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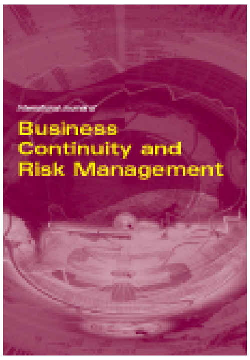

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Blending enterprise resource planning on supply chain management in the aerospace sector in India and analysis using multi-scale adaptive dilated convolutional LSTM

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Blending enterprise resource planning on supply chain management in the aerospace sector in India and analysis using multi-scale adaptive dilated convolutional LSTM

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Abstract: Aerospace organisations, which have already executed enterprise resource management (ERP) tools along with the supply chain management (SCM) models are considered in this research work. At first, information is gathered from these organisations as a form of structured questions. These questions are then evaluated using relevant statistical methods to obtain the necessary goal. After that, the distribution of the questions to the authorised parties of these organisations is done. The authorities of these industries are requested provide information asked more precisely. At the final stage, the effectiveness of integrating the SCM with ERP is validated with the help of multi-scale adaptive dilated convolutional long-short-term memory (MADC-LSTM). The optimisation of the MADC-LSTM network's parameters is carried out by Golden Eagle with bee collecting pollen optimisation algorithm (GE-BCPOA). The effectiveness of integrating SCM with the ERP is analysed by conducting diverse experiments.

Keywords: enterprise resource planning; ERP; supply chain management; SCM; aerospace sector in India; statistical approach; multi-scale; adaptive dilated; convolutional long short-term memory; Golden eagle; bee collecting pollen optimisation algorithm; India.

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Biographical notes: Joydeep Banerjee is a Mechanical Engineer by qualification with Masters in Business Administration having 19 years of experience with TCS, GE & HAL-ARDC. He is pursuing his Doctorate in Entrepreneurship Management. He intends to build a career with leading corporate organisations in an environment encompassed with committed and dedicated people.

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1 Introduction

The effects of sudden technological growth and industrialisation lead business organisations to face intense rivalry in local as well as international markets. Some executives in these organisations try to tackle these issues by changing their companies' regulations and working with highly effective management concepts like 'total productive maintenance (TPM), total quality management (TQM), and just-in-time (JIT)' (Kannabiran, 2009). Using the above-mentioned methods, certain companies achieved an upper hand over their rival companies. The industry now faces a number of issues which includes the "need for advancement in technology, more stringent quality standards, improved efficiency in manufacturing efficiency, price competitiveness demands over other rivalry organisations, and practices to aid in the production of environmentally friendly products" are all the result of rising globalisation (Thakkar et al., 2012). For Indian small and medium enterprises (SMEs) to enhance and utilise new and unique technologies for manufacturing quality products, certain limitations exist, which are

1 inadequate resources and funding sources

2 failure to comprehend the demands of a product in the market and its competitions

3 lack of long-term goals

4 inadequate cohesion between the companies in a cluster (Menon et al., 2019).

Also, there exist some macro-level issues that the Indian SME faces. These macro-issues are as follows:

1 unpredictability in demand
2 altering the product and schedule of production as per the specifications provided by clients
3 rising number of domestic and global rivals
4 inadequate cooperation, transportation and communication methods
5 instability in country's political policies
6 insufficient and unreliable trustworthiness regarding the information on the most recent technological advancements, availability of qualified employees, and details on raw material and its monetary value.

A large number of certain well-known organisations' suppliers give full possession of their production data by enabling their ERP to make a direct connection with 'electronic data interchange (EDI)' (Abdullabhai and Acosta, 2012). Such agreement method clearly increases productivity, but they are not much welcomed by the suppliers as well as the buyers' interests (Jakhar, 2014).

An integration system created for the purpose of integrating and automating business operations and activities that is known as an ERP (Ranjan et al., 2017). ERP is an essential attribute that lays the way for companies to operate in an environmentally sustainable manner, especially with regard to their SC (Chang, 2022). But, to deploy ERP, an enormous amount of work has to be contributed by the organisations. Since most of the companies fail to provide these efforts, they are incapable of yielding the benefits they anticipated prior to the deployment of the ERP (Luthra et al., 2014). Due to this factor, numerous researches have been carried out to discover probable characteristics and methods that will assist organisations by guiding them to successfully implement the ERP in their organisation (Marudhappan and Chandrasekhar, 2022). In the business sector around the world, an advanced SCM approach has emerged because of economic growth and technological advancement. The actual independent single-enterprise method is replaced by a new collaborative approach that involves both downstream and upstream SC of organisations (Singh et al., 2022). Several parties like the 'manufacturers, suppliers, customers, and retailers', are involved in the SC. The SC is formed by the innovation processes and activities of all the organisation's entities. In order to increase the competitiveness of the SC, all the organisations and parties in the SC should jointly generate innovative plans (Ni et al., 2020).

The issues associated with SCM are successfully decreased by the ERP method. To cover all aspects of SCM issues, all the ERP firms are constantly improving their ERP systems. The role of ERP in the present era plays an important part in SC planning (Gupta and Goyal, 2021). SCM entails controlling the complicated transfer of data, resources, and monetary between various functional sectors of a company as well as with other organisations (Bhadu et al., 2022). The main objectives of SCM are to create value-added procedures that produce timely, inventive, high-quality, and inexpensive goods with more responsiveness and lesser cycles for development cycles (Arnold et al., 2010). Organisations are thus able to recognise, assess, prioritise, and handle their risks in SC. While launching a new item, a company's motive towards cost and speed also affects the SC (Chinchanikar and Shaikh, 2022). Together with utilising the basic skills of collaborating companies, the SC also need to be ready to cope with any threats that may result from their environmental and ethical practices (Mumani et al., 2022). Inventory management is the conventional and simplest method to manage the risks associated with SC. However, the rapid shift in demands of the customers and the lesser life cycle of the product make the inventory method a risky approach to handling SC. SC risk management also necessitates trade-offs. This is because, while relying on a single supplier can be problematic, however, a lower level of risk is associated with intellectual properties when a single supplier is involved in SC (Nayak et al., 2019). As mentioned before, the risks in SCM cannot be totally eradicated from supply networks. Nevertheless, the dynamics within the factors associated with risks in an SC are recognised, and the strategies to manage risk in SC can be established.

1 To analyse the effects of integrating ERP with the SCM system by collecting the response from the industrial authorities in Indian aerospace organisations.

2 Preparation of a questionnaire regarding the integration of SCM with ERP and then carrying out a detailed analysis regarding the asked questions. The questions are asked of about one hundred industrial authorities of Indian aerospace companies.

3 To predict the response provided by the authorities with the help of an adaptive model called MADC-LSTM in which the parameters are tuned using the heuristic approach for enhancing the prediction performance.

4 Tuning of the parameters like the hidden neurons, epochs, and the steps per epochs in the LSTM model using the implemented GE-BCPOA in order to improve the prediction rate of the MADC-LSTM framework.

5 The validation of the suggested response analysis framework by comparing it with existing algorithms and classifiers, and to analyse its performance by carrying out the statistical evaluation with traditional models.

This paper is organised as follows. In Section 2 of the paper, a survey on the existing frameworks is carried out. In Section 3 of the paper, the heuristic-based performance enhancement of developed deep learning technique for ERP-based SCM analysis is discussed. In Section 4 of the paper, the knowledge of aerospace companies about the ERP-based SCM system in Indian industries of the aerospace sector is carried out. In Section 5 of the paper, the development of the MADC-LSTM model for the analysis of the ERP-based SCM system is provided. In Section 6 of the paper, the results and discussion on the performance of the suggested model are executed. In Section 7 of the paper, the suggested work is summarised.

2 Literature survey

2.1 Related works

In 2017, Das and Mallik have described SCM and ERP along with the process of integrating SCM with ERP. The main goal of this research included doing an empirical study on SCM and ERP as well as understanding the problems, difficulties, and advantages of employing ERP in the field of SCM. The primary data source was the secondary sources. The opinions of SCM and ERP specialists gathered through casual conversations were also included. The complications in the SCM were rising with time, along with the development of ERP. The importance of utilising ERP in SCM was still considered a complicated task even though it has been used in SCM for a quiet long time.

In 2016, Rao et al. have achieved enhanced satisfaction of vendor satisfaction and improved dependency on suppliers in the aerospace industry using new techniques. A win-win relationship and the development of the benefits from the integrated SCM was achieved by on-time payment, knowledge of quick services available in the market, correlating with the vendor's requirements, maintaining a conversation with the entire tires of the organisation, and service level agreements.

In 2019, Goldston have identified an SCM threat factor that affects businesses of any size. SME were not able to execute the prevention methods recommended in these studies because most of the research on these critical failure factors was based on large organisations. A qualitative study was done with one large firm and seven SMEs along distinct stages of ERP deployment techniques to investigate this topic. Data analysis demonstrated effective collaboration, visibility, and communication between entire stakeholders during the implementation of ERP in organisations to minimise the threats that were detected in earlier initiatives. Given their limitations and lack of research when compared with larger organisations, SMEs account for 99.7% of employer firms in the United States, so it was crucial to learn more about SME.

In 2015, Kumar et al. have highlighted the key reasons that limited the application and maintenance of lean methods in the aerospace industry and solutions to prevent gradual deterioration within the lean cycle. Survey methods were utilised to evaluate the post-lean management installation setting in this exploratory study. In accordance with the data gathered through case study and survey, the study's cross-sectional focus was on the aerospace sector. The causes of the lean initiative's delayed operation were found. The idea gathered from this case study suggested that a particular department had successfully turned around. A comparison of the case study results with the auto sector revealed the necessary tips and associated problems that had to be avoided using appropriate examples.

