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Article

Combining DEA and ARIMA Models for Partner Selection in the Supply Chain of Vietnam's Construction Industry

Han-Khanh Nguyen

Faculty of Economics, Thu Dau Mot University, Number 6, Tran Van On Street, Phu Hoa Ward, Thu Dau Mot 590000, Vietnam; khanhnh@tdmu.edu.vn or nguyenhankhanh@gmail.com; Tel.: +84-933-727-969

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Abstract: The competition between enterprises in the construction market is fierce. If enterprises are unable to afford financial and technological capabilities, they could go bankrupt. Therefore, the implementation of alliances between businesses can help increase their competitiveness. In this study, the authors simultaneously used data envelopment analysis (DEA), the Grey model (GM (1,1)), and autoregressive integrated moving average (ARIMA) to choose a suitable strategic partner to boost the strength of each business and cut the cost of transportation and personnel in an attempt to help managers come up with suitable solutions, offer sustainability, and develop creative management. The results show that the chosen solution improves the business efficiency of construction businesses and offers cost savings on materials, production, and transportation. Management agencies can use the results of this study to propose suitable orientations, strengthen decision-making, and ensure strategic planning to develop the construction sector in Vietnam.

Keywords: data envelopment analysis model; ARIMA model; develop sustainably; grey forecasting

1. Introduction

Urbanization in Vietnam increased over the years. The urbanization rate of Vietnam in 2018 was 38%, a 0.9% increase compared to that in 2017. However, the target urbanization rate of 2025 is 50% [1]. The coverage ratio of general urban construction planning is 100%; construction sub-zone planning is approximately 78% (a 1% increase compared to that of 2016); detailed planning is approximately 39% (a 2% increase compared to that 2017); rural construction planning is 100% (a 0.6% increase compared to that of 2017). In the coming years, construction growth is expected to slow down, mainly because the construction of residential buildings, non-residential buildings, and infrastructure is not as booming as before, leading to a downward trend in fluctuation of the construction industry index (Figure 1).

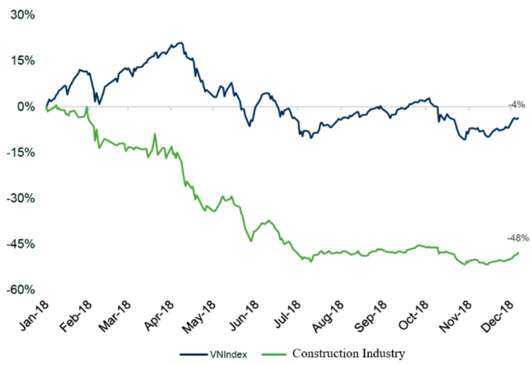

Figure 1. Volatility in construction industry index and Vietnam index [2].

Vietnam's construction industry witnesses great differentiation and fierce competition among businesses. The country has more than 67,000 construction firms, accounting for 13% of all enterprises. These firms mostly compete on bid prices and contractor's capacity to complete the project. These factors are mostly determined by the following factors [3]:

(1) Finance scale;
(2) Construction technology;
(3) Project management capacity.

Accordingly, foreign-invested construction enterprises have the greatest competitive edge, followed by private enterprises, and state-owned ones [3]. As a whole, Vietnam's construction industry in the period of 1990–2018 underwent six complete accelerating–decelerating cycles lasting about 4–5 years each, as demonstrated in Figure 2.

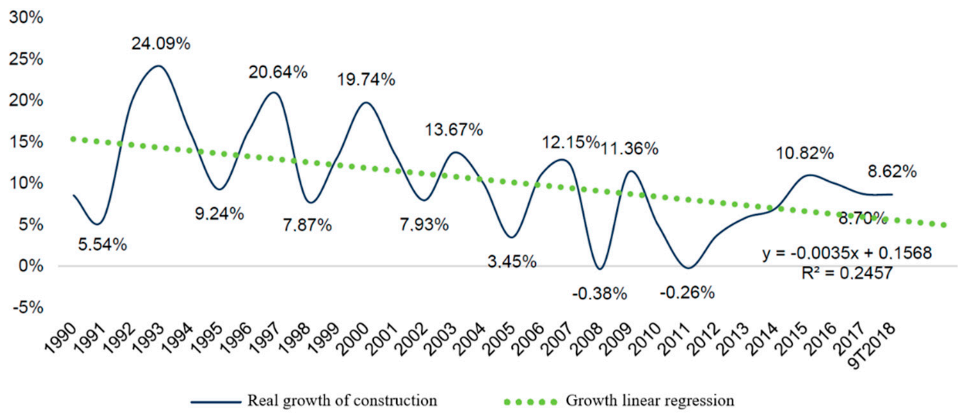

Figure 2. Real growth of Vietnam's construction industry (1990–2018) [3].

However, the business side of construction companies still faces many difficulties and challenges. As with other sectors, construction companies continue to suffer from economic difficulties. The infrastructure business in industrial zones is sluggish due to lack of investors. On the other hand, many industrial parks suffer from low occupancy. Huge debts are unresolved, especially in key projects, which have large capital scale and indirectly increase bad debt. Receivables of most enterprises lead to financial imbalances. Due to the lack of capital, the mobilization of capital sources in difficult situations enhances the negative impact on the production and business of enterprises in the construction industry. In addition, the transportation costs and input prices of raw materials and other supplies increased, while the selling price of products did not. This affected production and business efficiency.

Therefore, construction companies should find appropriate partners to deal with these issues by using the Grey model (GM (1,1)) to forecast business situations for the period of 2019–2022 [4]. Additionally, the super-slack-based measure (Super-SBM-I-V) model helps choose the most appropriate strategic combination in order to promote the strengths of each business and achieve goals. This model predicts future business and measures operation efficiency by using critical input and output variables. The autoregressive integrated moving average (ARIMA) model was used with data strings on the revenues of enterprises chosen to form alliances in the period 2009–2018 to determine future jobs and revenue trends of enterprises when carrying out the alliances [5]. These models were considered a prerequisite for the development of other activities in the construction industry to meet the goals of sustainable development. For the above reasons, integrating three models—the Super-SBM-I-V model, the GM (1,1) model, and the ARIMA model—in alliance decision-making is a new effective approach in this research.

The Grey system theory is an interdisciplinary scientific field, introduced in 1982 by Deng [6]. It is used to process, predict, and estimate the behavior of future data based on an initial range of constraints.

In the past, researchers worldwide used the data envelopment analysis (DEA) model to analyze and find strategic alliances in a variety of industries. Candace and contributors (2011) stated that strategic alliance is needed for innovation [7]. Kauser and Shaw (2004) further clarified the goals and motives of international strategic alliance by empirically studying strategic alliance agreements among the United Kingdom and Northern Ireland companies and their European, Japanese, and United States partners [8]. Chia-Nan Wang and Xuan-Tho Nguyen used the DEA and Grey theoretical models to analyze and select strategic partners in the automotive industry [9]. The results of this research possibly showed a strategic coalition in the automotive sector between Nissan and its partner, Renault. In addition, using the DEA and Grey method, Chia-Nan Wang and Han-Khanh Nguyen (2017) studied and found partnerships in textile enterprises in Vietnam [10]. According to the results of their research, textile enterprises should engage in strategic alliance to enhance their strengths and develop sustainably.

However, previous studies did not use a combination of multiple models to forecast the revenue of businesses after a union. Meanwhile, considering the development trend of employment, the revenue of businesses after a union is extremely important and helps managers decide whether to implement the alliance or not. In this study, the authors use the ARIMA model to solve this problem, offering managers a multi-dimensional perspective when making business decisions.

