Journal of Algorithms and Computations
journal homepage: http://jac.ut.ac.ir

Comparative Analysis of Metaheuristic Algorithms and Linear Regression in Predicting the CEO Selection

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ABSTRACT

The purpose of this study is to perform a comparative analysis of metaheuristic algorithms and linear regression in predicting the selection of CEO of companies listed on the Tehran Stock Exchange for 1050 data consisting of 15 companies for the years 2018 to 2024. The research data was analyzed by combining the particle swarm optimization algorithm and forbidden search algorithms, multilayer perceptron neural network, and gray wolf optimization, in order to predict the selection of CEO. the relationships between variables were examined using the regression method and the results obtained from the metaheuristic algorithms were compared. The results show that the variables of profitability, sales growth, return on assets, and managerial ability are important in all research algorithms in determining the type of CEO. Prediction based on the linear regression model is also possible. The results show the superiority of the neural network model.

Keywords: CEO Selection, Particle Swarm Optimization algorithm, Forbidden Search algorithm, Neural Network algorithm, Grey Wolf Optimization algorithm

AMS subject classification: 41A05

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ARTICLE INFO

Article history:
Research paper
Received 21, April 2026
Accepted 20, May 2026
Available online 24, May 2026

1 Introduction

The CEO is recognized as the main representative and executive leader of a company or organization, responsible for achieving strategic goals and business success. Their duties include designing long-term strategies, managing daily operations, overseeing various teams, and fostering relationships with shareholders and business partners [6]. This vital role is directly related to the organization's performance and growth; therefore, leadership skills, strategic decision-making, and crisis management are essential qualities of a successful CEO. The CEO, or Chief Executive Officer, is the highest-ranking executive in an organization, responsible for guiding and supervising all company operations and strategies. This person makes key decisions, manages resources, and leads executive teams [1]. Typically, the CEO is the top administrative or executive officer who manages the entire corporation or organization and reports to the board of directors. A CEO usually has several subordinate executive managers, each responsible for specific operational functions. The executive team may include roles such as Chief Technical Officer, Chief Financial Officer, Chief Commercial Officer, Chief Marketing Officer, Chief Sales Officer, Chief Information Officer, Chief Communications Officer or Public Relations Manager, Chief Administrative Officer, Chief Human Resources Officer, Chief Procurement Officer, and Chief Training Officer. The CEO's responsibilities are assigned by the board of directors and other authorities. Their primary task is to align the organization's objectives internally and externally, based on the company's vision and goals [4]. As the head and leader of the organization, the CEO acts as a decision-maker, employer, and executor of responsibilities. They serve as a liaison with external stakeholders such as the media and employers, as well as internal members and employees. The CEO advises the board on necessary matters and manages daily company operations as an employer. Their duties include directing, guiding, leading, and evaluating the activities of other leaders, deputies, and managers according to the organization's reporting and assessment structure [3]. The CEO must ensure that organizational goals and achievements are successfully attained. Strategic planning development and execution to guide other managers is another key responsibility. CEOs are also accountable for forecasting and completing organizational operations in line with defined strategic plans. In other words, they must pay attention to organizational design in a way that supports and equips various operations. Engaging in professional activities and social responsibility efforts at local, provincial, and national levels is also part of the CEO's role. Other managers may participate in these activities if assigned or interested. Active participation in industry-related events and programs enhances the CEO's reputation and skills. The CEO must ensure that all employees understand the importance of these participations and strive toward organizational success [5]. Demonstrating leadership to steer the organization toward its mission involves setting a clear vision, recruiting organized personnel, and focusing on all leadership aspects to achieve success. Collaborating with teams that support the CEO in fulfilling their duties is crucial. To ensure organizational success, the CEO must perform all job responsibilities outlined in their role description, with the help of properly recruited personnel [7]. The CEO should foster a learning organization where all members have opportunities for growth, development, and continuous acquisition of skills and knowledge. Only through individual development within the organization can success and growth be realized. The CEO plays a fundamental role in steering the organization toward victory and success. When the CEO's duties are well executed, the organization moves toward higher profitability and prosperity, achieving its positive goals one after another. The CEO must also inform other managers about necessary performance evaluations through various methods [2]. These evaluations may include supervision and guidance, reward systems, or disciplinary regulations concerning managers'

performance. Selecting the CEO is critically important for every organization or company, large or small. As the highest executive officer, the CEO holds extensive responsibilities in directing, planning, executing, and overseeing organizational activities. An effective and efficient CEO selection can lead to organizational success and advancement, while a poor choice may result in failure and irreparable losses [13]. The CEO determines the organization's direction with their decisions and actions and influences its performance. The importance of CEO selection can be highlighted by the following points: The CEO leads the organization toward success by setting goals and strategies and ensures all members move in alignment. In various situations, the CEO makes critical decisions and chooses the best course of action for the organization [8]. As the organization's representative, the CEO interacts with internal and external stakeholders such as shareholders, employees, customers, and partners, safeguarding the organization's interests. The CEO monitors the performance of different organizational units to ensure activities progress according to plans [9]. The CEO identifies opportunities and threats, fosters development and innovation, and supports company growth through appropriate decisions. The CEO is responsible for securing the financial, human, and physical resources the organization needs and plans to prevent resource wastage [12]. The CEO executes approved organizational plans and programs, ensuring their proper implementation through close supervision. By creating a suitable and motivating work environment, the CEO enhances employee productivity and organizational performance. As the legal representative of the organization, the CEO participates in various meetings and forums and defends the organization's rights and interests [10]. The CEO evaluates organizational performance and submits periodic reports to the board of directors and shareholders. In summary, selecting a suitable and effective CEO is a fundamental step toward achieving organizational success and sustainable development [11].