In 2014, Kandananond has fused the information of resource planning by monitoring the process of production from initial resources to completed goods. Four essential components were considered for installing ERP with effectiveness. A further essential component for the effective implementation of ERP was organising the learning procedures. Mapping the process to 'to-be' from the 'as-is' framework was regarded as another effective strategy that made deployment easier by determining the futuristic and present process models. In addition, the ERP system should have the features required to operate a green SC, such as the ability to store and observe the information regarding resources from the manufacturers, generate reports for generating completed goods from resources, maintenance of transportation and logistics, and work with other manufacturers' ERP platforms.

In 2022, Liu et al. have studied a model that contrasted the SC with a buyer who tried to purchase a product for the least amount. The vendor is provided with secret knowledge of constrained capacity. At first, a reward for purchasing commitment was provided for all buyers. A SC contract was established. An 'EDI' was used to connect the buyer to the ERP system of the supplier. The asymmetric was eliminated by providing linkage. The contract was more cost-effective, but the supplier hesitated to accept it. A 'hybrid' contract which gave the vendor the profits as the SC contract while giving the buyer the efficiency as in another contract. They discovered that the hybrid contract was preferred because of the enhanced investment.

Table 1 Features and challenges of existing ERP in SC analysis systems in the aerospace sector

Author [citation]	*Features*	*Challenges*
Das and Mallik (2017)	• It provides a detailed explanation of the improvement in quality, resource requirements, skills and productive activities in the aerospace industry. • Moreover, it analyses cost reduction strategies.	• It needs a detailed study on the relationship between ERP and supply chain networks.
Rao et al. (2016)	• It effectively analyses the critical factors affecting ERP implementations.	• It only analyses the simple risk tasks in ERP, but the high-risk factors are not evaluated.
Goldston (2019)	• It rationalises the consolidating contracts and supply base. • It establishes the long-term relationship among suppliers.	• It needs good governance and good vigilance to take the right decision.
Kumar et al. (2015)	• It accurately identifies the reasons for the weak sustenance in the aviation industry. • The relationship between quality and efficiency is analysed.	• It needs industrial input from a live environment that may lead to an increase the time complexity.
Kandananond (2014)	• It keeps the environmental data in regard to transportation and logistics to maintain a good relationship between suppliers.	• The cross-country comparison is not carried out in the analysis model.
Liu et al. (2022)	• It reduces emissions by using the green supply chain network. • It analyses a variety of external and internal factors that may affect the characteristics of both parties.	• It is suffered from high computational overhead while processing through large dimensional datasets.
Smith et al. (2020)	• It is more restrictive, and the linkage can avoid information asymmetry.	• It takes more time to take the report on customer and supplier-related contracts in the automotive industry.
Zhang et al. (2021)	• It sensitively classifies and summarises the textual information created by the node enterprises in terms of logistics, storage, sales and production.	• There is a possibility of eliminating information asymmetries during analysis.

In 2020, Smith et al. have used a progressive game system to a multi-level green SC for assessing multiple external and internal variables which influence both entities' behaviour. This was simulated to determine the stability to minimise cooperated emission. A stability system was obtained while

1 the total value of government subsidies and the benefits from cooperative emission minimisation exceeded the cooperative emission shortage input cost and 'free rider' rewards

2 the rate of unilateral release minimisation benefits exceeded the initial benefit costs.

These income enhancements had a direct impact on the path of development. When this value was high, the green manufacturers and green suppliers were more likely to reduce emissions together, thus hastening the system's convergence. Only the application of regulatory penalties would accelerate the emission reductions at both the downstream and upstream businesses of the green SC.

In 2021, Zhang et al. have organised the SC scenario's mass data which recorded node firms' innovative activity using an enhanced domain ontology-based text classification algorithm. Without the requirement of a training set, this technique categorised the SC-related node company's documents. It surpassed the baseline technique by attaining a document classification accuracy of 80%. In addition, this work has developed domain ontology of SC-related company's technology innovation that significantly improved the semantic connection among words. As a result, it categorised and summarised the textual data produced by node companies which were engaged in the design, manufacture, storage, sale of products, and logistics.

2.2 Problem statement

ERP is the integrated information system to overlook the process of manufacturing from raw materials to finished products. The ERP is mainly dependent on the factors like maintaining and upgrading factors, preparing users and systems and defining business cases. But this takes more time, and the valuable information is not analysed in enterprises. Hence, the supply chain (SC) network is introduced to provide a higher relationship between enterprises and suppliers. However, the SC network is more complicated in this era because of increased law regulations and enforcement, no locations are unreachable, and no boundaries are unattainable. Hence, a deep analysis is needed to solve the failures and find the root causes in the enterprises in Indian industries. The major advantages and disadvantages of the conventional models are described in Table 1. The integration of ERM with SC management (Das and Mallik, 2017) provides a detailed explanation of the improvement in quality, resource requirements, skills and productive activities in the aerospace industry. Moreover, it analyses cost reduction strategies. But it needs a detailed study on the relationship between ERP and SC network. The qualitative study (Rao et al., 2016) effectively analyses the critical factors affecting ERP implementations. Yet, it only analyses the simple risk tasks in ERP, but the high-risk factors are not evaluated. The vendor satisfaction report (Goldston, 2019) rationalises the consolidating contracts and supply base. In addition, it establishes the long-term relationship among suppliers. But it needs good governance and good vigilance to take the right decision. The investigation of lean management (Kumar et al., 2015) accurately identifies the reasons for the weak sustenance in the aviation industry. Furthermore, the relationship between quality and efficiency is analysed. However, it needs industrial input from a live environment that may lead to an increase in the time complexity. The roadmap system (Kandananond, 2014) keeps the environmental data in regard to transportation and logistics to maintain a good relationship between suppliers. Moreover, the cross-country comparison is not carried out in the analysis model. The government regulation model (Liu et al., 2022) reduces emissions by using the green SC network. For instance, it analyses a variety of external and internal factors that may affect the characteristics of both parties. Yet, it is suffered from high computational overhead while processing through large dimensional datasets. The ERP technology (Smith et al., 2020) is more restrictive, and the linkage can avoid information asymmetry. But it takes more time to take reports on customer and supplier-related contracts in the automotive industry. The knowledge organisation (Zhang et al., 2021) sensitively classifies and summarises the textual information created by the node enterprises in terms of logistics, storage, sales and production. Moreover, there is a possibility of eliminating information asymmetries during analysis.

3 Heuristic-based performance enhancement on developed deep learning technique for enterprise resource planning-based SC management analysis

3.1 SC management data

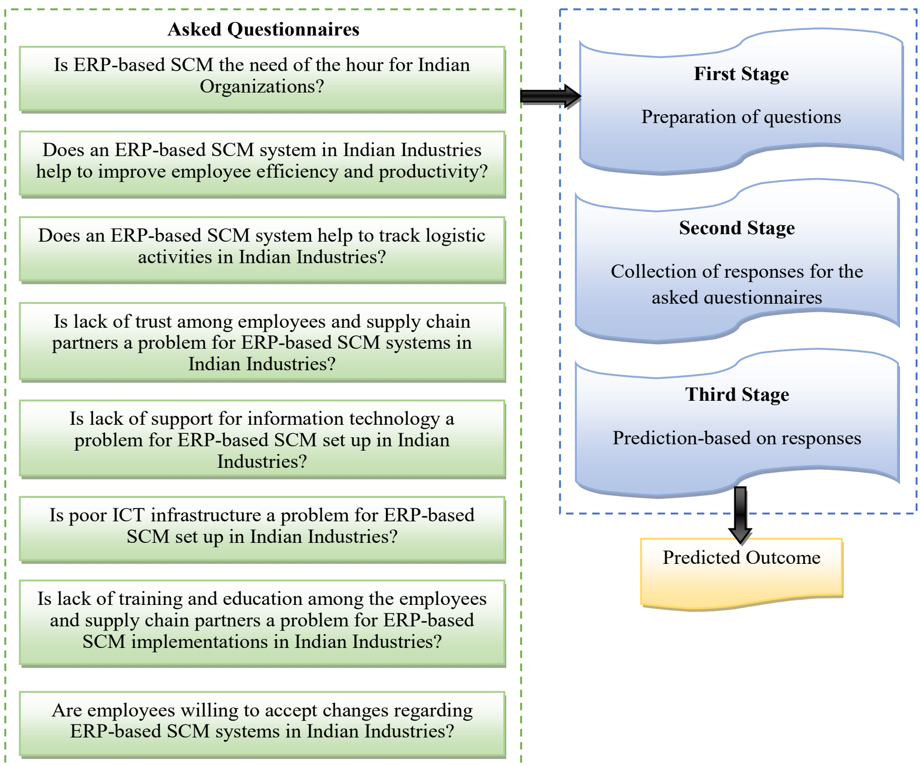
Today's organisations are mostly data-driven. This makes it more competitive than ever. Hence, a proper planning strategy is needed to operate these organisations in an effective way. This planning strategy can be implemented effectively with the help of technology. The collection of data for better decision-making is achieved with the help of ERP. The same process regarding the SC is performed using the SCM system. However, if SCM and ERP are not integrated properly, then data gets stored in separate divisions, which is absolutely undesirable for business organisations nowadays. In order to create a delivery system that is much more effective, it is now imperative to create a model integrating the SCM and ERP, where various sectors, outside entities and methods are integrated. Better decision-making for the growth of the organisation, its flexibility, and versatility would be obtained as a result of integrating these two systems. The major goal of this work is to evaluate the constraints that serve as potential obstacles in the process of integrating SCM with ERP in the Indian aerospace industries. Some of the questions that are considered while implementing this research work are listed below:

- Is ERP-based SCM the need of the hour for Indian organisations?
- Does an ERP-based SCM system in Indian Industries help to improve employee efficiency and productivity?
- Does an ERP-based SCM system help to track logistic activities in Indian industries?
- Is lack of trust among employees and SC partners a problem for ERP-based SCM systems in Indian industries?
- Is lack of support for information technology a problem for ERP-based SCM setup in Indian industries?
- Is poor ICT infrastructure a problem for ERP-based SCM setup in Indian industries?
- Is lack of training and education among the employees and SC partners a problem for ERP-based SCM implementations in Indian industries?

