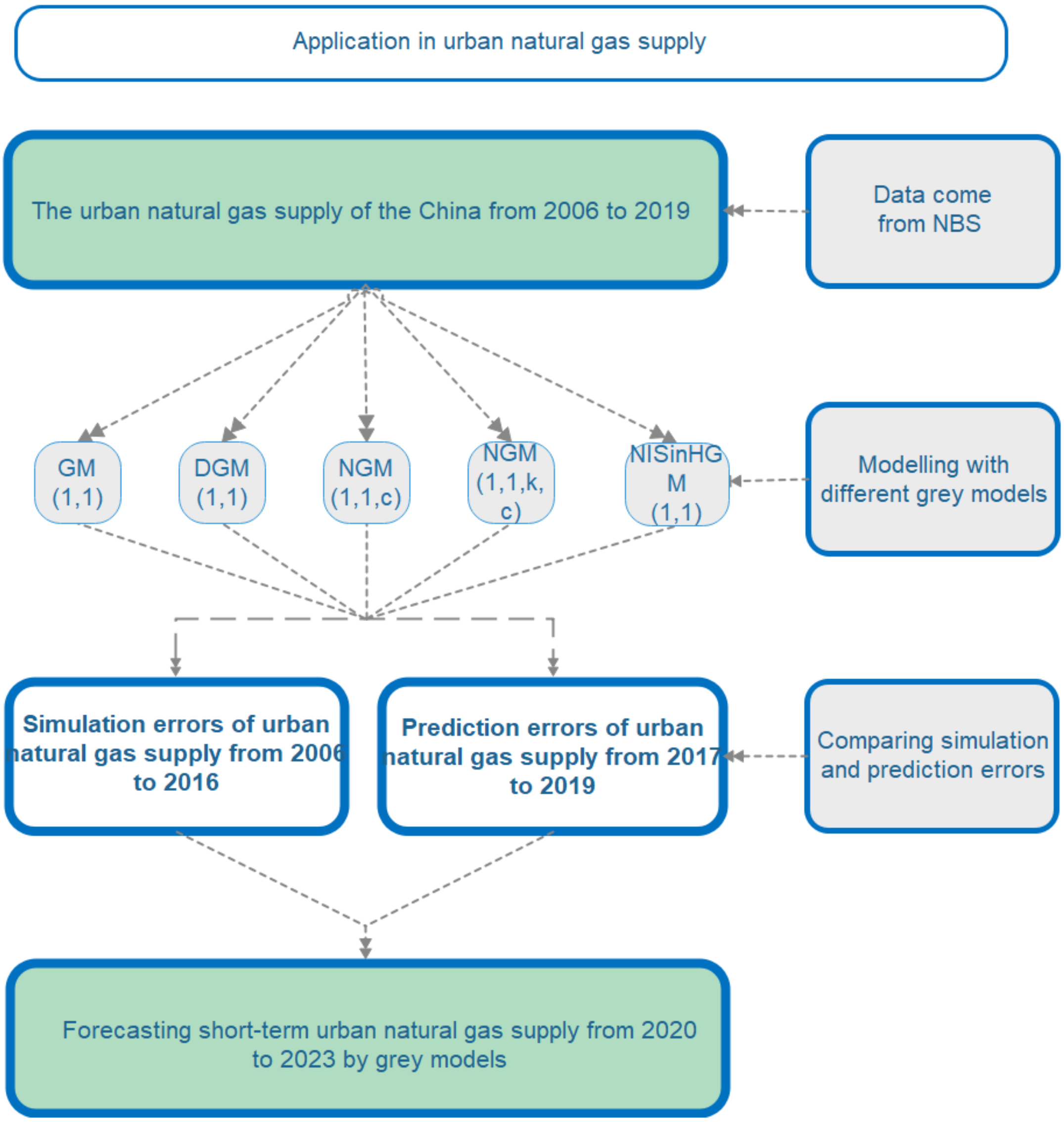

Figure 2. The flowchart of the modeling process

Table 3. The calculation results of urban natural gas supply

Year	Raw data	GM (1,1)	DGM (1,1)	NGM (1,1,*k*)	NGM (1,1,*k*,*c*)	NISinHGM (1,1)
2006	244.77	244.77	244.77	244.77	244.77	244.77
2007	308.64	360.08	360.69	171.30	224.92	318.27
2008	368.04	413.32	414.11	285.20	317.74	395.80
2009	405.10	474.42	475.43	396.68	412.26	477.16
2010	487.58	544.56	545.84	505.81	508.53	562.53
2011	678.80	625.06	626.67	612.63	606.56	652.10
2012	795.04	717.47	719.48	717.20	706.39	746.10
2013	900.99	823.54	826.02	819.56	808.05	844.75
2014	964.38	945.29	948.35	919.75	911.59	948.32
2015	1040.79	1085.04	1088.79	1017.83	1017.02	1057.14
2016	1171.72	1245.44	1250.02	1113.83	1124.39	1171.72
2017	1263.75	1429.57	1435.14	1207.80	1233.73	1293.02
2018	1443.95	1640.91	1647.67	1299.79	1345.08	1423.21
2019	1608.56	1883.50	1891.67	1389.84	1458.47	1567.73

Table 4. Calculation errors under different models

Year	GM (1,1)	DGM (1,1)	NGM (1,1,*k*)	NGM (1,1,*k*,*c*)	NISinHGM (1,1)
2006	0.00	0.00	0.00	0.00	0.00
2007	16.67	16.87	44.50	27.13	3.12
2008	12.30	12.52	22.51	13.67	7.54
2009	17.11	17.36	2.08	1.77	17.79
2010	11.69	11.95	3.74	4.30	15.37
2011	7.92	7.68	9.75	10.64	3.93
2012	9.76	9.50	9.79	11.15	6.16
2013	8.60	8.32	9.04	10.31	6.24
2014	1.98	1.66	4.63	5.47	1.66
2015	4.25	4.61	2.21	2.28	1.57
2016	6.29	6.68	4.94	4.04	0.00
2017	13.12	13.56	4.43	2.38	2.32
2018	13.64	14.11	9.98	6.85	1.44
2019	17.09	17.60	13.60	9.33	2.54
MAPEsimu	9.66	9.72	11.32	9.08	6.34
MAPEfore	14.62	15.09	9.34	6.18	2.10
MAPEtotal	10.80	10.96	10.86	8.41	5.36

Table 5. Comparison of five model predictions

Year	GM (1,1)	DGM (1,1)	NGM (1,1,*k*)	NGM (1,1,*k*,*c*)	NISinHGM (1,1)
2020	2161.95	2171.80	1477.98	1573.95	1740.90
2021	2481.56	2493.42	1564.26	1691.55	1981.12
2022	2848.43	2862.67	1648.72	1811.31	2392.22
2023	3269.54	3286.60	1731.39	1933.26	3255.91

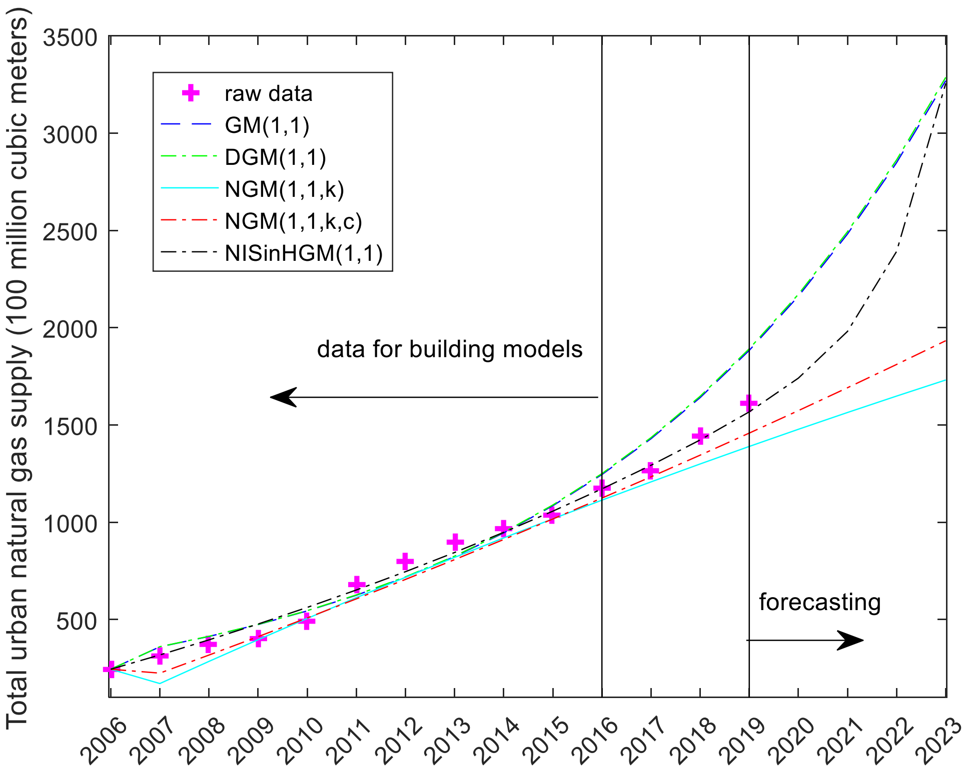

Figure 3. Five models' calculation results of urban natural gas supply

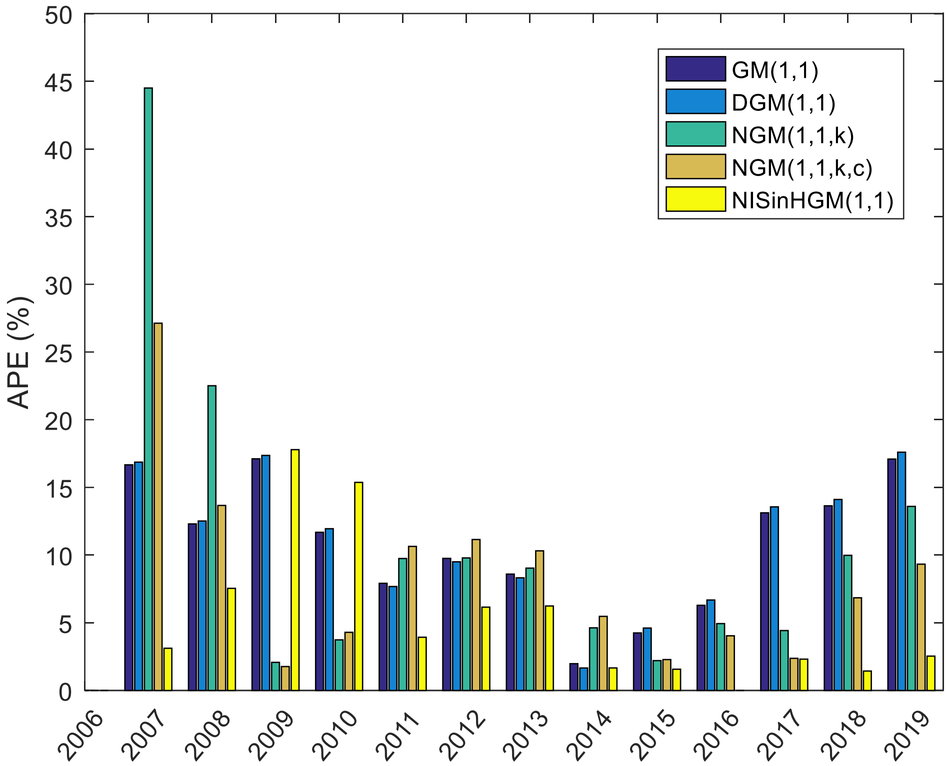

Figure 4. Absolute Percentage Error graphs under five models

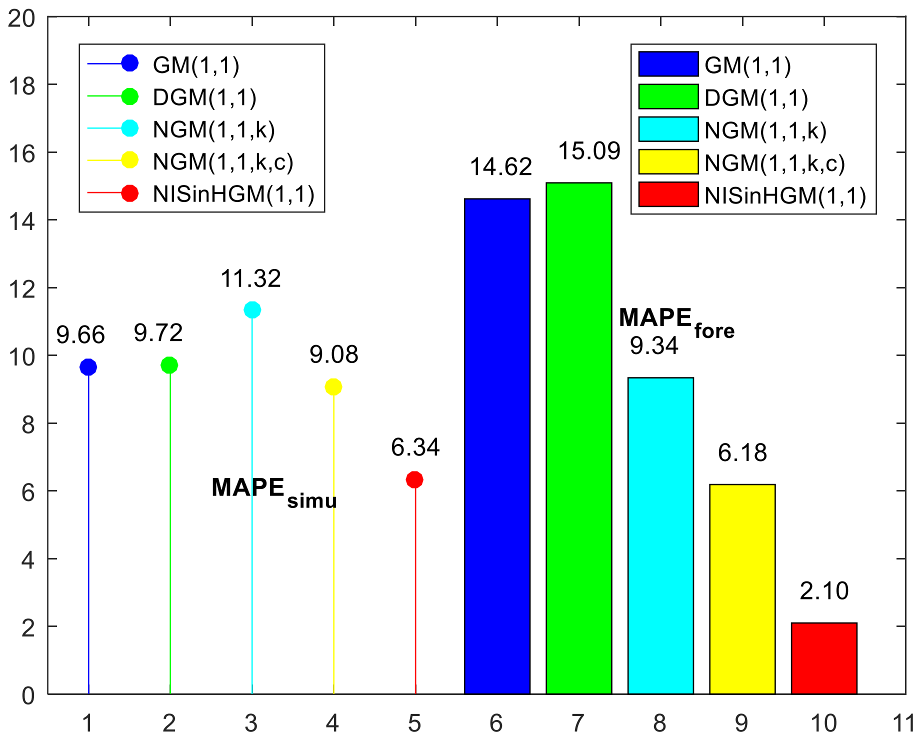

Figure 5. Comparison of Mean Absolute Percentage Errors of five forecasting models

The current study demonstrates that moderate improvement in the grey model is possible with the aid of the new information priority methods, and the resultant model can outperform the original model in terms of accuracy. Combining the new information priority accumulation method into the grey model is a good way to improve the accuracy and increase its range of applicability. In the future, some other multivariate forecasting models with new information priority accumulation will be considered.

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Taguchi Grey Relational Optimization of the Multi-mechanical Characteristics of Kaolin Reinforced Hydroxyapatite: Effect of Fabrication Parameters

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Abstract: Comparative study of kaolin reinforced hydroxyapatite (KHAp) and pure HAp using different production parameters has been done through traditional experimentation. However, the quantitative effect, optimization of kaolin reinforcement and fabrication parameters have not been investigated. Hence, this study examines the effect of kaolin reinforcement, compaction pressure and sintering temperature on the experimental mechanical properties of HAp. Taguchi design assisted by grey relational analysis was employed with L36 (2**2 3**1) orthogonal array. The Minitab 16 software was used to analyze the Taguchi design. The result showed a disparity in kaolin reinforcement as the optimum condition for individual mechanical properties, but the grey relational analysis showed better mechanical properties with kaolin reinforcement, 500 Pa compaction pressure and 1100 ^{o}C sintering temperature. The obtained result further revealed kaolin reinforcement as a strong and promising reinforcing material for high strength clinical application, having a contribution of 93.16% on compressive strength of HAp. Therefore, future studies can be conducted in the use of different wt% of kaolin on the multi-response mechanical characteristics of HAp.

Keywords: Grey relational analysis; optimization; hydroxyapatite; kaolin; production parameters; mechanical properties

1. Introduction

Hydroxyapatite (HAp) with the chemical formula of Ca10(PO4)6(OH)2 is a calcium phosphate based bio-ceramic because it forms a mechanically strong bond to bone and typically no fibrous particles are found inherent on the implants' surface. These attractive properties make HAp a good material in clinical applications such as bio-medical implants and substitutes for the repair of damaged bones (Caliman *et al.*, 2017; Adeogun *et al.*, 2018). The constant use of HAp is due to its unique chemical composition, in addition to its biological and crystallographic similarity with the mineral portion of hard tissues, for instance, bones and teeth. HAp has received attention as a good candidate for biomedical application, due to its excellent biocompatibility and high rate of cell proliferation. Because of its poor mechanical strength, extensive research has been geared towards the improvement of HAp mechanical properties. The use of foreign material as a reinforcing agent has been reported in the literature (Santos *et al.*, 1994; Lahiri *et al.*, 2012; Zhao *et al.*, 2018; Singh *et al.*, 2020; Singh *et al.*, 2021). Reinforcement is an action or process of reinforcing or strengthening a weak material.

Taguchi design of the experiment is a method of mitigating laboratory robustness and also a way of optimizing design parameters or process parameters of singular response of a product or system. The design was named after the Japanese quality guru Genichi Taguchi who invented it (Taguchi & Phadke, 1989; Taguchi, 1993; Taguchi *et al.*, 2005). While Grey Relational Analysis (GRA) is employed when there is a need to optimize design parameters for multiple response characteristics. It is also used when a process or design is uncertain or complicated (Julong, 1989; Javed, 2019). This study employed Taguchi design assisted by the GRA to mitigate the indecision on the best combination of fabrication parameters for better mechanical integrity of HAp. Taguchi-grey relational analysis has been usedare as follows: Sylajakumari *et al.* (2018) optimized production parameters on the multi-wear responses of a co-continuous composite with the help of Taguchi-grey relational analysis. Bademlioglu *et al.* (2020) employed Taguchi grey relational analysis to investigate and to optimize the working parameters affecting the multiple performance characteristics of an organic Rankine cycles. Almetwally (2020) carried out multi-objective optimization of woven fabric parameters using Taguchi-grey relational analysis.

In light of the synthesis and mechanical improvement of hydroxyapatite, Abifarin *et al.* (2019) synthesized and characterized pure HAp for biomedical application. The mechanical properties of the synthesized HAp were further worked upon by Obada *et al.* (2020) and Obada *et al.* (2021) using 15 wt% kaolin and different sintering parameters. Recently, Abifarin (2021) employed Taguchi grey relational analysis to determine and to optimize quantitatively the effect of sintering parameters on pure HAp. Kaolin was employed as a reinforcement in the bulk HAp because it is a silica based materials with excellent biocompatibility (Obada *et al.*, 2021). The reinforcement of HAp with kaolin in this study is referred to as kaolin reinforced HAp. Having reported traditional experimentation of 15 wt% kaolin reinforcement and the effect of compaction pressure and sintering temperature on the mechanical properties of HAp, it is expedient to examine the quantitative effect and the optimization of fabrication parameters of kaolin reinforced HAp. Hence, this study employed Taguchi grey relational analysis as the statistical tool to investigate the optimum production parameters and its quantitative effect on the mechanical properties of HAp. Table 1 describes the employed based materials and its fabrication parameters.

Table 1. Definitions of base materials and fabrication parameters

Variable	Definition	Reference
Hydroxyapatite	Hydroxyapatite is a calcium phosphate based ceramic, having chemical formula of $Ca_{10}(PO_4)_6(OH)_2$	Posner *et al.* (1958); Orlovskii *et al.* (2002)
Kaolin	Kaolin is a silica based material with a chemical formula of Al_2O_3 $2SiO_2$	Murray (1980); Chen *et al.* (1997); Schroeder and Erickson (2014)
Reinforcement	Reinforcement is an action or process of reinforcing or strengthening a weaker material.	Seward (1956); Byrne and Clore (1970)
Kaolin reinforced hydroxyapatite	Kaolin reinforced hydroxyapatite is a composite showing hydroxyapatite as the main matrix, strengthened by kaolin	The present work
Sintering temperature	It is the annealing temperature at which material mechanical and microstructural properties are improved	Kuang *et al.* (1997); Abifarin (2021)
Compaction pressure	It is the pressure at which a material scaffold is formed or made	German (2010); Abifarin (2021)

2. Materials and Method

HAp/KHAp synthesis, characterization and mechanical properties evaluation have been reported in the previous study (Obada *et al*., 2021). This study employed statistical Taguchi grey relational analysis to examine the quantitative effect of kaolin reinforcement and production parameters (compaction pressure and sintering temperature) on the reported experimental hardness and compressive strength. Figure 1 shows the overall experimental procedure on how the mechanical properties were obtained in the study of Obada *et al.* (2021).

2.1 Taguchi experimental design

The factors and their respective levels were employed based on the design consideration based on the previous study (Obada *et al*., 2021), and was formulated using Taguchi design strategy as shown in Table 2. The suitable orthogonal array employed according to Minitab 16 software was L36 (2**2 3**1), and it is displayed in Table 3. The corresponding experimental hardness, compressive strength and resultant grey relational grade were analyzed using Taguchi on Minitab. The steps for generating the resultant grey relational grade for the experimental mechanical properties are shown in section 2.2, and are similar to the work of Abifarin (2021) and Awodi *et al.* (2021). All the plotted graphs were obtained using Minitab. Figure 2 shows the overview of Taguchi-grey relational optimization analysis.