2. Theoretical Foundations and Literature Review

The CEO is not merely an executive title but the central figure in decision-making, guidance, and shaping the future of the organization. The CEO's responsibilities extend beyond daily management; they must bridge the gap between the overarching vision and operational realities. Below, we examine five key CEO duties from a specialized perspective. One of the primary responsibilities of the CEO is setting the organization's strategic direction [14]. This involves decisions such as selecting target markets, defining competitive advantages, formulating long-term goals, and determining the type of political relations and policies. The CEO must make data-driven decisions but also possess the courage to innovate and drive change. The CEO oversees the performance of various organizational units from finance and human resources to operations and marketing. Using key performance indicators (KPIs), the CEO monitors growth or decline in each sector and makes timely decisions to correct or reinforce paths [15]. Another vital duty of the CEO is establishing effective, transparent, and professional communication with the board of directors. The CEO must provide periodic reports on organizational performance, outline future plans, and secure necessary approvals for strategic decisions. The CEO's skill lies in building trust and coordination with board members. No organization can succeed without alignment among its management team. The CEO is responsible for creating unity, motivation, and direction among deputies and senior managers. Regular meetings, intelligent delegation of authority, and purposeful feedback are key tools in this process [16]. In crises such as economic recessions, sudden market changes, or internal emergencies, the CEO must maintain composure, make swift and effective decisions, and protect the organization from harm. Experience, rapid analytical ability, and stakeholder management skills are crucial traits for fulfilling this role. Within

organizational settings, some seemingly similar titles have quite different duties and statuses. For instance, the distinction between "CEO" and "General Manager" is important to understand. The CEO is the highest executive officer responsible for the overall leadership of the company, designing strategies, and liaising with the board and other stakeholders. Their decisions are usually decisive and long-term [20]. The General Manager focuses more on managing a specific unit or executing operations within a segment of the organization. They play a key role in policy implementation and ensuring operational progress in their domain. Simply put, the CEO maps the organization's overall trajectory, while the General Manager ensures effective and accurate movement along that path [21]. Properly defining the role of the CEO in an organization is critically important and can have extensive effects on organizational performance, culture, and overall success. Below are some reasons why this definition matters: The CEO determines the strategic orientation of the organization. Their decisions affect all aspects of organizational performance from product development to entering new markets and forming business partnerships [17]. All successful CEOs worldwide have their unique strategies. Key decisions by the CEO can either accelerate growth or cause organizational decline. Developing effective strategies and implementing them requires a CEO with a clear and well-defined understanding of their duties and responsibilities. A CEO with a clear definition can effectively lead executive teams and ensure coordination among various organizational units. Leaders who understand their roles and responsibilities precisely can better motivate their teams. Effective team management requires a deep understanding of the organization's goals and overall strategies [18]. A well-defined CEO can create a positive organizational culture and help attract and retain top talent. Employees look for leaders who are transparent, honest, and make smart decisions. A well-defined CEO role can help build trust and confidence among employees. The CEO plays a vital role in managing the organization's financial resources [19]. His or her financial decisions can impact the organization's sustainability and growth. Accurate and strategic financial decisions require a thorough understanding of the CEO's role and responsibilities. Effective financial management can help increase productivity and reduce costs. The CEO is the organization's primary representative to shareholders, customers, suppliers, and the media. A well-defined role can help improve external relations and enhance the organization's image. Effective stakeholder relationships can lead to new political connections and increased market trust in the organization [22]. The ability to communicate effectively and represent the organization directly depends on a well-defined and well-understood role of the CEO. A clearly defined CEO can lead more effectively in times of crisis and organizational change [24]. A clear understanding of duties and responsibilities helps the CEO make quick and effective decisions in times of crisis. Managing change requires strong leadership and strategic planning, which is possible with a clear definition of the CEO role. A clear definition of the CEO role can help increase the productivity and efficiency of the organization. By having a CEO with clear duties, all units in the organization know what is expected of them and how they should achieve organizational goals. Better coordination and reduced internal conflicts can lead to improved overall organizational performance [25]. Defining the CEO in the right way not only helps in transparency and clarity in his duties and responsibilities, but can also have positive effects on all aspects of the organization's performance. From setting strategic directions and managing executive teams to attracting and retaining talent and managing financial resources, all of these aspects depend on a clear understanding and definition of the CEO role [23]. This definition can lead to the creation of a positive organizational culture, improved relationships with external stakeholders, and increased organizational productivity and efficiency [32]. The absence of a CEO in an organization can have several negative effects, including disruption in

day-to-day management, reduced efficiency and productivity, lack of decisive decision-making, weakening employee morale, and ultimately, damage to the organization's performance and position in the market [30]. In the absence of a CEO, the organization's daily activities may be delayed and uncoordinated. This can lead to reduced efficiency and productivity in performing tasks and projects. Also, the absence of a single leader for decision-making can lead to confusion and delay in making important decisions, which in turn can negatively affect the organization's overall performance [26]. In addition, the absence of a CEO can weaken employee morale and reduce their motivation to work. Employees may feel unstable and uncertain, which can negatively affect their individual and group performance. Ultimately, the absence of a CEO can lead to a decrease in trust in the organization by customers and business partners, which can damage the organization's reputation and position in the market [31]. CEO failure or inefficiency can have a devastating effect on the performance and sustainability of an organization. These effects include reduced efficiency, reduced profitability, loss of trust from shareholders and employees, and ultimately, the failure of the organization. An ineffective CEO may not be able to properly manage the organization's resources, optimize processes, or make the right strategic decisions [27]. This leads to a decrease in productivity and efficiency in the organization. CEO inefficiency can lead to reduced revenues, increased costs, and ultimately, a decrease in the organization's profitability. This can put the organization at risk of bankruptcy. Shareholders look to the CEO as the person who is responsible for leading the organization and creating value for them [28]. If the CEO is ineffective, shareholders lose their trust in him and the organization in general and may sell their shares. Employees also look to the CEO as their leader [33]. If the CEO is ineffective, employees lose trust in him or her and the organization as a whole, and may lose motivation and commitment. This can lead to lower employee morale and higher turnover rates. CEO inefficiency can damage the organization’s reputation. This can lead to lower sales, lower customer acquisition, and ultimately, a decrease in the organization’s value. In extreme cases, CEO inefficiency can lead to the complete failure of the organization. This happens when the organization is unable to cope with the problems caused by the CEO’s inefficiency and ultimately goes bankrupt [29].