- Are employees willing to accept changes regarding ERP-based SCM systems in Indian industries?

The above questions are asked of various authorities in the aerospace sector, and their responses are collected for this work.

Figure 1 Generated framework for assessing the ERP in SCM in Indian aerospace industry (see online version for colours)



3.2 *Proposed model of analysing ERP in SCM in Indian aerospace industries*

Several industrial systems are using ERP system along with the SCM system. But the effectiveness and impacts of integrating the ERP system with the SCM system is not well known. This research work is implemented to analysis the effects and advantages of integrating the ERP system with the SCM system. This work is mainly divided into three stages.

- In the first stage of the developed model a questionnaire containing eight questions are prepared regarding the integration of ERP system with the SCM system.
- The generated questionnaire is distributed to various industrial authorities in the aerospace sector located in Bangalore City and their responses are obtained. The responses are deeply analysed and the conclusion are derived in the third stage.

- A deep learning-based model named MADC-LSTM framework is developed for predicting the response of integrating the ERP system with the SCM system. The parameters in the MADC-LSTM model are tuned with the help of GE-CPOA. The parameter such as the number of hidden neurons, the number of epochs, and the steps per epochs are tuned by the implemented GE-BCPOA. The prediction error in the MADC-LSTM model is minimised by optimising these parameters.

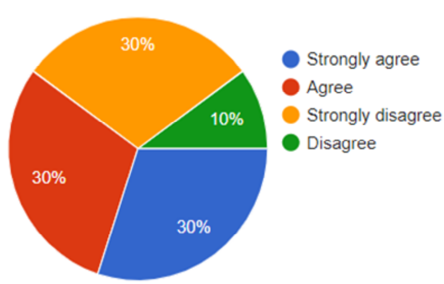
A total of eight questions are generated and the responses from one hundred industrial authorities are collected. These responses are further utilised in this model. The generated framework for assessing the ERP in SCM in Indian aerospace industry is illustrated in Figure 1.

4 Knowledge of aerospace companies about the enterprise resource planning-based SC management system in Indian industries of the aerospace sector

4.1 Is ERP-based SCM the need of the hour for Indian organisations?

The answer to the question "is ERP-based SCM the need of the hour for Indian organisations?" is analysed in this section which is given in Figure 2. This question was raised, and the response was collected from 100 industrial parties. A total of 30% of people strongly disagree with this question, indicating the integration of SCM with ERP is not performed as a result of time. 10% of the people from whom the responses were collected disagreed with this question. Around 30% of the entire survey population strongly agreed with the question. And the remaining 30% of people also considered the integration of SCM and ERP to be due to time constraints. Thus, they agreed with this question.

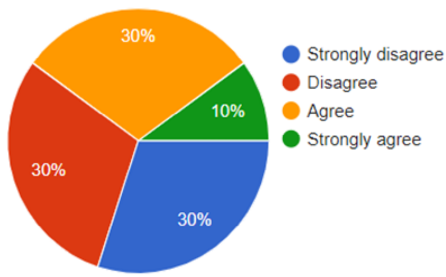
Figure 2 Response to the question "is ERP-based SCM the need of the hour for Indian organisations?" (see online version for colours)



4.2 Does an ERP-based SCM system in Indian industries help to improve employee efficiency and productivity?

The response to the question "does ERP-based SCM system in Indian industries help to improve employee efficiency and productivity?" is analysed in Figure 3, and it is discussed in this section. This question was raised, and the responses were gathered from 100 industrial authorities. A total of 30% of entire authorities agreed with this question, believing an enhanced efficacy and productivity from their employees because of the integration of SCM and ERP. About 10% of the industrialist strongly agreed with this question. Around 30% of the survey population disagreed with the question. And the remaining 30% of people also disagreed with this question. From the analysis, it is seen that the integration of SCM and ERP does not have any impact on increasing the productivity and efficacy of the employees.

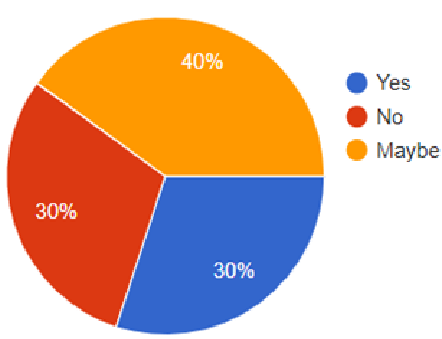
Figure 3 Response to the question "does ERP-based SCM system in Indian Industries help to improve employee efficiency and productivity?" (see online version for colours)



4.3 Does an ERP-based SCM system help to track logistic activities in Indian industries?

The response to the question "does ERP-based SCM system help to track logistic activities in Indian industries?" is provided in Figure 4, and the discussion on the response is elaborated in this section. This question was asked to about 100 authorities from the aerospace industry in India. About 30% of the people believe that they can track the logistic activity by integrating the SCM with the ERP. Around 30% of the responses suggest that the authorities do not think that there is a relationship between the SCM and ERP integration and tracking of logistic activities. The remaining 40% of the population thinks there might be a chance for tracking the logistic activity while integrating ERP with SCM, but they are not sure about it. The exact answer to this question still remains inaccurate.

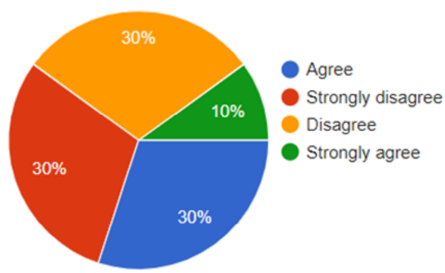
Figure 4 Response to the question "does ERP-based SCM system help to track logistic activities in Indian industries?" (see online version for colours)



4.4 Is lack of trust among employees and SC partners a problem for ERP-based SCM systems in Indian industries?

The response to the question "is lack of trust among employees and SC partners a problem for ERP-based SCM systems in Indian industries?" is examined in this section and is depicted in Figure 5. This question was raised, and the responses were obtained from 100 executives of aerospace industries in India. A total of 30% of questioned authorities agreed with this question. About 30% of the authorities strongly disagreed with this question. Around 30% of the survey population disagreed with the question. And the remaining 30% of people also disagreed with this question. And the remaining 10% of people strongly agreed with this question. As the majority of the population disagreed with the question, it is seen that the mistrust between the SC parties and the employees is not the reason for the complications in integrating the SCM with ERP.

Figure 5 Response to the question "is lack of trust among employees and SC partners a problem for ERP-based SCM systems in Indian industries?" (see online version for colours)



4.5 Is lack of support for information technology a problem for ERP-based SCM setup in Indian industries?

The answer to the question "is lack of support of information technology a problem for ERP-based SCM setup in Indian industries?" is examined in this section on the basis of the validation given in Figure 6. This question was raised, and the responses were gathered from 100 authorities in the aerospace industry. A total of 33.3% of the industrial authorities agreed with this question. They believe much better information technology can lessen the complications in integrating the ERP with the SCM system. Around 11.1% of the authorities strongly agreed with this question. However, 33.3% of the executives with whom the survey was carried out disagreed with this opinion. And 22.22% of the population of authorities from the aerospace industries strongly disagreed with this reason for the failure of integrating SCM with ERP. As the majority of the authorities disagree with this cause for integrating ERP with SCM, it is proved that information technology is not the reason behind the complications in integrating the ERP with the SCM.

4.6 Is poor ICT infrastructure a problem for ERP-based SCM setup in Indian industries?

The response from aerospace industrial authorities regarding the question "is poor ICT infrastructure a problem for ERP-based SCM setup in Indian industries?" is depicted in

Figure 7, and further discussion is explained in this segment. This question was asked to some of the aerospace organisational authorities in India, and the responses from 100 industrial authorities were collected. A total of 30% of authorities disagreed with this question, and 10% of the population strongly disagreed with this question, implying that there is no correlation between ICT and the integration of ERP and SCM. About 30% of the authorities strongly agreed with this question. And 30% of the population agreed with this question. And the remaining 30% of people also disagreed with this question. Thus it is seen that there exists a strong correlation between ICT and the integration of ERP and SVM system in the aerospace industry from the evaluation.