2.2 Grey relational analysis

Integration of GRA into the Taguchi method can improve the performance of Taguchi method for optimization (Chang *et al*., 2000). As it is impossible to directly average experimental hardness and compressive strength, grey relational analysis was employed to address the impossibility (Julong, 1989; Javed *et al*., 2019). First, hardness and compressive strength values were converted to grey relational generation (normalizing the sequence) using the larger-the-better consideration as shown in Equation 1. The larger-the-better was employed because high hardness and compressive strength is desired. After sequence normalization, deviation sequence of the reference sequence was computed using Equation 2. Next, grey relational coefficient was generated using Equation 3, and thereafter the resultant hardness and compressive strength grey relational coefficients were average to have grey relational grade (GRG) using Equation 4.

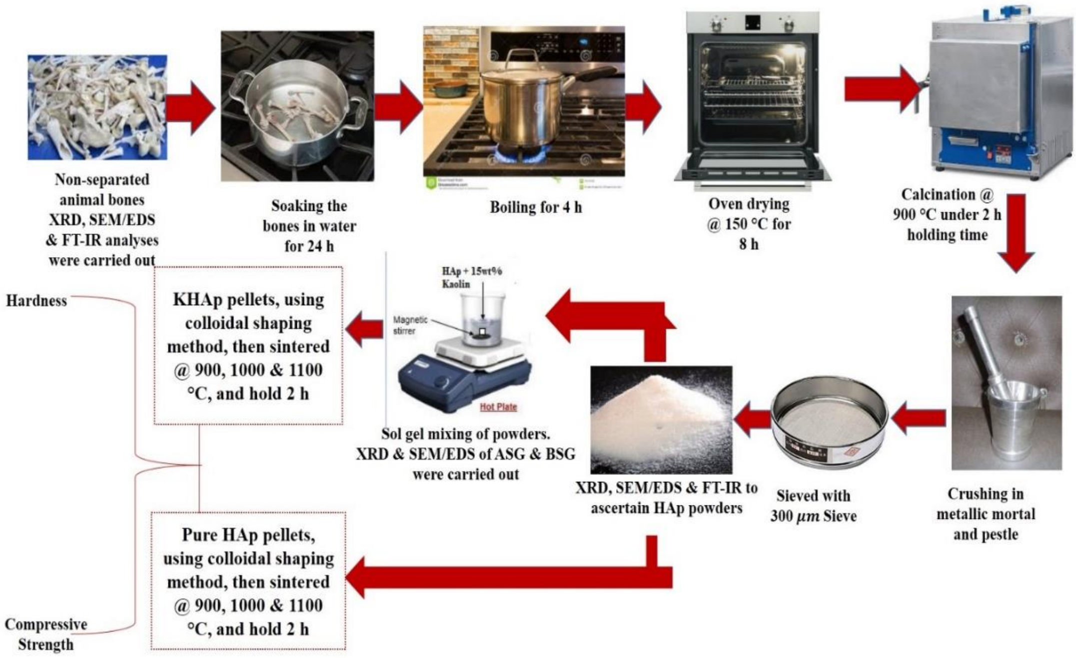

Figure 1. Mechanical synthesis of pure and kaolin reinforced hydroxyapatite

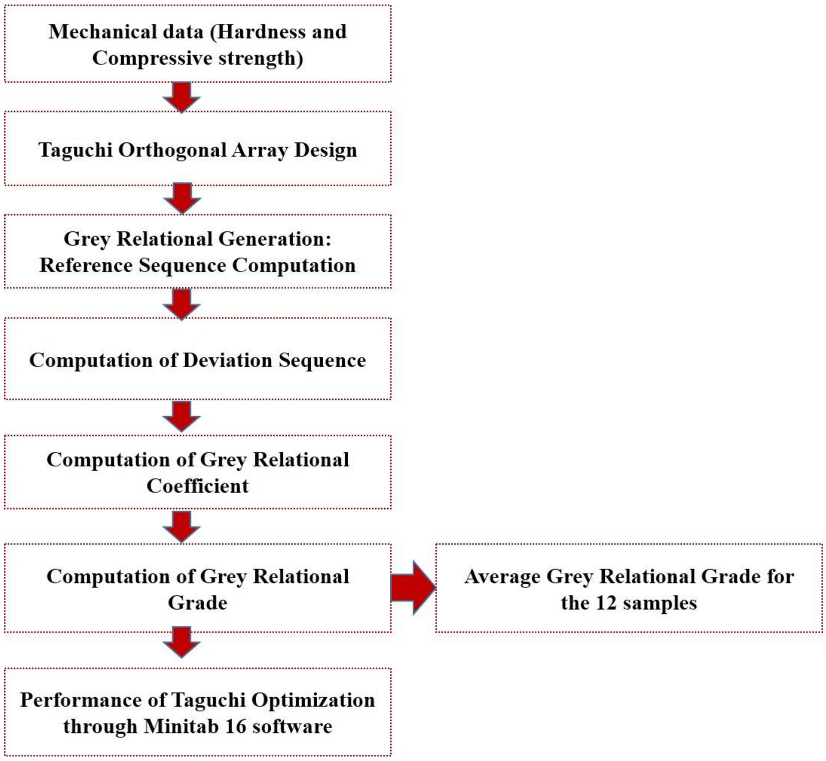

Figure 2. Taguchi-grey relational optimization analysis

$$x_i(k) = \frac{y_i(k) - \min y_i(k)}{max\, y_i(k) - \min y_i(k)} \tag{1}$$

Note that $x_i(k)$ is the normalized data for the *i*th experiment, and $y_i(k)$ denotes the initial sequence of the mean of the responses

$$\Delta_{0i}(k) = |x_0(k) - x_i(k)| \tag{2}$$

Here, $\Delta_{0i}(k)$, $x_0(k)$, and $x_i(k)$ are the deviation, reference and comparability sequences respectively.

$$\xi_i(k) = \frac{\Delta_{min} + \zeta\Delta_{max}}{\Delta_{0i}(k) + \zeta\Delta_{max}}, \zeta \in (0,1) \tag{3}$$

where $\xi_i(k)$ symbolizes GRC of individual response variables calculated as a function of Δ_{min} and Δ_{max}, the minimum and maximum deviations of each response variable. ζ is the distinguishing coefficient (Mahmoudi *et al.*, 2020) whose value was considered 0.5 in the current study.

$$\gamma_i = \frac{1}{n}\sum_{i=1}^{n} \xi_i(k) \tag{4}$$

where γ_i is the GRG determined for the *i*th experiment, *n* is the aggregate count of the performance characteristics. Since the Taguchi orthogonal array design displayed three replications for the experimental run, the average grey relational grade (AGRG) for each treatment (sample) was computed afterwards.

Table 2. Factors and their levels

Fabrication parameter	Wt% kaolin	Compaction pressure(Pa)	Sintering temperature (°C)
Level 1	0	0	900
Level 2	15	500	1000
Level 3	-	-	1100

Table 3. Taguchi experimental design strategy

Experimental no.	Wt% kaolin	Compaction pressure (Pa)	Sintering temperature (°C)
1	0	0	900
2	0	0	1000
3	0	0	1100
4	0	0	900
5	0	0	1000
6	0	0	1100
7	0	0	900
8	0	0	1000
9	0	0	1100
10	0	500	900
11	0	500	1000
12	0	500	1100
13	0	500	900
14	0	500	1000
15	0	500	1100
16	0	500	900
17	0	500	1000
18	0	500	1100
19	15	0	900
20	15	0	1000
21	15	0	1100
22	15	0	900
23	15	0	1000
24	15	0	1100
25	15	0	900
26	15	0	1000
27	15	0	1100
28	15	500	900
29	15	500	1000
30	15	500	1100
31	15	500	900
32	15	500	1000
33	15	500	1100
34	15	500	900
35	15	500	1000
36	15	500	1100

3. Results and discussion

3.1 Effect of kaolin and production parameters on hardness

Figure 3 shows effect of kaolin, compaction pressure and sintering temperature on HAp hardness value. The result revealed that 15 wt% of kaolin dropped HAp hardness value, but 500 Pa compaction pressure had a little increasing effect on the hardness value. However, increase in sintering temperature had a significant increasing effect on HAp hardness value. Hence, the optimal factors levels for better hardness are HAp without kaolin reinforcement, 500 Pa compaction pressure and 1100 °C sintering temperature.

3.2 Quantitative effect of reinforcement and production parameters on HAp hardness

Statistical ANOVA data of the Taguchi result is highlighted in Table 4. As effect of the considered factors has been discussed in section 3.1, it is important to have their quantitative effect which is displayed in Table 3. The result revealed that when kaolin reinforcement was not employed, there was a significant contribution of 46.04%. The sintering temperature factor shows the most significant contribution of 50.76% on HAp hardness value. Even though, 500 Pa

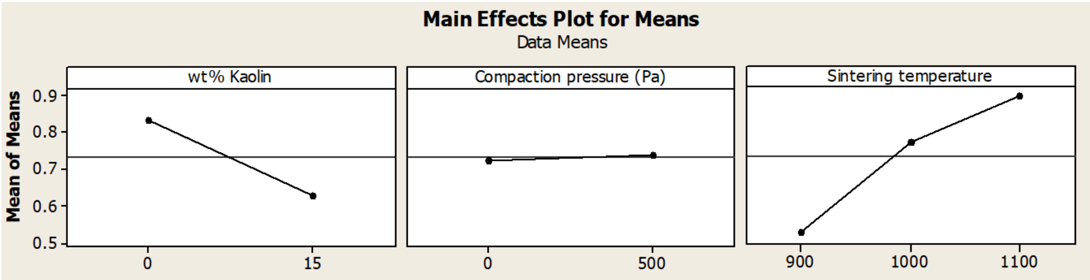

Figure 3. Effect of factors on hardness

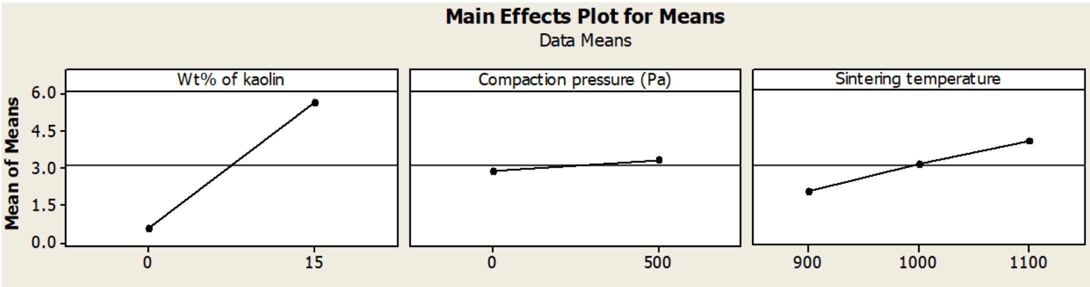

Figure 4. Effect of factors on compressive strength

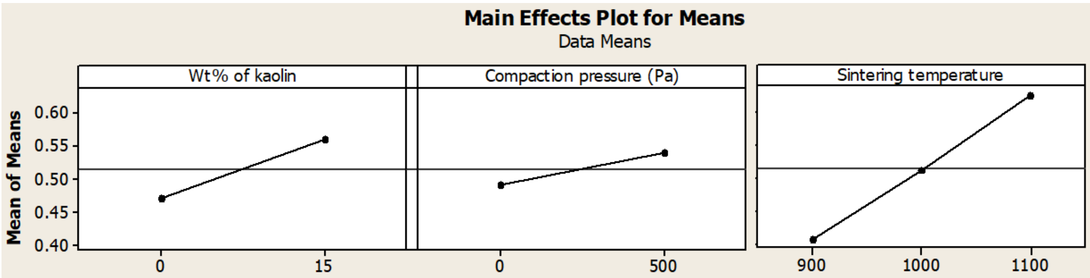

Figure 5. Effect of factors on grey relational grade

compaction pressure had a little increasing effect, its contribution (0.24%) and the contribution of residual error (2.96%) on HAp hardness are insignificant.

3.3 Effect of kaolin and production parameters on compressive strength

It is important to note from the compressive strength result revealed in Figure 4 was significantly increased with inclusion of kaolin. The reason for the increment has been discussed in the previous study (Obada *et al.*, 2021). Equally, this result showed that the two production parameters considered in this study had an increasing effect on the compressive strength of HAp. Meaning, the optimal factors are 15 wt% of kaolin reinforcement, 500 Pa compaction pressure and 1100 ^{o}C sintering temperature.

Table 4. ANOVA for HAp hardness value

Fabrication parameter	DOF	Adj SS	Adj MS	F	Contribution %	Remark
Wt% of kaolin	1	0.128133	0.128133	15.54	46.04	Significant
Compaction pressure	1	0.000655	0.000655	0.08	0.24	Insignificant
Sintering temperature	2	0.282524	0.141262	17.13	50.76	Significant
Residual error	7	0.057720	0.008246		2.96	Insignificant
Total	11		0.278296	S = 0.09081	R^2 = 87.7%	R^2_{Adj} = 80.7%

3.4 Quantitative effect of reinforcement and production parameters on HAp compressive strength

The quantitative effect of addition of kaolin and production parameters are shown in Table 5. Interestingly, other factors did not have much significance on HAp compressive strength except kaolin reinforcement having contribution of 93.16%. Meaning, without the consideration of the production parameters, kaolin reinforcement has a robust increasing effect on the compressive strength of HAp.

3.5 Grey relational evaluation

It is essential to optimize input processing parameters of HAp for its multiple mechanical properties. Grey relational analysis gives conclusive input parameters for high strength HAp. Table 6 and Table 7 highlight the analysis of grey relational grade, while Figure 5 and Table 5 show the effect of kaolin reinforcement, compaction pressure and sintering temperature on the multi-response grey relational grade. It is important to note that, for the multi-response mechanical properties, kaolin reinforcement had an increasing effect on the mechanical properties. Also, compaction pressure, 500 Pa shows a higher increasing effect compared with the individual hardness and compressive strength properties. As the sintering temperature increased, the multi-response mechanical properties increased as it is on individual hardness and compressive strength. Hence, it can be conclusively said that, kaolin reinforcement had a positive impact on the overall mechanical properties of HAp, and the optimal conditions for high strength of HAp are 15 wt% kaolin reinforcement, 500 Pa compaction pressure and 1100 ^{o}C sintering temperature.

Table 7 and Figure 6 show the grey relational grade (GRG) result. The graph in Figure 6 displays experimental number 30, 33, and 36 as the highest GRG, which is also depicted in Table 8. Since the experimental numbers displaying the highest GRG, it was then average to have the mean value of GRG, which gave 0.7445 as the experimental optimum GRG value.

Table 5. ANOVA for HAp Compressive strength

Fabrication parameters	DOF	Adj SS	Adj MS	F	Contribution %	Remark
Wt% of kaolin	1	77.335	77.335	85.92	93.16	Significant
Compaction pressure	1	0.6832	0.6832	0.76	0.82	Insignificant
Sintering temperature	2	8.1961	4.0980	4.55	4.94	Insignificant
Residual error	7	6.3007	0.9001		1.08	Insignificant
Total	11		83.016	S = 0.949	R^2 = 93.2%	R^2_{Adj} = 89.3%

Table 6. Response mean for GRG

Level	Wt% of kaolin	Compaction pressure	Sintering temperature
1	0.4704	0.4911	0.4075
2	0.5585	0.5378	0.5111
3	-	-	0.6248
Delta	0.0882	0.0467	0.2173
Rank	2	3	1
Note: Total mean of GRG: 0.515			

3.6 Quantitative effect of reinforcement and production parameters on HAp GRG

As the qualitative effect has been revealed above, Table 9 reveals the quantitative effect of the controlling factors on GRG values. The result revealed sintering temperature as the most significant production factor having a contribution of 60.21%, followed by kaolin reinforcement with a contribution of 29.72%, and compaction pressure with a contribution of 8.32%. Importantly, the result revealed that the residual error was insignificant on the HAp GRG.

3.7 Confirmation analysis

3.7.1 Confidence interval analysis: After determining the optimal fabrication parameters, its predicted grey relational grade was computed as 0.6911 using Table 5 and Equation 5 (Ross, 1996; Abifarin, 2021; Abifarin *et al.*, 2021).

$$\gamma_{predicted} = \gamma_m + \sum_{i=1}^{q} \gamma_0 - \gamma_m \quad (5)$$

γ_0 highlights the highest GRG response under each fabrication parameter, while γ_m is the total average GRG value. q is the number of fabrication parameters.

To investigate the authenticity of the predicted response and experimental response, confidence interval (CI) was calculated using Equation 6 (Taguchi & Phadke, 1989; Abifarin, 2021; Awodi *et al.*, 2021):

Table 7. Reference and deviation sequence after pre-processing of data

Experiment run	Reference Sequence x_i^*		Deviation Sequence Δ_{0i}	
	HV	CS	HV	CS
1	0.269663	0.00515	0.73034	0.99485
2	0.603371	0.03995	0.39663	0.96005
3	0.730337	0.06443	0.26966	0.93557
4	0.247191	0.01418	0.75281	0.98582
5	0.775281	0.02706	0.22472	0.97294
6	0.689888	0.06959	0.31011	0.93041
7	0.325843	0.01933	0.67416	0.98067
8	0.469663	0.0451	0.53034	0.9549
9	0.77191	0.07861	0.22809	0.92139
10	0.424719	0	0.57528	1
11	0.755056	0.02062	0.24494	0.97938
12	1	0.05284	0	0.94716
13	0.451685	0.01418	0.54831	0.98582
14	0.746067	0.03995	0.25393	0.96005
15	0.88764	0.0451	0.11236	0.9549
16	0.358427	0.00515	0.64157	0.99485
17	0.651685	0.02062	0.34831	0.97938
18	0.853933	0.0567	0.14607	0.9433
19	0.258427	0.37887	0.74157	0.62113
20	0.541573	0.5683	0.45843	0.4317
21	0.396629	0.82603	0.60337	0.17397
22	0.348315	0.38144	0.65169	0.61856
23	0.477528	0.67139	0.52247	0.32861
24	0.5	0.9317	0.5	0.0683
25	0.255056	0.34536	0.74494	0.65464
26	0.460674	0.65851	0.53933	0.34149
27	0.651685	0.82861	0.34831	0.17139
28	0.105618	0.54768	0.89438	0.45232
29	0.364045	0.86856	0.63596	0.13144
30	0.606742	0.9317	0.39326	0.0683
31	0	0.47552	1	0.52448
32	0.320225	0.71005	0.67978	0.28995
33	0.503371	0.9884	0.49663	0.0116
34	0.149438	0.55799	0.85056	0.44201
35	0.304494	0.72552	0.69551	0.27448
36	0.588764	1	0.41124	0

$$CI = \sqrt{F_\alpha(1, f_e)V_e\left[\frac{1}{\eta_{eff}} + \frac{1}{R}\right]} \quad (6)$$

$F_\alpha(1, f_e)$ is the required F ratio for risk, α; f_e is the degree of freedom (DOF) of error; V_e is variance of error; η_{eff} is effective number of replications. If *R* represents the number of experimental repetitions when the investigation is done for affirmation and *N* represents all the experiments carried out then η_{eff} is given by:

$$\eta_{eff} = \frac{N}{1 + (total\ DOF\ of\ control\ factors)} \quad (7)$$

Therefore, if V_e= 0.001372; f_e= 7; DOF of all the control factors is 4; *R* is 1; *N* is 36; α= 0.5 under 95% confidence interval (CI), then $F_{0.5}(1,7) = 5.59$ based on the F-statistical table. Consequently, $\eta_{eff} = \frac{36}{1+4} = 7.2$ and $CI = \sqrt{5.59 \times 0.001372\left[\frac{1}{7.2} + \frac{1}{1}\right]} = \pm 0.0935$. 95% of confidence interval for the optimal grey relational grade predicted is given in Equation 8 (Abifarin, 2021),

Table 8. Rank of grey relational coefficient (GRC) and grey relational grade (GRG)

Experiment run	Grey relational coefficient, $\varepsilon_i(k)$		GRG γ_i
	HV	CS	
1	0.40639	0.33448	0.37044
2	0.55764	0.34245	0.45005
3	0.64964	0.34829	0.49896
4	0.3991	0.33651	0.36781
5	0.68992	0.33946	0.51469
6	0.6172	0.34955	0.48337
7	0.42584	0.33768	0.38176
8	0.48528	0.34367	0.41447
9	0.68673	0.35177	0.51925
10	0.46499	0.33333	0.39916
11	0.67119	0.33798	0.50459
12	1	0.3455	0.67275
13	0.47696	0.33651	0.40673
14	0.66319	0.34245	0.50282
15	0.81651	0.34367	0.58009
16	0.43799	0.33448	0.38624
17	0.5894	0.33798	0.46369
18	0.77391	0.34643	0.56017
19	0.40271	0.44598	0.42435
20	0.52169	0.53665	0.52917
21	0.45316	0.74187	0.59752
22	0.43415	0.447	0.44058
23	0.48901	0.60342	0.54622
24	0.5	0.87982	0.68991
25	0.40162	0.43304	0.41733
26	0.48108	0.59418	0.53763
27	0.5894	0.74472	0.66706
28	0.35858	0.52503	0.44181
29	0.44016	0.79184	0.616
30	0.55975	0.87982	0.71978
31	0.33333	0.48805	0.41069
32	0.42381	0.63295	0.52838
33	0.50169	0.97733	0.73951
34	0.37022	0.53078	0.4505
35	0.41823	0.64559	0.53191
36	0.54871	1	0.77435

Table 9. Grey relational grade (GRG), and average grey relational grade (AGRG)

Sample	Experiment run	GRG	AGRG	Sample	Experiment run	GRG	AGRG
Sample 1	1	0.370	0.373	Sample 7	19	0.424	0.427
	4	0.368			22	0.441	
	7	0.382			25	0.417	
Sample 2	2	0.450	0.460	Sample 8	20	0.529	0.538
	5	0.515			23	0.546	
	8	0.414			26	0.538	
Sample 3	3	0.499	0.501	Sample 9	21	0.598	0.652
	6	0.483			24	0.690	
	9	0.519			27	0.667	
Sample 4	10	0.399	0.397	Sample 10	28	0.442	0.434
	13	0.407			31	0.411	
	16	0.386			34	0.451	
Sample 5	11	0.505	0.490	Sample 11	29	0.616	0.559
	14	0.503			32	0.528	
	17	0.464			35	0.532	
Sample 6	12	0.673	0.604	Sample 12	30	0.720	0.745
	15	0.580			33	0.740	
	18	0.560			36	0.774	

Table 10. ANOVA for HAp GRG

Fabrication parameter	DOF	Adj SS	Adj MS	F	Contribution %	Remark
Wt% of kaolin	1	0.023324	0.023324	17.00	29.72	Significant
Compaction pressure	1	0.006530	0.006530	4.76	8.32	Significant
Sintering temperature	2	0.094503	0.047252	34.43	60.21	Significant
Residual error	7	0.009607	0.001372		1.75	Insignificant
Total	11		0.078478	S = 0.03705	R^2 = 92.8%	R^2_{Adj} = 88.7%

$$\gamma_{predicted} - CI < \gamma_{experimental} < \gamma_{predicted} + CI \quad (8)$$

$$0.5976 < \gamma_{experimental} < 0.7846 \quad (9)$$

The CI findings showed that the experimental GRG value of 0.6911 correlates with the predicted optimal GRG value. This affirms the efficacy of the optimal fabrication parameters on the multi-mechanical characteristics of kaolin reinforced hydroxyapatite.

