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Original Research

# Examining the critical success factors related to enterprise resource planning: a case study in Ordu province

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**Abstract:** Enterprise Resource Planning (ERP) and success factors are systems that enable effective and efficient management of businesses by facilitating coordination and interaction among different units. Therefore, the decision to select the right and applicable ERP implementation and success factors for businesses is a crucial matter. However, due to the cost of ERP implementations and the lengthy adaptation periods for businesses, selecting the relevant systems and success factors requires careful consideration. Identifying ERP implementations and success factors that are suitable for the business processes and structure of the company is a significant decision-making problem, which can be considered as a gap in the literature. In this regard, this study used the Neutrosophic Decision Making Trial and Evaluation Laboratory (DEMATEL) method to analyze the critical success factors for ERP in production companies that had more than 10 employees. The results show that project management and top management support were the most important factors. The results have significant implications for business managers and stakeholders involved in the subject matter in terms of cost and resource efficiency as well as gaining competitive advantage.

**Keywords:** Enterprise resource planning, Critical success factors of enterprise resource planning, Neutrosophic DEMATEL

## Introduction

Businesses, in order to stay alive and even gain a competitive edge over their peers, have the need to rapidly and effectively adapt to the changes in the environment and the advancements recorded in information technology (IT). In an era where IT has gained substantial traction and tremendous importance in most aspects of life, the application of IT in their operations, by itself, portends success for the business. The recent uptake in the demand for the Enterprise Resource Planning (ERP) program, for instance, may just be the great overture to the application of technology to most parts of the business. In great demand recently, which can be considered as one of these applications.The efficiency of software used in various sectors can be assured through open-source coded software and this can be seen from past studies and applications [1].

ERP can be defined as organizational information systems that facilitate interdepartmental information flow by integrating business functions [2]. Erdil and Başlıgil stressed

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that these systems are programs used to effectively meet customer needs by achieving the organization's strategic goals. This encapsulates efficiency in planning, coordinating and controlling supply, production, and distribution in different environments at reduced costs [3].

According to Mabert et al., ERP systems are the most successful business practices, tools, and approaches that can be used to identify and implement the integration of management units and business processes in order to help businesses gain competitive advantage [4]. They also propose integrated solutions to meet the requirements of information management, efficiently manage the components and resources of the organization, and share information with both internal and external stakeholders without any physical limitations [5].

The software that makes the ERP systems has customizable flexibility specifications to address the different needs of various sectors. They also allow for real-time data access and storage with analysis and management functionality in modular structure via systematic software. In other words, the ERP software can support individual sectors such as petrochemical, banking, healthcare, and aviation with the options of language and multicurrency that have critical importance for international firms [6]. Siriginidi found the system having an integrated arrangement composed of all kinds of information geared towards increasing firms productivity, quality, and competitiveness [7]. According to Jagoda and Samarnayake, ERP systems can be defined as applications that integrate the departments of an organization (such as production, accounting, personnel, and sales), automate the crucial points of business processes, enable the sharing of documents, data, and knowledge throughout the entire business, and allow immediate data processing and access via a common database [8].

The success rate of ERP applications has often been found to be considerably low despite the aforementioned advantages. This crummy performance has been attributed, in large part, to the selection of systems not suited to firm structure. The implication being that the criterion of the ERP system selection and the nature of the system itself has great influence on the extent of its success [9].

According to Dinn, it is difficult to define and measure the success of this software. The meaning attributed to the success of the program may differ depending on the user. Firstly achievement depends on the viewpoint and changes according to the employees' views. Success criteria can be considered as the yield of ERP system and return on investment rate for a number of corporations. Researchers often argue that the forecasting of these criteria [10].

Each business evaluates the success of ERP from its own perspective. This evaluation can be made in line with the benefits that contribute to the business, such as reducing the number of personnel needed after implementation, better inventory control, and improvements in order and cash management. From an academic point of view, some authors evaluate the success based on the situation directly during the project implementation phase, while others evaluate the success based on the outcome of the project [11]. According to Law and Ngai, there is a positive relationship between process improvement and the success of ERP system, and as business processes dictate operational performance, an improvement in that respect will inevitably engender improvement in organizational performance [12].