Figure 6 Response to the question "is lack of support of information technology a problem for ERP-based SCM setup in Indian industries?" (see online version for colours)

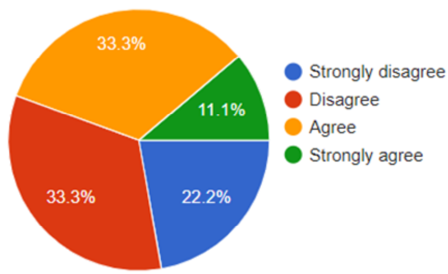
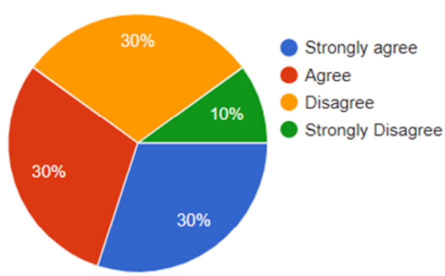


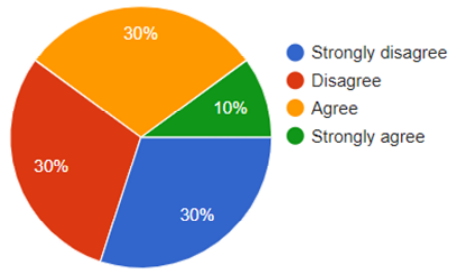
Figure 7 Response to the question "is poor ICT infrastructure a problem for ERP-based SCM setup in Indian industries?" (see online version for colours)



4.7 Is lack of training and education among the employees and SC partners a problem for ERP-based SCM implementations in Indian industries?

The response to the question "is lack of training and education among the employees and SC partners a problem for ERP-based SCM implementations in Indian industries?" is illustrated in Figure 8, and the following discussion is elaborated in this section. This question was raised, and the responses were gathered from 100 industrial authorities. A total of 30% agreed with this question. About 10% of the authorities strongly agreed with this question. Around 30% of the survey population disagreed with the question. And the remaining 30% of people strongly disagreed with this question. It is sensed that proper education of the employees and SC parties has no relationship with the integration of ERP with the SCM system.

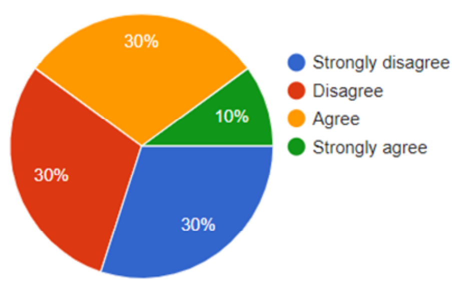
Figure 8 Response to the question "is lack of training and education among the employees and SC partners a problem for ERP-based SCM implementations in Indian industries?" (see online version for colours)



4.8 Are employees willing to accept changes regarding ERP-based SCM systems in Indian industries?

The response to the question, "are employees willing to accept changes regarding ERP-based SCM systems in Indian industries?" is shown in Figure 9, and the discussion carried out is provided in this section. This question was raised, and the responses were gathered from 100 industrial authorities. A total of 30% of the industrial authorities agreed with this question. About 10% of the industrialist strongly agreed with this question. Around 30% of the survey population disagreed with the question. And the remaining 30% of people strongly disagreed with this question. From the analysis, it is seen that the employees in the aerospace industry are not ready to accept the integration of SCM and ERP systems.

Figure 9 Response to the question, "are employees willing to accept changes regarding ERP-based SCM systems in Indian industries?" (see online version for colours)



5 Multi-scale adaptive dilated convolutional long short-term memory for the analysis of enterprise resource planning-based SC management

5.1 Long-short-term memory

The disappearing gradient issues associated with the conventional RNN are tackled by the introduction of an advanced RNN structure called LSTM (Alizadeh et al., 2021). Unlike the traditional RNN, the LSTM makes use of an additional hidden structure known as the cell state p_r to track down the prior information on sequential input data.

With the help of three gates, namely, the 'input, forget, and output gate'," the short- and long-term dependency of data and the backward propagation's gradient flow are controlled. The data to the LSTM undergo the following procedures. In the initial step, the quantity of the data from the prior cell state $p_r - 1$ that has to be summed up with the ongoing cell state $q_r \otimes p_{r-1}$ is determined by the forget gate. The symbol ⊗ indicates point-wise multiplication. The forget gate q_r is represented in equation (1).

$$q_r = \sigma\left(F_q s_r + G_q t_{r-1} + u_q\right) \tag{1}$$

In equation (1), q_r can be in the range (0, 1). If the value of q_r is 1, the prior data will be retained. If the value of q_r is 0, then entire information from the history will be eliminated. Once the forget gate is determined, and then the cell state at present is evaluated with the help of three other procedures, which are provided below. In a time interval of r, a new cell state $\widetilde{p_r}$ is obtained by utilising a trigger function called tanh to transform the value of the input s_r and the prior hidden state t_{r-1} within the range [–1, 1]. The new cell state is evaluated as given in equation (2).

$$\tilde{p}_r = \tanh\left(F_p s_r + G_p t_{r-1} + u_p\right) \tag{2}$$

Using the values obtained from the input gate v_r, the cell state p_r is upgraded to $v_r \otimes \tilde{p}_r$ in a similar way to that of the forget gate. The information from the input sequence and the prior hidden units are altered by the input gate at a time r. The input gate is mathematically formulated as in equation (3).

$$v_r = \sigma\left(F_v s_r + G_v t_{r-1} + u_v\right) \tag{3}$$

The amended cell state values from the earlier procedures are summed up to get the newly updated cell state which is given by equation (4).

$$p_r = q_r \otimes p_{r-1} + v_r \otimes \tilde{p}_r r \tag{4}$$

The amount of data that has to pass to the next hidden unit of the LSTM is determined with the help of the output gate w_r. The output gate is expressed as in equation (5).

$$w_r = \sigma\left(F_w s_r + G_w t_{r-1} + u_w\right) \tag{5}$$

The hidden unit t_r of the LSTM is computed with the help of equation (6).

$$t_r = w_r \otimes \tanh\left(p_r\right) \tag{6}$$

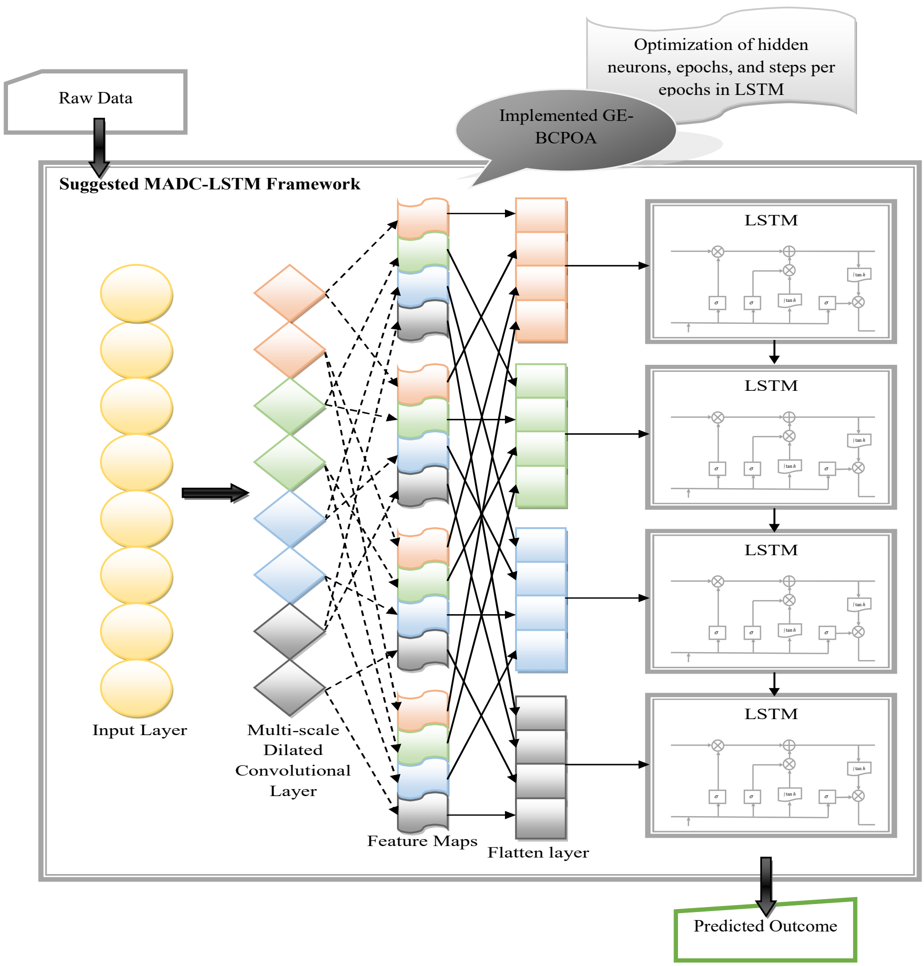
The term G in equations (1), (2), (3) and (5) indicates the weight matrix of LSTM, t_{r-1} indicates the prior hidden state, σ indicates the sigmoid trigger function, F indicates the weight matrix, and u indicates the network bias.