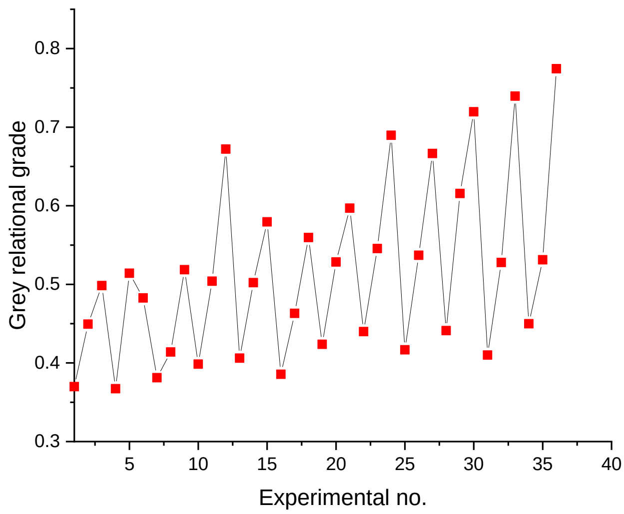

Figure 6. Grey relational grades

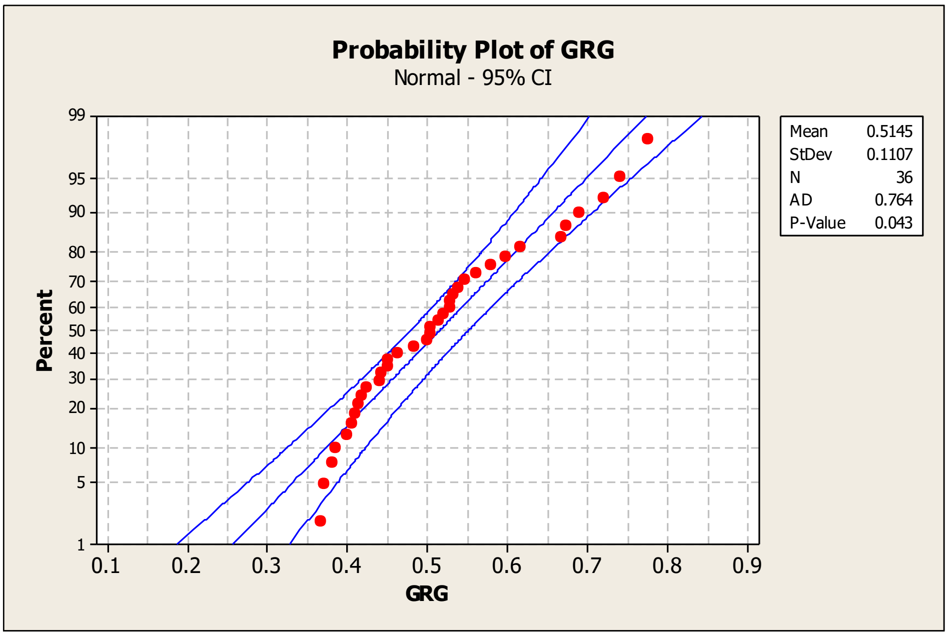

Figure 7. Probability plot of Grey Relational Grades

3.7.2 Probability distribution analysis: Figure 7 shows the probability plot and the statistical information of the multi-mechanical response of kaolin reinforced hydroxyapatite. The plot shows that all the GRG values except one are within the 95% confidence interval, which is supported by the confirmation analysis.

4. Conclusion

The quantitative effect of kaolin reinforcement, compaction pressure and sintering temperature has been examined with the help of statistical analysis technique assisted by grey relational analysis. It was noted that there was disparity in kaolin reinforcement as the optimum condition for individual mechanical properties, showing better hardness but poorer compressive strength when HAp was not reinforced. However, the grey relational analysis showed better mechanical properties with kaolin reinforcement. 500 Pa compaction pressure and 1100 ^{o}C sintering temperature are the optimum fabrication parameters for better mechanical properties, and was the same for individual mechanical properties. It is interesting to note that kaolin reinforcement significantly increased the compressive strength of HAp with a contribution of 93.16%. This influenced GRG values, resulting to 15 wt% kaolin as the optimum with 500 Pa and 1100 ^{o}C sintering temperature as the optimal fabrication parameters for high strength of HAp. The confirmation analysis also revealed that the experimental multi-mechanical response is within the 95% confidence interval.

These findings are useful in orthopedics industry in order to produce a mechanically fitted HAp for load bearing clinical application. These findings recommend fabrication parameters at which mechanically improved clinical hydroxyapatite would be achieved. Further studies are also recommended conducted investigate the use of different wt% of kaolin on the multiple mechanical characteristics of HAp.

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Indonesian Trade Deficit with China: Background and Grey Forecasting

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Abstract: Indonesia's trade balance with China has remained negative since 2010. The current study forecasts Indonesia's trade deficit with China for five years using the Even Grey Forecasting model EGM (1,1,α,θ). The sample was conducted by collecting the data of traded deficits for the past ten years. Data were collected from the official websites of Indonesia's Central Bureau of Statistics of (BPS), Ministry of Trade, among others. By building upon the literature, the study argues that trade deficits might have occurred from internal and external factors, such as the lack of infrastructure, the depreciation of the Rupiah (Indonesian currency) against the U.S. dollar, and the ASEAN-China Free Trade Agreement. Comparative analysis with Linear Regression (LR), Exponential Regression (ER), and Exponential Triple Smoothing (ETS) revealed the superiority of the grey forecasting model for trade deficit prediction. The study found that the trade deficit was minimum during the COVID-19 pandemic. It also showed an increasing trade deficit in the post-COVID period. The study concludes with some recommendations for Indonesia to minimize the trade deficit.

Keywords: Import; export; trade deficit; east Asia; grey forecasting

1. Introduction

The economic condition of a nation, especially in terms of international trade, can be seen by looking at the country's trade balance. The trade balance is one of the instruments in the balance of payments that displays a country's exports and imports (Salvatore, 2011). Existing trade balance statistics will disclose not only the status but also the output of a country's exports and imports. The trade balance can have several conditions. The first condition is that of surplus. If the number of exports exceeds the amounts of imports, the trade balance is said to be in surplus. A country's trade balance is said to be in surplus when the number of imports exceeds the number of exports (Mankiw & Taylor, 2020).

Deficit trade balance pressures are commonly used as a measure of a country's low economic health. However, a trade deficit doesn't necessarily represent poor economic health. The ability to determine whether the deficit trade balance condition is poor or favorable is heavily dependent on domestic and international economic conditions (Nabila, 2017). However, if the trade balance deficit conditions persist, this should be taken into account because it can imply weak economic conditions, especially in terms of export results.

China's economy is resilient to disruptions, and its performance during the COVID-19 pandemic has just confirmed the fact (Javed *et al.*, 2021), and thus trade relations with China are highly valued in many nations, particularly in developing countries. China is one of the important trading partners of Indonesia (Sugiartiningsih, 2020). Between 1999 to 2007, Indonesia was excessively surplus with China, and Indonesia only experienced a deficit with China in 2008 (Adam & Negara, 2010). As China's economic contribution also accounts for one-third of the world's economic growth, China is a significant trading partner (IMND, 2019). Thus, all world trade, including Indonesia, will be affected if China faces a crisis. The story of China's economic slowdown would likely affect commodity demand and a range of consumer goods. Slowing economic activity would reduce import demand. That means that the share of exports in growth will also decrease so that economic growth in Indonesia will also affect its export output if exports worsen.

A matter of concern that prompted the current study was that Indonesia's trade balance with China has remained negative since the last decade. This shortfall does not guarantee that the Indonesian economy is in trouble or that its export output is poor. However, this idea must be considered and looked after since a trade imbalance may be an indication of other issues in a country's domestic economy or at an international economic level that impacts the state of a country's trade balance (Ginting, 2017).

The rest of the study is organized as follows: The second section reviews literature, the third section presents the research methodology, the fourth section involves data and results, and the fifth section presents the conclusion and recommendations.

2. Literature Review

2.1 Indonesia and its international trade

The Indonesian economy has gone through ups and downs and can be easily divided into two periods; 1945 – 1965 and 1965 – 1998. In the first part, despite achieving impressive gains in health and education, the economy engaged in battling inflation and stagnation, while in the second part, it was engaged in consolidating the gains and strengthening the economic development of the country but at the expense of increasing economic disparities between haves and have-nots (Sudari, 2017; Kompas, 2018; Britannica, 2021; Tjoe, 2018). By buying more than it sells, by importing more than it exports, a nation endangers its balance of payments and, thus, its currency (Stalin, 1954). In 2020, Indonesia maintained a trade deficit with several key trading partners, including China, Australia, and Thailand. The biggest trade deficit was 5.32 billion dollars, followed by 1.5 trillion US dollars from Thailand, and 874 million US dollars in January-June 2020 from Australia (Fauzan, 2020). The trade deficit is problematic because it is only financed by capital flows (from trade-surplus countries), and its sudden cessation of capital flows creates instability at the national level and internationally (Yilmazkuday, 2021). The bilateral trade deficit does not need to be so concerned by a country with a bilateral trading deficit, but the bilateral trade deficit takes on significant importance, particularly in cases of chronic multilateral trade deficits. Then, it becomes necessary to identify countries with large commercial deficits in a country-specific analysis of trade to mitigate the trade deficit problem with such countries to reduce the deficit problem (Basu & Datta, 2007). Table 1 summarizes important literature on Indonesia-China trade and economic relationships.

Sutrisno (2014) explains the issue of how to eliminate trade deficit in the trade balance. Trade deficits in the trade balance can be overcome by merging monetary and fiscal policies. One way to minimize the current account deficit (CAD) is to increase exports while decreasing imports, resulting in a trade balance surplus that can then be used to reduce the CAD. This study examined oil and gas exports and imports, as well as non-oil and gas imports. Several reasons contributed to the rise in the trade deficit on the import side, including an increase in energy demand, an increase in global oil prices, and an increase in the number of motorized vehicles. Meanwhile, on the export front, the average price of Indonesia's raw-goods export commodities has dropped.

Table 1. The summary of selected literature on China-Indonesia economic relations

Year	Description	Literature
1999	The study argued that with China's joining of WTO and other regional trade agreements both China and its trading partners including Indonesia are likely to benefit.	Atje and Gadhu (1999**)**
2007	The study compares China's and Indonesia's development strategies and identify similar and distinctly different development patterns.	Hofman *et al.* (2007)
2011	The study argued that through in past the relationships between China and Indonesia didn't go smooth however with time their interests are converging and relationships are improving. The strategic implications of these closer relations for Australia are presented.	Nabbs-Keller (2011)
2012	The ups and downs of trade protectionism in Indonesia are studied while highlighting Indonesia's ability to use regional and international engagement to counterbalance rising protectionism.	Basri and Patunru (2012)
2014	The impact of Indonesia-China trade liberalization on the Indonesian trade and the lives of Indonesian households has been study.	Sabaruddin *et al.* (2014)
2014	The study argued that through in past the relationships between China and Indonesia were strained but post-Suharto Indonesia has significantly improved its economic and political relations with China. Consequently, not only new opportunities have arisen some challenges and contradictions have also emerged.	Fukuoka & Verico (2014)
2015	By building an econometric model to estimate the direct impacts of the ASEAN–China Free Trade Agreement (ACFTA) on Indonesia and China the study argued that though the agreement modestly increased trade surplus for Indonesia overall, it contributed to to a larger bilateral deficit with China.	Marks *et al.* (2015)
2015	The study reports resentment among Indonesian business sector towards skewed trade relations between China and Indonesia resulting from the ACFTA whom they believe to be responsible for Indonesia's increasing trade deficit with China. The study discusses the necessity of the ACFTA and why it needs continued implementation.	Siwi (2015)
2016	The study reports the positive impact of ACFTA on Indonesia's production, investment, trade and national income growth whereas the negative impact of the depreciation of Rupiah against the U.S. dollar on Indonesia's production and trade performance consequently causing the national income deficit.	Jamilah *et al.* (2016)
2019	The study argues that with the economic rise of China the unipolar world is becoming multipolar, and the Belt and Road Initiative is likely to consolidate the gains resulting from the multilateralism while improving the relations between China and its trading partners like Indonesia.	Putri and Ma'rif (2019)

Ginting (2014) examines the evolution of Indonesia's trade balance from 2006 to 2013 to determine what factors contributed to the country's trade deficit over that period. This journal identifies the factors causing the trade deficit. From 2006 to 2011, Indonesia's trade balance results consistently showed a trade surplus, indicating that the country's export value was still greater than its import value. However, Indonesia's trade balance started to show a trade deficit from late 2011 to April – June 2013. The trade balance shortfall in 2012 was caused by strong imports of Indonesian oil and gas exceeding exports. Furthermore, Indonesia's non-oil and gas imports continue to rise. Meanwhile, on the export front, the average price of Indonesia's export goods, which are raw materials, has dropped. According to this journal, the relationship between domestic demand and the real exchange rate hurts the trade balance in Indonesia in the short term. When domestic demand increases, so do imports. Unlike the exchange rate, where it is understood that each Rupiah depreciates, the trade surplus rises. This event occurs because the low level will boost the export competitiveness of Indonesian goods due to the low price. On the other hand, foreign income considerations have a favorable relationship with Indonesia's trade balance. The greater

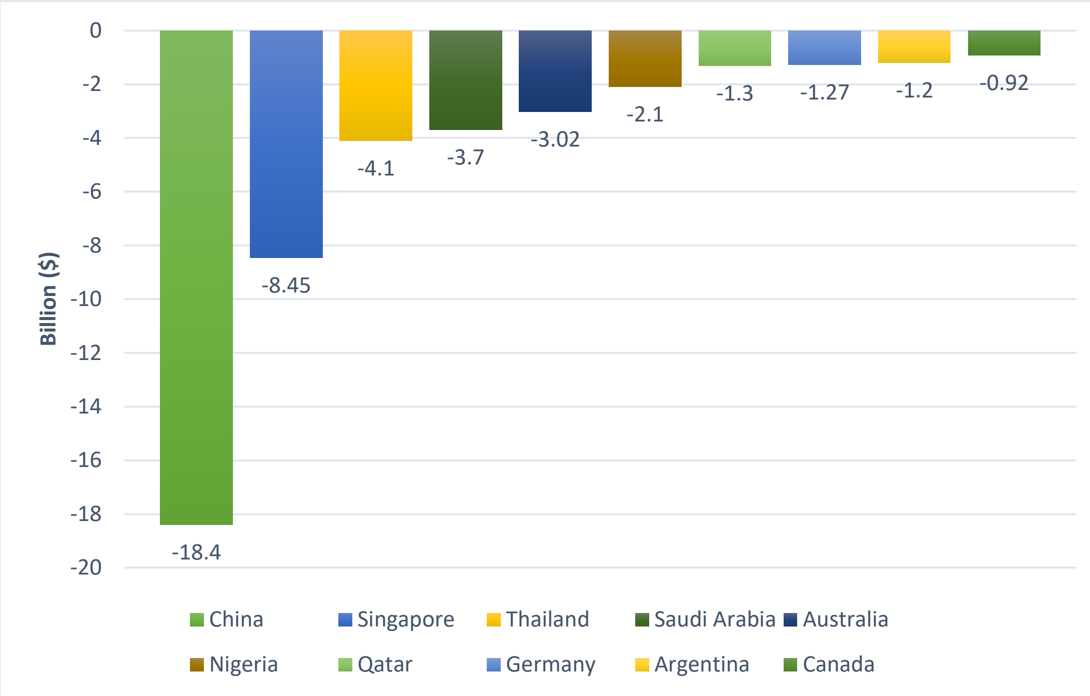

Figure 1. Top 10 countries with which Indonesia faces largest trade deficit (Data: WITS, 2018)

the other countries' international profits or GDP, the greater Indonesia's exports. Ginting (2014) concluded that the key cause of the trade imbalance in Indonesia's trade balance during that period was the strong imports relative to exports.

Indonesia traded with 210 countries from around the world and with 130 of them, it experienced a surplus, and with the remaining 80 it recorded a deficit (WITS, 2018). The top 10 countries that Indonesia had the largest trade deficit with, in 2018, are shown in Figure 1.

Indonesia has the most significant trade deficit with China at \$18.4 billion, followed by Singapore (\$8.45 billion), Thailand (\$4.1 billion), Saudi Arabia (\$3.7 billion), Australia (\$3.02 billion), Nigeria (\$2.1 billion), Qatar (\$1.3 billion), Germany (\$1.27 billion), Argentina (\$1.2 billion), and Canada (\$0.92 billion). China is an important trading partner as well as Indonesia's largest trading partner, controlling 24.13% of Indonesia's market share in import partners and 15.05% in export partners (WITS, 2018).

2.2 Trade deficit and its causes

Trade deficits occur when a country's spending on consumption and investment exceeds the value of the goods and services produced (Mankiw, 2018). In this case, Indonesia is spending more than it can earn, which results in a deficit in the balance of trade (BoT). Indonesia's trade balance deficit is influenced by internal and external factors (Nabila, 2017). Internal factors include lack of infrastructure and weakening of Rupiah (Indonesian currency), while external factors include ASEAN-China Free Trade Agreement and the U.S.-China trade conflict.

2.2.1 Lack of infrastructure: Infrastructure is one aspect of the trade balance deficit. Lack of public infrastructure means lacking highways, public transit, clean water, bridges, airports, harbors, reservoirs, electricity, flood control, etc. (Kompas, 2013). Lack of infrastructure can affect the trade deficit. For instance, the use of fuel, creation of infrastructure needs substantial financing. The allocation of infrastructure funds is around Rp 201 trillion in the state budget for 2013. Infrastructure subsidies spent are less than the energy subsidies spent, which is estimated at Rp 274 trillion of Rp 1683 trillion of the total government spending (Tri Haryanto, 2013). Increasing fuel usage and decreasing oil production have further increased imports of petroleum products, which makes exports of petroleum and gas no longer cover them (Mangeswuri, 2014). In the meantime, the gasoline subsidies are partly financed by new government debt. Many residents enjoy subsidized gasoline, but a lack of public transit makes many people purchase cars. Oil and gas exports totaled only USD 34 billion during January-November 2012, while imports of petroleum and gas amounted to USD 39 billion. The deficit was almost US$5 billion. The greater the fuel subsidy, the greater the shortfall of the government's budget. This is to the detriment of citizens' access to better health services and infrastructure. Funds have also been reduced to develop technical advances and enhance defense and protection.

2.2.2 Weakening of Rupiah: A significant part of the trade balance deficit is the Rupiah's exchange rate (Ningsih, 2019). Weakening the dollar exchange rate would undoubtedly harm the Indonesian economy and affect rising rates, which use the dollar as a tool for transactions (Diana & Dewi, 2019). Under the weakening of the exchange rate Rupiah, the price of imported items would increase fast. The decline in the rupiah exchange rate represents a decline in the rupiah currency demand society, either due to the decreasing position of the national economy as a vehicle for international payments or to the rising demand for foreign currency. The effect is that the cost of importing raw materials increases.

The exchange rate varies on a free market, depending on many factors that affect foreign exchange supply and demand (Chomas *et al.*, 2014). This exchange is essential for outgoing payment transactions across countries (imports). As the level of growth in income (relative to other countries) increases, more demand for foreign currency is maximized. Foreign exchange rates begin to rise, and currency prices themselves are falling.