While most studies on ERP only considered the ultimate success or failures of the systems, others have examined the implementation aspect, which may itself get bogged down by an array of problems before it can be able to run. These studies have outlined certain critical success factors that help determine and manage expectations in the implementation of ERP [13-16]. The main purpose of the critical success factors is to provide a framework of vital steps that need to be executed in the implementation process. Most of these success factors are may be applicable for any information system project [17].

Owing to their importance, considerable attention has been paid to the ERP critical success factors in the past decades with an eye on deriving maximum effectiveness and productivity from the application of this often expensive software. Some of the commonly cited criteria in ERP include; appropriate software selection; supplier selection; top management support; project and change management; measurement of determined vision, goals, and performance; redesign/management of business processes; resource allocation; data reliability; interdepartmental communication/coordination; degree of troubleshooting and software test [18-26].

Many critical factors affect the successful implementation of ERP systems. These factors determine the cost, speed, and efficiency of the switch to the new system. The factors under consideration here have been considered in the literature and defined and examined using different methods such as correlation and regression analysis, tests and tructural equation modeling [27].

In line with the expertise, experience, and knowledge of decision-makers (DMs), ERP critical success factors are identified based on their intended contribution such as reduction of operating costs, effective resource management, and creation of customer value [1]. The sustainability efforts of businesses, the desire to increase the speed of change, take advantage of global opportunities, and effectively use the available technology all the while striving for overall resource efficiency, have created a new relationship between ERP critical success factors and businesses and led to new modeling.

This study takes the case of the integration of ERP critical success factors and transportation strategies of manufacturing businesses with a view to reducing costs, reducing loss of reputation, and evaluating the environment in a way that improves customer experience.

The study seeks to be a critical component in reaching an effective and applicable solution to the decision-making problem involving ERP critical success factors in a vital area such as manufacturing. We achieve this by creating a model that will enable businesses to make self-assessments in ERP critical success criteria and production management. The study also examines the similarities and differences of ERP critical success factors in the business enterprises in the relevant sector with the intention of providing a practical roadmap for the implementation process of the ERP critical success factors for the manufacturing sector.

Whereas the results obtained in this study were from the manufacturing sector, the framework allows for comparison with other sectors. In that respect, the study could be thought to have a wider contribution to the business world and the literature in general regarding the implementation of ERP critical success factors.

The purpose of this study was to determine and prioritize the ERP critical success factors in manufacturing firms with 10 or more employees in Ordu using neutrosophic DEMATEL. The remaining parts of the study can be stated as follows; ERP and related critical success factors are analyzed in the literature review in the second section. Single-valued neutrosophic sets (SVNS) and SVNS-based DEMATEL are explained under the methodology section. The case study and results are given in the fourth section. Discussions and future suggestions are mentioned in the last section.

## Literature review

Some of the prominent studies on enterprise resource planning and critical success factors are highlighted below:

In a study aimed at evaluating ERP projects, Teltumbde outlined the following 10 factors of ERP software selection as part of their evaluation criteria: strategic alignment, technology, change management, risk, applicability, business functionality, vendor identity, flexibility, cost and benefit [28]. Fui-Hoon Nah et al. on the other hand highlighted top management support, redesigning business processes, effective project management, personnel education, software-hardware adaptability, and data reliability as essential factors for the ERP installation process [24]. Similarly, Kumar et al. put forth the following as the factors vital in ERP software and supplier selection; functionality, reliability, adaptation to organization systems, integration, vendor title, adaptation to other systems, vendor support, privatization convenience, upgrading version, low costs, and suitability to business processes [29].

Baki and Çakar set out to determine and prioritize the criteria for ERP software selection through literature review and focus group discussions. The result was a total of 17 different factors from which the parent company systems emerged as the most significant selection factor [30]. Perçin used stated the analytic network process (ANP) to determine two main and twelve sub-factors for ERP software selection [31]. Keçek and Yıldırım used the AHP technique to compare and determine the most efficient ERP software for the automotive sector [32].