2. Research Development

In this study, the GM (1,1) was used to predict the business results of the decision-making units (DMUs) for the 2019–2022 period; the Super-SBM-I-V model was used to select strategic partners for the construction companies; the ARIMA model was used to determine the jobs and revenue trends of enterprises in the future for forming the alliances. They are described below. This study used the following steps (Figure 3):

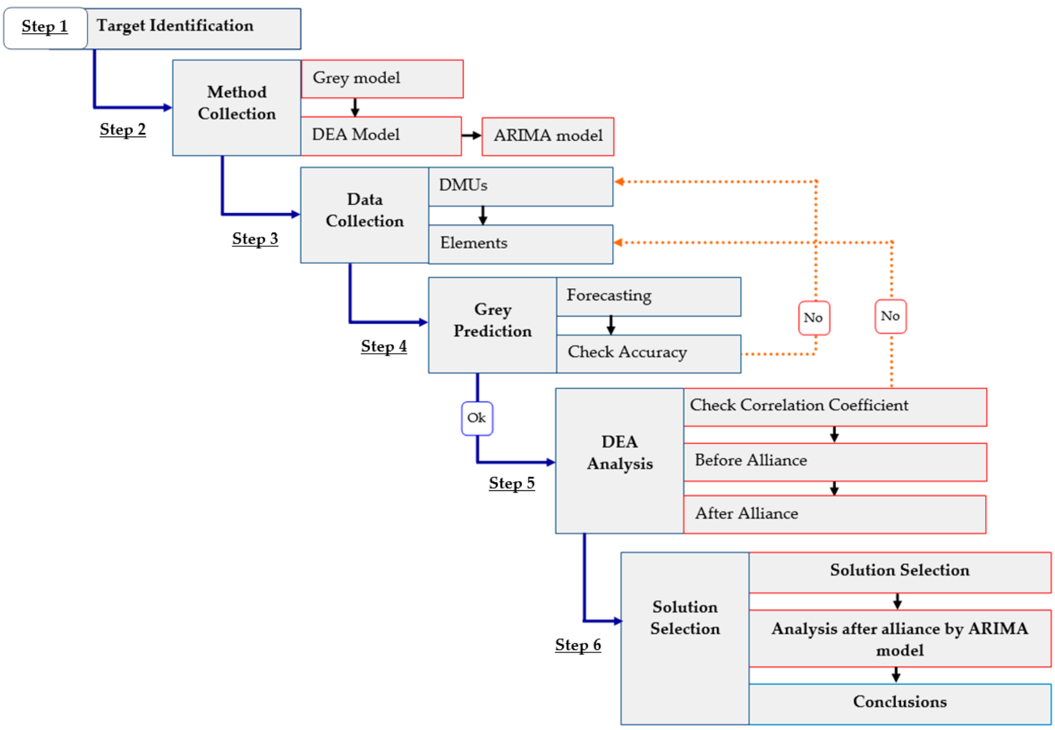

Figure 3. Research process.

Step 1. Determining targets: according to current state of the construction industry, the labor, material, and equipment transportation costs are increasing. The authors find that the issues of costs and human resources need to be resolved to reduce prices, thereby giving construction enterprises in the Vietnamese market a competitive edge.

Step 2. Defining predictive methods: In this research, the authors concurrently employed several common models to analyze and assess the business efficiency of enterprises, which is described below.

The non-radial super efficiency model (Super–SBM) of DEA was used to assess the efficiency of the investment in technique and technology and the business efficiency of construction enterprises in Vietnam in the period 2015–2018. This result was the basis for the authors' selection of strategic partners for the enterprises in the future.

The Grey forecasting model GM (1,1) was used to forecast all indicators used for the analysis in this research in order to forecast the business performance of construction enterprises in Vietnam for the period 2019–2022.

Each predictive method used in this research has its own pros and cons, depending on the statistical inputs and purpose of each model. The autoregressive integrated moving average model (ARIMA) was used by the authors as it is suitable for linear relationships among data in past, present, and future predictions [11]. This model was used in conjunction with the data strings on the revenues in the period 2009–2018 of the enterprises chosen to carry out the alliance to determine the jobs and revenue trends of the enterprise in the future when carrying out the alliance.

Step 3. Collecting data:

In this research, the authors collected the data from the website of the General Statistics Office of Vietnam.

Collecting the factors for analysis:

Input factors were as follows: total assets (TA); cost of goods sold (CS); total operating expense (TE); owners' equity (OE).

Output factors were as follows: net sales (NS); profit after tax (PT).

Step 4. Grey prediction: The authors used the business data of the enterprises in the period 2015–2018 and used GM (1,1) to predict the business performance result for the period 2019–2022. Afterward, the authors used the mean absolute percentage error (MAPE) method to check the compatibility of the samples. If the error was not sufficiently reliable, the authors re-chose the sample enterprises.

Step 5. DEA analysis: Firstly, the authors used the Pearson coefficient to examine the correlation between the inputs and outputs in accordance with the requirements for using DEA. If the correlation coefficient was unsatisfactory, the authors repacked the components to ensure compatibility with the model. Afterward, the non-radial super efficiency model was used to compute, analyze, and assess the business performance of enterprises. From this result, the authors chose the target enterprise to carry out the alliance with other enterprises.

Step 6. Selecting solutions: After matching the target enterprise with 13 other enterprises, the authors used the result to select a suitable alliance solution for construction enterprises in Vietnam. After the appropriate alliance was chosen for the enterprises, the ARIMA model was used to determine the jobs and revenue trends of the enterprises in the future when carrying out the alliance. From such results, the authors provided the optimal evaluation and assessment of the chosen alliance for construction enterprises in Vietnam.

3. Research Method

3.1. Grey Forecasting Model

When using the GM (1,1), original data must satisfy the following expression [12–16]:

$$\delta_i = \frac{x^{(0)}(i-1)}{x^{(0)}(i)};\ (i = 2; 3; \ldots; n). \tag{1}$$

Values must fall within the range of

$$\delta^{(0)}_{(i)} = (e^{-\frac{2}{\mathrm{n}+1}}; e^{\frac{2}{\mathrm{n}+1}}). \tag{2}$$

GM (1,1) is based on $\frac{dx^{(1)}(k)}{dk} + ax^{(1)}(k) = b$ (a and b are coefficients).
Original data are from the following value chain:

$$\mathrm{X}^{(0)} = (\mathrm{x}^{(0)}(1), \mathrm{x}^{(0)}(2), \ldots, \mathrm{x}^{(0)}(n)); n \geq 4. \tag{3}$$

The original values that satisfy the above conditions are implemented in the following order:
Step 1. Use the cumulative plus method:

$$\mathrm{X}^{(1)} = (\sum_{k=1}^{1} x^{(0)}_{(k)}; \sum_{k=1}^{2} x^{(0)}_{(k)}; \ldots; \sum_{k=1}^{n} x^{(0)}_{(k)}) = (x^{(0)}_{(1)}; x^{(0)}_{(1)} + x^{(0)}_{(2)}; \ldots; x^{(0)}_{(1)} + \ldots + x^{(0)}_{(n)}) = (x^{(1)}_{(1)}; x^{(1)}_{(2)}; \ldots; x^{(1)}_{(n)}). \tag{4}$$

Step 2. Establish the GM (1,1) equation:

$$x^{(0)}_{k} + az^{(1)}_{k} = b\ (k = 2, 3, \ldots, n);\ \text{where } \mathrm{z}^{(1)}_{k} = 0.5\mathrm{x}^{(1)}_{1}(k) + 0.5\mathrm{x}^{(1)}_{1}(\mathrm{k}-1);\ (k \geq 2). \tag{5}$$

Step 3. Calculate the parameters a and b based on the least-squares method:

$$\hat{a} = \begin{bmatrix} a \\ b \end{bmatrix}^{T} = (B^{T}B)^{-1}B^{T}\overline{Y}_{N}; where\ \mathrm{B} = \begin{bmatrix} -z^{(1)}_{(2)} & 1 \\ \ldots\ldots\ldots & .. \\ -z^{(1)}_{(n)} & 1 \end{bmatrix}; Y = \begin{bmatrix} x^{(0)}_{(2)} \\ \ldots\ldots \\ x^{(0)}_{(n)} \end{bmatrix}. \tag{6}$$