2.2.3 ASEAN-China Free Trade Agreement: In 2010, Indonesia was one of the 6 ASEAN countries that decided to sign a cooperation agreement with China called the ASEAN-China Free Trade Agreement (ACFTA). It aimed to either reduce or remove trade barriers of goods, increase access to market services for both tariff and non-tariff products, control investment policy and provision, thus improving economic cooperation between ASEAN countries and China (Sari & Suhadak, 2017). This agreement led to an increase in trade volume in both the import and export sectors between Indonesia and China. However, over time, the trade balance between Indonesia and China became asymmetrical where Indonesia focused on exporting products such as mining, oil, and gas (natural resources) while China exported manufactured products such as low priced electronics, machinery, and transportation-related goods, turning Indonesian-made goods inferior to those made in China (Muslihati, 2010). The huge price difference between imported products from China and domestically made products naturally makes consumers prefer imported goods from China over local products. This made local producers unable to compete and unbalanced Indonesia's trade balance.

2.2.4 The U.S.-China trade conflict: The high tension between China and the United States which began in July 2018, affected almost many other economies, including Indonesia, even though Indonesia was not directly involved in the trade war. Both China and the U.S. are Indonesia's main trading partners. The trade war between China and the U.S. left a negative impact on Indonesia, namely the second-round effect, a situation in which China and the U.S. reduced imports of raw materials from Indonesia due to an economic slowdown resulting from high tensions (Wangke, 2020). The effect can be shown in Table 2, where the demand for oil and gas that was exported to China declined dramatically in 2019 from $2.72 Billion to $2.06 Billion. The decline in commodities' demand led to a reduction in the commodity prices as well, especially in the primary commodity that Indonesia exports, such as kernel oil, palm oil, and coal that experienced a contraction of -39.53%, -16.90%, and -7.41% (Iqbal *et al.*, 2020).

Table 2. Indonesian data on oil and gas and non-oil and gas exports (Data: KPRI, 2021)

Export	2016	2017	2018	2019	2020
Oil and gas	1.67	1.73	2.72	2.06	1.84
Non-Oil and gas	15.1	21.3	24.4	25.8	29.9

3. Research Methodology

3.1 Data collection

The Indonesian import and export data concerning China from 2011 to 2020 was obtained from TE (2020) and KPRI (2021). The Trade Deficit (TD) and Trade Surplus (TS) were calculated from the formula of Balance of Trade (BoT), the difference between exports (E) and imports (I), as given below,

$$BoT = \begin{cases} TS;\ E - I > 0 \\ TD;\ E - I < 0 \end{cases}$$

The future balance of trade was estimated through the same formula but instead of using actual data, the data simulated through the most accurate forecasting model was used.

3.2 Grey forecasting model

Deng (1982) proposed the Grey System Theory. The theory helps handle problems containing objective uncertainty (Javed & Cudjoe, 2021) without requiring a large sample size with a specific probability distribution (Mahmoudi *et al.*, 2021). Grey forecasting theory is an important offshoot of the Grey System Theory. Ma *et al.* (2019) and Javed *et al.* (2020a) applied grey forecasting in the tourism sector. Quartey-Papafio *et al.* (2020) and Zeng *et al.* (2020) used it for forecasting cocoa production and grain production, respectively. Javed and Liu (2018) and Ikram *et al.* (2019) used it to predict the number of research publications and ISO certifications of selected countries, respectively. Wu *et al.* (2020) and Xie *et al.* (2021) used it to predict CO_2 emissions. Thus, with time the grey forecasting modeling is only becoming popular and seeing a large number of applications.

Even Grey Model EGM (1,1) is an important model of the grey forecasting theory (Liu *et al.*, 2017). EGM (1,1,α,θ) is an optimized form of the EGM (1,1), and is the grey model with a differential equation of first order containing a single variable and a weighted background value that contains a conformable fractional accumulation. It was proposed by Javed *et al.* (2020b), and the steps to calculate EGM (1,1,α,θ), are reproduced below.

Let the actual data sequence be

$$X^{(0)} = \left(x^{(0)}(1), x^{(0)}(2), \dots\ x^{(0)}(n)\right)$$

And the compatibility series of accumulated fractional data is

$$X^{(\alpha)} = \left(x^{(\alpha)}(1), x^{(\alpha)}(2), \dots\ x^{(\alpha)}(n)\right), \alpha \in (0,1], k = 1,2, \dots, n$$

where, $x^{(\alpha)}(k) = \sum_{i=1}^{k}\left(\frac{x^{(0)}(i)}{i^{1-\alpha}}\right)$.

The approximate regressive equation is stated as

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

The time response function is

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

EGM (1,1,α,θ) has the advantage of being able to change the parameters of α and θ with data variance. Data noise may have various shapes. Contrary to the conventional model EGM (1,1), the two parameter EGM model (1,1,α,θ) is dynamic and changes the values of its parameters as noise in data varies, thus generating relatively more precise forecasts.

In the current study, Even Grey Model EGM (1,1,α,θ) was used for forecasting Indonesian exports to China and Chinese imports to Indonesia. For comparative analysis, Linear Regression (LR), Exponential Regression (ER), and Exponential Triple Smoothing (ETS) methods were used.

The model EGM (1,1,α,θ) was built in MS Excel. For running LR, ER, and ETS, the built-in functions of MS Excel were used.

3.3 Forecast error measurement

The current study will use five metrics (Ofosu-Adarkwa *et al.*, 2020) for the measurement of forecast error. These are Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Normalized RMSE (NRMSE), Mean Absolute Percentage Error (MAPE), and Normalized MAPE (NMAPE), respectively given by

$$MAE = \frac{1}{n} = \sum_{k=1}^{n} |x(k) - \hat{x}(k)|$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{k=1}^{n}\left(x(k) - \hat{x}(k)\right)^2}$$

$$NRMSE = \frac{\sqrt{\sum_{k=1}^{n}\left(x(k) - \hat{x}(k)\right)^2}}{\sqrt{\sum_{k=1}^{n}\left(x(k)\right)^2}}$$

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

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

where, $x(k)$ represent actual data and $\hat{x}(k)$ represent simulated data.

4. Results and discussion

4.1 Analysis of Trade between Indonesia and China

As part of the ASEAN-China Free Trade Area (ACFTA), the flow of goods between China and Indonesia can move freely almost without a barrier, so the total trade between the two sites has significantly increased to a higher level. China is Indonesia's largest trading partner with a share of 15.05%. The most imported products by Indonesia are non-oil and gas products such as electronics (HS 85) and machine goods (HS 84), while on the other hand, Indonesia exports oil and gas products such as mineral fuels, petroleum, distillation products (HS 27) and animal, vegetable fats and oils, cleavage products (HS 03) (Adharsyah, 2019).

In 2018, products imported to Indonesia accounted for the largest quantity worth $45.53 Billion while the largest amount of products exported to China was in 2020, worth $31.77 Billion, as shown in Figure 2 and Table 3.

Figure 2. Total import and export between Indonesia and China (2011-2020)

Table 3. Historic data on Indonesian balance of trade ($ billion) with China

Year	Indonesian Exports to China	Indonesian Imports from China	Balance of Trade
2011	22.94	26.21	-3.27
2012	21.65	29.38	-7.73
2013	22.6	29.84	-7.24
2014	17.6	30.62	-13.02
2015	15.04	29.41	-14.37
2016	16.79	30.8	-14.01
2017	23.08	35.76	-12.68
2018	27.13	45.53	-18.4
2019	27.96	44.93	-16.97
2020	31.77	39.63	-7.86

4.2 Calculating trade deficit between Indonesia and China

To determine whether a country has a trade surplus (TS) or trade deficit (TD), we can calculate the Balance of Trade. Balance of Trade (BoT) is the difference between a country's exports (E) and imports (I). Table 3 highlights the BoT between Indonesia and China.

Since joining the ASEAN-China Free Trade Area (ACFTA) in 2010, Indonesia has never printed a trade surplus with China. The gap between imports and exports between China and Indonesia is also getting wider every year, as Chinese products satisfy consumers' needs in Indonesia with better quality and competitive prices (Rakhma, 2017). In 2020, due to the COVID-19 outbreak in China, the number of imported products from China dropped to $39.63 Billion or 11.8%. With the declining imports from China, Indonesia narrowed the trade deficit gap with China. However, this gain came at a cost borne by the industries and people affected by the pandemic.

4.3 Forecasting trade deficit between Indonesia and China

In this study research, the forecasts of Indonesia's current account deficit were made from 2021 until 2025. In this forecast, we use export, import, and balance of trade data from 2011 until 2019. The year 2020 was ignored because of the impact of the COVID-19. We use four forecasting methods; Even Grey Forecasting Model EGM $(1,1,\alpha,\theta)$, linear regression, error, trend, seasonal (ETS), and exponential regression. The forecasts are shown in Table 4. The results revealed that the trade deficit between Indonesia and China would likely grow in the next five years. Indonesia's import and export trends are shown in Figures 3 and 4, respectively. Using the forecast data, the balance of trade was estimated, and the results are shown in Figure 5, where the role of the COVID-

Table 4. Forecasting Indonesia's trade balance ($ billion)

	Actual			*EGM (1,1,α,θ)*			*Linear Regression*			*ETS*			*Exp. Regression*		
Year	**E**	**I**	**BoT**	**E**	**I**	**BoT**	**E**	**I**	**BoT**	**E**	**I**	**BoT**	**E**	**I**	**BoT**
2011	22.9	26.2	-3.3	22.9	26.2	-3.27	19.2	24.6	-5.4	23.07	27.1	-4.0	20.4	23.6	-3.2
2012	21.7	29.4	-7.7	17.1	26.3	-7.73	19.8	26.8	-7.0	23.68	29.3	-5.7	20.9	25.1	-4.2
2013	22.6	29.8	-7.2	18.2	28.4	-7.24	20.4	29.1	-8.7	24.29	31.6	-7.3	21.4	26.8	-5.4
2014	17.6	30.6	-13.0	19.3	30.6	-13.02	21.0	31.4	-10.3	24.90	33.9	-8.9	22.0	28.6	-6.6
2015	15.0	29.4	-14.4	20.5	33.0	-14.37	21.6	33.6	-12.0	25.52	36.1	-10.6	22.5	30.5	-7.9
2016	16.8	30.8	-14.0	21.8	35.6	-14.01	22.3	35.9	-13.6	26.13	38.4	-12.2	23.1	32.5	-9.4
2017	23.1	35.8	-12.7	23.1	38.4	-12.68	22.9	38.1	-15.3	26.74	40.6	-13.9	23.6	34.6	-11.0
2018	27.1	45.5	-18.4	24.5	41.4	-18.4	23.5	40.4	-16.9	27.35	42.9	-15.5	24.2	36.9	-12.7
2019	28.0	44.9	-17.0	25.9	44.6	-16.97	24.1	42.6	-18.5	27.96	45.1	-17.2	24.8	39.3	-14.5
2020	31.8	39.6	-7.86	27.5	48.1	-20.6	24.7	44.9	-20.2	28.57	47.4	-18.8	25.4	41.9	-16.5
2021				29.1	51.8	-22.7	25.3	47.1	-21.8	29.18	49.7	-20.5	26.1	44.7	-18.7
2022				30.8	55.9	-25.0	25.9	49.4	-23.5	29.79	51.9	-22.1	26.7	47.7	-21.0
2023				32.6	60.2	-27.6	26.5	51.7	-25.1	30.40	54.2	-23.8	27.4	50.8	-23.5
2024				34.6	64.9	-30.3	27.1	53.9	-26.8	31.02	56.4	-25.4	28.0	54.2	-26.1
2025				36.6	70.0	-33.4	27.8	56.2	-28.4	31.63	58.7	-27.1	28.7	57.8	-29.0

*Data from 2011 to 2019 was used for forecasting purposes. 2020 data was ignored because of the COVID-19 pandemic.
E: Exports, **I**: Imports, **BoT**: Balance of Trade

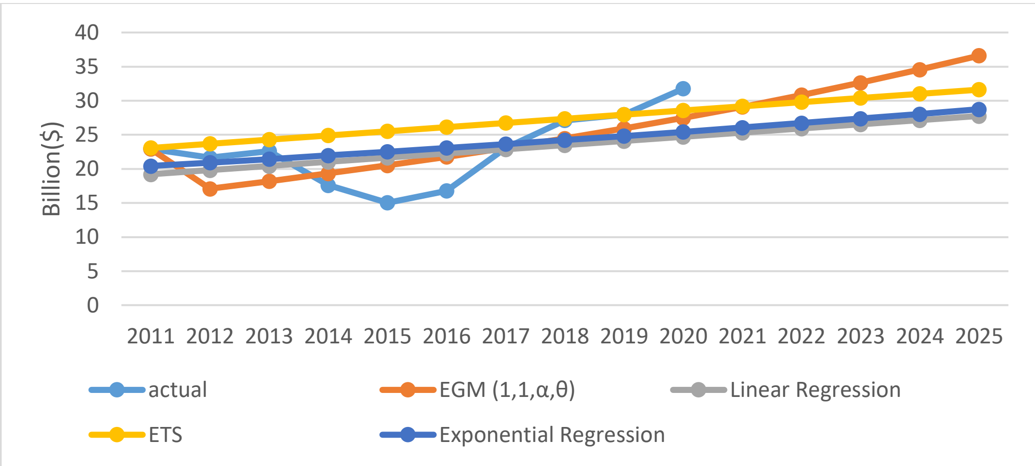

Figure 3. Forecast of Indonesia's export trend

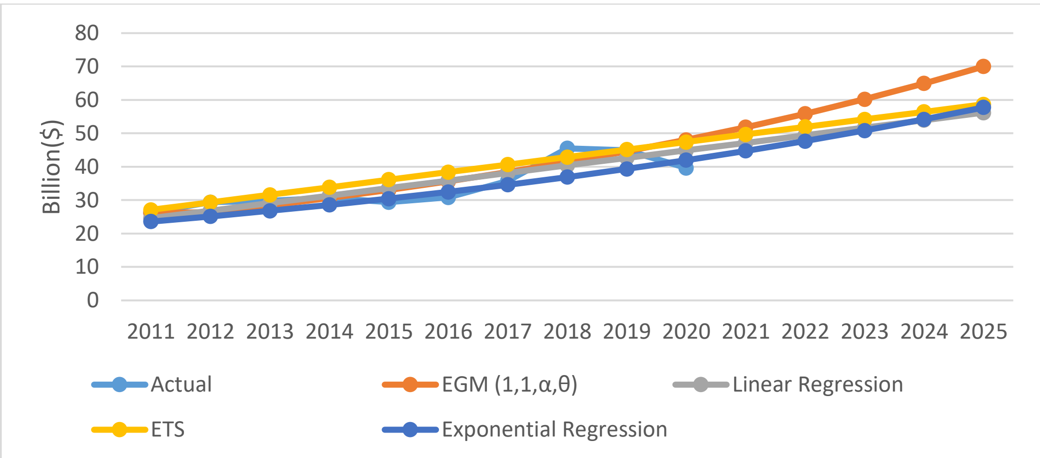

Figure 4. Forecast of Indonesia's import trend

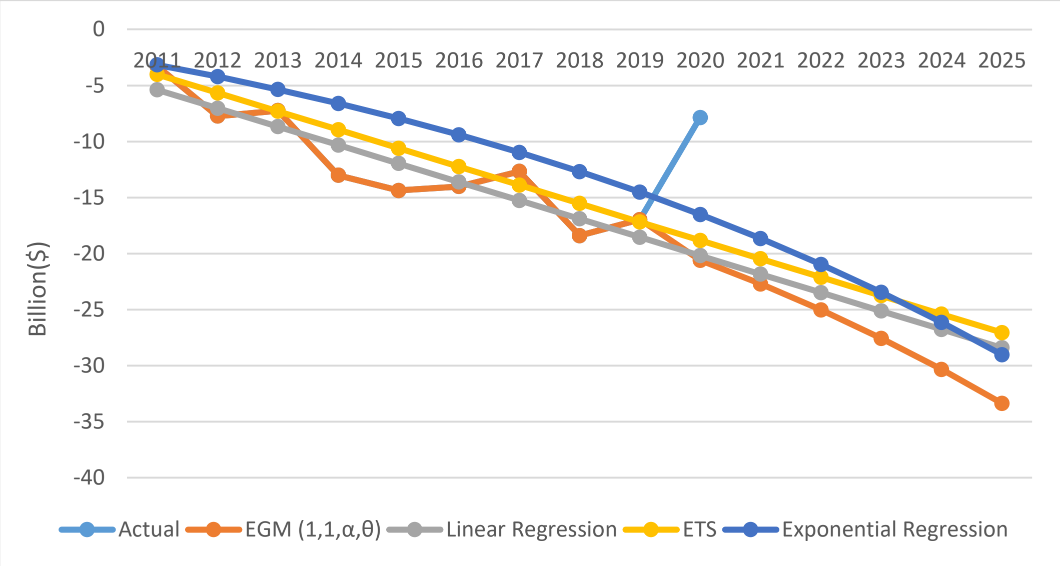

Figure 5. Estimates of Indonesia's Balance of Trade trend

Table 5. Forecast error measurement of the forecasting models

Model	MAE		RMSE		NRMSE		MAPE (%)		NMAPE (%)	
	Export	*Import*	*Export*	*Import*	*Export*	*Import*	*Export*	*Import*	*Export*	*Import*
EGM (1,1,α,θ)	3.2	2.5	3.7	3.0	0.17	0.09	16.7	7.5	14.93	7.43
Linear regression	3.4	2.7	3.9	3.2	0.18	0.09	17.6	8.2	13.99	7.63
ETS	3.9	3.1	5.5	4.0	0.25	0.12	22.3	9.7	17.82	9.22
Exp. Regression	3.2	3.3	4.0	4.1	0.18	0.12	17.3	9.4	14.95	9.93

19 in reducing the trade deficit is visible. The forecast errors are shown in Table 5. Based on the error analysis, it can be argued that from all forecasting models, the EGM (1,1,α,θ) provided the most accurate picture of the trade deficit between Indonesia and China.

If one looks at Figure 5, one can see the impact of the COVID-19 on Indonesia's trade balance with China. If the COVID-19 outbreak wasn't a factor of influence, the current study predicts that Indonesia's trade deficit with China was likely to reach -$20.6 Billion by 2020 (here negative sign shows deficit). Even though the COVID-19 pandemic may have reduced Indonesia's trade deficit with China for a year, it is not something to celebrate as the cause of this reduction is alarming. Further, the pandemic is temporary, and delays in fighting the COVID-19 may temporarily reduce Indonesia's trade deficit with China but would ultimately hurt Indonesia because the wheels of the national economy would become increasingly fragile with time, paving way for increasing unemployment and poverty, and making companies vulnerable to bankruptcy claims. Thus, there is a need to take serious lessons from the pandemic and its effects on the Indonesian economy.

5. Conclusion and recommendations

The trade deficit happens when a country's imports surpass exports. A small trade deficit is acceptable, but a large trade deficit can be a sign of worry. Since 2008, Indonesia never had a trade surplus with China. The trade data between Indonesia and China in the last ten years provide us information on several causes of the trade deficit between Indonesia and China. These factors, both internal and external, are highlighted in the current study. Using a grey forecasting model, the study forecasts Indonesia's trade deficit with China to reach -$33.4 Billion in 2025. As compared to three statistical forecasting models, the grey forecasting model showed superior performance.

The widening gap between imports and exports is a sign of worry. Indonesian policymakers need to revisit their trade relationship with China by fully grasping the strengths and limitations of the nation and its industries. It is suggested that the Indonesian government adopt a mixed policy to prevent the worsening trade deficit between Indonesia and China, a mixed policy consisting of fiscal and monetary policies. It should include granting tax breaks for imports of raw goods, improving agricultural products, increasing biodiesel made from palm oil, and supporting the provision of land for the agricultural sector. The monetary policy that provides incentives to domestic exporters should be enforced, and Bank Indonesia must maintain interest rates and the exchange rate of the Indonesian currency to support the policies.

The study has five recommendations for the Indonesian policymakers: (a) Indonesia should negotiate with China under ACFTA's circumstances in deregulation of tariff restrictions and import quotas to prevent imbalance and industrialization. (b) The government needs to develop bilateral and multilateral ways to introduce the local products with the aid of international shows. The products to be displayed are authentic products such as ground coffee, prawn crackers, instant noodles, and coffee beans. (c) Increasing the use of biodiesel made from palm oil (Indonesia is the largest exporter of palm oil, with an export rate of 50%). By slowly replacing diesel with biodiesel made from palm oil, Indonesia can reduce diesel imports because of the reduction in the trade deficit. Following in the footsteps of China, a shift toward electric vehicles is another option. (d) The government should encourage the production of food items like garlic, onions, sugar, potatoes, and chilies, which are usually imported products from China. Based on the provision of land will lead to food self-sufficient, which means we can reduce the trade deficit. (e) Investments in tertiary industries and the technology-driven industries of the future should be improved. Also, lessons can be learned from China's way of trading with other nations.