Asl et al. used Delphi-integrated Shannon Entropy to identify and rank the most important criteria in ERP selection. They determine their criteria as cost, product quality, vendor, and software capabilities, and rank vendor as the most significant [33]. Vatansever and Uluköy, applied Fuzzy AHP and fuzzy MOORA methods to evaluate ERP systems in manufacturing firms [34].

Vahidi et al. analyzed the criteria of functionality, cost, and firm support for ERP selection under the fuzzy environment [35]. Kılıç et al. considered the business, cost, and technical criteria using integrated ANP and PROMETHEE methods to select the best ERP system [36].

Ecer used the ARAS method to evaluate the ERP software alternatives with respect to cost, functionality, ease of use, flexibility, software security, firm awareness, support, and service criteria [37]. Zeng et al. integrated fuzzy logic, grey system theory, and AHP methods in ERP systems selection by looking at firm, investment, quality, business processes-related factors, and sub-factors [38]. Ayçin integrated MACBETH and MABAC methods for ERP systems selection and found functionality, ease of use, and brand image as the most important factors. SAP was found to be the best system alternative [39].

Çark and Marşap examined the factors of ERP implementation that had the most impact on its value to the users. They found that the technological dimension which included system quality and ERP service (provider) quality; the organizational dimension which had shared common belief and system-work compliance, and coordination as an aspect of the environmental dimension were the main factors that affect user value [40]. Çakırlı et al. used the Interpretative Structural Modeling and MICMAC (Cross Impact Matrix Multiplication Applied to Classification) to identify and determine the relationship between ERP implementation barriers [41].

Güdelci and Güdelci, looked at the ERP system of a company that had just transitioned to a new system with a view to determine how the transition impacted users and the impact an ERP system has on the firm's revenue cycle. Speed and automation were the first reported impacts of the new system positively impacted revenue cycle efficiency as well as user satisfaction [42]. Yağar looked at the application of the ERP system in the health sector by reviewing the expected advantages and possible negatives. On top of the timely and improved access to information, the institution is likely to benefit from added technological strength; processes are better organized and the limited sources are used efficiently [43].

Another sector that could benefit from ERP systems is the construction sector. However, as Tekin and Atabay found out in their study that sought to explore the integration between ERP and Building Information Modeling (BIM) which is currently used in the sector, barriers abound. Nonetheless, such an integration is not out of the realm and they have a proposal on just how that could be achieved [44].

**Table 1.** Studies related to ERP and critical success factors

| Author(s) | Year | Method(s) | Research focus | Country |
|---|---|---|---|---|
| **Teltumbde** | 2000 | AHP- nominal group technique | Propose a framework for evaluating ERP projects in a public sector undertaking | India |
| **Fui-Hoon Nah et al.** | 2001 | Literature review | Examine the critical factors for initial and ongoing ERP implementation success | USA |
| **Kumar et al.** | 2003 | Descriptive statistics- conceptually clustered matrices-cross case analysis | Identify a number of critical management challenges in the ERP implementation activities, such as training, upgrading infrastructure, project management and stabilizing ERP systems. | Canada |
| **Baki and Çakar** | 2005 | Literature review-focus group discussions-single informant method-descriptive statistics | Determine and prioritize criteria related to ERP package selection for manufacturing companies | Turkey |
| **Perçin** | 2008 | ANP | Select and benchmark ERP systems for automotive supplier industry | Turkey |
| **Keçek and Yıldırım** | 2010 | AHP | Select the most efficient ERP software in automotive sector | Turkey |
| **Asl et al.** | 2012 | Delphi- Shannon Entropy | Identify and rank the effective factors on selecting ERP system | Iran |
| **Vatansever and Uluköy** | 2013 | Fuzzy AHP- Fuzzy MOORA | Determine the most proper ERP software for manufacturing sector | Turkey |
| **Vahidi et al.** | 2014 | Triangular fuzzy numbers-Mamdani inference | Propose a model related to ERP system selection | Iran |
| **Kılıç et al.** | 2015 | ANP-PROMETHEE | Address the ERP selection problem for small and medium sized enterprises (SMEs) | Turkey |
| **Ecer** | 2016 | ARAS | Select ERP software | Turkey |
| **Zeng et al.** | 2017 | Delphi-AHP- Fuzzy comprehensive evaluation-Grey relational analysis | Present a new approach for the selection of SME-specific ERP systems | China |
| **Ayçin** | 2019 | MACBETH-MABAC | Select ERP systems | Turkey |
| **Çark and Marşap** | 2019 | Partial least squares- Structural equation modeling (SEM) | Determine the factors that increase the user acceptance value and benefits of ERP system from the perspective of the users and the effects of these factors | Turkey |
| **Çakırlı et al.** | 2020 | Interpretive structural modeling- MICMAC | Identify and determine the relationship between ERP implementation barriers for SMEs | Turkey |
| **Güdelci and Güdelci** | 2020 | Literature review- interviews | Examine the revenue cycle in terms of understanding of ERP for an industrial enterprise | Turkey |
| **Yağar** | 2021 | Literature review | Evaluate ERP in health institutions | Turkey |
| **Wijaya et al.** | 2021 | Literature review | Consider scientific publications related to ERP critical success factors in terms of system modification | Indonesia |
| **Tekin and Atabay** | 2022 | Document and content analysis | Examine the roles of Building Information Modeling (BIM) and ERP in the construction sector, analyze the obstacles toward this integration and consider the BIM cooperation process | Turkey |
| **Sislian and Jaegler** | 2022 | SEM | Examine the relationship between blockchain and ERP systems in terms of constructing a more sustainable performance in supply chain system | Europe |
| **Rahardja** | 2022 | Multiple regression analysis | Examine the ERP application in terms of increasing the essential effect of management control systems | Indonesia |