Step 4. Build the formula to calculate the predicted values as follows:

$$\hat{\mathrm{X}}^{(1)}(k+1) = [x^{(0)}_{1} - \frac{b}{a}]e^{-a\kappa} + \frac{b}{a}\ (\kappa = 1,\ 2,\ 3, \ldots,\ n). \tag{7}$$

Find the GM (1,1) model's predictive values using the following formula:

$$\hat{\mathrm{X}}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k);\ (where\ \hat{x}^{(0)}(1) = x^{(0)}(1));\ (\kappa = 1, 2, 3, \ldots, n). \tag{8}$$

3.2. Non-Radial Super Efficiency Model (Super Slacks-Based Measure (SBM))

DEA is a powerful quantitative, analytical tool for measuring and evaluating performance. DEA was successfully applied to a host of different types of entities engaged across the industry sector. In DEA, there are several methods for measuring efficiency changes over time, in which DEA has two clusters: non-radial and radial. Non-radial models are based on the slacks-based measure (SBM) of efficiency. This SBM type model has nine variations. The first six, Super-SBM-I-C, Super-SBM-I-V, Super-SBM-I-GRS, Super-SBM-O-C, Super-SBM-O-V, and Super-SBM-O-GRS are "oriented", while the other three, Super-SBM-C, Super-SBM-V, and Super-SBM-GRS, are "non-oriented". In this research, the authors used the slacks-based measure of efficiency model to measure the business efficiency of the enterprises. The slacks-based measure of efficiency model was applied and developed by many researchers in various fields, which brought about good results [17–21]. Accordingly, the slacks-based measure of efficiency model was established according to the following equations:

$$\min\rho = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} s^{-}_{i}/x_{i0}}{1 + \frac{1}{s}\sum_{i=1}^{s} s^{-}_{i}/y_{i0}}, \tag{9}$$

$$\text{s.t}:\ x_0 = \mathrm{X}\lambda + S^{-},\ y_0 = Y\lambda - S^{+},\ (\lambda \geq 0, \mathrm{X} \geq 0, Y \geq 0). \tag{10}$$

Suppose (p^*, λ^*,s^{-*}, s^{+*}) is the optimal condition of SBM, and (x_0, y_0) is SBM efficient of DMU.

When $p^* = 1$, $s^{-*} = 0$ and $s^{+*} = 0$ (in fact, the inputs are irredundant, and the outputs change). Therefore, the researchers developed it into the super-efficiency model, as determined in accordance with the following formulas:

$$\min\delta = \frac{\frac{1}{m}\sum_{i=1}^{m} \overline{x}_i / x_{i0}}{\frac{1}{s}\sum_{r=1}^{s} \overline{y_r} / y_{r0}}, \tag{11}$$

$$\text{s.t}\ \overline{x} \geq \sum_{j=1,\neq 0}^{n} \lambda_j x_j, \overline{y} \leq \sum_{j=1,\neq 0}^{n} \lambda_j x_j, \overline{x} \geq x_0, \overline{y} \leq y_0, \overline{y} \geq 0, \lambda \geq 0. \tag{12}$$

However, while the inputs are fixed, the outputs are still non-specific. To solve this issue, the researchers continued to use the DEA Solver Pro 4.1 Manual as follows:

Suppose $y_{ro} \leq 0$. It defines γ_r^+ and γ_{-r}^+ as follows:

$$\overline{y}_r^+ = \max_{j=1,\ldots,n} \left\{ y_{rj} \middle| y_{rj} > 0 \right\}, \tag{13}$$

$$\overline{y}_r^+ = \min_{j=1,\ldots,n} \left\{ y_{rj} \middle| y_{rj} > 0 \right\}. \tag{14}$$

If there is no positive component in the output r, it becomes $\overline{y}_r^+ = y_{-r}^+ = 1$. The element s_r^+ / γ_{r0} becomes a replacement, while γ_{r0} is unchanged.

When $\overline{\gamma}_r^+ > \overline{\gamma}_{-r}^+$, the element is

$$s_r^+ / \frac{\gamma_{-r}^+ \left(\overline{\gamma}_r^+ - \gamma_r^+ \right)}{\overline{\gamma}_r^+ - \gamma_{r0}}. \tag{15}$$

When $\overline{\gamma}_r^+ = \overline{\gamma}_{-r}^+$, the element becomes

$$s_r^+ / \frac{\left(\gamma_{-r}^+ \right)^2}{\mathrm{B}(\overline{\gamma}_r^+ - \gamma_{r0})};\ (\mathrm{B} = 100). \tag{16}$$

3.3. *Autoregressive Integrated Moving Average Model (ARIMA)*

The ARIMA model was introduced by Box and Jenkins in 1970 [22]. The ARIMA model consists of three main components: (1) AR (autoregression component); (2) I (stationarity of time series); (3) MA (moving averages component). The steps of applying the ARIMA conjecturing model are as follows [23–27]:

Step 1. Identify the three p, d, and q components of the ARIMA model.

The authors used the augmented Dickey–Fuller unit root test and the Phillips–Perron test to test the stationarity of the series.

$$\Delta Y_t = \beta_0 + \beta_1 t + \pi Y_{t-1} + \sum_{j=1}^{p} \Psi_j \Delta Y_{t-j} + \varepsilon_t. \tag{17}$$

The autoregression model of order p, notated as AR(p), is defined as

$$(Y_t - \delta) = \alpha_1 (Y_{t-1} - \delta) + \alpha_2 (Y_{t-2} - \delta) + \ldots + \alpha_p (Y_{t-p} - \delta) + u_t. \tag{18}$$

Y_t is the time series, while δ is the expected value of Y_t, and u_t is white noise.

The moving average model of order q in the MA(q) model is calculated as follows:

$$\Delta Y_t = \mu + \beta_0 u_t + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \ldots + \beta_q u_{t-q}. \tag{19}$$

Combining Equations (18) and (19), we have the ARIMA(p,q) model as follows:

$$\Delta Y_t = \theta + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \ldots + \alpha_p Y_{t-p} + \beta_0 u_t + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \ldots + \beta_q u_{t-q}. \quad (20)$$

We then calculate the appropriate p, d, q values in the ARIMA model, in which, p and q depend on the PACF = f(t) and ACF = f(t) graphs.

Step 2. Estimate the parameters and select the model using Statistical Package for the Social Sciences software.

Step 3. Check the model: The research used the mean absolute percent error (MAPE) index to assess the reliability of the conjecturing model.

Step 4. Conjecturing: After the errors of the conjecturing models were checked, the models were used to conjecture the trends for the enterprises if they were suitable.

3.4. Evaluation of Volatility Forecasts

To test the accuracy of the predicted values, the authors used MAPE, which is a popular and reliable tool for measuring accurate values in statistics. When MAPE is smaller, the predicted value is closer to the actual value [28,29].

$$\text{MAPE} = \frac{1}{n}\left[\sum_{i=1}^{n}\left|\frac{\text{A}_i - F_i}{\text{A}_i}\right| \times 100\right]. \quad (21)$$

MAPE is divided into four ranks, as shown in Table 1.

Table 1. The grades of mean absolute percent error (MAPE).

MAPE Valuation (%)	**≤10**	**10–20**	**20–50**	**≥50**
Accuracy	Excellent	Good	Qualified	Unqualified

Source: Reference [30].

3.5. Materials and Methods

3.5.1. DMU Collection

In order to meet the requirements of the Grey theory and DEA models used in this study, DMUs (decision-making units) must meet the following mandatory requirements in terms of scale and time of operation: business data must be accurate, specific, and clear. After finding DMUs from the General Statistics Office's website in the construction industry in Vietnam, we collected 14 suitable DMUs, as shown in Table 2.