By reducing the trade deficit of Indonesia with China, the COVID-19 has highlighted another deficit – humanity's deficit with nature, where we extract more resources from nature than we invest in nature. This deficit rarely finds its mention in the rooms of economic policymakers and corporate boardrooms except for some talk about it in the media and the Sustainability Reports. The study concludes with some important questions for the readers, in general, and the policymakers, in particular. Also, in the future, efforts should be made to improve the trade forecasting models. A grey forecasting model may also be proposed, especially for trade deficit predictions.

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Grey Relational Evaluation of the Supplier Selection Criteria in Indonesian Hospitality Industry

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Abstract: The study aims to identify and evaluate the key criteria for food supplier selection in the Indonesian hospitality industry. A survey was sent to experts in Indonesia and based on their opinions the supplier selection criteria were evaluated using the Grey Relational Analysis (GRA). The study found that price is the most important supplier selection criteria, followed by food quality, and return-ability of problematic food. The study also reports that the variation in the distinguishing coefficient of the GRA influences the ranking.

Keywords: Suppliers selection criteria; hospitality industry; grey relational analysis

1. Introduction

There are many factors contributing to the success of an industry. One of the factors driving an industry to be successful is its supply chain management practices. Sustainable business practices improve companies' image and win reputation and new customers while ensuring long-term success (Ullah *et al.*, 2021; Han *et al.*, 2011). If an industry has a sustainable supply chain, the goods and services offered to its customers would be well-received by the consumers and can generate positive feedback from the customer. This point is hard to overlook in the hospitality industry because the industry is most valued by the goods and services offered and customers' feedback. Companies in tourism and hospitality industry supply chains cannot thrive without the support of satisfied customers (Chi & Gursoy, 2009). Therefore, hospitality supply chains must be well-managed for the success of the hospitality industry and to create better value for the customers it serves.

The key to sustainable supply chain management, including hospitality supply chain management, is the right selection of suppliers. If an industry can choose its suppliers correctly and provide better goods and services to its customer, it will increase the performance value of the industry and help in materializing aggregate plans more effectively and efficiently. However, the selection of the right suppliers depends on the right criteria for the supplier evaluation. Numerous scholars have discussed essential criteria to be considered in selecting suppliers through different analysis models (see, e.g., Ali, 2019; Önder & Kabadayi, 2015; Chung, 2015), but not many have discussed the priority levels of these criteria in the hospitality industry. Also, most studies focus on evaluating suppliers, while only a few focus on evaluating criteria. Meanwhile, rarely the hospitality industry supplier selection criteria evaluation has been done through the Grey Relational Analysis

(GRA). On top of that, some studies have argued that the variations in the GRA's distinguishing coefficient do not influence the final ranking (see, Sallehuddin *et al.*, 2008; Jiang *et al.*, 2002), while others have argued the opposite (see Mahmoudi *et al.*, 2020). This debate needs to be settled. Thus, the current study attempts to answer the following research questions: (a) What are the key criteria that the Indonesian hospitality industry considers important when selecting suppliers of food?, (b) Which criteria are most important for the industry?, (c) Is the GRA an effective approach to evaluate supplier selection criteria?, and (d) Does the variation in Deng's GRA model influence the prioritization of criteria?

The rest of the paper is structured as follows: Firstly, a broad review of literature is presented that discusses supplier selection, food industry, and criteria, followed by the introduction to the GRA model. Later, research methodology is discussed, followed by a presentation and discussion on the results. Lastly, the study is finalized with a conclusion and recommendations.

2. Literature Review

2.1 Hospitality Supply Chain Management

Supply Chain Management (SCM) can be defined as an approach to manage the flow of supplies from a vendor to the final recipient in a supply chain (Mentzer *et al.*, 2001), and if the supply chain is of the hospitality industry, it is referred to as Hospitality Supply Chain Management. According to Odoom (2012), acquiring strategic management of a supply chain allows firms to provide advanced quality supplies with lower costs. Hence, enhancing a firm's SCM is necessary to compete and have ultimate performances in the growing business environment (Adebayo, 2012).

While many firms in various industries have been improving SCM, with some even building their unique supplier management systems, firms in the hospitality industry also started to enhance the firm performance by investing in their SCM practices (Fantazy *et al.*, 2010). As noted by Chi and Gursoy (2009), the hospitality industry thrives on customer satisfaction. Hence, the Hospitality Supply Chain (HSC), where it involves the supply of goods and services to customers, is mandatory for sustainable management to provide good supplies and gain customers' satisfaction for the industry's success (Xu & Gursoy, 2015).

Xu and Gursoy (2015) ascertained that the first step of establishing sustainable management in HSC should start by selecting sustainable suppliers. Sethu (2007) mentioned several steps to be implemented in hospitality SCM, i.e., identify, evaluate, select, and manage the suppliers. Several studies show that increased customer satisfaction leads to greater customer loyalty (Xu and Gursoy, 2015). Greater customer loyalty leads to the improvement of a firm's financial performance and sustainability (Xu & Gursoy, 2014) because loyal customers are insensitive to the credited price (Jensen & Drozdenko, 2008). Then, improved financial performance helps firm to achieve capital (Biddel *et al.*, 2009). Moreover, Taherdoost and Brand (2019) also stated that suitable supplier selection would reduce purchasing costs, increase profits, shorten product lead time, grow customer satisfaction, and strengthen the competitiveness of firms. These constant impacts will encourage firms in the hospitality industry to advance their SCM for positive results in their financial performance (Xu & Gursoy, 2014). The selection of suitable suppliers that leads to sustainable SCM is the key to achieve success.

2.2 Food Supplier Selection Criteria

Poor quality food can spoil the image of the hospitality industry and can produce dissatisfied customers. Thus, the matter of food supplier selection is of utmost importance for the businesses operating in the hospitality industry. For the last few years, the reported outbreaks of food-borne illnesses have increased public awareness and concern towards food safety (Marucheck, 2016). A single food safety incident can have serious ramifications not only for the company that failed but also for the industry as a whole, with supply chain partners being particularly vulnerable (Marucheck, 2016). Not to mention, food is an essential contributor to physical well-being as well as a key source of pleasure, anxiety, and stress (Rozin *et al.*, 1999), assuring the safety and quality of food becomes mandatory.

Food safety refers to any issue relating to the hygiene and safety of the food that reaches customers; food is expected to be "safe" and thus devoid of contaminants that could be harmful to one's health (Escanciano & Santos, 2014). Meanwhile, the physical features of a food product, such as its look, texture, flavor, and microbiological elements, are referred to as food quality (Marucheck, 2016), where the quality of food is the significant contribution to its safety.

A way of protection to ensure food quality is the packaging of food. Packaging is prevalent and necessary in today's culture because it protects the products, from processing and manufacturing to handling and storage to the final recipient (Robertson, 2012). Packaging ensures that food is not contacted with any external contaminants or harms, avoids any leakage and most importantly, secure the quality of the food. In addition, proper labeling of nutrition should be included on the packaging as well. Since purchasing managers or responsible parties when selecting suppliers do not have participated in the food-making process, food supply shall be informative. Because misinformation is also frowned upon because it can harm consumers and, in some cases, result in their deaths (Ababio *et al.*, 2012).

Another important point to be noted when ensuring food safety is the food handlers. It is to ensure whether do the suppliers proceed healthy workforce and healthy workplace during the product making process. Maintaining a high degree of personal hygiene and cleanliness is an important approach to avoid food contamination (Mukhopadhyay *et al.*, 2012). Food handlers serve critical responsibilities in the food service system, thus they should keep themselves clean and wear appropriate protective clothing, headgear, and footwear (Qoura & Ali, 2016). Furthermore, the working environment of food handlers shall also be hygienic to free any possible hazards in the food-making process because an unhygienic workplace will cause a potential carrier of any disease (Sneha, 2019).

The way food quality is monitored and guaranteed across the network is critical to chain performance. Aside from being a performance indicator in and of itself, product quality is linked to other food attributes such as integrity and safety (Van *et al.*, 2009). Therefore, quality control and assurance have become increasingly essential in the food business (Wilcock *et al.*, 2004). According to Holleran (1999), while a quality assurance system helps monitor food safety, it also provides a liability defense that will assist in reaching the food safety regulations and standards. The assurance can be proved through certification such as ISO 22000. It outlines the standards for a Food Safety Management System when an organization in the food chain needs to demonstrate its competence to control hazards related to food safety to ensure that the food is safe to be consumed (Escanciano & Santos-Vijande, 2014). Another certified method to be considered is Hazard Analysis Critical Control Point (HACCP), a tool for controlling food hazards and has been widely acknowledged as the best method of assuring food safety (Khandka & Mayes, 1998).

However, while making the purchase decision, consumers might not have proper information about the true quality of a product (Yoo, 2014), causing dissatisfaction with a product to occur and having the disqualified product. Hence, the main reason why a return policy is needed is clearly due to the quality problem of a product (Yoo, 2014).

Lastly, procurement and supply of products at an appropriate price and within the agreed delivery lead time now have a significant impact on market demand (Noori *et al.*, 2017), making price and delivery time are also considered as an important factor in the supplier selection process

The selection of supplier criteria that have met the requirements sought can be specified through the identification stage. Jharkhariaa and Shankarb (2007) stated that the identification stage is a very important stage as this stage is aimed at the elimination of unsuitable suppliers. This research paper aims to sort out a few criteria for supplier selection in the hospitality industry that are most qualified based on the food safety standard. Moreover, this may go along with supplier segmentation on which appropriate suppliers are sectioned based on the sort of service rendered (Rezaei & Ortt, 2012). Figure 1 illustrates multiple criteria for food supplier selection that are compiled through literature review.

Figure 1. The supplier selection criteria for hospitality industry

Figure 1 mentions nine supplier selection criteria: food quality, safe packaging, healthy workforce, healthy workplace, proper labeling of information, timely delivery of food, return-ability of problematic food, price, and certifications from regulatory bodies. Each of these criteria is important for food businesses in the world, in general, and Indonesia, in particular. These criteria will be evaluated in the current study. The complete list of the criteria to be evaluated in the current study with their description and sources is presented in Table 1. The supplier selection framework that considers these criteria is better equipped to evaluate suppliers comprehensively, especially in the hospitality industry like restaurants and hotels where good supplies are a source of satisfied customers.

2.3 Supplier Selection through Grey Relational Analysis

Purchasing departments' main goals are to get the ideal product at the right price, quantity, quality, timing, and source (Sarkis & Talluri, 2002). Hence, selecting a proper supplier is not an easy process as many factors are being considered in the decision-making process. Because supplier selection is dependent on criteria, the definition and selection of criteria play a critical part in the decision-making (Banaeian *et al.*, 2015). Selecting suppliers who best meet the standards based on a set of criteria can improve the intended qualities of purchased goods and services and the performance of supplier evaluation (Lau *et al.*, 2018).

Multi-criteria decision-making is an important stream of research within operations research and has seen widespread application in supplier selection problems. MCDM allows a decision-maker to evaluate multiple options against multiple criteria (Liu *et al.*, 2019). In literature, scholars have used different kinds of tools for supplier selection, e.g., Analytic Hierarchy Process (Deng *et al.*, 2014), Best Worst Method (Rezaei *et al.*, 2016), Ordinal Priority Approach (Mahmoudi *et al.*, 2021a; 2021b), TOPSIS (Kamalakannan *et al.*, 2020), etc. However, when the sample size is small, or the system contains uncertainty, traditional MCDM methods have their limitations, and thus approaches like fuzzy logic and grey system theory become natural choices (Mahmoudi *et al.*, 2021; Javed *et al.*, 2021a; Xie *et al.*, 2021). Table 2 summarizes the literature review where MCDM approaches have been used to evaluate suppliers in the hospitality industry.

Table 1. The supplier selection criteria for hospitality industry

Code	Criteria	Description	Source
C1	Food Quality	Is the food quality provided qualified?	Marucheck (2016); Wilcock *et al.* (2004)
C2	Safe Packaging	Is the food properly packaged?	Robertson (1998)
C3	Healthy Workforce	Is there any health protocols/procedures applied while working?	Mukhopadhyay *et al.* (2012); Qoura and Ali (2016)
C4	Healthy Workplace	Is the workplace hygienic?	Sneha (2019)
C5	Proper Labeling of Information	Are the necessary information about the product such as composition, expiry date, etc., are properly labelled on the food's package?	Ababio *et al.*, (2012)
C6	Timely Delivery of Food	Does the supplier deliver food exactly on time?	Noori *et al.* (2017)
C7	Return-ability of Problematic Food	Is there any return policy for disqualified food?	Yoo (2014)
C8	Price	Is there a budget for price or considering the price offered by the supplier?	Noori *et al.* (2017)
C9	Certifications from Regulatory Bodies	Does the supplier have ISO 22000 certification to certify the safety and quality of their product? Does the supplier have HACCP certification to ensure their food hygiene?	Escanciano and Santos Vijande (2014); Khandka and Mayes (1998)

Grey System Theory (GST) was initiated in the 1980s by Deng Julong, and the concept of the "grey" hereby, stands for the system proportion where it concludes the separation between the white and the black (Deng *et al.*, 1982; Javed *et al.*, 2020b). It can effectively deal with uncertain decision-making problems resulting from human cognition's objective complexity and limitations (Du *et al.*, 2021). The framework of Grey System Theory has been successfully utilized for cases where data contain uncertainty, incompleteness, or insufficiency (Ertugrul *et al.*, 2016; Ikram *et al.*, 2020; Javed *et al.*, 2021c).

Grey Relational Analysis (GRA) is a popular MCDM model and is at the heart of GST. The basic idea of GRA is to conclude the degree of relationship between factors by comparing geometrical patterns of data (Javed *et al.*, 2020b; Dong *et al.*, 2018). GRA has been applied for solving supplier selection problems (Diba & Xie, 2019; Yang & Chen, 2006), temperature-disease transmissibility relationship analysis (Irfan *et al.*, 2021), optimization of engineering processes (Obara *et al.*, 2021), evaluations of barriers to university enrollment (Fahim *et al.*, 2021) and healthcare resource factors (Peng *et al.*, 2021), among others. The implementation of GRA then being applied to Grey Relational Grade (GRG) to estimate the count relation of factors (King & Wen, 2007). The GRA depends on the correlation factors and being estimated between the reference orders and all comparative factors in sequences. To summarize the GRG, the comparability sequence should have the highest grade to be the best choice. GRG is given by,

$$\gamma_{0i} = \gamma(X_0, X_1) = \frac{1}{n}\sum_{k}^{n}\gamma(x_0(k), x_i(k)), \quad (1)$$

where $\gamma(x_0(k), x_i(k))$ is the Grey Relational Coefficient (GRC) given by,

$$\gamma(x_0(k), x_i(k)) = \frac{min_i min_k|x_0(k) - x_i(k)| + \xi\, max_i max_k|x_0(k) - x_i(k)|}{min_k|x_0(k) - x_i(k)| + \xi\, max_i max_k|x_0(k) - x_i(k)|} \quad (2)$$

Here, ξ is the distinguishing coefficient whose value ranges between 0 and 1 though most scholars usually assume its value to be 0.5. However, following Mahmoudi *et al.* (2020), the current study will apply Deng's GRA while performing the sensitivity analysis on different values of ξ so reliable and rigorous results can be obtained.

Table 2. Summary of literature on supplier selection in hospitality industry

Literature	Short description	Method
Hsu *et al.* (2014)	Low carbon supplier selection in the hotel industry of Taiwan	FDM; DANP; VIKOR
Sakhuja *et al.* (2015)	Selection of outsourcing strategies in hotel industry in India	F-AHP; F-TOPSIS
Chung (2015)	Supplier selection in the hospitality industry of Taiwan	AHP
Önder & Kabadayi (2015)	Supplier selection in hospitality industry in Turkey	ANP
Darmaja *et al.* (2018)	Groceries supplier selection at Melia Bali Hotel Indonesia	DSR
Sureeyatanapas *et al.* (2018)	Egg supplier selection in food industry in Thailand.	ROC; TOPSIS
Ali (2019)	Vendor performance assessment in hospitality industry in Yogyakarta, Indonesia	F-AHP

F-AHP: Fuzzy Analytical Hierarchy Process; AHP: Analytical Hierarchy Process; ANP: Analytic Network Process; TOPSIS: The Technique for Order Preference by Similarity to Ideal Solution; ROC: Rank Order Centroid; DSR: Descriptive Statistical Research; F-TOPSIS: Fuzzy TOPSIS; DANP: DEMATEL-based Analytic Network Process; VIKOR: VIseKriterijumska Optimizacija I Kompromisno Resenje; FDM: Fuzzy Delphi Method

Table 3. Demographic information of the respondents

Characteristics	Demographic Characteristic	Number	%
Industry	Bakery	1	5.9
	Cafe	2	11.8
	Event Management	1	5.9
	Hotel	7	41.1
	Restaurant	4	23.5
	Tourism and Travel	2	11.8
Job Position	Entry level job	13	76.5
	Middle level job	3	17.6
	Upper level job	1	5.9
Work Experience	1 - 3 years	15	88.2
	4 - 6 years	1	5.9
	More than 6 years	1	5.9
Age	Less than 25	14	82.4
	25 to 34	3	17.6
Gender	Male	7	41.2
	Female	10	58.8

3. Research Methodology

Data were gathered through an online survey created on Google Form. It was sent to potential respondents in Indonesia, and 17 experts filled it properly on a 9-point Likert scale, where 9 showed most important and 1 showed least important. In the current study, A represents respondent and C represents criterion. Table 3 shows the demographic information of the respondents. Most of the respondents were female employees with at least three years of experience working in the hotel

Table 4. The original data

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
C1	4	5	8	1	6	9	9	9	9	6	9	7	1	1	7	9	2
C2	2	5	8	1	7	4	9	9	9	7	9	7	3	2	7	6	3
C3	2	6	9	3	7	8	9	9	9	7	9	7	5	1	8	8	1
C4	1	6	9	3	7	8	9	9	9	7	8	7	5	1	8	8	1
C5	5	6	7	3	8	6	8	8	8	8	8	7	5	3	8	6	3
C6	4	4	9	5	7	7	9	9	9	7	9	7	2	1	7	9	1
C7	5	4	9	1	7	5	8	8	8	7	9	7	2	1	8	7	2
C8	3	1	6	1	6	4	8	8	8	6	7	8	1	3	8	9	2
C9	4	6	8	4	8	7	9	9	9	8	9	7	5	2	8	4	4

Table 5. Grey relational coefficients at ξ=0.5.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
C1	0.57	0.50	0.36	1.00	0.44	0.33	0.33	0.33	0.33	0.44	0.33	0.40	1.00	1.00	0.40	0.33	0.80
C2	0.80	0.50	0.36	1.00	0.40	0.57	0.33	0.33	0.33	0.40	0.33	0.40	0.67	0.80	0.40	0.44	0.67
C3	0.80	0.44	0.33	0.67	0.40	0.36	0.33	0.33	0.33	0.40	0.33	0.40	0.50	1.00	0.36	0.36	1.00
C4	1.00	0.44	0.33	0.67	0.40	0.36	0.33	0.33	0.33	0.40	0.36	0.40	0.50	1.00	0.36	0.36	1.00
C5	0.50	0.44	0.40	0.67	0.36	0.44	0.36	0.36	0.36	0.36	0.36	0.40	0.50	0.67	0.36	0.33	0.67
C6	0.57	0.57	0.33	0.50	0.40	0.40	0.33	0.33	0.33	0.40	0.33	0.40	0.80	1.00	0.40	0.44	1.00
C7	0.50	0.57	0.33	1.00	0.40	0.50	0.36	0.36	0.36	0.40	0.33	0.40	0.80	1.00	0.36	0.40	0.80
C8	0.67	1.00	0.44	1.00	0.44	0.57	0.36	0.36	0.36	0.44	0.40	0.36	1.00	0.67	0.36	0.33	0.80
C9	0.57	0.44	0.36	0.57	0.36	0.40	0.33	0.33	0.33	0.36	0.33	0.40	0.50	0.80	0.36	0.57	0.57

industry. The nine selection criteria reported in Table 1 were considered for supplier evaluation. The equally weighted Grey Relational Analysis (GRA) will be applied to prioritize the nine criteria against the responses of the seventeen respondents with MS Excel's aid. The collected data is shown in Table 4.