Wijaya et al. conducted a literature review on critical success factors of ERP with special attention on ERP modification to fit the business. They then gave an elaboration of the various types of misfits and modifications that will lead to a better understanding of ERP modification and what it entails [45].

Blockchain is a relatively new technology. But this did not prevent Sislian ve Jaegler from examining if a link could be established between blockchain and ERP systems to establish a more sustainable performance in a company's supply chain system. Their study based on a previous one that looked at sustainable supply chain management and blockchain. They used SEM to examine the potential impact the integration of ERP and blockchain will have on the organization's financial performance [46].

Rahardja examined the ERP application in Indonesia for increasing the essential effect of management control systems. There are a lot of studies examining the critical success factors for ERP systems according to the literature review. But this study gives novelty to literature from the perspective of the application sector and place [47].

Studies aforementioned are summarized in Table 1 shown as below:

A detailed literature review revealed that there are few studies that consider ERP success factors in production companies. This study fills the gap in the literature, and considering the methods used and the scope of application, it is believed that the study will greatly contribute to the literature.

# Methodology

## Neutrosophic Set

Smarandache proposed the Neutrosophic Sets (NS) having with a degree of truth, indeterminacy, and falsity membership functions which all of them are totally independent [48]. Suppose U as a universe of discourse and $x \in U$. A NS N can be defined via a truth membership function $T_N(x)$, an indeterminacy membership function $I_N(x)$ and a falsity membership function $F_N(x)$, and shown as

$$N = \{< x : T_N(x), I_N(x), F_N(x) >, x \in U\}$$

Besides the functions, $T_N(x)$, $I_N(x)$ and $F_N(x)$ are real standard or real nonstandard subsets of $]0^-,1^+[$, and can be indicated as $T, I, F : U \rightarrow\ ]0^-,1^+[$ There is no restriction on the sum of the functions of $T_N(x)$, $I_N(x)$ and $F_N(x)$, so

$$0^- \leq \sup T_N(x) + \sup I_N(x) + \sup F_N(x) \leq 3^+$$

The complement of a NS N is indicated via $N^C$ and defined as follows:

$$T_N^C(x) = 1^+ \ominus T_N(x) \quad (1)$$

$$I_N^C(x) = 1^+ \ominus I_N(x) \quad (2)$$

$$F_N^C(x) = 1^+ \ominus F_N(x) \text{ for all } x \in U \quad (3)$$

A NS, N is contained in another NS P in other words, $N \subseteq P$ if and only if $\inf T_N(x) \leq \inf T_P(x)$, $\sup T_N(x) \leq \sup T_P(x)$, $\inf I_N(x) \geq \inf I_P(x)$, $\sup I_N(x) \geq \sup I_P(x)$, $\inf F_N(x) \geq \inf F_P(x)$, $\sup F_N(x) \geq \sup F_P(x)$ for all $x \in U$ [49]