5.2 Developed MADC-LSTM-based ERP in SCM analysis

The raw questionnaire data are given as the input to the recommended MADC-LSTM model. The MADC-LSTM is developed by replacing the convolutional layer in the conventional LSTM with a multi-scale dilated convolutional layer. From the MADC-LSTM framework, the predicted response outcome is obtained. The parameters, such as the hidden neurons, epochs, and the steps per epoch, are tuned with the help of the executed GE-BCPOA. The parameters are tuned for the purpose of minimising the RMSE and MAE values. This objective is mathematically given by equation (7).

$$Oct = \underset{\{HD_{qs}^{LSTM}, EC_{io}^{LSTM}, SP_{pd}^{LSTM}\}}{\arg\min} (AP + OC) \tag{7}$$

Figure 10 Graphical illustration of the implemented MADC-LSTM-based ERP in SCM analysis framework (see online version for colours)



The term AP in equation (7) indicates the MAE, OC represents the RMSE, EC_{io}^{LSTM} indicates the tuned number of the epochs in the LSTM, which is optimised in a range [5, 50], HD_{qs}^{LSTM} denotes the tuned number of hidden neurons of the LSTM model which in the range [5, 255], and SP_{pd}^{LSTM} denotes the tuned number of steps per epochs which is in the limit [500, 1,000]. The tuning of these parameters helps to minimise the RMSE and MAE value. The RMSE HU is determined using the formula given in equation (8).

$$HU = \sqrt{\frac{\sum_{dd=1}^{cc} \left(bb_{dd1} - aa_{dd2}\right)^2}{cc}} \tag{8}$$

In equation (8), the term *dd* denotes the computation factor that has to be added together with the fitted point, *cc* indicates the number of fitted points, *bb* indicates the predicted value, and *aa* denotes the actual value. The MAE *AP* is estimated with the help of equation (9).

$$AP = \frac{\sum_{dd=1}^{cc} |aa - bb|}{cc} \tag{9}$$

The graphical illustration of the implemented MADC-LSTM-based ERP in SCM analysis model is given in Figure 10.

5.3 Proposed GE-BCPOA-based parameter tuning

For optimising the hidden neurons, epochs, and steps per epoch, the suggested GE-BCPOA is utilised in this research work. The enhanced exploration ability of the GEO algorithm makes it an ideal choice for this work. For improving the performance, the BCPOA is added along with the GEO algorithm. The BCPOA is chosen because of its flexibility in solving multi-objective optimisation issues. A position-based update using the adaptive concept is utilised in the developed GE-BCPOA for updating the final position. The position-based adaptive concept is given in equation (10).

$$Ptn = Ptn_{old} + median\left(\frac{Ptn1 + Ptn2}{20}\right) \tag{10}$$

In equation (10), the ptn_{old} term represents the old position obtained from the prior iteration, $Ptn1$ indicates the final position obtained from the GEO algorithm, $Ptn2$ denotes the final position obtained from the BCPA, and Ptn denotes the optimal solution obtained from the GE-BCPOA.

- *GEO:* The 'Aquilla Chrysaetos' serve as the motivation for the modelling of the GEO (Mohammadi-Balani et al., 2020) algorithm. The hunting behaviour and the prey-searching behaviour of the 'Aquilla Chrysaetos' are adopted in the GEO algorithm. The cruise, hunt, and transition between these two phases are the major steps that are incorporated into the GEO algorithm.
- *Circular motion adopted by the Golden Eagle (GE):* Initially, the GE visits various locations to figure out the ideal prey. All the locations being visited are remembered by the GE. A portion of food is picked arbitrarily from another GE's *c* memory by a GE *a* at the beginning of every cycle. The GE *a* would surround the prey in the GE *c* territory and starts moving in a circular motion around the prey. At the same time, it keeps revolving around its best prey that is spotted by itself. Thus we acquire $c \in \{1, 2, \ldots, b\}$.

- *Picking up the prey:* The best prey from the memory of the entire GE flock is considered the ideal solution in each cycle, and the entire search agents would try to move towards it. Once the prey is selected, then the hunt or cruise process will take place. In GEO, the 'one-to-one mapping' method in an arbitrary manner is selected to pick up prey from the memory of the other GE in the flock. A single prey is dedicated to every GE in the GEO in every cycle. Once the prey is selected, either hunt or cruise operation will be performed.
- *Hunting phase:* This phase served as the exploitation phase of the GEO algorithm. The vector of hunting is formulated by beginning from the location of the GE at present and ending at the location of the selected prey. The vector of hunting is formulated as provided in equation (11).

$$\vec{B}_a = \vec{C}_c^* - \vec{C}_a \tag{11}$$

  In equation (11), the ideal location of the prey that is spotted by the other GE c is indicated as $\vec{C}_c^*$, the vector of hunting is indicated by $\vec{B}_a$, and the location of the a^{th} GE at present is indicated as $\vec{C}_a$.
- *Cruise phase:* The vector of the cruise is computed from the vector of hunting. The vector of the cruise is formed such that it is 90° to the vector of hunting and is tangent to the spiral movement. The linear motion of the GE towards the prey is given by this vector of the cruise. In order to determine the vector of the cruise, the 'tangent hyperplane' has to be determined initially. The 'tangent hyperplane' at the f^{th} dimension is computed as in equation (12).

$$k_1 j_1 + k_2 j_2 + \ldots + k_f j_f = g = \sum_{d=1}^{f} k_d j_d \tag{12}$$

  The variable vector is represented by $\vec{E} = [j_1, j_2, \ldots, j_f]$, the random point in the 'hyperplane' is represented as $\vec{H} = [l_1, l_2, \ldots, l_f]$, and the nominal vector is represented as $\vec{A} = [k_1, k_2, \ldots, k_f]$ denotes the general vector representation. The value of in equation (13) is determined with the help of equation (13).

$$g = \vec{A} \cdot \vec{E} = \sum_{d=1}^{f} k_d j_d \tag{13}$$

  The hyperplane of the cruise $\vec{D}_a^i$ of the a^{th} GE in between the vector of hunting $\vec{B}_a$ when taken as the nominal value of the 'hyperplane' and the location $\vec{C}_a$ of the a^{th} GE when considered as a random point in the 'hyperplane' is given by equation (14).

$$\sum_{d=1}^{f} e_d j_d = \sum_{d=1}^{f} e_d^i j_d^* \tag{14}$$

The prey's position is represented by $\vec{C}^* = [j_1^*, j_2^*, \ldots, j_f^*]$ in equation (14), the vector of hunting is represented as $\vec{B}_a = [e_1, e_2, \ldots, e_f]$, and the vector of design parameter is given by $\vec{C} = [j_1, j_2, \ldots, j_f]$. To obtain the vector of cruise from 'hyperplane' of cruise, an arbitrary point *D* from the 'hyperplane' of cruise is selected. The number of cycles in the GEO algorithm is denoted by *i*. The dimension of the search area is denoted by *f*. The vector of cruise begins from the present location of the GE. To satisfy the condition of "hyperplane", the final dimension is selected in such a way that 1-dimension is fixed and *f* – 1 dimensions are variable. A random variable is selected from the *f* constant variables, which are indicated as *h*. It should be noted that the rigid variable should not result in making the vector of hunting $\vec{B}_a$ as 0. The value of is fixed, and hence all the other variables are assigned with arbitrary values. The fixed variable is computed with the aid of equation (15).

$$D_h = \frac{g - \sum_{d, d \neq h} e_d}{e_h} \tag{15}$$

The d^{th} term in the vector of hunting is denoted by e_d in equation (15), the h^{th} term in the vector of hunting is represented by e_h, and the h^{th} term of the destination point is denoted as D_h. In the 'hyperplane' of the cruise, the destination point is determined using equation (16).

$$\vec{D}_0 = \left(m_1 = n, m_2 = n, \ldots, m_h = \frac{g - \sum_{d, d \neq h} e_d}{e_h}, \ldots, m_f = n \right) \tag{16}$$

In equation (16), the term *n* indicates an arbitrary variable. The vector of the cruise is determined as the 'hyperplane' of the cruise is established. The attraction is of the GE other than the location of the prey is done by the vector of the cruise, thus aiding in the exploration.

- *Changing the location:* The movement of the GE is determined by the 'step vector'. The 'step vector' Δj_a is determined using equation (17).

$$\Delta j_a = \vec{o}_1 \, l_e \frac{\vec{B}_a}{\left\| \vec{B}_a \right\|} + \vec{o}_2 \, l_m \frac{\vec{D}_a}{\left\| \vec{D}_a \right\|} \tag{17}$$

Two arbitrary variables in the limit [0, 1] are represented by $\vec{o}_1$ and $\vec{o}_2$ in equation (17), the hunting parameter is represented by l_e, the cruising parameter is denoted by l_m, and the Euclidean distance of hunting and cruise is denoted by $\left\| \vec{B}_a \right\|$ and $\left\| \vec{D}_a \right\|$, respectively. The vector of hunting's Euclidean distance is computed as in equation (18).

$$\left\|\vec{B}_a\right\| = \sqrt{\sum_{d=1}^{f} e_d^2} \tag{18}$$

The vector of the cruise's Euclidean distance is determined using equation (19).

$$\left\|\vec{D}_a\right\| = \sqrt{\sum_{d=1}^{f} m_d^2} \tag{19}$$

The GE's location at the next iteration is determined by considering the 'step vector', as shown in equation (20).

$$j^{i+1} = j^i + \Delta j_a^i \tag{20}$$

The fitness value for the location of the GE is determined. When the fitness of the upgraded location is better, then GE will upgrade its location to the new location. If the fitness is not good, then the same process keeps on repeating. The computation of the GE's new location and the 'step vector' keeps on looping until the final criteria are met.