2-1-Research hypotheses

Hypothesis 1: It is possible to predict the selection of CEO (public or private) in companies listed on the stock exchange based on a combined model of particle swarm optimization algorithm and forbidden search.

Hypothesis 2: It is possible to predict the selection of CEO (public or private) in companies listed on the stock exchange based on a combined model of particle swarm optimization algorithm and multilayer perceptron neural network.

Hypothesis 3: It is possible to predict the selection of CEO (public or private) in companies listed on the stock exchange based on a combined model of particle swarm optimization algorithm and gray wolf optimization.

Hypothesis 4: It is possible to predict the selection of CEO (public or private) in listed companies based on a linear regression model.

Hypothesis 5: The accuracy of predicting the selection of CEO (public or private) based on the linear regression model is lower than that of the metaheuristic algorithms.

3- Research Methodology

This research is classified according to its purpose as applied research and its research type is correlational and its methodology is post-event. The purpose of this type of research is to examine the existing relationships between variables and data are collected and analyzed from an environment that has existed naturally or from past events that have occurred without the direct intervention of the researcher. Also, the statistical population of the research is all companies listed on the Tehran Stock Exchange. The systematic elimination method was used to select the sample. For this purpose, the following criteria were considered and if a company meets all the criteria, it is selected as the research sample and the rest are eliminated. Companies that have been active on the stock exchange during the research period. The company should not be from the group of political relations, holdings and financial intermediation companies. The company's fiscal year should not change during the research period. The financial information of the companies should be available. Finally, 1050 data consisting of 15 companies for 7 consecutive years were selected as the research sample. In the present study, MATLAB software was used to implement the algorithms. MATLAB software is one of the most powerful mathematical software that has wide applications in other fields. The many ready-made toolboxes that this software provides to its users make working with it very easy. In the present study, a combined model of the particle swarm optimization algorithm with each of the forbidden search algorithms, the multilayer perceptron neural network, and the gray wolf optimization algorithm were used to test the hypothesis. The process of separating data into training and evaluation data is as follows: Usually, the error rate on the learning data is lower than the error rate on the data that has not been seen in the learning process. Therefore, in addition to the learning data set, a set of data is required for evaluation, and also to select the appropriate variables for each model, in addition to the two sets of learning and evaluation data, another set of data is required, called the validation data set, which is selected from the learning data set. For this purpose, the K-Fold Cross Validation method was used in this study. In this study, the data set was randomly divided into 10 equal parts. In the first run, 10 parts were used for evaluation, and the remaining 1-10 parts were used for learning and validation, of which 20% was used as validation data and 80% as learning data. In the second run, the second part of the 10 parts were used for evaluation, and the remaining 1-10 parts were used for learning and validation, and the algorithm was run 10 times in the same manner. After dividing the data into three groups of learning, validation, and evaluation data, first the influential components for predicting the selection of the independent auditor must be found separately for each of the algorithms. For this purpose, the particle swarm optimization algorithm is combined with each of the models of the forbidden search algorithm, multilayer perceptron neural network, and gray wolf optimization. To select the influential components for predicting the selection of the CEO, first 16 independent variables of the problem must be coded so that they can be entered into the combined model. For this purpose, a 16-digit string containing zeros and ones was used. The presence or absence of each variable in the models of the forbidden search algorithm, multilayer perceptron neural network, and gray wolf optimization algorithm was determined by the particle swarm optimization algorithm. The learning data was used to find the components that influenced the prediction of CEO selection, and the validation data was used to evaluate the selected components in the particle swarm optimization algorithm. After dividing the samples into three categories of learning data, validation and evaluation data, and selecting the components that influenced the prediction of CEO selection, the forbidden search algorithm, multilayer perceptron neural network, and gray wolf optimization models were trained using the training data, and then the accuracy of the model's prediction was measured using the evaluation data that the model had not seen before. To evaluate the predictive models, an evaluation criterion called the recognition rate was used,

which is calculated using the relationship, recognition rate = (prediction accuracy) / (total sample number). The closer the recognition rate is to 100, the closer the algorithm's prediction is to reality. To select the independent variables of the study, a list of variables including 39 financial accounts and ratios was prepared. Then, using analysis of variance, the fluctuation of values was estimated for each variable, and 16 financial accounts and ratios (including turnover, operating profit, CEO compensation, board size, sales growth, current liabilities, managerial ability, profitability, current ratio, debt ratio, debt solvency ratio, financial leverage, gross profit, political relations, total liabilities, return on assets) were identified with $p<0.005$ as significant variables in determining the behavior of the dependent variable. CEO selection is the dependent variable in this study, in which CEOs are divided into two groups: private sector and public sector companies.

3-1-Research Algorithms

3-1-1-Particle Swarm Optimization Algorithm

In fact, the particle swarm optimization algorithm consists of a certain number of particles that randomly take an initial value. For each particle, two values of position and velocity are defined, which are modeled with a position vector and a velocity vector, respectively, as the n-dimensional model. These particles move iteratively in the problem space to search for new possible options by calculating the optimality value as a measurement criterion. The dimension of the problem space is equal to the number of parameters in the function to be optimized. One memory is allocated to store the best position of each particle in the past and one memory is allocated to store the best position among all particles. With the experience gained from these memories, the particles decide how to move in the next turn. In each iteration, all particles move in the problem dimension until finally the n-dimensional optimal point of the general space is found.