Table 2. List of companies [10]. DMU—decision-making unit.

DMUs	**Code**	**DMUs**	**Code**
DMU1	HU3 JSC	DMU8	THG JSC
DMU2	C32 JSC	DMU9	HU6 JSC
DMU3	CTD JSC	DMU10	TV2 JSC
DMU4	HU1 JSC	DMU11	VC1 JSC
DMU5	DXG JSC	DMU12	VC2 JSC
DMU6	HU4 JSC	DMU13	VC3 JSC
DMU7	SC5 JSC	DMU14	VC9 JSC

3.5.2. Input/Output Collection

Because the inputs/outputs have a direct impact on the results of the analysis and evaluation of the study, we carefully selected four inputs and two outputs from the financial statement of the DMUs.

The input factors were as follows:

Total assets (TA) reflect all tangible and intangible assets of the business;

Owners' equity (OE) is the capital owned by the business owner;

Cost of goods sold (CS) is one of the costs that account for a large proportion of the production process;

Total operating expenses (TE) reflect the total daily cost of sales and management or research and development.

The output factors were as follows:

Net sales (NS) reflects the turnover of selling goods and providing service of enterprises;

Profit after tax (PT) reflects the business results (profit and loss) after income tax.

The above factors reflect the overall business situation of the enterprises (assets, costs, and profits). These factors are a highly reliable and sufficient basis for analysis, calculation, and evaluation in the study. The authors summarized the data of enterprises in the period of 2015–2018, calculated according to each year, in Tables 3–7.

Table 3. Data in 2015 (in million Vietnamese dong (VND)) [10]. TA—total assets; OE—owners' equity; CS—cost of goods sold; TE—total operating expenses; NS—net sales; PT—profit after tax.

DMUs	Inputs				Outputs	
	(I)TA	(I)OE	(I)CS	(I)TE	(O)NS	(O)PT
DMU1	620,161	177,678	371,279	38,010	426,554	16,468
DMU2	445,496	325,687	413,001	24,658	557,407	101,287
DMU3	7,815,096	3,242,536	12,557,080	364,408	13,668,916	799,525
DMU4	632,857	179,595	595,002	27,063	629,294	8634
DMU5	3,573,347	1,771,359	735,260	277,948	1,394,505	554,605
DMU6	738,418	244,283	172,733	23,791	195,091	6506
DMU7	2,254,213	311,234	1,358,256	42,690	1,431,205	35,771
DMU8	602,210	204,906	549,159	91,770	699,471	56,077
DMU9	171,734	93,210	26,023	16,926	54,412	9947
DMU10	1,666,729	605,067	320,629	34,472	416,693	63,352
DMU11	578,886	240,065	342,574	14,625	367,520	11,945
DMU12	1,564,386	276,713	604,079	52,074	673,198	14,826
DMU13	1,232,421	242,305	390,277	41,837	477,037	42,965
DMU14	1,335,468	190,956	695,206	54,678	755,093	11,077

Table 4. Data in 2016 (in million VND) [10].

DMUs	Inputs				Outputs	
	(I)TA	(I)OE	(I)CS	(I)TE	(O)NS	(O)PT
DMU1	610,046	181,458	501,990	34,613	557,289	16,723
DMU2	552,905	380,276	382,480	35,357	520,269	93,327
DMU3	1,1740,871	6,233,628	18,983,319	299,422	20,782,721	1,422,144
DMU4	653,954	175,646	361,757	17,949	385,414	2968
DMU5	5,562,791	3,537,355	1,454,880	441255	2,506,517	791,643
DMU6	986,077	251,440	267,696	26,183	303,203	13,540
DMU7	1,987,448	319,615	1,389,419	40,714	1,471,018	41,926
DMU8	693,526	275,639	643,742	92,720	829,611	86,648
DMU9	179,954	95,298	50,566	14,510	76,009	10,884
DMU10	1,998,479	653,337	420,233	15,613	476,012	37,770
DMU11	799,291	238,715	514,582	28,469	555,272	12,843
DMU12	2,539,223	292,291	899,563	69,822	1,043,090	30,878
DMU13	1,157,266	299,950	433,356	33,295	557,042	75,352
DMU14	1,375,140	191,411	790,342	53,792	848,714	13,877

Table 5. Data in 2017 (in million VND) [10].

DMUs	Inputs				Outputs	
	(I)TA	(I)OE	(I)CS	(I)TE	(O)NS	(O)PT
DMU1	742,475	195,429	330,224	43,297	393,984	19,685
DMU2	747,661	439,990	418,738	39,100	559,746	91,653
DMU3	15,877,318	7,306,688	25,137,241	394,619	27,176,837	1,652,679
DMU4	966,959	174,063	504,847	25,526	542,399	4645
DMU5	10,264,403	4,653,845	1,149,440	606,189	2,879,241	1,419,950
DMU6	701,752	248,757	259,228	19,267	289,973	9056
DMU7	2,013,640	345,438	1,849,664	85,329	1,967,025	59,982
DMU8	860,951	321,664	683,568	125,279	909,854	90,803
DMU9	151,125	95,692	55,862	15,493	80,900	8485
DMU10	2,191,711	698,002	524,721	49,300	637,466	64,227
DMU11	813,115	240,134	560,231	51,619	623,227	15,176
DMU12	2,259,759	305,715	1,860,963	159,349	2,096,871	31,406
DMU13	785,519	332,441	457,728	38,680	542,239	43,506
DMU14	1,684,956	190,531	991,995	51,492	1,063,354	12,608

Table 6. Data in 2018 (in million VND) [10].

DMUs	Inputs				Outputs	
	(I)TA	(I)OE	(I)CS	(I)TE	(O)NS	(O)PT
DMU1	744,126	168,295	560,514	42,859	627,430	21,363
DMU2	782,679	491,588	552,524	67,430	722,333	92,446
DMU3	16,823,062	7,962,493	26,727,845	505,474	28,560,857	1,515,408
DMU4	953,267	165,729	445,947	40,437	496,346	8595
DMU5	13,728,715	6,199,094	2,030,544	970,488	4,645,319	2,267,163
DMU6	582,109	198,610	144,269	12,820	165,349	3381
DMU7	1,916,641	349,156	2,497,980	51,032	2,596,707	39,684
DMU8	972,467	349,366	730,035	138,058	956,687	80,354
DMU9	155,853	88,719	9066	17,008	35,502	9680
DMU10	2,192,694	698,983	1,474,988	127,566	1,840,415	225,105
DMU11	885,562	238,765	461,133	53,868	501,708	15,807
DMU12	2,282,518	303,394	1,228,574	108,685	1,363,487	24,038
DMU13	843,835	383,562	234,507	35,528	290,305	22,787
DMU14	1,570,296	184,214	1,339,947	59,571	1,384,872	8152

Table 7. Data of DMU8 from 2015 to 2018 (in million VND).

Year	Inputs				Outputs	
	(I)TA	(I)OE	(I)CS	(I)TE	(O)NS	(O)PT
2015	602,210	204,906	549,159	91,770	699,471	56,077
2016	693,526	275,639	643,742	92,720	829,611	86,648
2017	860,951	321,664	683,568	125,279	909,854	90,803
2018	972,467	349,366	730,035	138,058	956,687	80,354

Sources: Collected by researcher [10].

4. Results

4.1. Results and Analysis of the Grey Forecasting

We used GM (1,1) to predict the business performance of DMUs in the 2019–2022 period. The predicted data were calculated as outlined below (we use total assets of DMU8 in Table 7 to explain this process).