- *Exploration to exploitation stage transition:* The parameters l_e and l_m alters the value of "step vector" on the basis of the vector of hunting and vector of the cruise. Initially, the GE is more font of the cruise, and it gradually reduces, and the GE is the font of hunting at the later stages. The cruise and hunting operation is determined by these two parameters l_e and l_m. The value of l_m is a descending one, and the value of l_e is an ascending one with respect to the increase in iteration count. The values of these two coefficients are fixed by the user at the initial and final stages. The value of l_e and l_m while executing the GEO algorithm is computed with the help of equation (21).

$$\begin{cases} l_e = l_e^0 + \dfrac{i}{i_{mx}}\left[l_e^{i_{mx}} - l_e^0\right] \\ l_m = l_m^0 + \dfrac{i}{i_{mx}}\left[l_m^{i_{mx}} - l_m^0\right] \end{cases} \tag{21}$$

The maximum number of iterations is represented by i_{mx} in equation (21), the final value for the attraction towards hunting is denoted by $l_e^{i_{mx}}$, the initial value for the attraction towards hunting is denoted by l_e^0, the final value for the attraction towards cruise is represented as $l_m^{i_{mx}}$, and the initial value for the attraction towards cruise is represented as l_m^0. The final position obtained from the GEO algorithm is denoted as $Ptn1$. This $Ptn1$ is used to update equation (10).

- *BCPA:* The swarm of honey bees while collecting the pollen from the flower is taken as the inspiration for designing BCPA (Lu and Zhou, 2015). Two major processes of the bee colony are adopted in the BCA, which includes the 'nectar exploration and waggle dance'.

- *Exploration for nectar:* Let us consider T number of bees from the entire bee swarm chosen as the foragers to explore in search of nectar. By iteration method, these foragers form the solution to the optimisation problem. In search of the nectar, the forager bee wanders from one plant to another. The path of the forager bees while searching for the nectar forms the disjunctive graph which represents the possible solution maps. The bee which forages in search of nectar should only visit a nectar location once, beginning from the source node and ending at the sink node. The movement of the foraging bee to the next node is limited by certain constraints. The transition rule in equation (22) is used to determine the next source of nectar by the foraging node.

$$M_{yP}(R) = \frac{[\lambda_{yP}(R)]^{\gamma} \cdot \left[\frac{1}{J_{yP}}\right]^{\mu}}{\sum_{P \in U} [\lambda_{yP}(R)]^{\gamma} \cdot \left[\frac{1}{J_{yP}}\right]^{\mu}} \tag{22}$$

In equation (22), the term U denotes the nodes that are allowed for the foraging bees to explore y and P denotes the nodes in between which the bees forage, J_{yP} denotes the distance that exists within the nodes y and P, M_{yP} denotes the possibility of reaching the branch form y and P nodes, and λ_{yP} denotes the nodes y and P edge rating. The edge rating λ_{yP} in between y and P are computed using equation (23).

$$\lambda_{yP} = \begin{cases} \dfrac{1 - S\gamma}{V - S} \\ \gamma \end{cases} \tag{23}$$

In equation (23), the term V denotes the number of nodes that are allowed by the foraging bee to explore, S denotes the total count of the desired paths, and γ denotes the value given to the recommended path. The value of γ is provided such that $\frac{1}{10} > \gamma$. The weightage between the distance between the nodes and the desired path is provided by the coefficients γ and μ. The edge with the shortest distance that is present in the desired path is considered the best solution for the optimisation problem. The time taken to process the node P is given by the distance J_{yP}. Once the entire path is covered by a foraging bee, the travelled edge and the span of the obtained solution are provided to 'waggle dance' as it goes back to the hives.

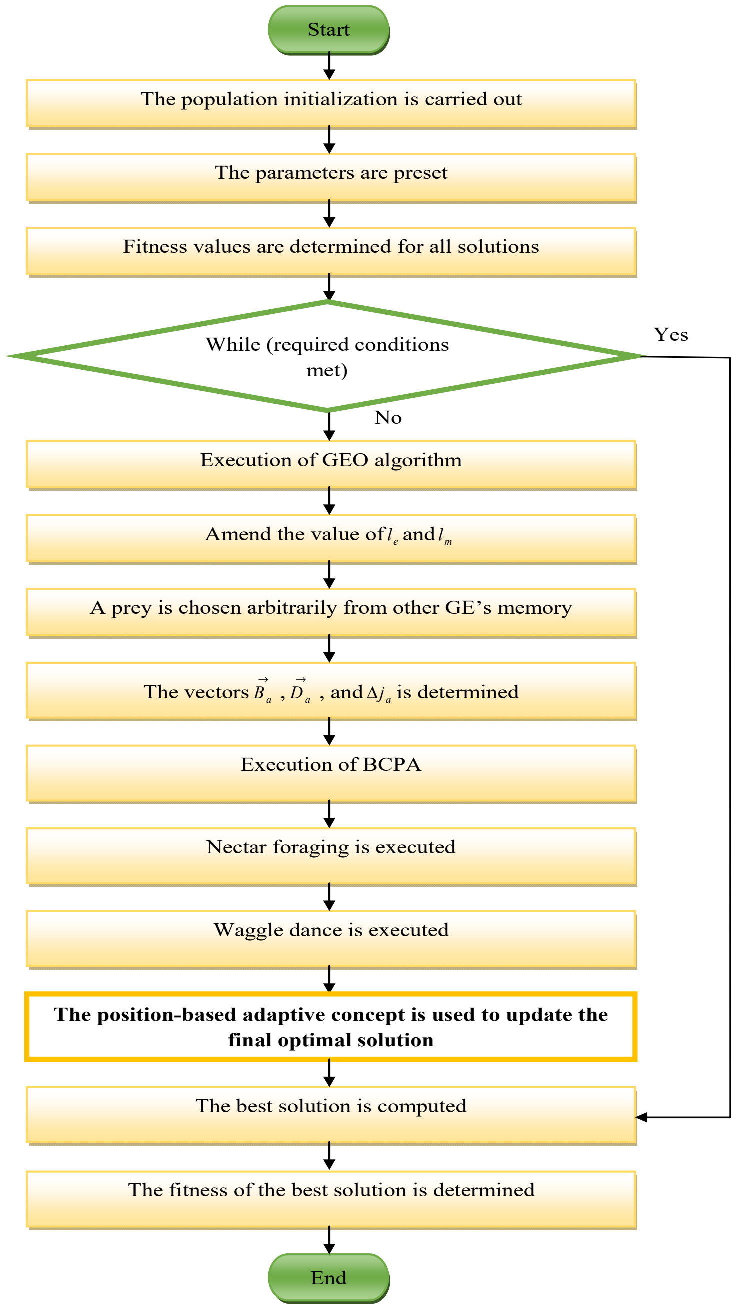
- *'Waggle dance':* The foraging bee x_y, after completing the nectar exploration, will have a possibility z for 'waggle dancing' on the dance floor as it goes back to the hive for a time period of $I = W_y K$ in, which K represents the scaling factor of 'waggle dance' phase and. The foraging bee will also monitor and tries to execute another dance which is chosen arbitrarily with the possibility of L_y. The possibility rating has the ability to alter this possibility L_y. The possibility L_y is time-variant in nature. If the foraging bee selects the randomly chosen dance, then the guidance path to the nectar is performed as the dance by the foraging bee. The path guiding the bees from the hives to the nectar is regarded as the desired path in the BCPA. The objective function of BCPA is associated with the rating of profitability Mx_y. The rate of profitability for the foraging bee is computed using equation (24).

$$Mx_y = \frac{1}{N_{mx}^{y}} \tag{24}$$

Algorithm 1 Generated GE-BCPOA

```
The population initialisation is carried out.
The parameters are preset.
Fitness values are determined for all solutions.
While (required conditions met)
    For (Y = 1 to Y_mam)
        For (Z = 1 to Z_mam)
            Execution of GEO algorithm.
            For (every cycle i)
                Amend the value of le and lm using equation (21)
                For (every GE a)
                    A prey is chosen arbitrarily from other GE's memory.
                    The vector of hunting B_a (vector) is determined using equation (11)
                    If (B_a (vector) ≠ 0)
                        The vector of the cruise D_a (vector) is computed.
                        The 'step vector' Δj_a is evaluated.
                        The location is amended.
                        Determine the fitness of the amended location.
                        If (new fitness is better)
                            The new location is replaced.
                        End
                    End
                End
            End
            Execution of BCPA.
                Nectar foraging is executed using equation (22).
                The ideal solution is stored.
                'Waggle dance' is executed using equation (26).
            If (the difference is small)
                Generate a new colony of the bee population.
            End
        End
    The position-based adaptive concept is used to update the final optimal solution as given in
    equation (10).
    End
The best solution is computed.
The fitness of the best solution is determined.
End
```

Figure 11 Flowchart of the executed GE-BCPOA (see online version for colours)



In equation (24), the term N_{mx}^{y} denotes the span that is made by the foraging bee x_y. The mean value of the rating of profitability of the entire bee colony is computed using equation (25).

$$Mx_Q = \frac{1}{O}\sum_{P=1}^{O}\frac{1}{N_{mx}^{y}} \tag{25}$$

The term Q in equation (25) indicates the bee colony and O denotes the 'waggle dance' count that occurs within a time stamp R. The 'waggle dance' is performed for a duration indicated in equation (26).

$$W_y = \frac{Mx_y}{Mx_Q} \tag{26}$$

The alteration of the value of L_y with respect to Mx_y and Mx_Q is listed in Table 2.