4. Results and discussion

The study applied Deng's GRA model to the data collected from 17 respondents. Table 5 presents the Grey Relational Coefficient values. The rank defines the positions of each criterion that closely stand the food standards based on experts surveyed. Table 6 will show us Grey Relational Grades at different values of ξ (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9). This sensitivity analysis helps us get an overall picture of the problem. It also confirmed the thesis put forward by Mahmoudi *et al.* (2020), i.e., the variation in ξ changes ranks. In Table 6, the ranks are shown within

Table 6. Grey Relational Grades and ranks at different values of ξ

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	GRG [Rank]	**GRG [Rank]**	**GRG [Rank]**	**GRG [Rank]**	**GRG [Rank]**	**GRG [Rank]**	**GRG [Rank]**	**GRG [Rank]**	**GRG [Rank]**
C1	0.293 [2]	0.373 [2]	0.434 [2]	0.484 [2]	0.525 [2]	0.56 [3]	0.589 [3]	0.615 [3]	0.638 [3]
C2	0.230 [7]	0.335 [5]	0.410 [5]	0.468 [4]	0.514 [4]	0.553 [4]	0.586 [4]	0.614 [4]	0.638 [4]
C3	0.244 [6]	0.330 [7]	0.396 [7]	0.449 [7]	0.492 [7]	0.529 [7]	0.561 [7]	0.589 [7]	0.613 [7]
C4	0.277 [3]	0.354 [4]	0.414 [4]	0.464 [5]	0.506 [5]	0.541 [5]	0.572 [5]	0.599 [5]	0.622 [5]
C5	0.150 [9]	0.256 [9]	0.336 [8]	0.400 [8]	0.452 [8]	0.495 [8]	0.532 [8]	0.563 [8]	0.591 [8]
C6	0.245 [5]	0.332 [6]	0.399 [6]	0.452 [6]	0.497 [6]	0.534 [6]	0.566 [6]	0.593 [6]	0.618 [6]
C7	0.264 [4]	0.357 [3]	0.425 [3]	0.479 [3]	0.523 [3]	0.560 [2]	0.591 [3]	0.618 [2]	0.641 [2]
C8	0.315 [1]	0.405 [1]	0.471 [1]	0.522 [1]	0.564 [1]	0.599 [1]	0.628 [1]	0.653 [1]	0.675 [1]
C9	0.153 [8]	0.257 [8]	0.335 [9]	0.397 [9]	0.448 [9]	0.491 [9]	0.527 [9]	0.558 [9]	0.585 [9]

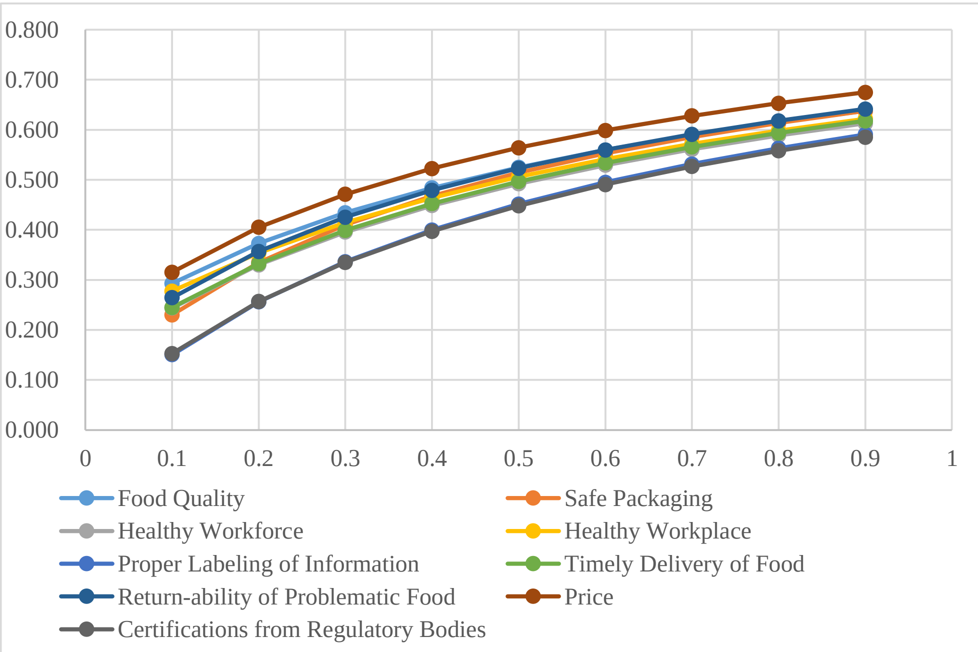

Figure 2. Grey Relational Grades at different values of the distinguishing coefficient

Figure 3. Ranks at different values of the distinguishing coefficient

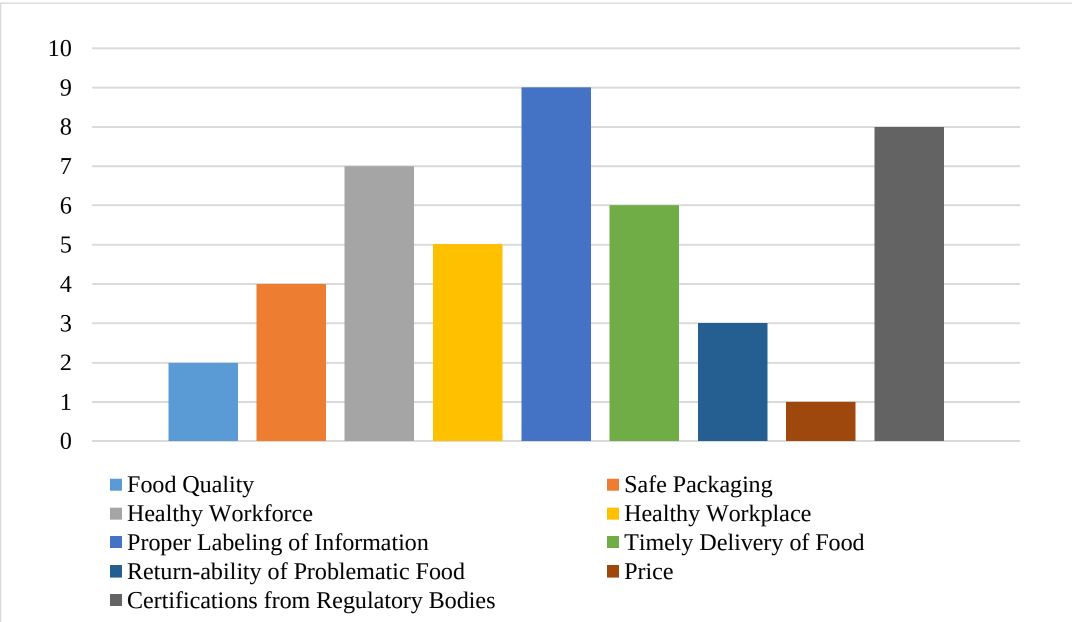

Figure 4. Ranking of the hospitality sector supplier selection criteria with GRA (ξ = 0.5)

square brackets. Grey Relational Grades and ranks at different values of Distinguish Coefficient (DC) are shown in Figures 2 and 3, respectively.

Furthermore, even though different values of DC have been applied, the calculation results show that one of the best criteria, namely Price, always occupies the top rank, while the distinguishing coefficient range defines the rank of other criteria. The ranking produced through Deng's GRA (at ξ = 0.5) is shown in Figure 4.

In the end, as the result of the ξ (0.5) based on the rank and valued by experts, Price occupies the first rank as the most important criteria as rated to supplier selection and followed by related criteria in sequences, i.e., Food Quality, Return-ability of Problematic Food, Safe Packaging, Healthy Workplace, Timely Delivery of Food, Healthy Workforce, Certifications from Regulatory Bodies, and Proper Labeling of Information.

5. Conclusion

Hospitality is a customer-oriented service industry where it mainly thrives by customer's satisfaction. Hence one shall be able to provide good service to run the business. The Hospitality Industry has an orientation where its supply chain management is important for the success of one industry. If one's supply chain is well-managed, goods and services will be well provided, increasing customer satisfaction, which improves performance's value. The results can contribute to improving the well-being of one's industry, specifically for the hospitality industry. Thus, in arranging to set up a well-managed supply chain, selecting the right supplier is the critical first step. The right supplier helps adds value to the goods and services demanded by the customer, thus paving the way for better outcomes while increasing the industry's surplus, where apparently, these procedures work as a cycle. Consequently, satisfied customers are produced through satisfying supplies.

Nine criteria based on health, safety, and food standards identified through several literature studies have been discussed to select the right supplier in the hospitality industry. Later, these criteria have been prioritized by GRA in different scenarios built through the variation in the distinguishing coefficient. Also, the study confirmed the thesis of Mahmoudi *et al.* (2020) by arguing that the variation in the distinguishing coefficient does indeed influences ranks.

The results revealed Price to be the most important criteria that experts should consider in the process of selecting supplier as it consecutively ranked first at different distinguish coefficient values calculated. To be precise ($\xi = 0.5$), Price took first place followed by the rest of the criteria, i.e., Food Quality, Return-ability of Problematic Food, Safe Packaging, Healthy Workplace, Timely Delivery of Food, Healthy Workforce, Certifications from Regulatory Bodies, and Proper Labeling of Information. Hence, in selecting a supplier in the hospitality industry, experts can consider the proposed criteria based on health, safety, and food standards that have been ranked out. In the future, these criteria can be used to evaluate suppliers in the hospitality industry.

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Grey Forecasting of the Exports of Indonesian Palm Oil to India

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Abstract: Palm oil is one of the leading export commodities of Indonesia. Knowing demand in advance can help policy-makers better prepare for the situation. India is one of the major importers of Indonesian palm oil. The study forecasted the Indonesian palm oil's exports to India from till 2025 using the grey forecasting model EGM (1,1, α, θ). The comparative analyses with Linear regression and exponential regression showed that the grey forecasting technique is relatively more accurate to forecast palm oil exports despite huge uncertainty in the data trend. The secondary data on Indonesian palm oil exports to India from 2011-2018 was obtained from the Indonesian Central Statistics Agency (BPS). Mean absolute percentage error was used for error measurement. Despite uncertainty in data, the results show an increasing trend in palm oil exports.

Keywords: Grey forecasting; palm oil; exports; Indonesia; India

1. Introduction

Indonesia is a country that has a wealth of natural resources that are widespread across its different regions. Also, it is an archipelagic country well-known for its agricultural products and green landscapes. It is primarily an agricultural country where most people earn their livelihood by working on farms. Besides, Indonesia is also famous for its fertile soil for planting and vegetation (Sjamsir, 2017). Also, its richness in natural resources, both on land and waters, makes Indonesia an ideal place to develop the agriculture sector. It is the largest tropical agricultural country in the world after Brazil. Of the 27% of the tropical zones in the world, Indonesia has 11% of the tropical area. These characteristics are a significant source of strength for the country's agriculture sector (Kandhani, 2020).

Agriculture is a prominent sector in the Indonesian economy. This means that agriculture is the prominent sector that develops almost half of the country's economy. Agriculture also has a fundamental role as a source of foreign exchange through exports (Sjamsir, 2017). Agriculture is the life and blood of nations and the long-term sustainability of any economy is impossible without sustainable development of its agriculture sector. The existence of farmers is essential for an agricultural country to participate in contributing to improving public welfare. In improving the economy and general welfare, the agriculture sector also has an essential role in fulfilling domestic food needs. Indonesia is known for its plantation products, such as rubber, palm oil, tobacco, cotton, coffee, rice and sugarcane (Gischa & Naifular, 2019).

Based on the statements in the previous paragraph, Indonesian Agriculture consists not only of the agriculture subsector and the food subsector but also have the plantation subsector, the livestock subsector and the fisheries subsector. The plantation subsector is an agricultural subsector that has traditionally been one of the country's exchange-earners (BPS, 2019). Plantation products that have become export commodities include rubber, palm oil, tea, coffee, cocoa, sugarcane and tobacco. Most of the plantation crops are smallholder plantations, while large farms cultivate the rest, both government and private (Soetrisno, 2002). Of the seven commodities, palm oil is in the top rank and is a mainstay of Indonesia (Supriyatna, 2017).

Palm oil is essential for the largest producer and consumer of palm oil in the world. Indonesia supplier approximately half of the world's palm oil supply (McClanahan, 2013). The area of palm oil plantations in Indonesia 6 million hectares (twice the size of Belgium). In 2015, Indonesia planned to build 4 million hectares of a farm to produce biofuel sourced from palm oil. In 2012, Indonesia produced 35% of the world's CSPO certified sustainable palm oil (Sarif, 2011).

The growth of palm oil, rubber, and cocoa is experiencing a rapid rate among other plantation crops, which is above 5%/year. Palm oil is one of the leading commodities in Indonesia. But it turns out that Indonesian palm oil is not only a commodity in Indonesia but also in the world because Indonesia is the largest producer of palm oil in the world (GreenPalm, 2015). However, Indonesia is not only the largest palm oil-producing country but also Malaysia, Thailand, Columbia and Nigeria (GreenPalm, 2015). Figure 1 (data from OurWorldInData.org) shows the five largest palm oil-producing countries. Based on data, Indonesia is in the top 5 palm oil-producing countries. The first place with the highest production results in 2018 reaching 40.57 million tones, Malaysia in the second place with the most increased production result in 2014 reaching 19.67 million tonnes, Thailand in the third place with the most increased production result in 2018 getting 2.78 million tonnes, Colombia in the fourth place with the highest show result in 2017 and 2018 reaching 1.63 million tonnes and Nigeria in the fifth place with the highest production result in 2018 reaching 1.05 million tonnes. Indonesia was the top exporter of palm oil in 2019 with the record output of 36.18 million tons, showing palm oil and its products are an important contributor to Indonesian economy (Reuters, 2020).

Based on data from The World Factbook, Indonesia is one of the 50 countries with the highest number of exports. For Indonesia, exports of goods and services are one of the primary sources of foreign exchange to fill the State Foreign Exchange Reserves (Sasono, 2012). Export activities have a positive relationship with a country's economic growth (Sutedi, 2014). The more export activities in that country that can make more economic growth will increase. The potential of palm oil exports in the past ten years has become a separate force for Indonesian economic growth. The government has also declared the palm oil industry as one of the strategic sectors in Indonesia's development (Purba, 2018).

The Central Bureau of Statistics (BPS) data suggests that the largest export destination countries for Indonesian palm oil are India, the Netherlands, China, Pakistan, and the US. The first highest palm oil export was in 2017, amounting to 7325100, the second in 2018 amounting to 6346200, and the third in 2013 amounting to 5752400 and all export destinations to India. The current study chose India for it is the largest export destination of Indonesian palm oil, as shown in Figure 2 (data from www.bps.go.id) and decided to forecast Indonesian palm oil exports to India using a grey forecasting model. For comparative analyses, two statistical models will be used.

The rest of the study is organized as follows: the second section presents the Indonesian palm oil industry background. The third section discussed the research methodology, presenting data collection, forecasting techniques, and forecast error measurement techniques. In the fourth section, results are presented. In the last section, the study is concluded.

2. Background

One of the most consumed and produced oils in the world is palm oil. Palm oil is obtained from the *mesocarp* of the oil palm tree. It is vegetable oil, generally from the *elaeis guineensis* species and a

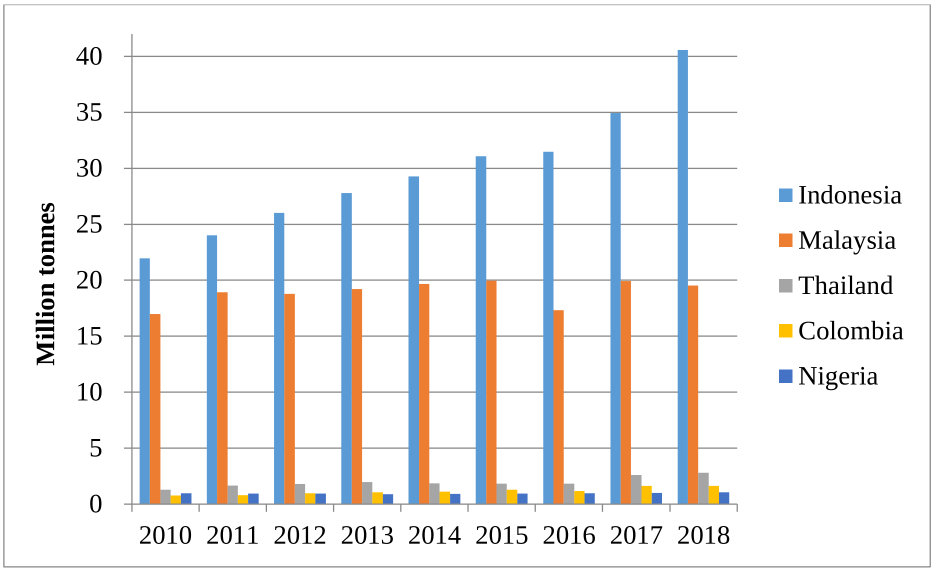

Figure 1. Major palm oil producing countries

little from *elaeis oleifera* and *attalea maripa* species. Naturally, palm oil has red colour due to its high alpha and beta-carotenoid content. Although it comes from the same fruit kernel, palm oil is different from palm kernel oil. Palm oil is also different from coconut oil which is produced from the kernel of the coconut fruit (Cocos nucifera) (McGee, 2004).

A common cooking ingredient in tropical countries in Africa, Southeast Asia and parts of Brazil is palm oil. Asia, Africa and South America have warm temperatures and high sunshine and rainfall, because of this, palm oil can grow well in these countries because palm oil needs it to maximize production. Its use in the commercial food industry in other parts of the country is driven by its low production cost (USDA, 2006) and its oxidative stability when used for frying. Almost all food products in supermarkets use palm oil. Palm oil has the advantage as a raw material for food products. Its advantages include (GAPKI, 2017): (a) relatively low price, (b) contains natural antioxidants that act as natural preservatives, (c) makes food textured smooth and creamy, (d) free of trans fats, (e) tasteless and odourless, and (f) enhances the taste of food. Besides being cheap, palm oil is easy to extract and is used for a wide variety of cosmetics, food, hygiene products, and can also be used as a source of biofuel or biodiesel (Indonesia Investments, 2017).

Although the Indonesian Palm Oil industry and plantations are more than century-old, they are still overgrowing. In 2006, Indonesia overtook Malaysia as the king of world palm oil and Indonesia also defeated the United States as the king of world vegetable oil. "Indonesian palm oil is the main actor in the tropical vegetable oil revolution that can shake the world vegetable oil market," says, *The Tropical Oil Crop Revolution* published by Standford University. Land for palm oil production in Indonesia reached 16.38 million hectares, proving that Indonesia is the largest producer and producer of palm oil in the world. Indonesia is also the first country in the world to successfully implement B30 and continue to develop its innovations until it reaches B100 (100% palm-based biofuels) (RedaksiWE, 2020).

Indonesia's Palm Oil production continues to increase every year. In 2015, Indonesia's Palm Oil production reached 31.07 million tons and increased to 51.8 million tons in 2019. The majority of palm oil production in Indonesia is allocated for export and generates a foreign exchange of more than US$20 billion per year (RedaksiWE, 2020)

There are 1,731 oil palm plantation companies consisting of 162 PBNs (Large State Companies), and 1,569 PBS (Large State Companies) spread across 25 provinces in Indonesia. Based on the percentage of distribution, around 57% of the total plantation companies are located in Sumatra, and 38% are on the island of Borneo. North Sumatra province has the largest number of oil palm plantation companies in Indonesia, namely 329 companies (RedaksiWE, 2020).

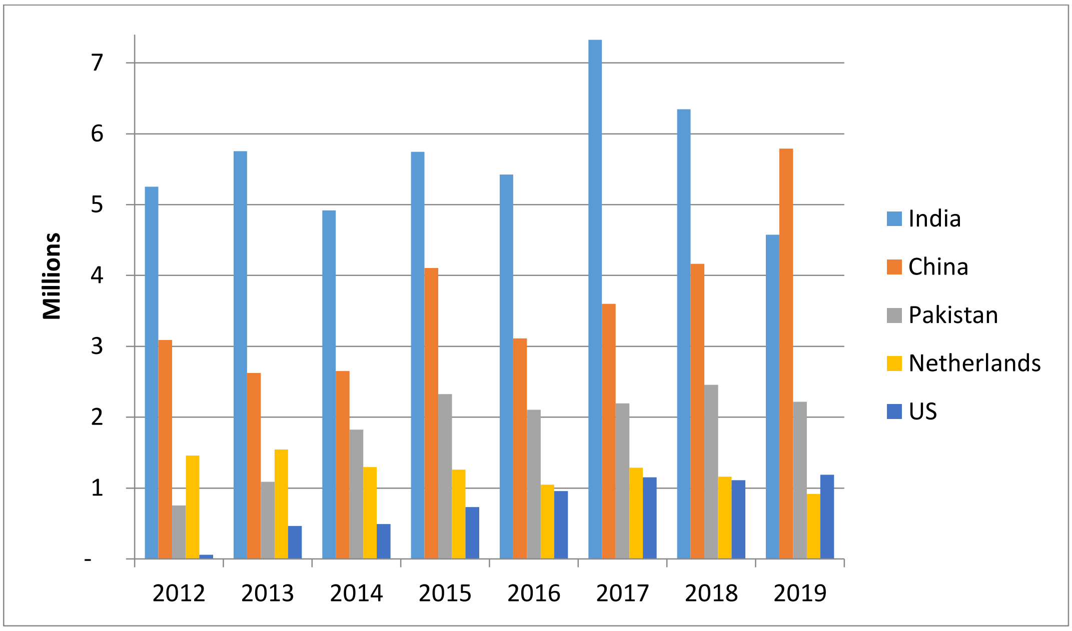

Figure 2. The five biggest export destinations for Indonesian palm oil

Because forest destruction for palm oil plantations is threatening the habitat of Orangutans in Indonesia, which is an endangered species. In 2004, the Roundtable on Sustainable Palm Oil (RSPO) was formed to deal with palm oil plantations in its territory by imposing minimum limits on state land as forest (Scott-Thomas, 2012).