The base range is the actual data for the 2015–2018 periods as follows:

$$X^{(0)} = (602210; 693526; 860951; 972467).$$

Using the accumulated generating operation (AGO) method, we obtain the following:

$$\begin{aligned}
X^{(1)} &= (602210;\ 1295736;\ 2156687;\ 3129154);\\
x^{(1)}_{(1)} &= x^{(0)}_{(1)} = 602210;\\
x^{(1)}_{(2)} &= x^{(0)}_{(1)} + x^{(0)}_{(2)} = 1295736;\\
x^{(1)}_{(3)} &= x^{(1)}_{(2)} + x^{(0)}_{(3)} = 2156687;\\
x^{(1)}_{(4)} &= x^{(1)}_{(3)} + x^{(0)}_{(4)} = 3129154.
\end{aligned}$$

The GM (1,1) equation is established as follows:

$$\begin{aligned}
z^{(1)}_{(2)} &= 0.5 \times (602210 + 1295736) = 948973;\\
z^{(1)}_{(3)} &= 0.5 \times (1295736 + 2156687) = 1726211.5;\\
z^{(1)}_{(4)} &= 0.5 \times (2156687 + 3129154) = 2642920.5.
\end{aligned}$$

To find the coefficients of *a* and *b*, the initial values are placed in the following system of equations:

$$\begin{cases} 693526 + a \times 948973 = b \\ 860951 + a \times 1726211.5 = b \\ 972467 + a \times 2642920.5 = b \end{cases}.$$

The above equation is converted into a matrix as follows:

$$\text{Let B} = \begin{bmatrix} -948973 & 1 \\ -1726211.5 & 1 \\ -2642920.5 & 1 \end{bmatrix};\ \hat{\theta} = \begin{bmatrix} a \\ b \end{bmatrix};\ \text{Y}_\text{N} = \begin{bmatrix} 693526 \\ 860951 \\ 972467 \end{bmatrix}.$$

The least-squares method is used to find *a* and *b* as follows:

$$\begin{bmatrix} a \\ b \end{bmatrix} = \hat{\theta} = \left(B^T B\right)^{-1} B^T y_N = \begin{bmatrix} -0.1634 \\ 552665.542 \end{bmatrix}.$$

The two coefficients *a* and *b* are used to generate the whitening equation of the differential equation as follows:

$$\frac{dx^{(1)}}{dk} - 0.1634 \times x^{(1)} = 552665.542.$$

The predicted values are calculated using the following formula:

$$\hat{X}^{(1)}(k+1) = \left[x^{(0)}_{(1)} - \frac{b}{\text{a}}\right] \times e^{-a\kappa} + \frac{b}{\text{a}} = \left[602210 + \frac{552665.542}{0.1634}\right] \times e^{0.1634\kappa} - \frac{552665.542}{0.1634}.$$

In turn, the values of *k* are replaced as follows:

$k = 0; \qquad x^{(1)}_{(1)} = 602{,}210;$
$k = 1; \qquad x^{(1)}_{(2)} = 1{,}309{,}482.399;$
$k = 2; \qquad x^{(1)}_{(3)} = 2{,}142{,}296.171;$
$k = 3; \qquad x^{(1)}_{(4)} = 3{,}122{,}935.003;$
$k = 4; \qquad x^{(1)}_{(5)} = 4{,}277{,}637.952;$
$k = 5; \qquad x^{(1)}_{(6)} = 5{,}637{,}301.527;$
$k = 6; \qquad x^{(1)}_{(7)} = 7{,}238{,}306.391;$
$k = 7; \qquad x^{(1)}_{(8)} = 9{,}123{,}490.801.$

Using the accumulated generating operation (AGO) method to compute the predicted values based on the original data, we obtain the following results:

$$\hat{x}^{(0)}_{(1)} = \mathrm{x}^{(1)}_{(1)} = 602210;$$
$$\hat{x}^{(0)}_{(2)} = \hat{x}^{(1)}_{(2)} - \hat{x}^{(1)}_{(1)} = 707272.399;$$
$$\hat{x}^{(0)}_{(3)} = \hat{x}^{(1)}_{(3)} - \hat{x}^{(1)}_{(2)} = 832813.772;$$
$$\hat{x}^{(0)}_{(4)} = \hat{x}^{(1)}_{(4)} - \hat{x}^{(1)}_{(3)} = 980638.832;$$
$$\hat{x}^{(0)}_{(5)} = \hat{x}^{(1)}_{(5)} - \hat{x}^{(1)}_{(4)} = 1154702.95 - \text{Result of 2019};$$
$$\hat{x}^{(0)}_{(6)} = \hat{x}^{(1)}_{(6)} - \hat{x}^{(1)}_{(5)} = 1359663.58 - \text{Result of 2020};$$
$$\hat{x}^{(0)}_{(7)} = \hat{x}^{(1)}_{(7)} - \hat{x}^{(1)}_{(6)} = 1601004.86 - \text{Result of 2021};$$
$$\hat{x}^{(0)}_{(8)} = \hat{x}^{(1)}_{(8)} - \hat{x}^{(1)}_{(7)} = 1885184.41 - \text{Result of 2022}.$$

Similarly, we can obtain the forecast value of the enterprises in the 2019–2022 period, as shown in Tables 8–11.

Table 8. Data in 2019 (in million VND).

DMUs	Inputs				Outputs	
	(I)TA	(I)OE	(I)CS	(I)TE	(O)NS	(O)PT
DMU1	838,708.92	169,400.37	535,903.13	48,839.72	610,615.71	24,286.45
DMU2	944,641.58	559,548.14	654,438.07	91,456.08	838,388.03	91,593.75
DMU3	20,386,203.04	9,044,473.61	32,093,863.81	650,102.90	339,46913.15	1,621,838.81
DMU4	1,177,887.82	162,183.59	521,392.58	58,801.25	587,549.95	13,702.14
DMU5	20,538,708.63	8,098,952.01	2,302,395.13	1,398,279.30	6,213,266.41	3,589,967.93
DMU6	423,473.25	186,253.03	131,746.90	9383.82	149,351.13	2558.77
DMU7	1,903,487.71	368,301.52	3,300,602.61	67,908.02	3,404,956.25	45,264.84
DMU8	1,154,702.95	395,374.97	776,552.54	169,504.38	1,032,111.01	79,989.01
DMU9	138,840.44	86,922.12	15,615.18	18,342.79	36,031.38	8466.04
DMU10	2,325,846.83	729,796.26	2,290,102.19	259,478.27	2,853,432.09	294,582,81
DMU11	923,571.18	239,254.57	462,997.05	73,546.81	511,242.15	17,749.81
DMU12	2,109,580.93	311,633.92	1,626,628.32	148,664.52	1,787,202.62	22,821,13
DMU13	636,219.23	431,402.81	229,348.37	38,033.29	267,258.20	13,657.43
DMU14	1,739,166.58	181,663.63	1,722,528.71	61,170.85	1,750,642.10	7061.55

Sources: Calculated by researcher.

Table 9. Data in 2020 (in million VND).

DMUs	Inputs				Outputs	
	(I)TA	(I)OE	(I)CS	(I)TE	(O)NS	(O)PT
DMU1	920,388.73	163,592.73	576,597.29	53,899.36	658,731.09	27,355.68
DMU2	1,107,361.86	635,138.19	795,181.01	131,959.31	997,366.88	91,156.55
DMU3	24,046,944.07	10,190,457.85	37,604,817.24	841,388.44	39,335,282.20	1670,044.04
DMU4	1,387,056.51	157,599.83	570,011.21	88,986.48	655,095.89	23,655.38
DMU5	30,648,721.83	10,713,923.29	2,845,969.24	2,102,832.46	8,730,537.55	5,895,976.32
DMU6	321,592.67	166,929.98	102,225.25	6,665.80	116,060.35	1464.87
DMU7	1,869,976.43	384,565.29	4,422,365.07	72,884.54	4,510,032.97	44,331.58
DMU8	1,359,663.58	443,812.74	827,046.52	204,002.94	1,107,205.95	77,191.40
DMU9	128,572.45	83,947.77	10,188.93	19,872.79	27,335.22	7,923.89
DMU10	2,432,788.32	754,310.21	4,861,631.62	649,432.98	6,318,919.13	793,845.02
DMU11	973,262.66	239,279.53	440,499.21	95,558.97	488,636.45	19,605.23
DMU12	1,995,608.51	317,394.22	1,801,587.19	171,235.15	1,952,098.64	20,373.04
DMU13	530,320.47	488,564.30	180,982.47	39,189.76	205,415.87	7769.89
DMU14	1,847,449.12	178,248.83	2,253,604.97	64,581.99	2,240,448.59	5578.47

Sources: Calculated by researcher.