3-1-2-Multilayer perceptron neural networks

are a type of feedforward neural network that is one of the most widely used models of artificial neural networks. Each perceptron, through its weight coefficients, aggregates the output of all the perceptron of the previous layer and sends it to the next layer through a functional function. Backpropagation learning computational algorithms are very diverse and have different results and functions. In the simplest algorithm, the network weight coefficients are changed to minimize the network objective function (which is the gradient of the network output judgment error). Therefore, in each training stage, the weight coefficients are changed as follows. In $w_{k+1} = w_k - a_k g_k$. $w_k$is the vector of network weight coefficients, g_k is the gradient of the network output error, and $a_k$is the network learning coefficient. Which is called the gradient reduction algorithm, it can be implemented in two ways: incremental or batch. In the incremental mode, the error gradient is calculated after each observation of one of the training examples and the weight coefficients are improved. In the closed mode, this is done after observing a complete period of training examples and calculating the total gradient. In most cases, the incremental method performs better than the closed method, so this method was used in this study.

3-1-3-Forbidden Search

To reach the optimal solution in an optimization problem, the forbidden search algorithm first starts from an initial solution. Then the algorithm selects the best neighboring solution from among the neighbors of the current solution. If this solution is not in the forbidden list, the algorithm moves to the neighboring solution; otherwise, the algorithm will check a criterion called the breathing criterion. Based on the breathing criterion, if the neighboring solution is better than the best solution found so far, the algorithm will move to it, even if that solution is in the forbidden list. After the algorithm moves to the neighboring solution, the forbidden list is updated; This

means that the previous move that led to the neighbor solution is put in the forbidden list to prevent the algorithm from returning to that solution and creating a cycle. In fact, the forbidden list is a tool in the forbidden search algorithm that prevents the algorithm from being in a local optimum. After placing the previous move in the forbidden list, a number of moves that were previously in the forbidden list are removed from the list. The duration for which the moves are in the forbidden list is determined by a parameter called the forbidden time. The move from the current solution to the neighbor solution continues until a termination condition is met. Different termination conditions can be considered for the algorithm. For example, a limit on the number of moves to the neighbor solution can be a termination condition.

3-1-4-Gray Wolf Optimization Algorithm

Gray Wolf Optimization is a nature-inspired exploratory search algorithm that simulates the hunting behavior and social hierarchy of gray wolves in the wild. This algorithm was introduced in 2014 as a swarm intelligence technique for solving optimization problems. The social structure of wolves plays a key role in this algorithm, such that the pack is led by an alpha wolf, while beta and delta wolves follow him and participate in the decision-making process, and omega wolves have the lowest rank. This social hierarchy helps balance exploration and exploitation and is effective in finding optimal solutions. In the gray wolf optimization algorithm, the optimization process consists of three main stages: encircling the prey, hunting, and attacking or moving towards new solutions. In the siege phase, wolves adjust their positions based on the best-known solutions. In the hunting phase, alpha, beta, and delta wolves collectively estimate the location of the prey and lead the pack to the best solutions. Finally, the attack phase occurs when wolves approach the prey and the search focus increases to accelerate convergence to the optimal solution. If further exploration of the search space is required, wolves move away from each other to avoid getting stuck in local optima. One of the important advantages of gray wolf optimization is its simplicity and ability to solve complex optimization problems with fewer control parameters than other algorithms such as genetic algorithms or particle swarm optimization. The high efficiency of this algorithm in finding global optima makes it suitable for various applications such as power system optimization, feature selection in machine learning, and structural engineering. In addition, its ability to balance exploration and exploitation preserves diversity in the search process and reduces the likelihood of getting stuck in local optima. [3] In power system applications, gray wolf optimization has been widely used to optimize network configuration, increase resilience, and reduce operational costs. For example, in the design of resilient distribution networks, this algorithm is used to optimally allocate feeder paths, substation equipment, and network reinforcement strategies against physical attacks or natural disasters. Considering technical and economic constraints, this algorithm strikes a balance between resilience and cost. Its adaptability to large-scale problems makes it very useful in complex power network scenarios where multiple variables need to be optimized. Despite its significant advantages, gray wolf optimization also has limitations, including dependence on the initial population and the possibility of slow convergence in high-dimensional problems. To improve its performance, researchers have proposed hybrid methods that combine Gray Wolf Optimization with other techniques such as fuzzy logic, artificial neural networks, or differential evolution. These modifications aim to increase the accuracy, speed, and adaptability of the algorithm in dynamic environments. Overall, Gray Wolf Optimization remains a powerful and flexible optimization tool with broad applications in engineering, machine learning, and power system resilience.

4- Research Results

4-1- Metaheuristic Algorithm Model

After selecting the influential components for predicting CEO selection using a combined particle swarm optimization and forbidden search algorithm, the training data is applied to the forbidden search algorithm. Equation (1) is the function that the forbidden search algorithm tries to find the coefficients $b_i, i = 1, \dots, m$ when the maximum is a multiple of 16.

$$z = sign(b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_m x_m) \quad (1)$$

where $b_i, i = 1, \dots, m$ are the weights of each of the 16 variables (x_1) that are in the interval [-1,1]. The forbidden search algorithm finds these parameters using the learning data, which is called model training, and then here the number m. With the evaluation data, the model is evaluated by the variables selected by the combined particle swarm optimization and forbidden search algorithm. Table (1) shows the components selected to predict the CEO selection using the combined particle swarm optimization and forbidden search algorithm. According to the findings of the above figure, out of the 16 components, only the components (profitability, sales growth, gross profit, operating profit, return on assets, board size, managerial ability, current ratio, debt ratio, financial leverage, political relations) are effective in predicting the CEO according to the forbidden search algorithm method.