## Single-valued neutrosophic sets (SVNS)

Wang et al. (2010) proposed the term of Single Valued Neutrosophic Set (SVNS) for dealing with indeterminate, inconsistent and incomplete information [50]. They used the interval [0,1] rather than $]0^-,1^+[$ for better applying in real-world problems. Suppose U as a universe of discourse and $x \in U$. A single valued neutrosophic set B in U is defined via a truth membership function $T_B(x)$, an indeterminacy membership function $I_B(x)$ and a falsity membership function $F_B(x)$. When U is continuous, an SVNS, B is depicted as

$$B = \int_X \frac{< T_B(x), I_B(x), F_B(x) >}{x} : x \in U$$

When U is discrete, a SVNS B is showns as

$$B = \sum_{i=1}^{n} \frac{< T_B(x_i), I_B(x_i), F_B(x_i) >}{x_i} : x_i \in U$$

[51]. The functions of $T_B(x)$, $I_B(x)$ and $F_B(x)$ are real standard subsets of [0,1] that is $T_B(x): U \rightarrow [0,1]$, $I_B(x): U \rightarrow [0,1]$ and $F_B(x): U \rightarrow [0,1]$. Also the sum of $T_B(x)$, $I_B(x)$ and $F_B(x)$ are in [0,3] that $0 \leq T_B(x) + I_B(x) + F_B(x) \leq 3$ [52]. Consider a single-valued neutrosophic triangular number

$$\tilde{b} = \langle (b_1, b_2, b_3); \alpha_{\tilde{b}}, \theta_{\tilde{b}}, \beta_{\tilde{b}} \rangle$$

as a special neutrosophic set on R. Besides $\alpha_{\tilde{b}}, \theta_{\tilde{b}}, \beta_{\tilde{b}} \in [0,1]$ and $b_1, b_2, b_3 \in R$ where $b_1 \leq b_2 \leq b_3$ Truth, indeterminacy, and falsity membership functions related to this number are calculated as follows [53].

$$T_{\tilde{b}}(x) = \begin{cases} \alpha_{\tilde{b}}\left(\frac{x-b_1}{b_2-b_1}\right) & (b_1 \leq x \leq b_2) \\ \alpha_{\tilde{b}} & (x = b_2) \\ \alpha_{\tilde{b}}\left(\frac{b_3-x}{b_3-b_2}\right) & (b_2 < x \leq b_3) \\ 0 & otherwise \end{cases} \quad (4)$$

$$I_{\tilde{b}}(x) = \begin{cases} \frac{b_2 - x + \theta_{\tilde{b}}(x-b_1)}{b_2-b_1} & (b_1 \leq x \leq b_2) \\ \theta_{\tilde{b}} & (x = b_2) \\ \frac{x - b_2 + \theta_{\tilde{b}}(b_3-x)}{b_3-b_2} & (b_2 < x \leq b_3) \\ 1 & otherwise \end{cases} \quad (5)$$

$$F_{\tilde{b}}(x)=\begin{cases}(\frac{b_2-x+\beta_{\tilde{b}}(x-b_1)}{b_2-b_1})(b_1\le x\le b_2)\\ \beta_{\tilde{b}} \quad (x=b_2)\\ (\frac{x-b_2+\beta_{\tilde{b}}(b_3-x)}{b_3-b_2})(b_2< x\le b_3)\\ 1 \quad otherwise\end{cases} \tag{6}$$

where $\alpha_{\tilde{b}},\theta_{\tilde{b}}, and\, \beta_{\tilde{b}}$ represent maximum truth, minimum indeterminacy, and the minimum falsity membership degrees. Suppose $\tilde{b}=\langle(b_1,b_2,b_3);\alpha_{\tilde{b}},\theta_{\tilde{b}},\beta_{\tilde{b}}\rangle$ and $\tilde{c}=\langle(c_1,c_2,c_3);\alpha_{\tilde{c}},\theta_{\tilde{c}},\beta_{\tilde{c}}\rangle$ as two single-valued triangular neutrosophic numbers and $\lambda\neq 0$ as a real number.Addition of two single-valued triangular neutrosophic numbers is obtained as below [53].