Table 2 Alteration of L_y for performing 'waggle dance'

'Rating of probability'	*'Rating of profitability'*
$L_y = 0.6$	$0.9\ Mx_Q > Mx_y$
$L_y = 0.2$	$0.95\ Mx_Q > Mx_y \geq 0.9\ Mx_Q$
$L_y = 0.02$	$1.15\ Mx_Q > Mx_y \geq 0.95\ Mx_Q$
$L_y = 0$	$Mx_y \geq 1.15\ Mx_Q$

To prevent the BCPA from falling into local solution, an arbitrary variable is generated. A new colony of the bee is created for every cycle in order to model the natural life cycle of the honey bee. This creation of a new population helps in expanding the lookup region. A 'bulletin' value is used as a reference point to compare the location of the bee. The bee's location is better than the 'bulletin', then the 'bulletin' is regarded as the correct solution and thus aids in searching globally. The maximum number of iterations is considered the end condition in the BCPA. So, the BCPA would continue till the cycle reaches a maximum count of X_{mx}. The final position obtained from the BCPA is denoted as *Ptn*2. This *Ptn*2 is used to update equation (10). The GE-BCPOA pseudocode is given in Algorithm 1.

Figure 11 depicts the flowchart of the executed GE-BCPOA.

6 Result and discussion

6.1 Experimental setup

The implemented response analysis model was deployed with the help of MATLAB 2020a software. The executed GE-BCPOA-MADC-LSTM response analysis model was contrasted with other algorithms such as glowworm swarm optimisation (GSO)-MDAC-LSTM (Marinaki and Marinakis, 2016), rain optimisation algorithm (ROA)-MADC-LSTM (Moazzeni and Khamehchi, 2020), GEO-MADC-LSTM (Mohammadi-Balani et al., 2020), and BCPOA-MADC-LSTM (Lu and Zhou, 2015) and validated against other response analysis models like convolutional neural network (CNN) (Kollias and Zafeiriou, 2021), gated recurrent unit (GRU) (Gang-Qiang et al., 2023), LSTM (Alizadeh et al., 2021), and MADC-LSTM, respectively. The implemented model was designed with a chromosome length of 3, an iteration count of 100, and a population size of 10.

6.2 Error measures

The error measures used to validate the performance of the deployed response analysis model are listed below.

a The 'L2 norm' CG is determined with the help of equation (27).

$$CG = \left(\sum_{dd=1}^{cc} ee_{dd} \right)^2 \tag{27}$$

In equation (27), the term ee denotes the L-norm matrix.

b The 'mean absolute scaled error (MASE)' is evaluated with the aid of equation (28).

$$KR = mn \left(\frac{|aa|}{\frac{1}{cc-1} \sum_{dd=1}^{cc} |bb_{dd} - bb_{dd-1}|} \right) \tag{28}$$

The term mn in equation (28) denotes the averaging operation.

c The 'symmetric mean absolute percentage error (SMAPE)' TD determined using equation (29).

$$TD = \frac{100\%}{cc} \sum_{dd=1}^{cc} \frac{|aa - bb|}{\frac{(|bb| + |aa|)}{2}} \tag{29}$$

d The 'module error permeability (MEP)' WC determined using equation (30).

$$WC = \frac{100\%}{cc} \sum_{dd=1}^{cc} \frac{bb - aa}{bb} \tag{30}$$

e The 'L1-norm' QL is computed using equation (31).

$$QL = \sum_{dd} |ee_{dd}| \tag{31}$$

f The 'infinity norm' RF is calculated using equation (32).

$$RF = \max_{1 \le dd \le cc} |ee_{dd}| \tag{32}$$

6.3 Cost function validation

The cost function validation on the implemented response analysis model is illustrated in Figure 12. The cost requirement of the implemented GE-BCPOA-MADC-LSTM response analysis framework is 20%, 20%, 80%, and 87.5% lesser than the GEO-MADC-LSTM, BCPA-MADC-LSTM, ROA-MADC-LSTM, and GTO-MADC-LSTM models respectively at an iteration count of 30.

Figure 12 Cost function validation of the generated response analysis framework (see online version for colours)

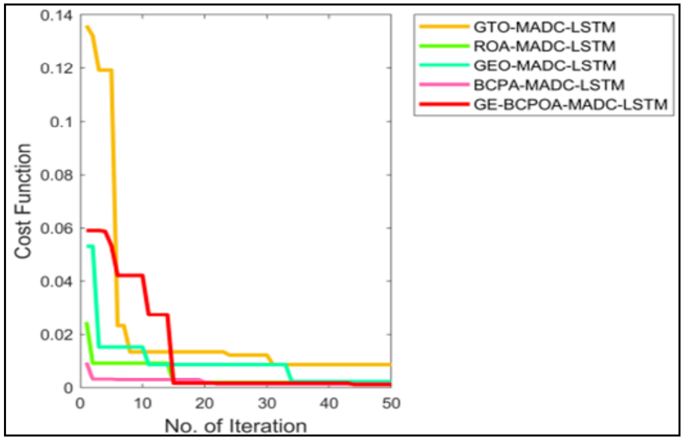


Figure 13 Algorithmic performance assessment of the implemented response analysis model in terms of, (a) L1-norm (b) L2-norm (c) MAE (d) MASE (e) MEP (f) RMSE (g) SMAPE (see online version for colours)

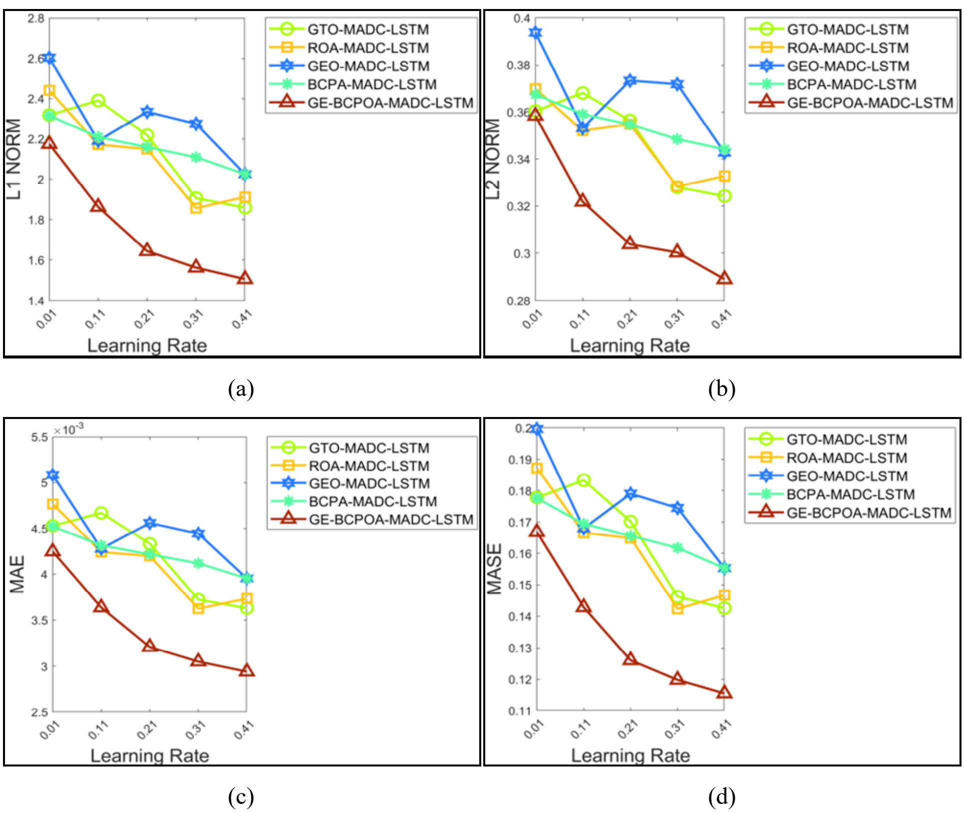
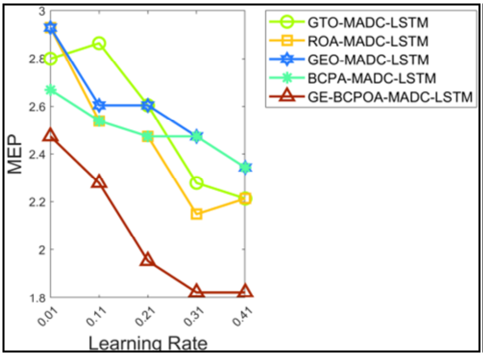
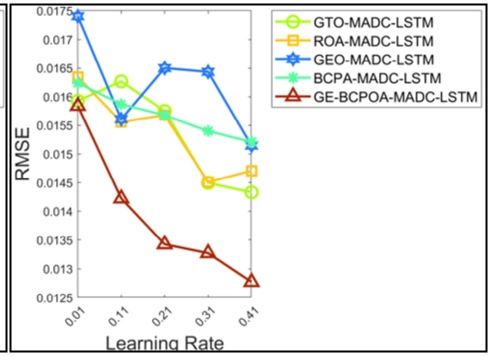


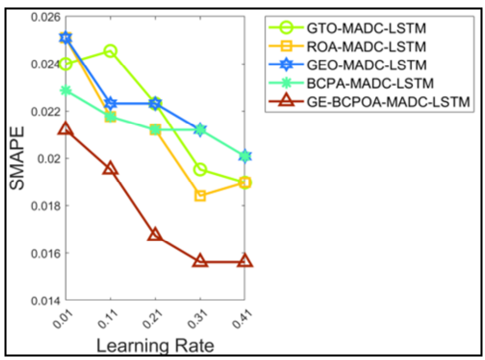
Figure 13 Algorithmic performance assessment of the implemented response analysis model in terms of, (a) L1-norm (b) L2-norm (c) MAE (d) MASE (e) MEP (f) RMSE (g) SMAPE (continued) (see online version for colours)



(e)



(f)



(g)