Table 1. List of selected components of the combined particle swarm optimization and forbidden search algorithm

Variable number	Variable name	Coding
X_1	Profitability	1
X_2	Sales growth	1
X_3	Total liabilities	0
X_4	Current liabilities	0
X_5	Gross profit	1
X_6	Operating profit	1
X_7	Return on assets	1
X_8	CEO compensation	0
X_9	Board size	1
X_{10}	Management ability	1
X_{11}	Current ratio	1
X_{12}	Debt ratio	1
X_{13}	Internal control weaknesses	0
X_{14}	Trading turnover	0
X_{15}	financial Leverage	1
X_{16}	Political relations	1

Figure (1) shows an accuracy for training and testing data for the forbidden search algorithm method.

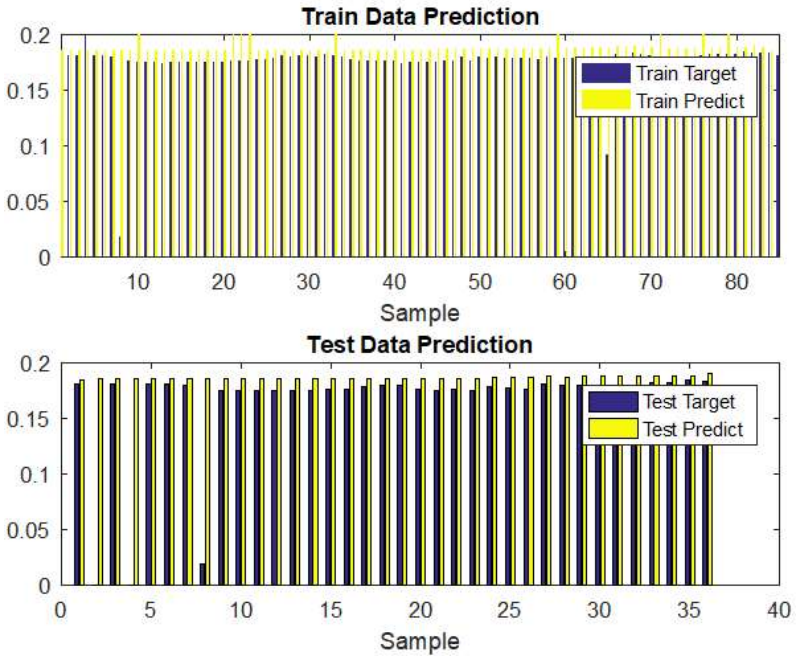

Figure (1) an accuracy for training and testing data for the forbidden search algorithm method.

Table (2) presents the results of the average prediction accuracy (identification rate) after performing 10-Fold Cross-Validation for the evaluation data of the forbidden search algorithm.

Table 2. Detection rates for the evaluation data of the forbidden search algorithm.

Fold	**Identification rate**	**Fold**	**Identification rate**
1	81.68	6	90.25
2	86.78	7	88.37
3	84.45	8	79.14
4	88.65	9	86.34
5	92.31	10	87.64
Average	**86.65**	-	-

Table (3) presents the results of type I and type II errors for the evaluation data of the forbidden search algorithm.

Table 3. Type I and Type II errors for the evaluation data of the forbidden search algorithm

Error type	Error value
Type I Error	31.58%
Type II Error	4.19%
Identification Rate	88.52%

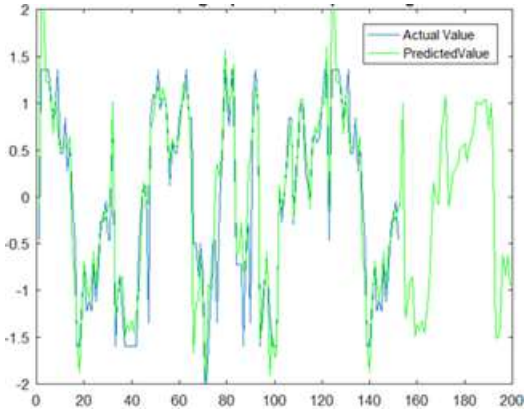

Figure 2. Prediction using the forbidden search algorithm

After selecting the influential components for predicting the CEO selection using the combined particle swarm optimization algorithm and multilayer perceptron neural network, the training data was applied to the multilayer perceptron neural network algorithm. To apply the training data to the multilayer perceptron neural network, the number of inputs, the number of hidden layers, the number of neurons in each hidden layer, and the overall internal structure of the multilayer perceptron neural network had to be determined first, which was followed by trial and error to select a 1-7-15 error backpropagation neural network, which can be seen in Figure (3) of this network. The error backpropagation algorithm is a gradient descent search algorithm that tries to minimize the mean squared total error between the desired output and the target output of neural networks. In the error backpropagation algorithm, at each stage, the newly calculated output value is compared with the actual value and the network weights are corrected according to the error obtained. In such a way that at the end of each iteration, the resulting error size is less than the amount obtained in the previous iteration. Each neuron in this network consists of a weighted sum of its inputs filtered by a sigmoid transfer function. After training the model using the training data, the network model was saved to be used in the evaluation phase. Table (3) presents the selected components for predicting CEO selection using the particle swarm optimization algorithm and the multilayer perceptron neural network.