Table 10. Data in 2021 (in million VND).

DMUs	Inputs				Outputs	
	(I)TA	(I)OE	(I)CS	(I)TE	(O)NS	(O)PT
DMU1	1,010,023.14	157,984.19	620,381.59	59,483.15	710,637.88	30,812.79
DMU2	1,298,111.71	720,939.79	966,192.02	190,400.23	1,186,492.00	90,721.43
DMU3	28,365,042.67	11,481,644.55	44,062,076.43	1,088,957.62	45,578,943.18	1,719,682.06
DMU4	1,633,369.27	153,145.62	623,163.42	134,667.09	730,407.04	40,838.63
DMU5	45,735,307.28	14,173,210.57	3,517,876.16	3,162,389.90	12,267,667.43	9,683,244.39
DMU6	244,222.84	149,611.63	79,318.77	4735.06	90,190.18	838.62
DMU7	1,837,055.13	401,547.25	5,925,376.41	782,25.75	5,973,761.74	43,417.57
DMU8	1,601,004.86	498,184.66	880,823.79	245,522.85	1,187,764.70	74,491.63
DMU9	119,063.83	81,075.21	6648.29	21,530.42	20,737.87	7416.46
DMU10	2,544,646.94	779,647.59	10,320,701.88	1,625,427.81	13,993,232.57	2,139,262.36
DMU11	1,025,627.72	239,304.49	419,094.58	124,159.25	467,030.31	21,654.60
DMU12	1,887,793.57	323,260.99	1,995,364.51	197,232.52	2132,208.78	18,187.56
DMU13	442,048.58	553,299.77	142,816.17	40,381.40	157,883.57	4420.39
DMU14	1,962,473.47	174,898.23	2,948,418.40	68,183.35	2,867,296.46	4406.87

Sources: Calculated by researcher.

Table 11. Data in 2022 (in million VND).

DMUs	Inputs				Outputs	
	(I)TA	(I)OE	(I)CS	(I)TE	(O)NS	(O)PT
DMU1	1,108,386.83	152,567.92	667,490.67	65,645.41	766,634.82	34,706.79
DMU2	1,521,719.38	818,332.44	1,173,980.52	274,722.93	1,411,479.87	90,288.40
DMU3	33,458,540.23	12,936,431.67	51,628,134.94	1,409,371.27	52,813,655.96	1,770,795.45
DMU4	1,923,422.13	148,817.29	681,271.94	203,797.56	814,376.12	70,503.80
DMU5	68,248,142.40	18,749,424.69	4,348,414.06	4,755,828.19	17,237,846.26	15,903,256.19
DMU6	185,466.91	134,089.99	61,545.14	3363.56	70,086.54	480.10
DMU7	1,804,713.41	419,279.12	7,939,210.13	83,958.39	7,912,542.89	42,522.40
DMU8	1,885,184.41	559,217.75	938,097.84	295,493.16	1,274,184.78	71,886.29
DMU9	110,258.42	78,300.93	4338.02	23,326.30	15,732.79	6941.53
DMU10	2,661,648.77	805,836.05	21,909,699.41	4,068,188.16	30,987,982.90	5,764,907.91
DMU11	1,080,810.22	239,329.46	398,730.03	161,319.43	446,379.54	23,918.19
DMU12	1,785,803.46	329,236.21	2,209,984.37	227,176.87	2,328,936.76	16,236.52
DMU13	368,469.54	626,612.78	112,698.53	41,609.27	121,350.03	2,514.82
DMU14	2,084,659.36	171,610.61	3,857,451.13	71,985.54	3,669,528.06	3481.33

Sources: Calculated by researcher.

To verify the accuracy of the predicted values to ensure an appropriate predictive method, we used MAPE. The results are shown in Table 12.

Table 12. MAPE.

DMUs	Average MAPE (%)	DMUs	Average MAPE (%)
DMU1	7.09	DMU8	1.61
DMU2	3.28	DMU9	13.38
DMU3	2.85	DMU10	14.84
DMU4	4.95	DMU11	3.88
DMU5	5.42	DMU12	11.68
DMU6	6.37	DMU13	6.37
DMU7	6.55	DMU14	2.72
Average MAPE of 14 DMUs		6.50 (%)	

Source: Calculated by researcher.

As shown in the above result, there were 11 DMUs with MAPE <10% (the average MAPE of 14 DMUs was 6.50%). According to the convention in Table 6, the predictive values in this study had high accuracy. This shows that GM (1,1) used in this study is consistent, predictive, and highly reliable.

4.2. Pearson Correlation

We used the Super-SBM-I-V model to find strategic alliance partners for the businesses. To ensure suitability when using DEA, we used the Pearson coefficient to determine the appropriate correlation between the factors (i.e., the correlative coefficient between non-negative or zero elements; if this coefficient is close to 1, the linear relationship between those two elements is stronger). Results are shown in Tables 13–16.

Table 13. Correlation in 2015.

	TA	OE	CS	TE	NS	PT
TA	1.0000	0.9647	0.9157	0.9172	0.9282	0.9242
OE	0.9647	1.0000	0.8839	0.9587	0.9030	0.9839
CS	0.9157	0.8839	1.0000	0.7919	0.9990	0.8165
TE	0.9172	0.9587	0.7919	1.0000	0.8176	0.9799
NS	0.9282	0.9030	0.9990	0.8176	1.0000	0.8414
PT	0.9242	0.9839	0.8165	0.9799	0.8414	1.0000

Source: Calculated by researcher.

Table 14. Correlation in 2016.

	TA	OE	CS	TE	NS	PT
TA	1.0000	0.9766	0.9225	0.7790	0.9364	0.9685
OE	0.9766	1.0000	0.8885	0.8454	0.9077	0.9970
CS	0.9225	0.8885	1.0000	0.5353	0.9990	0.8893
TE	0.7790	0.8454	0.5353	1.0000	0.5722	0.8510
NS	0.9364	0.9077	0.9990	0.5722	1.0000	0.9088
PT	0.9685	0.9970	0.8893	0.8510	0.9088	1.0000

Source: Calculated by researcher.

Table 15. Correlation in 2017.

	TA	OE	CS	TE	NS	PT
TA	1.0000	0.9929	0.8470	0.8626	0.8770	0.9767
OE	0.9929	1.0000	0.8439	0.8538	0.8744	0.9855
CS	0.8470	0.8439	1.0000	0.4892	0.9982	0.7475
TE	0.8626	0.8538	0.4892	1.0000	0.5403	0.9210
NS	0.8770	0.8744	0.9982	0.5403	1.0000	0.7863
PT	0.9767	0.9855	0.7475	0.9210	0.7863	1.0000

Source: Calculated by researcher.

Table 16. Correlation in 2018.

	TA	OE	CS	TE	NS	PT
TA	1.0000	0.9947	0.7910	0.8851	0.8413	0.9391
OE	0.9947	1.0000	0.8010	0.8747	0.8504	0.9368
CS	0.7910	0.8010	1.0000	0.4236	0.9961	0.5443
TE	0.8851	0.8747	0.4236	1.0000	0.5015	0.9849
NS	0.8413	0.8504	0.9961	0.5015	1.0000	0.6160
PT	0.9391	0.9368	0.5443	0.9849	0.6160	1.0000

Source: Calculated by researcher.