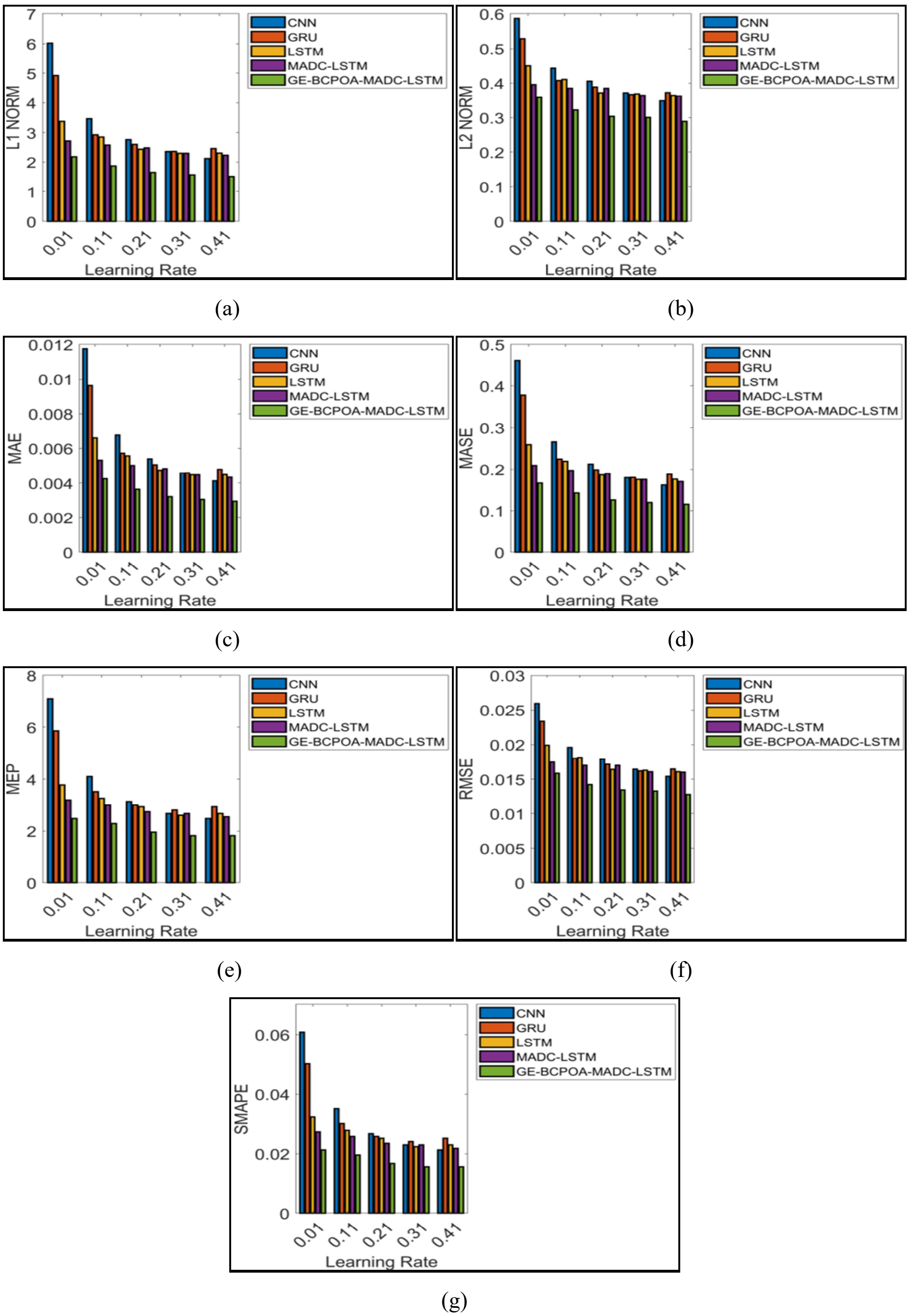
6.4 *Algorithmic performance assessment of the implemented response analysis model*

The algorithmic performance assessment on the implemented response analysis model is shown in Figure 13. The RMSE of the implemented GE-BCPOA-MADC-LSTM response analysis framework is 8.62%, 8.62%, 14.52%, and 19.7% lesser than the GTO-MADC-LSTM, ROA-MADC-LSTM, BCPA-MADC-LSTM, and GEO-MADC-LSTM algorithms respectively at a learning rate of 0.31.

6.5 *Performance validation of the executed response analysis framework against traditional prediction models*

The classifier-based performance validation on the executed response analysis model is given in Figure 14. The MAE of the executed GE-BCPOA-MADC-LSTM response analysis framework is 28%, 35.71%, 37.93%, and 47.83% lesser than the MADC-LSTM, LSTM, GRU, and CNN classifiers respectively at a learning rate of 0.11.

Figure 14 Classifier-based performance validation of the executed response analysis model in terms of, (a) L1-norm (b) L2-norm (c) MAE (d) MASE (e) MEP (f) RMSE (g) SMAPE (see online version for colours)



6.6 Statistical analysis of the recommended response analysis framework

The statistical analysis of the recommended response analysis framework is depicted in Table 3. The mean value of the recommended GE-BCPOA-MADC-LSTM response analysis model is 72.32%, 67.69%, 29.69%, and 83.77% lesser than the GTO-MADC-LSTM, ROA-MADC-LSTM, GEO-MADC-LSTM, and BCPA-MADC-LSTM algorithms respectively.

Table 3 Statistical analysis of the recommended response analysis framework

Measures/ algorithm	*GTO-MADC-LSTM (Marinaki, and Marinakis, 2016)*	*ROA-MADC-LSTM (Moazzeni, and Khamehchi, 2020)*	*GEO-MADC-LSTM (Mohammadi-Balani et al., 2020)*	*BCPA-MADC-LSTM (Lu and Zhou, 2015)*	*GE-BCPOA-MADC-LSTM*
Worst	13.594	2.456	5.320	0.952	5.903
Median	1.226	0.194	0.875	0.135	0.167
Mean	2.294	0.430	0.936	0.216	1.332
Best	0.873	0.194	0.226	0.135	0.115
Standard deviation	3.462	0.437	1.009	0.135	2.012

6.7 Performance assessment of the suggested response analysis framework

The performance assessment of the suggested response analysis framework is listed in Table 4. The RMSE of the suggested GE-BCPOA-MADC-LSTM response analysis framework is 19.21%, 18.1%, 18.52%, and 17.47% lesser than the CNN, GRU, LSTM, and MADC-LSTM classifiers respectively.

Table 4 Performance assessment of the suggested response analysis framework

Error measures/ algorithm	*CNN (Kollias and Zafeiriou, 2021)*	*GRU (Gang-Qiang et al., 2023)*	*LSTM (Alizadeh et al., 2021)*	*MADC-LSTM*	*GE-BCPOA-MADC-LSTM*
RMSE	1.450	1.451	1.643	1.540	1.327
MASE	14.621	14.237	17.449	16.179	11.984
L1 norm	190.630	185.630	227.500	210.940	156.250
MEP	227.860	214.840	247.400	247.400	182.290
SMAPE	1.953	1.842	2.121	2.121	1.563
L2 norm	32.805	32.832	37.186	34.848	30.033
MAE	0.372	0.363	0.444	0.412	0.305

6.8 Algorithm-based performance assessment of the proposed response analysis framework

The algorithm-based performance assessment of the proposed response analysis framework is tabulated in Table 5. The MAE value of the proposed GE-BCPOA-MADC-LSTM response analysis model is 18.03%, 15.82%, 31.32%, and

25.93% lesser than the GTO-MADC-LSTM, ROA-MADC-LSTM, GEO-MADC-LSTM, and BCPA-MADC-LSTM algorithms respectively.

Table 5 Algorithm-based performance assessment of the proposed response analysis framework

Error measures/ algorithm	*GTO-MADC-LSTM (Marinaki, and Marinakis, 2016)*	*ROA-MADC-LSTM (Moazzeni, and Khamehchi, 2020)*	*GEO-MADC-LSTM (Mohammadi-Balani et al., 2020)*	*BCPA-MADC-LSTM (Lu and Zhou, 2015)*	*GE-BCPOA-MADC-LSTM*
MAE	0.458	0.460	0.447	0.447	0.305
MEP	266.930	279.950	260.420	266.930	182.290
L2 norm	37.177	36.672	36.858	36.388	30.033
MASE	18.000	18.048	17.569	17.569	11.984
SMAPE	2.288	2.400	2.232	2.288	1.563
L1 norm	234.690	235.310	229.060	229.060	156.250
RMSE	1.643	1.621	1.629	1.608	1.327

7 Conclusions

A detailed review on integrating the ERP with SCM in aerospace organisations in India was carried out in this research work. For this purpose, the aerospace organisations in Bangalore City were considered. The entire work was divided into three sections. In the initial stage, the data were collected from different aerospace companies with the help of a structured questionnaire and were analysed with appropriate statistical tools to figure out the desired objective. In the second phase, the questionnaires were distributed to the different companies and the industrial authorities were requested to fill up the precise information. In the third place, to realise the effect of integrating the ERP with the SCM system, the analysis was carried out with the help of MADC-LSTM, where the parameters were optimised with the help of GE-BCPOA. The performance of the suggested GE-BCPOA-MADC-LSTM response analysis framework was validated by comparing it with other existing methods. The RMSE of the suggested GE-BCPOA-MADC-LSTM response analysis framework is 19.21%, 18.1%, 18.52%, and 17.47% lesser than the CNN, GRU, LSTM, and MADC-LSTM classifiers respectively. Thus, the effect of integrating the ERP with the SCM system was known in this work.

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