In recent years, Indonesia has experienced a weakening trade balance due to the relatively low growth in exports compared to imports. At the same time, the export of goods and services plays an essential role in driving economic growth, reducing unemployment and poverty. To maintain export growth, it is essential to increase the quality or value-added of products and expand the export market. Indonesia's 5 leading non-oil and gas export commodities are commodity palm oil, fisheries, textile and textile products, wood and wood processing, and paper and paper goods. In 2018, the cumulative total non-oil and gas exports reached the US $ 162.65 billion, an increase of 6..25% from 2017 and continued to increase in 2019. In 2019, the non-oil and gas trade balance contributed to a surplus of US $ 2.8 billion (Boestami, 2020).

Since a long time ago, palm oil is one of Indonesia's natural products that has entered the world market. The two largest export destinations for Indonesian Palm Oil are India and the European Union. The two countries have so far contributed around 40% of the total Palm Oil Export (Boestami, 2020).

The Indian market is very welcoming to palm oil products from Indonesia. Because although there are several policies to increase import duties and imports of Indonesian palm products, these policies have been reviewed. India's condition, which requires products with very competitive characteristics in terms of price, has made palm oil products more likely to have a bigger market than other vegetable oil products (Boestami, 2020).

3. Research Methodology

3.1 Data Collection

Availability of reliable data is a prerequisite for running a forecasting model. For the current study, secondary data concerning Indonesian palm oil export to India for 8 years, from 2011 – 2018 in net weight (tonnes) was obtained from the Central Bureau of Statistics (BPS) Indonesia. Data from 2011 – 2016 was used for forecasting and data from 2017 – 2018 was used for out-of-sample testing.

3.2 Forecasting techniques

Forecasting cannot be separated from the business world. Forecasting is needed to determine the number of products to be produced in an organization or economy. Without forecasting, there can difficulty in determining how many raw materials are needed and which must be made annually. If the amount of production is too much, the company will experience a loss if the demand is small, while if the amount of output is too little and it turns out that market demand is very high, the company will lose a large profit. In full, forecasting is an essential input in the process of making operations management decisions in providing information about future demand to determine how much capacity or supply is needed to make staffing decisions, budgets that must be prepared, ordering goods from suppliers and partners in the chain. Supply and demand information is required in making realistic plans and forecasting play important role in it (Stevenson, 2009).

In recent years, Indonesian palm oil exports to several countries have experienced an increase and a decrease, one of which is to India. But the rise and fall are still in a stable state. This paper aims to look at the forecasting of Indonesian palm oil exports to India in the next 7 years, namely from 2019-2025 using secondary data on Indonesian Palm Oil Exports to India for 8 years, from 2011-2018 obtained from the Central Statistics Agency (BPS) Indonesia. The goal is to see whether Indonesia's palm oil exports to India will continue to be stable or not for the next few years, especially with the COVID-19 pandemic this year.

3.2.1 Even grey forecasting model EGM (1,1, α, θ). Grey System Theory was first developed by Deng (1982). After more than four decades of development, it has shaped a somewhat broad theoretical system and solved numerous practical problems in a lot fields (Du *et al.*, 2021). Grey Forecasting Model or commonly called GM (1,1) is a forecasting model for limited data. The model uses a first-order differential equation with one variable. There is ample of evidence that suggests even with limited data or data containing uncertainty, GM (1,1) can provide an effective method for short-term forecasting (Xie *et al.*, 2021; Ikram *et al.*, 2019; Widyaningsih & Utami, 2015). Forecasting with GM (1,1) can be used for sequence forecasting, interval prediction, natural disaster forecasting, season forecasting and capital market forecasting. However, there should be at least four data values for forecasting (Javed *et al.*, 2020a).

Even Grey Model (1,1) (EGM) was proposed by Javed *et al.* (2020a) as a special case of the proposed model EGM(1,1,α,θ). The EGM with first-order differential equation containing one variable EGM (1,1) and Discrete Form of Grey Model with first-order differential equation containing one variable DGM (1,1) are two of the four basic models of grey forecasting theory. EGM is suitable for making predictions through non-exponential increasing data sequence and DGM is suitable for making predictions through a homogenous exponential data sequence (Liu *et al.*, 2017). below are some of the equations that can be used from EGM(1,1,α,θ) (Javed *et al.*, 2020a):

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

where, $x^{(\alpha)}(k) = \sum_{i=1}^{k}(\frac{x^{(0)}(i)}{i^{1-\alpha}})$, k = 1, 2, …, n. In the classical even grey model, α = 1, however, in EGM(1,1,α,θ), α ϵ (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 $Z^{(1)}(k) = \theta . x^{(\alpha)}(k) + (1-\ \theta). x^{(\alpha)}(k-1)$. In the classical even grey model, the background coefficient α = 0.5, however, in EGM(1,1,α,θ), θ ϵ (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

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

The inverse conformable fractional accumulation, which is needed to extract simulation of the actual data sequence $\hat{x}^{(0)}(k)$ from the simulation of the accumulated data sequence $\hat{x}^{(a)}(k)$, is executed through the following approximate regressive reduction 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 $x^{(0)}$, which is an exponential function of time, 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 model's complete algorithm and properties are available in Javed *et al.* (2020a). Later, Linear Regression and Exponential Regression models will be used for the comparative evaluation of Even Grey Model EGM (1,1, α, θ).

3.2.2 Linear regression. Linear regression is a statistical tool used to determine the effect of one or more variables on one other variable. Variables that influence are referred to as independent variables, independent variables, or explanatory variables. The general form of Linear Regression model is

$$Y = \alpha + \beta X$$

where, α and β are two parameters, and *Y* and *X* represent dependent and independent variables, respectively. To calculate linear regression in Microsoft Excel, in the current study, the formula below, *Y* =-87.371**periods*+5849.5, was used.

3.2.3 Exponential regression. Exponential regression is the process of getting the exponential function equation that best fits a set of data. This general form of Exponential Regression model is

$$Y = ae^{bX}, a \neq 0$$

where, *a* and *b* are two parameters, and *Y* and *X* represent dependent and independent variables, respectively. To calculate exponential regression in Microsoft Excel, the formula, Y=5828.7*EXP(-0.015**periods*), was used.

3.3 Forecast error measurement technique

For forecast error measurement, Mean Absolute Percentage Error (MAPE) was used as (Javed & Cudjoe, 2021; Javed et al., 2020b),

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

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

4. Results and discussion

This section will explain the results of Forecasting the Export of Indonesian Palm Oil to India from 2019-2025 using the Grey Forecasting Method and the Formula of Linear Regression Formula, Exponential Regression, Even Grey Model. Following Javed and Liu (2018), analyses of Relative Growth Rate and Doubling Time was also performed.

In Table 1 one can see the forecasting result on Indonesian palm oil exports to India using Linear Regression, Exponential Regression, and the grey forecasting model EGM (1,1, α, θ). According to the results of MAPE, one can conclude that: the in-sample error of the Linear Regression is 6.14%, Exponential Regression is 6.15%, and the even grey forecasting model is 4.84%, and the out-of-sample error of the Linear Regression is 23.67%, Exponential Regression

Table 1. Forecasting of exports of Indonesia palm oil to India (Tonne)

Years	Net Weight	LR	ER	EGM (1,1,α,θ)	Cumulative	RGR	$\overline{RGR}$	D_t	$\overline{D_t}$
2011	6165	5762	5742	6165	6165		0.34		1.88
2012	5254	5675	5656	5325	11419	0.62		1.18	
2013	5752.4	5587	5572	5362	17171	0.41		1.59	
2014	4920.4	5500	5489	5400	22092	0.25		2.07	
2015	5746	5413	5408	5438	27838	0.23		2.16	
2016	5424.6	5325	5327	5476	33262	0.18		2.42	
2017	7325.1	5238	5248	5514	5514	-	0.28		2.14
2018	6346.2	5151	5170	5553	11067	0.7		1.05	
2019		5063	5093	5592	16658	0.41		1.59	
2020		4976	5017	5631	22289	0.29		1.93	
2021		4888	4942	5670	27959	0.23		2.18	
2022		4801	4869	5710	33669	0.19		2.38	
2023		4714	4796	5750	39418	0.16		2.54	
2024		4626	4725	5790	45208	0.14		2.68	
2025		4539	4654	5954	51162	0.12		2.78	
MAPE% (In-sample)		6.14	6.15	4.03					
MAPE% (Out-of-sample)		23.67	23.45	18.61					

**In the cumulative column, the actual data is used for the years 2011–2018, and for the years 2019–2025, the simulation data are used.*
***LR and ER denotes Linear Regression and Exponential Regression.*
****$\overline{RGR}$ and $\overline{D_t}$ denotes Mean RGR and Mean D_t respectively.*

is 23.45%, and the even grey forecasting model is 18.61%. The parameter a = -0.006974422 and b = 5263.556472 for EGM (1,1, α, θ).

From the result, one can see that the performance of the three models is different. Only the results of all the MAPE-in samples averaged below 10%. But we can conclude that the results of the MAPE-in sample and MAPE-out sample Even Grey Model are the smallest than others, in sample is 4.84% and out sample is 18.81%. So the Even Grey Model is more accurate than others. And the result of forecasting of export Indonesia palm oil to India from 2019-2025 using Even Grey Model are continuing to increase. The accuracy of the models is evaluated in Figure 3. Unlike, Linear and Exponential Regression models, the Even Grey Model is revealing increasing exports, while the other two models are revealing decreasing trend. Despite uncertainty in data, the results of the Even Grey Model are more realistic.

5. Conclusion

Both organizations and economies need to know the demand for their products. Demand forecasting is important to develop aggregate plans so maximum demand can be met. The current study is intended to determine the accuracy of the EGM (1,1, α, θ) method for forecasting the export of Indonesia palm oil to India 2019-2025 by comparing the EGM (1,1, α, θ) method with two other forecasting methods: Linear Regression and Exponential Regression. Not all types of forecasting methods can be used for all data because many factors must be considered in choosing a forecasting method, such as the data pattern that is owned and the amount of data. The grey forecasting method is one of the forecasting methods used to determine short-term decisions and the grey forecasting model has a smaller error value. The grey forecasting model can be used in uncertainty, for example, for remote data and incomplete data information. And this study shows that The grey forecasting model can be used on fewer data and the results are more precise than

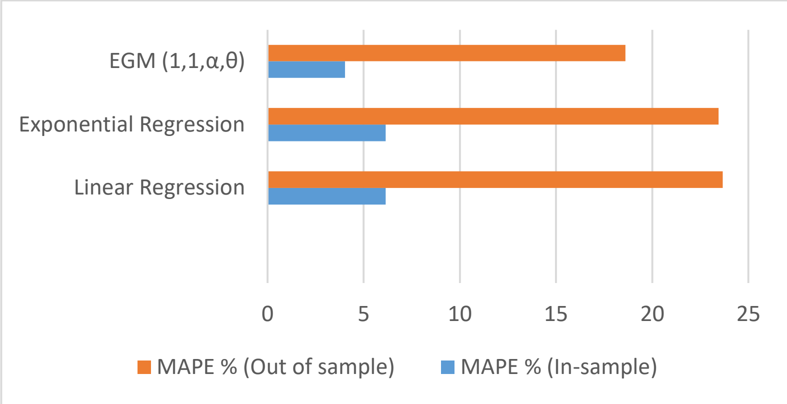

Figure 3. Forecast error evaluation

some of the statistical methods. The results showed increasing trend in Indonesian palm oil exports to India thus policy-makers should develop policies to sustain this trend, especially to minimize the effect of pandemic-induced disruptions. In future more accurate forecasting model should be developed to forecast palm oil exports that can incorporate the zigzag trend in data more effectively.

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Critical Factors in Process Quality of Engineering Construction Projects during Building Design Phase

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Abstract: Quality in construction is an important topic in the design phase due to the quick change in technological advancement. The current study focuses on the identification, measurement, and analysis of the critical elements which impact the process quality of building construction projects during the design stage in Pakistan. Elements were graded using the conservative Relative Importance Index (RII) and Grey Absolute Decision Analysis (GADA). The findings indicate that during the design phase, the critical element impacting process quality is the quality of codes and standards and was facilitated using a questionnaire survey. Similarly, the teamwork of parties in design firms and constructability analysis of the design are key factors during the design phase in Pakistan. Measures for the improvement of process quality in Pakistan were suggested. The building construction projects need to be modified to cover the important aspects of constructability analysis, continuous working on training programs, and many other related activities. These are performed through a proper commitment to continuous quality improvement in building construction projects. The results are important for improving process quality during the construction projects' design phase.

Keywords: Civil engineering; construction; grey system theory; project design; quality process

1. Introduction

Gone are the days when project management was viewed as a threat to established lines of authority and thus to the traditional way of managing organizational tasks as today it has been widely recognized as a competitive weapon to provide superior quality and services to the clients (Mahmoudi *et al.*, 2020; Kerzner, 2014). Quality is not a new concept for construction project managers. For construction companies, quality is considered the satisfaction of the customers and as the component that tends to fulfill the requirements within the specified budget. In the construction sector, quality control is considered as client satisfaction, cost, and time of obtaining anticipated quality. Quality is a paramount requirement for every stakeholder in the construction industry. The construction quality of projects depends on process quality during various construction phases. According to Arditi and Gunaydin (1998), several elements impact the process quality of building construction. These elements include general elements like employee training, teamwork, the interest of management and top management in promoting quality, etc., building industry-specific elements like the selection of appropriate firms, quality of drawings and specifications, adequacy of supervision, etc. Quality is one of the crucial matters for the construction industry, where clients' requirements are a certification of quality (Chung, 2002). Project quality management must address both the product quality and process quality of the project. One must comprehend the difference between process quality and product quality. Process quality represents the quality and standard of a process that indicates the product is up to par or not (Nagasaku & Oda, 1965), whereas the product quality suggests the quality of the elements, which are in direct association with the product itself. Delivering quality projects is extremely important for a project management firm to produce satisfied clients and thus the firm more profitable (Javed & Liu, 2018).

Evaluation of the critical success factors (CSFs) in project environment has received due attention by scholars for years, especially in the developing countries, where the studies on the CSFs of projects and industries have been seeking attention at least since the 1990s. Huirne *et al.* (1997) evaluated the CSFs for the dairy farmers in the Netherlands and Michigan (USA). Roos *et al.* (1999) assessed the Critical factors to bioenergy implementation in the USA and some European countries. With the globalization and quests for new markets in the developing world, the projects and industries in the developing countries also got some attention, especially in the last few years. For instance, Banihashemi *et al.* (2017) investigated the CSFs for integrating sustainability into construction project management practices in developing countries. Mashwama *et al.* (2017) assessed the critical success factor for reducing cost of poor quality in construction projects in Swaziland. Maqbool and Sudong (2018) studied the CSFs for renewable energy projects; empirical evidence from Pakistan. Batool and Abbas (2017) studied reasons for delay in selected hydropower projects in Khyber Pakhtunkhwa, a province of Pakistan. Li *et al.* (2019) present a very thorough review of CSFs (CSFs) for green building projects. They identified "Designers' performance" as one of the 28 CSFs. If one reviews the literature,, one finds that evaluating the critical factors in process quality of construction projects during the building design phase has never been done. Furthermore, if one digs deeper in the literature one finds studies involving CSFs of Pakistani projects have rarely been executed, let alone in the crucial context of designing. It has been observed that the construction industry of Pakistan and India has certain distinguishing characteristics compared with other developing countries. Each region has its own characteristic, and thus, the development of the economy and its heavy industries like construction and building industries always take place in its certain circumstances. The development of construction is always made in accordance with the environment of a country, weather, availability of raw material, and many other related attributes that are considered to have a bearing impact on the designing, processing and execution of construction industry projects. Even soft factors also play their influence e.g., employee behavior, attitude, motivational level, team management and training and development sessions. Studies (e.g., Belout and Gauvreau, 2004; Strain & Preece, 1999) have confirmed the role of human and individual factors' role in project success and deliverables. The role of human factors in organizational design and management has also been widely recognized (Carayon *et al.*, 2012). However, the critically important factors in construction projects during the building design phase were question none of the existing studies have fully answered. This can be attributed to two reasons; (a) the data collection during the project designing phase is hard to obtain in the countries like Pakistan where effective data management practices are fragile; (b) absence of policies that can ensure that project data is routinely recorded and transparently reported for future lessons, and avoiding mistakes in future.

In the context mentioned above, and the gap we just reported, the current study was initiated, with the primary aim of identification, measurement, and analysis of the critical elements that directly impact the process quality of building construction projects during the design phase in developing countries.

2. Literature Review

2.1 Process Quality

Aristotle thought that there is some good at which all actions aim (Ostenfeld, 1994). Engels argued that each action transforms quantity into quality, resulting from the quantitative change associated with the movement of the object experiencing the transformation (Stalin, 1976: p. 839). Quality has remained a topic of interest among scholars and practitioners alike for ages in its different forms. However, still, it is hard to define the term "quality," and there is no one definition that fits all purposes (Chan *et al.*, 2006; Javed *et al.*, 2019). It is, in fact, difficult to explain quality meaningfully and precisely in the case of building construction (Low & Goh, 1994). In project management literature, quality has been defined as "a continuous function of duration and cost" (Mahmoudi & Javed, 2020). As Heravitorbati *et al.* (2011) expressed, quality is the satisfaction of requirements of all the stakeholders engaged in construction projects. According to Juran (1988), quality is a good or flawless facility. Quality is also defined as the conformity of the constituted requirements (Burati *et al.*, 1992). Measuring the quality of a product or good is relatively easier than measuring the quality of services because of the intangibility associated with services (Javed and Liu, 2018).

Process quality is an aspect of management technique under Total Quality Management (TQM) which was first developed, applied and accepted by the Japanese construction industry in the 1970s and has subsequently been used to improve productivity, lessen product cost and increased product reliability (Arditi & Gunaydin, 1997). Jaber *et al.* (2018) explained the purpose of process quality: to reduce the occurrences of production or to assemble processes going out of control. Every phase of a project undergoes a process that must observe quality at every level. The quality of every process is key to the attainment of the total quality of the project. With this in mind, the process quality engineers the entire quality desired to be achieved. All elements in the process quality chain must not be overlooked as it might hinder the probability of reaching the utmost quality. In line with construction, for example, the erection of a strong and quality pillar depends not only on the quality and proportion of the components of concrete used but also the quality of the process by which they underwent.

The determination of the quality of a structure relies on adequate supervision and management of all activities undertaken during the construction project, which in simple terms is known as process quality. Optimized results are highly obtainable by evaluating projects and products through process quality. A process quality control approach was used to verify beam alignment in laser operations (Mourtzis *et al.*, 2018), which provided grounds for laser suppliers to shift business models to servitization. The elements such as management leadership, strategic planning, employee empowerment, and quality training are associated with TQM, which reflects the positive relation total quality management has with performance (Sahoo & Yadav, 2018). The construction industry is indifferent to applying quality management to improve performance, but the quality performance of a product or service cannot be checked independently, quality must be created with the process of the product (Ulewicz & Nový, 2019). The philosophy of attaining quality in improving products and services is generating breaking ground roots in a wide range of industries and sectors. To reach the quality of service in the education sector, Militaru *et al.* (2013) employed the principle of TQM in order to achieve excellence in the second cycle and university level. They established that a holistic approach of TQM in education must induct the seven elements: philosophy, vision, strategy, aptitudes, resources, rewards, and organization, which is expected to long-duration as productive results in education are seen in the future terms. A study conducted in Unite Arab Emirate evaluated TQM, which is seldom used in mechanical, electrical and plumbing and a conventional management approach thus the status quo procedures (Small & Al, 2017). The research concluded that TQM has a significate impact on productivity and project progress.

Process quality, therefore, measures the overall quality of products and services more realistic to be achieved.

2.2 Importance of Good Project Design for Project Success

The success of a project in relatively associated with its planning and design pattern. A good project design is significant to satisfy an expected objective as it stands to be a pillar and framework of the holistic project. A project design is characterized by a group of unique designers who interdependently captivates the priority and sequence of a good design process (Mujumdar & Maheswari, 2018). This bridges the gaps and ascertains the aim of the project. Iterations are inevitably looking at the complexity of a project such as construction. With the high level of uncertainty related to the requirement of a project, an iteration based on solution-oriented within the project design phase enables understanding and adapt solution to meet defined goal of the project (Gebhardt *et al.*, 2019). In the design of a project where adequate iterations are observed, quality is achieved in the project design.

All stages in a project design phase are very vital to undergo in order to prevent project failure as clarity is given on all contextual factors that plan an essential roll, such as resources and structures (Stritter *et al.*, 2018). Tjell and Bosch (2015) enlightened on visualization management as one important aspect in project design which is rarely known in the construction industry yet supports communication and mutual understanding during design. They also concluded that all actors in design teams actively engage and become more self-going by visual management. In other words, a good project design increases the productivity and quality of the project by making appropriate decisions. Also, the advantage of 2D or 3D visualization provides a vivid perspective on the outlook of the expected design, which is more flexible and easily understood by creating intense and direct relationship between the design and customers (Bieger & Carvalho, 2015).