The results shown from Tables 13–16 demonstrate that the inputs and the outputs in this research have strong correlation, which satisfies the requirements of the DEA. These factors were used to evaluate the business results of construction enterprises in order to find the most suitable strategic allies.

4.3. Analysis Alliance

4.3.1. Analysis before Alliance

Based on the data on the actual business performance of the enterprises in 2018, we used the Super SBM-I-V model of the DEA to assess the business performance of the enterprises. Based on this result, we chose the target enterprises to ally with other enterprises. The results are provided in Table 17.

Table 17. Ranking results in 2018.

Rank	DMUs	Score	Rank	DMUs	Score
1	DMU9	6.1153	8	DMU10	1.0449
2	DMU5	4.1682	9	DMU1	1.0017
3	DMU8	1.5765	10	DMU3	1.0000
4	DMU6	1.4048	11	DMU12	0.7946
5	DMU7	1.3230	12	DMU4	0.7743
6	DMU14	1.1026	13	DMU13	0.6488
7	DMU2	1.0813	14	DMU11	0.6384

Source: Calculated by researcher.

4.3.2. Analysis after Alliance

Based on the results of business performance analysis and business rankings derived from the Super-SBM-I-V software in Table 17, we established DMU_{12} as the alliance target for the enterprise. When choosing DMU_4, DMU_{13}, or DMU_{11}, it would be difficult to persuade other DMU alliances when their business situation is too low. When combining DMU_{12} with the 13 other DMUs, we found 27 coordinates. Using the DEA-Solver Pro 8.0-Super-SBM-I-V model to evaluate the business performance of these 27 combinations, we obtained the results shown in Table 18.

Table 18. Virtual results.

Rank	DMUs	Score	Rank	DMUs	Score
1	DMU9	6.1153	15	DMU3 + DMU12	1.0000
2	DMU6	1.4048	16	DMU12	0.7946
3	DMU8	1.3498	17	DMU14 + DMU12	0.7883
4	DMU7	1.3230	18	DMU2 + DMU12	0.7812
5	DMU5	1.2202	19	DMU1 + DMU12	0.7787
6	DMU8 + DMU12	1.1977	20	DMU4	0.7743
7	DMU14	1.1026	21	DMU9 + DMU12	0.7530
8	DMU2	1.0813	22	DMU4 + DMU12	0.7360
9	DMU3	1.0768	23	DMU6 + DMU12	0.6884
10	DMU7 + DMU12	1.0762	24	DMU11 + DMU12	0.6846
11	DMU10	1.0449	25	DMU13 + DMU12	0.6623
12	DMU10 + DMU12	1.0147	26	DMU13	0.6488
13	DMU5 + DMU12	1.0130	27	DMU11	0.6384
14	DMU1	1.0017			

Source: Calculated by researcher.

From the results of the analysis, we chose DMU_{12} as a target company to combine with other companies because the results of DMU_{12}'s business in 2018 were ineffective (rank $_{DMU12}$ = 11 (11/14 DMUs); score $_{DMU12}$ = 0.7946). In that situation, the DMU_{12} leaders needed to have practical solutions to change and improve the business situation. The solution of combining with other enterprises is a feasible new direction. On the other hand, DMU_{12} (Vietnam Construction Joint Stock Company No. 2) in Hanoi is one of the leading companies in the construction industry. Hanoi consists of good roads, railways, waterways, and air and sea transport systems. It is convenient for other businesses to choose DMU_{12} as a partner for the alliance.

Based on the results of assessing the business performance of the enterprises when joining the alliance, we divided them into two groups, as outlined below.

Group 1 (Table 19) includes effective alliances.

Table 19. Effective alliances.

Virtual	Target DMU12	Virtual Combination	Difference
Combine	**Ranking (a)**	**Ranking (b)**	**(a)–(b)**
DMU12 + DMU8	16	6	10
DMU12 + DMU7	16	10	6
DMU12 + DMU10	16	12	4
DMU12 + DMU5	16	13	3
DMU12 + DMU3	16	15	1

Source: Calculated by researcher.

These alliances can encourage managers to consider possible implementation in the future, as these alliances work well for all parties involved. In particular, before implementing the DMU12 alliance, ranked 11/14, the effective score was only 0.7946. However, after making a coalition with DMU8, the situation of the business improved significantly (rank 6/27, efficiency score 1.1977). This union would help both DMU8 and DMU12 to operate effectively.

Group 2 (Table 20) includes ineffective alliances.

Table 20. Ineffective alliances.

Virtual Combine	Target DMU12 Ranking (a)	Virtual Combination Ranking (b)	Difference (a)–(b)
DMU12 + DMU14	16	17	(−1)
DMU12 + DMU2	16	18	(−2)
DMU12 + DMU1	16	19	(−3)
DMU12 + DMU9	16	21	(−5)
DMU12 + DMU4	16	22	(−6)
DMU12 + DMU6	16	23	(−7)
DMU12 + DMU11	16	24	(−8)
DMU12 + DMU13	16	25	(−9)

Source: Calculated by researcher.

Alliances that would not work well should not be encouraged in the future.

4.3.3. Partner Alliance Selection

Based on the results of the assessment in Table 19, the proposal for the implementation of the alliance (DMU_{12} + DMU_8) was the best solution for all parties.

VC2 (Vietnam Construction Joint Stock Company No.2) was established in 1970, and it specializes in constructing and building civil works, industrial works, road transportation at all levels, bridges, irrigation works, posts, foundations, urban and industrial technical infrastructure works, lines, transformers, and water supply and drainage works, as well as installing technology pipeline and pressure, electrical works, etc.

THG (Tien Giang Investment and Construction Joint Stock Company) is the precursor of Tien Giang Investment and Construction Joint Stock Company. THG's board of directors is planning a strategy to promote its strength in irrigation construction, allying with strategic partners to expand to construction, industrial construction, and environment projects to strengthen its position, as well as increase revenue and profits.

Therefore, considering the fields of business and the strategies, this alliance can achieve positive results and expand the markets for all enterprises. When the alliance is established, the parties can develop policies to diversify possible products. In addition, the alliance will also have more customers by taking advantage of their different customer systems. If there are works in appropriate and advantageous locations for their allies, the parties can use the machinery, raw materials, and common labor of their allies in the location. This will assist in keeping production stabilized and timely, which in turn will reduce construction and transportation time, as well as production and workers living costs. As a result, this will help strengthen the enterprise's position and competitive edge in the market, thereby increasing business efficiency.

4.3.4. Analysis after Alliance by ARIMA Model

To ensure suitability when using the ARIMA model, we firstly examined the stationarity of the time series with respect to the revenue in the period 2009–2018 of the enterprises in the alliance. The result shows that the time series were non-stationary at a zero-degree difference; therefore, a first-degree difference was used to examine stationarity. After a first-degree difference was used, the time series were stationary (Figure 4).

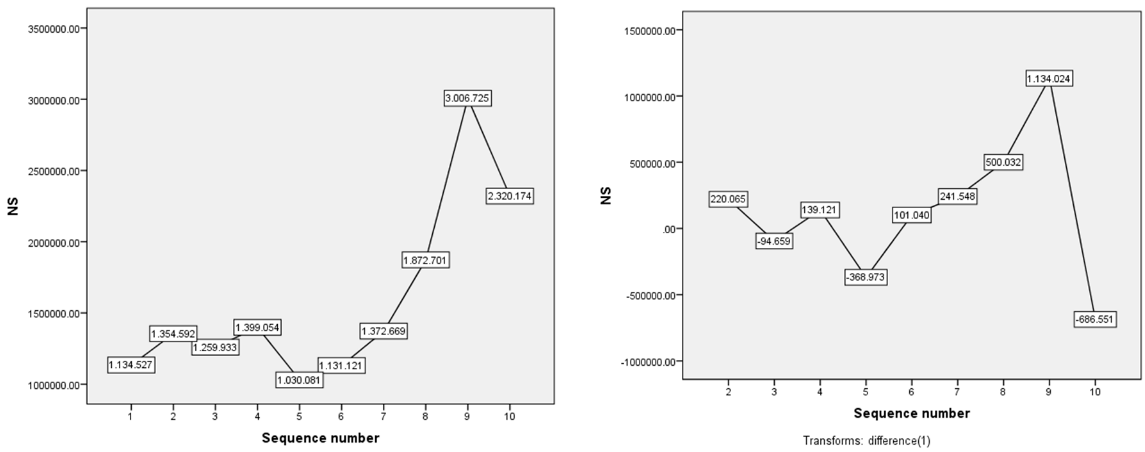

Figure 4. The time series were stationary after implementation of first-degree difference.