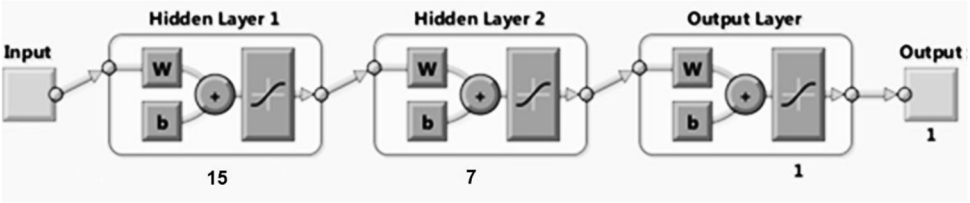

Figure 3: Proposed multilayer perceptron neural network

Table 4. List of selected components of the particle swarm optimization algorithm and multilayer perceptron neural network

Variable number	Variable name	Coding
X_1	Profitability	1
X_2	Sales growth	1
X_3	Total liabilities	0
X_4	Current liabilities	1
X_5	Gross profit	1
X_6	Operating profit	0
X_7	Return on assets	1
X_8	CEO compensation	0
X_9	Board size	0
X_{10}	Management ability	1
X_{11}	Current ratio	1
X_{12}	Debt ratio	0
X_{13}	Internal control weaknesses	0
X_{14}	Trading turnover	1
X_{15}	Leverage	0
X_{16}	Political relations	1

According to the findings in Table (4) of the 16 components, only the components (profitability, sales growth, current liabilities, gross profit, return on assets, managerial ability, current ratio, Trading turnover, political relations) are effective in predicting the selection of the CEO according to the multilayer perceptron neural network method. Figure (4) shows an accuracy for training and testing data for the multilayer perceptron neural network algorithm method.

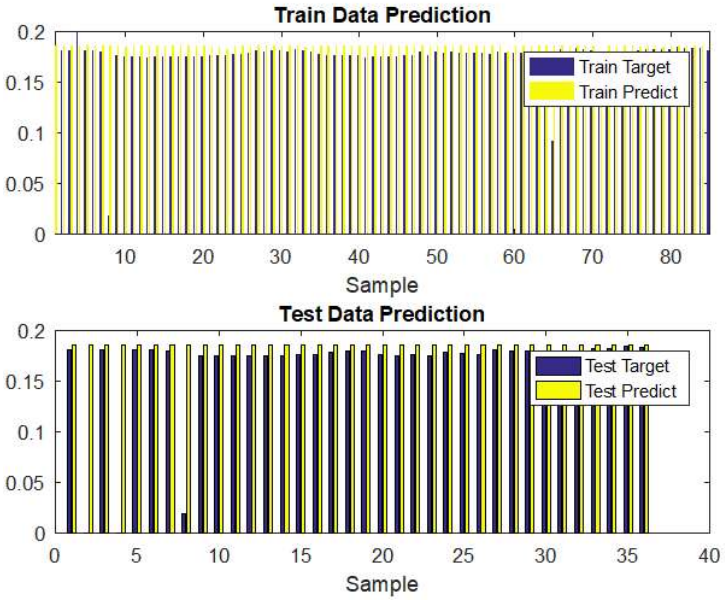

Figure 4. A accuracy for training and testing data for the Perceptron multilayer neural network algorithm method.

Table (5) shows the results of the average prediction accuracy (identification rate) after performing 10-Fold Cross-Validation.

Table 5. Identification rate for evaluation data of the Perceptron multilayer neural network algorithm.

Fold	Identification rate	Fold	Identification rate
1	88.61	6	89.12
2	89.78	7	90.24
3	85.40	8	86.14
4	86.22	9	87.19
5	91.43	10	89.28
Average	92.99	-	-

The results of type I and type II errors can also be seen in Table (6).

Table 6. Type I and Type II errors for evaluation data of the Perceptron multilayer neural network algorithm

Error type	Error value
Type I Error	33.74%
Type II Error	6.33%
Identification Rate	88.52%

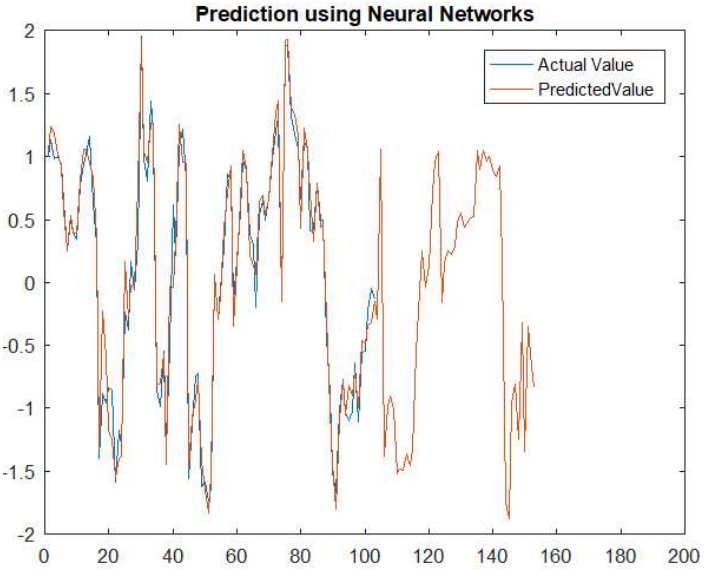

Figure 5. Prediction using the Perceptron multilayer neural network algorithm

After selecting the influential components for predicting CEO selection using the combined particle swarm optimization and gray wolf optimization algorithm, the training data is applied to

the SA algorithm. Equation (2) is a function that the SA algorithm tries to find the coefficients b_i,i=1,…,m when the maximum is m=1.

$$z = sign(b_0 + b_1x_1 + b_2x_2 + \cdots + b_mx_m) \quad (2)$$

where $b_i, i = 1, \dots, m$ are the weights of each of the 16 variables (x_i) that are in the interval [-1,1]. SA finds these parameters using the learning data, which is called model training, and then evaluates the model with the evaluation data. Here, m is the number of variables that the combined particle swarm optimization and gray wolf optimization algorithm has selected. Table (7) shows the components selected to predict CEO selection using a combination of particle swarm optimization and gray wolf optimization algorithms.