Looking at the health sector, design projects have gone a long was to improve the quality of care at the hospital. After an evaluation by project design, the German University Hospital developed an integrated care unite for children with cancer (Stritter *et al.*, 2018). Interventions have been made for patients to be treated appropriately to aid in quality health care. Rahmat *et al.* (2012) studied the impact and development on students as they accomplish an effective project design with the knowledge of mathematics and science to resolve engineering problems. Skills such as teamwork spirit, communication, engineering and critical thinking are highly developed which advances the students capacity. The high academic success achieved reflects the satisfaction that boost design capability and creativity (Dizdar, 2015).

2.3 Construction Industry and Quality Management in Pakistan

In Pakistan, the construction industry plays an active role in economic development and reduces unemployment. The construction industry (CI) provides many job opportunities with many business enterprises and other industries. The construction industry has good connections and strong relational impact to approximately forty (40) building and construction material industries, design engineering firms, and finance organizations. Community development is also at a rise which goes a long way to lessen penury by creating earnings for poverty-stricken families. During the year 2003-2004, about 5.3-5.5 % of the working population, thus 2.3 million people, benefited from the construction industry (Khan, 2008).

Farooqui *et al.* (2008) implemented TQM principles to investigate the behavior of contractors in the construction industry through questionnaires and direct interviews. The study highlighted the following to be the problems that influence a contract's behavior thus inadequate knowledge on quality, lacking construction industry education and the varying characteristics of The construction industry, and being corrupt. The contractors are overwhelmed by the approach of TQM, so they are reluctant to adopt the technique. Conclusions further stated that for quality improvement, it was crucial to focus on managerial leadership skills and be committed to employees' education and quality.

The key importance of Total Quality Management (TQM) is clearly discussed by Memon *et al.* (2013), a typical case study that describes the implementation of TQM system in Pakistan. The scholars explained that with the implementation of TQM, there is improved market share, performance is enhanced, attention is drawn to top management activities, and meeting the needs at the lower level. It further builds a good relationship between suppliers and customers where by the satisfaction of the client is met. TQM plays the role of measuring construction quality. Despite the benefits of the TQM technique, many loopholes hinder its effective practice. Many scholars have investigated the barriers that limit TQM, which were related to human resources, organizational culture, methods of training, management and attitudes towards quality, among others (Amar & Mohd Zain, 2002). Literature shows that quality is well known to experts in the field of construction in Pakistan, but however, there is less research on the potency of process quality and how it improves productivity. The study investigates quality management principles and its primary elements that improve construction projects during the design phase.

The free market model is being allowed in more countries, and these countries are opening up their borders for trading and investment; as a result, worldwide competition is becoming a greater concern (Lee, 2002). To remain in the struggle, an organization's main business strategy has to emphasize on strategic remuneration through the development of its business brilliance and enactment. Quality management has now become an indispensable and completely universal planned strength in the current tempestuous and vibrant professional world (Temtime, 2003). The growing amount of universal struggle has made this quality management a must requirement for existence. Due to business brilliance and greater performance, companies will become more economical and this is caused by adopting sound quality management practices (Lee, 2002).

The two aspects of construction project quality are process quality and product quality. A designer who lacks technical knowledge, especially concerning process quality in design, may develop faulty designs that may pose constructability issues later in the project's execution phase. It is unlikely to reach the quality of a construction project without considering the quality of every phase's processes. All actors or designers are to inclusively put into use all elements that aid quality in executing their expertise in the construction project.

3. Research Methodology

3.1 The Research Instrument

Numerous aspects of process quality impact building construction projects, e.g., employee training, teamwork, the interest of management and top management in promoting quality, and building industry-specific elements like selecting appropriate firms, quality of drawings, specifications, adequacy of supervision, etc. The data collection tool adapted in the current study was inspired by Arditi and Gunaydin (1997; 1998; 1999). Here it should be mentioned that it is the first time this tool has been applied in Pakistani projects' context. An alien tool can be applied in a new market if it shares certain characteristics (e.g., the construction sector of different countries shares some common characteristics), its validity is confirmed through appropriate response rate, and the results are rationale. This reasoning can be confirmed from the study by Ikram *et al.* (2019), which admissibly used a Korean tool in the Pakistani context.

There were two parts of the questionnaire, formulated in an elementary language considering the needs of the construction industry of Pakistan. Part I of the questionnaire consisted of the respondent's general information. It included marital status, gender, qualification, designation, level of management, working experience in the construction industry, name of the firm, category of enlistment in Pakistan Engineering Council (PEC), and place of the head office (district). Part II was the main body of the questionnaire. It contained seventeen (17) questions related to determining and identifying critical elements impacting process quality of building construction projects during the design phase in Pakistan.

3.2 Data Collection

Using multiple modes for data collection has been recognized as an established primary data collection approach. These modes include personal, cell phone, WhatsApp, email, and a blend of all methods. A list of valid design firms was obtained from the official website of the Pakistan Engineering Council (www.pec.org.pk). Most of the respondents were accessed through emails. 150 questionnaires were sent, and 71 were collected. From them, only 67 were filled correctly; thus, the response rate was 47.3%, which is acceptable in the project management context. The sample size was 67, which was small; therefore, the deployment of Grey System Theory-based model was considered a suitable approach for data analysis. However, the Relative Importance Index (RII) was chosen for comparative analysis. The two techniques are discussed in the succeeding sections.

3.3 Data Analysis

IBM SPSS and Microsoft Excel are used for data analysis. The data analysis contains general characteristics of the respondents, summary of respondents, reliability analysis, apply correlation analysis model for determining the relationship among variables, prioritization of factors based on calculations of standard deviation, mean, and RII, and listing of top five essential elements which impart on process quality in Pakistani building construction projects while in designing stage.

3.4 Sample Characteristics

The questionnaires comprised of general characteristics of respondents and their firms.

3.4.1 Respondent characteristics: The characteristics of the respondents include their qualification, level of management and years of experience. The qualification of the majority of the respondents (88%) participated in the survey was at least Bachelor's in Engineering, Civil Engineering or Project Management. However, some of the respondents were also the owners of the firms without a formal degree in construction-related disciplines. It shows that, in Pakistan, the ownership of a design firm does not necessarily lie with the people having qualifications related to construction-related disciplines. The majority of the respondents (51%) held the position among the top-level management in their firms. Varied years of professional experience ranges from 1-5 years to more than 20 years, showing that highly skilled professionals from the design firms responded to the survey. A detailed breakdown of respondents' characteristics is presented in Table 1.

3.4.2 Design firm characteristics: A total of sixty-seven respondents in twenty districts of Pakistan responded to the survey. The list of these districts and the number of respondents from each district are shown in Table 2. It was realized that the majority of the respondents were from Punjab (43%) and Sindh (25%), which is because a large number of the design firms are based in the cities Karachi and Lahore.

3.5 Reliability Analysis

Before carrying out any other test, it is strongly recommended to judge the reliability of the collected data. Since the data gathered was based on 5-point Likert scale; therefore, to check the reliability Cronbach's alpha was used with the aid of IBM SPSS software (v.20). It was found reliable as above 0.75 in all cases; therefore, the collected data passed the reliability test. The formula for the estimation of Cronbach's alpha is given by (Cronbach, 1951)

$$\alpha = (\frac{k}{k-1})(1 - \frac{\sum_{i=1}^{k} \sigma_{yi}^2}{\sigma_x^2})$$

where, k implies number of scale items, σ_{yi}^2 implies to variance associated with item i, σ_x^2 implies to the variance related to the observed total scores. Alternatively, the formula may also be written as (Kopalle & Lehmann, 1997),

Table 1. Demographic profile of the respondents

	Demographic	Number of Respondents	%	Cumulative %
Qualification	BE	35	52	52
	MS	24	36	88
	PhD	4	6	94
	B. Arch	2	3	97
	MBA	2	3	100
Level	First Level Management	23	34	34
	Middle Level Management	10	15	49
	Top Level Management	34	51	100
Experience in Years	1 – 5	18	27	27
	6 – 10	15	22	49
	11 – 15	16	24	73
	16 – 19	8	12	85
	20 +	10	15	100
Location	Federal Territory	7	10	10
	Punjab	29	43	53
	Sindh	17	25	78
	KPK	9	13	91
	Balochistan	3	5	96
	Gilgit Baltistan	1	2	98
	Azad Kashmir	1	2	100

$$\alpha = \frac{k * \bar{c}}{\bar{v} + (k-1)\bar{c}}$$

where, k implies the number of scale items, $\bar{c}$ implies the mean of all covariances between items, and $\bar{v}$ implies mean variance of each item. The literature suggests that $\alpha \geq 0.7$ suffices the reliability of data.

3.6 Factor Evaluation Techniques

For ranking the factors, a set of popular and novel approaches have been used, i.e., the Relative Importance Index (RII) and the Grey Absolute Decision Analysis (GADA) methods.

3.6.1 Relative Importance Index (RII): The relative importance index determines the importance of various factors with respect to other comparable factors. RII is a traditional way of ranking factors in project management literature and has seen many applications. To evaluate delaying factors in India's construction projects, Rajgor *et al.* (2016) implemented RII. The scope of their investigation involved office, residential and high-rise buildings which they concluded that in material management, shortage of skilled laborers is the primary cause of delay. Gunduz and Ahsan (2018) used RII for the evaluation of construction safety factors. Alsuliman (2019) used RII for evaluating causes of delay in Saudi public construction projects. Aziz and Abdel-Hakam (2016) used RII to evaluate delay causing factors construction projects in Egypt. Sheikh *et al.* (2019) used RII for ranking the factors affecting process quality in Pakistani construction projects. Wu *et al.* (2019) used RII for the evaluation of factors in the off-site construction projects in China. In short, RII has garnered a lot of attention in project management literature for evaluating different factors.

RII of each factor was calculated using the formula given below (Fagbenle *et al.*, 2004):

$$RII = \frac{\Sigma(P_i * U_i)}{N * n}$$

where RII is Relative Importance Index, P_i is the respondent's rating, U_i is the number of respondents with an identical rating, N is the sample size, and n is the highest value on the Likert scale.

Table 2. Location of design firms

District	Number of Respondents	District	Number of Respondents
Karachi	15	Wah Cant	1
Lahore	13	Taxila	1
Islamabad	7	Hyderabad	1
Rawalpindi	6	Jamshoro	1
Peshawar	5	Abbottabad	1
Multan	4	Kohat	1
Quetta	3	Swabi	1
Faisalabad	2	Laki Marwat	1
Gujranwala	1	Mirpur	1
Bahawalpur	1	Gilgit	1

3.6.1 Grey Absolute Decision Analysis (GADA): Grey System Theory was established by Professor Deng in 1982, and since then, it has seen its application in a wide range of areas, e.g., healthcare (Aydemir & Sahin, 2019; Quartey-Papafio *et al.*, 2019), environmental sustainability (Shahzad *et al.*, 2020), supply chain (Diba & Xie, 2019; Mahmoudi *et al.*, 2021a; 2021b), tourism (Javed *et al.*, 2020a) energy and emissions (Ofosu-Adarkwa *et al.*, 2020; Du *et al.*, 2019; Xie *et al.*, 2020), information systems (Esangbedo *et al.*, 2021), engineering (Abifarin *et al.*, 2021), economics (Camelia, 2015), etc. Also, it has seen applications in project management (Javed & Liu, 2019; Mahmoudi *et al.*, 2020; 2021c). Studies have reported that Grey System Theory based models are particularly useful when data is small or insufficient (Javed *et al.*, 2020b), as is the case in the current study. Considering the small data size in our research, we decided to use a Grey System Theory-based approach. Grey Absolute Decision Analysis (GADA) model, proposed by Javed *et al.* (2020c), is a new development in the theory of multi-attribute decision making (MADM) and is a kind of breakthrough as, unlike conventional MADM methods, it does not require normalization of data. Thus, the model is practically dimensionless and convenient to use. As mentioned earlier, the key advantage of this method lies in its simplicity and independence over the dimensions of the criteria.

The GADA method involves a procedure to estimate GADA Indexes and GADA Weights. If there are *M* criteria ($C(k)$; k = 1,2,…,M), *N* respondents (E_i; i=1,2,…, *N*) and *S* alternatives (A_j; j=1,2,…,*S*) then the GADA Indexes $\grave{r}_j$ and GADA Weights $\grave{R}_j$ are given by (Javed *et al.*, 2020c),

$$\grave{R}_j = \frac{\grave{r}_j}{\sum_{j=1}^{s} \grave{r}_j}$$

where,

$$\grave{r}_j = \left(\prod_{j=1}^{s} {r_j}^{\alpha_i}\right)^{1/\sum_{i=1}^{N}\alpha_i}$$

where r represents observations and α is Javed's parameter and ε is Liu's absolute degree of grey incidence, respectively given by

$$\alpha_i = \frac{1}{N}\left(\varepsilon_{i1} + \varepsilon_{i2} \ldots + \varepsilon_{iN}\right)$$

and,

$$\varepsilon_{ij} = \frac{1 + |s_i| + |s_j|}{1 + |s_i| + |s_j| + |s_i - s_j|}$$

where,

$$|s_i| = \left|\sum_{k=2}^{n-1} x_i^0(k) + \frac{1}{2}x_i^0(n)\right|, |s_j| = \left|\sum_{k=2}^{n-1} x_j^0(k) + \frac{1}{2}x_j^0(n)\right|,$$

Table 3. RII and GADA rankings of design phase elements

Factor No.	Factor*	RII	Rank (RII)	GADA Index	GADA Weight	Rank (GADA)
F1	Level of cooperation of design professionals	0.800	8	3.927	0.061	8
F2	Extent of teamwork of parties participating in the design phase	0.836	3	4.086	0.063	2
F3	Level of management leadership in promoting quality	0.788	11	3.854	0.060	11
F4	Level of management commitment to continuous quality improvement	0.806	7	3.935	0.061	7
F5	Use of statistical methods	0.651	16	3.076	0.048	16
F6	Existence of feedback system	0.734	14	3.481	0.054	14
F7	Constructability of the design	0.833	4	4.075	0.063	3
F8	Educational background of designers	0.800	8	3.898	0.060	9
F9	Extent of designers training	0.830	5	4.063	0.063	4
F10	Selection of appropriate design firm	0.827	6	4.021	0.062	6
F11	Characteristics of office practices	0.719	15	3.458	0.054	15
F12	Briefing of owner	0.800	8	3.896	0.060	10
F13	Budget allocated for design	0.770	13	3.685	0.057	13
F14	Appropriateness of project specifications	0.839	2	4.048	0.063	5
F15	Quality of codes and standards	0.881	1	4.344	0.067	1
F16	Characteristics of drafting practices	0.776	12	3.810	0.059	12
F17	Personalities of the participants	0.615	17	2.892	0.045	17

*The factors are adapted from Arditi and Gunaydin (1997; 1998; 1999).

$$|s_i - s_j| = \left| \sum_{k=2}^{n-1} (x_i^0 (k) - x_j^0 (k)) + \frac{1}{2} (x_i^0 (n) - x_j^0 (n)) \right|$$

For further details about the model, its parameters, and its properties, Javed *et al.* (2020c) can be consulted.

4. Results and discussion

The results of the ranking analysis of factors by relative importance index (RII) and Grey Absolute Decision Analysis (GADA) are shown in Table 3. The overall ranking by the two models reflects differently. The highest and lowest RII are 0.881 and 0.615 which corresponds to the quality of codes and standards and participants' personality, respectively. Similarly, the highest and lowest weight by GADA is 0.673 and 0.0448 but equally corresponds to the quality of codes and standards and the personality of participants, respectively. Therefore, an agreed consensus by the two models has been established to distinguish the significant effect on process quality of building projects in Pakistan.

After ranking the elements that impact the process quality of building projects in Pakistan during the design phase, the top five (5) critical elements were identified. Figure 1 shows top five critical success factors identified through the two techniques.

Following factor number 15, GADA demonstrates the teamwork of participating parties in the design phase and the constructability of the design as the 2nd and 3rd key factors influencing process quality in the design phase during construction projects in Pakistan. Meanwhile, RII rankings say otherwise, apart from the only similarities it has with GADA. For decision-making purposes, a clear preference or priority must be drawn. Grey method in its natural state revolves around uncertainty as to the fundamental analysis approach, thereby having a strong advantage of RII,

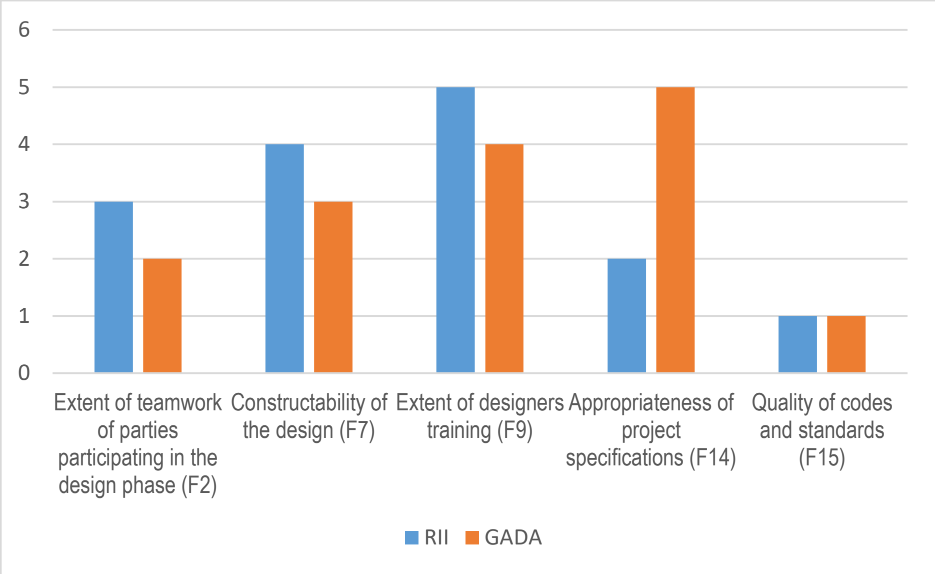

Figure 1. Top five critical success factors in process quality

which relies on a conservative approach. For that matter, it is suggested to use grey absolute decision analysis in the decision-making process when the decision-making process contains uncertainty. However, both approaches reveal the quality of codes and standards to be the most critical factor in the process quality of construction projects of Pakistan during the building design phase; thus the finding can be accepted with confidence.

Even though the list of top five factors is comparable, the relative position of factors is not entirely the same. One may ask, 'why the critical elements of RII and GADA have obvious differences?' Firstly, RII is a simple approach if one compares it with GADA, which is a more comprehensive approach of ranking parameters. Secondly, different factors may influence ranks. For instance, a study by Palczewski and Sałabun (2019) reports how just by changing the type of normalization method, rankings thus obtained can be very different. Mulliner *et al.* (2016) showed how different decision-making models could reveal different, and sometimes contradictory ranks. This is a well-known dilemma of decision-making under multiple attributes, and resolving it is beyond the scope of the current study.

5. Conclusion

The construction industry is an essential function for the progress of any country in this highly competitive business world. This industry contributes to the country's operational, economic development, and growth and cannot be neglected on any occasion. The design phase is one of the significant areas in the construction industry. Quality is paramount in the design. Therefore, the scope of this study was to evaluate the most critical elements in-process quality of construction building projects in Pakistan during the design phase to enable better performance improvement. The established data was accumulated through respondents registered with Pakistan Engineering Council. The constituted factors that are realized to affect the quality were successfully graded by RII and GADA models. The results revealed that the quality of codes and standards ranked superior for both models among the topmost five factors that critically impact greatly on the process quality of construction building projects in Pakistan. The remaining factors jumbled up at different positions by the two models. Nevertheless, preference is given to grey absolute degree analysis due to its strength in analyzing uncertainty systems, while RII draws evaluation based on exact presentation of data values.

Accordance with the results, the positive contribution of teamwork, especially for designing the firm structure and completing the project within a defined time frame, is considered an important aspect. This aspect revolves around determining the constructability with the proper support of designer training that leads to the quality process. This study ultimately reflected the research hypotheses, supported by the data, and led us to meaningful results.

It is highly recommended that there is still a need for improvement to develop the proper codes or standards concerning Pakistani culture. It is advised that Pakistani culture, business norms, and ethics should be attuned to the local designs and conditions. The construction sector can assist in this regard by executing research and surveys in this field which might help evolve comprehensive national codes and standards for buildings. The development of building codes and standards promotes project completion. One other important factor to consider is that the designers should emphasize project specifications, especially while adopting them from other projects. The local conditions of the area, requirements of the owner, and agreement of all parties to various definitions and terminologies must be given considerable importance. Advanced database and information system technologies should be used to minimize the chances of errors.

The study was limited to the design phase of firms registered under PEC in the construction sector, and as well the response rate from respondents was approximately half of the expected feedback. Nevertheless, analytical results prove to be reliable and efficient for good decision-making by project managers and all stakeholders at large. This research study may help future researchers to develop a comprehensive process quality framework for Pakistani building projects. Studies must be conducted to identify critical factors influencing process quality in other phases (construction, operation & maintenance phases) of building projects in Pakistan. Future studies may also be carried out to check the impact of process quality on time and the cost of building projects. This study encompasses building projects only. A similar study can be conducted to identify the critical factors that impact the process quality of roads, infrastructure, and other types of projects relevant to the construction industry of Pakistan.

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