Then, the authors used the experimental method of comparing the R^2-squared indexes to come up with a suitable conjecturing model. The comparison shows that the ARIMA (1,1,1) model is the most suitable model for the dataset with respect to the revenue in the period 2009–2018 (Figure 5).

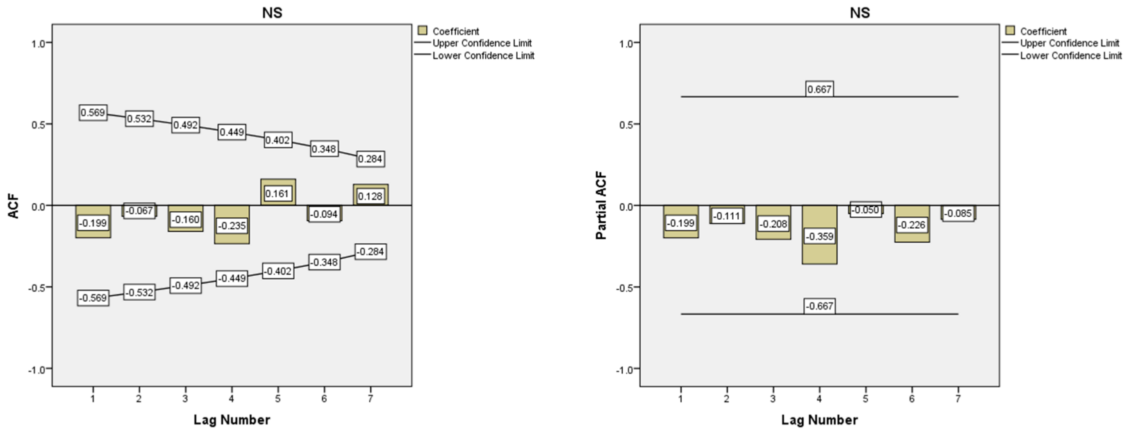

Figure 5. Upper and lower confidence limits of coefficient.

We continued to examine the suitability of the model by calculating the MAPE index of the ARIMA(1,1,1) model. The result in Table 21 shows that the model used in this research has high accuracy with MAPE = 19.642% (Sig. = 0.00).

Table 21. Model Statistics.

Model	Number of Predictors	Model Fit Statistics				Ljung-Box Q(18)			Number of Outliers
		Stationary R-Squared	RMSE	MAPE	Normalized BIC	Statistics	DF	Sig.	
NS-Model_1	0	0.220	526,530.961	19.642	27.081	.	0	.	0

The prediction result by the ARIMA model in Table 22 and Figure 6 shows that the revenue trend would be upward throughout the years following enterprise alliance. Specifically, when DMU8 makes an alliance with DMU12, the forecasted revenue for the years from 2019 to 2020 would be as follows: 2,429,442.05; 2,556,578.22; 2,692,219.24; 2,831,908.40. This means that, if they ally, they would have more contracts from bidding and build more civil and industrial construction work.

Table 22. Forecast.

Model		11	12	13	14
NS-Model_1	Forecast	2,429,442.05	2,556,578.22	2,692,219.24	2,831,908.40
	UCL	3,696,760.17	4,002,827.44	4,192,671.11	4,350,601.43
	LCL	1,162,123.94	1,110,328.99	1,191,167.36	1,313,215.38

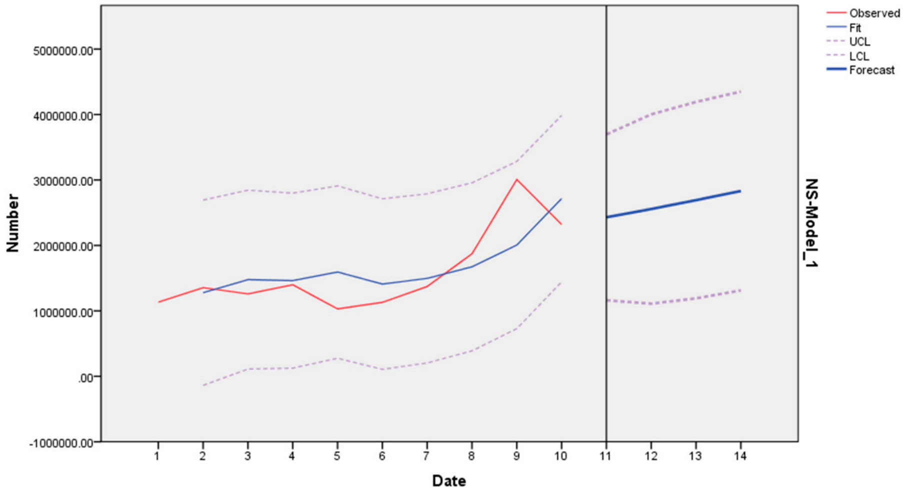

Figure 6. Forecast revenue trend after alliance.

Therefore, the conjectured result from the ARIMA model can help corporate managers and policy-makers put forward plans to deal with fierce competition in the future, as well as open up the opportunity for cooperation, promotion, and market expansion for enterprises. In addition, this research result allows corporate managers of construction enterprises to use the conjectured result in putting forward business plans to ensure a good implementation of their enterprise strategies.

5. Discussion and Conclusions

Currently, the competition among enterprises in the market is extremely fierce, and enterprises may become bankrupt if they do not have sufficient financial and technological capacity. Therefore, the alliance between enterprises can help them sharpen their competitive edge compared to other competitors. In this research, we used the DEA and GM (1,1) models to choose an appropriate strategic partner for a construction enterprise. Furthermore, the ARIMA model showed that, if the alliance is conducted, the revenue trend of the enterprises would increase, meaning that they would have more design and construction contracts. Therefore, the proposed solution can help companies assist each other, as well as cooperate and make use of existing resources related to investment, technology, techniques, and unskilled labor to design and build construction works.

In this study, we used the business data of the top 14 enterprises in construction investment, responsible for designing and executing the work for civil and industrial projects in Vietnam from 2015 to 2018. We used DEA models to evaluate the business performance of these businesses during the period of research, while we also used Grey system theory to forecast the business situation of companies for the period 2019–2022. Based on these results, we proposed alliances to benefit businesses in developing their own strengths and minimizing difficulties when the economy has many fluctuations, such as today. Then, we used the ARIMA model to predict the revenue trends of businesses when implementing the alliance. The use of multiple models which were considered and evaluated in this study can provide managers with a multi-dimensional and objective perspective to make decisions for businesses. The results of this study can help leading enterprises in the field of construction investment to have an appropriate coalition strategy in the context of a changing economy both in Vietnam and around the world. Regulatory authorities may use the results of this research to propose orientations, make decisions, and plan appropriate strategies to develop Vietnam's construction industry.

In addition to these important contributions, this research still has certain limitations. Specifically, the authors only analyzed, evaluated, and forecasted business results based on quantitative data but without an in-depth analysis of factors on business environment and legal factors. Therefore, in the future, research should be carried out in combination with environmental factors and regulations and policies of state management in the field of construction in order to have better solutions to provide managers with a better overview to plan strategies and make more accurate decisions.

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