Table 7. List of selected components of the combined particle swarm optimization and gray wolf optimization algorithm

Variable number	Variable name	Coding
X_1	Profitability	1
X_2	Sales growth	1
X_3	Total liabilities	0
X_4	Current liabilities	0
X_5	Gross profit	0
X_6	Operating profit	0
X_7	Return on assets	1
X_8	CEO compensation	0
X_9	Board size	1
X_{10}	Management ability	1
X_{11}	Current ratio	0
X_{12}	Debt ratio	1
X_{13}	Internal control weaknesses	1
X_{14}	Trading turnover	0
X_{15}	Leverage	1
X_{16}	Political relations	0

According to the findings of Figure (7), out of the 16 components, only the components (profitability, sales growth, Return on assets, Board size, Management ability, Debt ratio, Internal control weaknesses, Leverage) are effective in predicting CEO selection according to the combined model of particle swarm optimization algorithm and gray wolf optimization.

Figure (6) shows an accuracy for training and testing data for the gray wolf optimization algorithm method.

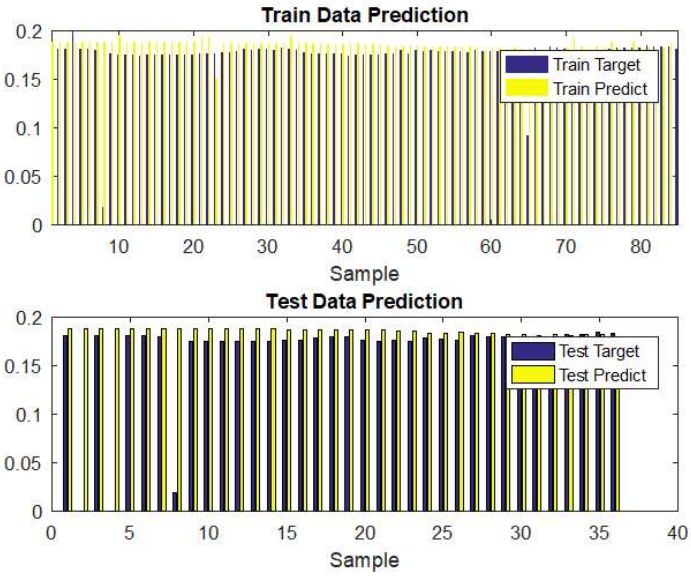

Figure 6. A plot of accuracy for training and testing data for the Gray Wolf optimization algorithm method.

Table (8) shows the average prediction accuracy (identification rate) after performing 10-Fold Cross-Validation for the evaluation data of the Gray Wolf optimization algorithm.

Table 8. Detection rate for the evaluation data of the Gray Wolf optimization algorithm.

Fold	**Identification rate**	**Fold**	**Identification rate**
1	89.10	6	88.39
2	85.23	7	92.56
3	88.13	8	88.19
4	89.47	9	89.84
5	90.43	10	90.12
Average	89.14	-	-

Table (10) shows the results of type I and type II errors for the evaluation data of the Gray Wolf optimization algorithm.

Table 9. Type I and Type II errors for the evaluation data of the Gray Wolf optimization algorithm

Error type	Error value
Type I Error	53.27%
Type II Error	2.37%
Identification Rate	81.57%

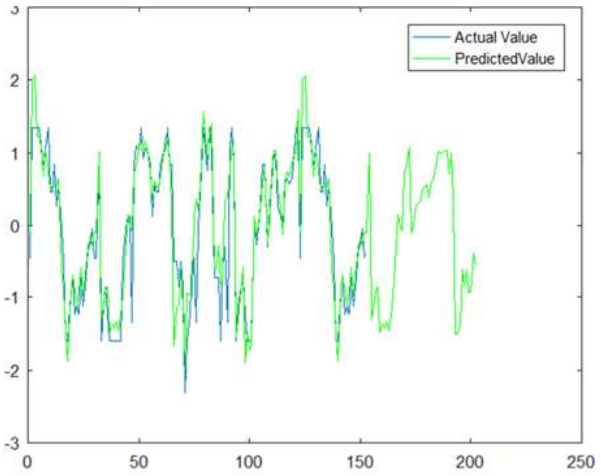

Figure 7. Prediction using the Gray Wolf optimization algorithm

Figure (8) shows the convergence graph for achieving lower prediction error.

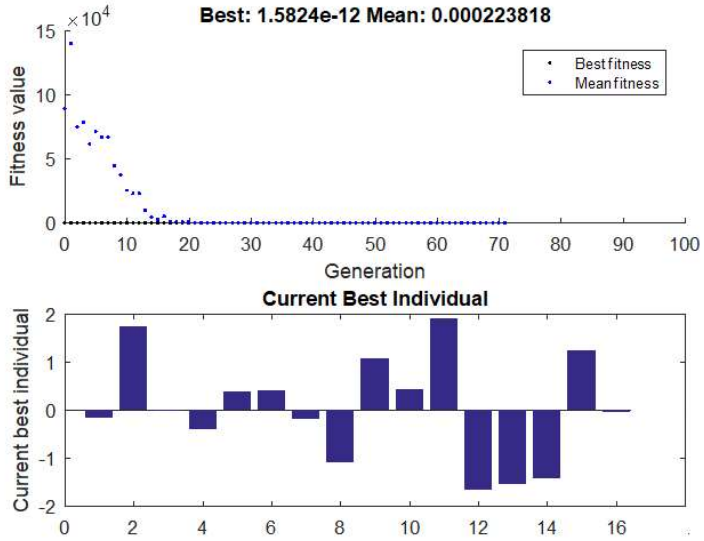

Figure 8. Convergence in reaching the prediction error

A summary of the results is presented in the table. In other words, in Table (10), the importance of variables in all research algorithms in determining the CEO is presented.

Table 10. Identified and significant variables in each of the research models

Variables	Multilayer Perceptron Neural Network Method	Forbidden search algorithm	Gray Wolf optimization algorithm
X_1	+	+	+
X_2	+	+	+
X_3	-	-	-
X_4	+	-	-

X_5	+	+	-
X_6	-	+	-
X_7	+	+	+
X_8	-	-	-
X_9	-	+	+
X_{10}	+	+	+
X_{11}	+	+	-
X_{12}	-	+	+
X_{13}	-	-	+
X_{14}	+	-	-
X_{15}	-	+	+
X_{16}	+	+	-

4-2-Linear Regression Model

This section presents the results of fitting the linear regression model (to examine the fourth hypothesis) to the research data. Table (11) summarizes the results of the fitted model. Table (12) also includes the results of the analysis of variance. Finally, Table 13 shows the results of the linear regression coefficients.

Table 11. Summary of fitted model results

model	R	R Square	Adjusted R Square
4	^{a}0.595	0.353	0.349

a/ Predictors: (Constant), X_1 X_2,X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}

Table 12. Results of analysis of variance

Model 1	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.38	9	0.265	72.881	^{b}0.000
Residual	4.36	1200	0.004		
Total	6.74	1209			

b. Predictors: (Constant), X_1 X_2,X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}

Table 13. Results of linear regression coefficients

variables	Unstandardized Coefficients beta	Standardized Coefficients beta		t	Sig.	Approve or reject
		Std. Error	B			
constant	-	0.027	0.037	1.343	0.125	reject
X_1	0.042	0.004	0.006	1.527	0.257	reject
X_2	0.240	0.015	0.094	6.158	0.001	Approve
X_3	0.027	0.002	0.001	0.670	0.220	reject
X_4	-0.059	0.003	-0.004	-1.457	0.145	reject
X_5	-0.042	0.002	-0.002	-0.861	0.183	reject
X_6	0.198	0.002	0.010	5.361	0.002	Approve
X_7	0.045	0.001	0.002	1.336	0.214	reject
X_8	0180	0.020	0.092	4.599	0.003	Approve
X_9	0.126	0.204	0.682	3.347	0.005	Approve
X_{10}	0.019	0.002	0.005	1.201	0.112	reject
X_{11}	0.032	0.014	0.089	1.004	0.314	reject

X_{12}	0.058	0.007	0.002	4.987	0.008	Approve
X_{13}	0.412	0.002	-0.003	1.357	0.146	reject
X_{14}	0.390	0.003	-0.003	5.910	0.000	Approve
X_{15}	0.205	0.005	0.005	5.314	0.000	Approve
X_{16}	0.033	0.011	0.086	0.897	0.286	reject

4-3- Comparison of results

The comparison of the results presented (in order to examine the fifth hypothesis) in Table 14 shows the superiority of the multilayer perceptron neural network model in terms of the coefficient of determination and the MSE index; so that the highest coefficient of determination for the multilayer perceptron neural network for the test data is 0.384 and for the linear regression model is 0.338. Also, the results of Table (14) showed that the MSE rate for metaheuristic algorithms for the test data is 0.003986, 0.001384, 0.002451, respectively, and for the linear regression model is 0.004821. Thus, the MSE index is also better, like the coefficient of determination, for metaheuristic algorithms.

Table 14. Comparison of the results of the coefficient of determination and MSE of meta-heuristic algorithms with the linear regression model

model	R-squared		MSE	
	Test	Training	Test	Training
Forbidden Search Algorithm	0.385	0.393	0.002451	0.003367
Multilayer Perceptron Neural Network Algorithm	0.384	0.399	0.001384	0.002652
Gray Wolf Optimization Algorithm	0.386	0.395	0.003986	0.004157
Linear regression	0.338		0.004821	

5- Conclusion and Discussion

Meta-heuristic algorithms have found a special place in improving everyday life due to their high efficiency and flexibility. These algorithms, using intelligent and approximate methods, provide the ability to solve complex and challenging problems in a more efficient and faster way. The use of neural networks in the world of artificial intelligence is considered an important issue. The use of neural networks allows a computer to think and make decisions for itself without the need for human help. They learn the relationships between complex input and output data and create a specific model from the relationships. In the present study, using a combined model of the particle swarm optimization algorithm with each of the forbidden search algorithm, the multilayer perceptron neural network, and gray wolf optimization, the variables determining the type of CEO were analyzed. The results of the study show that different algorithms consider different variables important in determining the type of CEO among the 16 selected variables. A summary of the results is presented in Table (10). As can be seen in Table (10), the variables of profitability, sales growth, return on assets, and managerial ability are important in all research algorithms in determining the type of CEO. Also, the variables of total debt and CEO bonus were not identified as criteria for determining the type of CEO selected in any of the algorithms. Also, the variables of gross profit, board size, current ratio, debt ratio, financial leverage, and political relations were identified as important in two of the three algorithms used in determining the type of CEO. The variables of current debt, operating profit, weakness of internal control, and transaction turnover were identified as important in one of the three algorithms used in determining the type of CEO.

Prediction based on the linear regression model is also possible. The results obtained from testing the research hypotheses and comparing the presented results show the superiority of the multilayer perceptron neural network model in terms of the coefficient of determination and MSE index; So that the highest coefficient of determination for the multilayer perceptron neural network is 0.384 for the test data and 0.338 for the linear regression model. Also, the results showed that the MSE for the multilayer perceptron neural network is 0.001384 for the test data and 0.004821 for the linear regression model. Thus, the MSE index is also better, like the coefficient of determination for the multilayer perceptron neural network.

Authors' Contribution Statement

All authors acknowledge that they have contributed to the conception and design, or analysis and interpretation of data, drafting the article, critically revising it for intellectual content, and final approval of the version to be published, and that all authors agree to be accountable for all aspects of the work.

Disclosure statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work report in this article.

Funding

The author(s) reported there is no funding associated with the work featured in this article.

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