$$\tilde{b}+\tilde{c}=\langle(b_1+c_1,b_2+c_2,b_3+c_3);\alpha_{\tilde{b}}\wedge\alpha_{\tilde{c}},\theta_{\tilde{b}}\vee\theta_{\tilde{c}},\beta_{\tilde{b}}\vee\beta_{\tilde{c}}\rangle \tag{7}$$

Subtraction of two single-valued triangular neutrosophic numbers is handled as below:

$$\tilde{b}-\tilde{c}=\langle(b_1-c_3,b_2-c_2,b_3-c_1);\alpha_{\tilde{b}}\wedge\alpha_{\tilde{c}},\theta_{\tilde{b}}\vee\theta_{\tilde{c}},\beta_{\tilde{b}}\vee\beta_{\tilde{c}}\rangle \tag{8}$$

Inverse of a single-valued triangular neutrosophic number $(\tilde{b}\neq 0)$ is shown as Eq.(9):

$$\tilde{b}^{-1}=\langle(\frac{1}{b_3},\frac{1}{b_2},\frac{1}{b_1});\alpha_{\tilde{b}},\theta_{\tilde{b}},\beta_{\tilde{b}}\rangle \tag{9}$$

Multiplication of a single-valued triangular neutrosophic number by a constant value is indicated as below:

$$\lambda\tilde{b}=\begin{cases}\langle(\lambda b_1,\lambda b_2,\lambda b_3);\alpha_{\tilde{b}},\theta_{\tilde{b}},\beta_{\tilde{b}}\rangle if(\lambda>0)\\ \langle(\lambda b_3,\lambda b_2,\lambda b_1);\alpha_{\tilde{b}},\theta_{\tilde{b}},\beta_{\tilde{b}}\rangle if(\lambda<0)\end{cases} \tag{10}$$

Division of a single-valued triangular neutrosophic number by a constant value is shown as Eq.(11):

$$\frac{\tilde{b}}{\lambda}=\begin{cases}\langle(\frac{b_1}{\lambda},\frac{b_2}{\lambda},\frac{b_3}{\lambda});\alpha_{\tilde{b}},\theta_{\tilde{b}},\beta_{\tilde{b}}\rangle if(\lambda>0)\\ \langle(\frac{b_3}{\lambda},\frac{b_2}{\lambda},\frac{b_1}{\lambda});\alpha_{\tilde{b}},\theta_{\tilde{b}},\beta_{\tilde{b}}\rangle if(\lambda<0)\end{cases} \tag{11}$$

Multiplication of two single-valued triangular neutrosophic numbers is shown as below:

$$\tilde{b}\tilde{c}=\begin{cases}\langle(b_1c_1,b_2c_2,b_3c_3);\alpha_{\tilde{b}}\wedge\alpha_{\tilde{c}},\theta_{\tilde{b}}\vee\theta_{\tilde{c}},\beta_{\tilde{b}}\vee\beta_{\tilde{c}}\rangle if\,(b_3>0,c_3>0)\\ \langle(b_1c_3,b_2c_2,b_3c_1);\alpha_{\tilde{b}}\wedge\alpha_{\tilde{c}},\theta_{\tilde{b}}\vee\theta_{\tilde{c}},\beta_{\tilde{b}}\vee\beta_{\tilde{c}}\rangle if\,(b_3<0,c_3>0)\\ \langle(b_3c_3,b_2c_2,b_1c_1);\alpha_{\tilde{b}}\wedge\alpha_{\tilde{c}},\theta_{\tilde{b}}\vee\theta_{\tilde{c}},\beta_{\tilde{b}}\vee\beta_{\tilde{c}}\rangle if\,(b_3<0,c_3<0)\end{cases} \tag{12}$$

Division of two single-valued triangular neutrosophic numbers is indicated as Eq.(13):

$$\frac{\tilde{b}}{\tilde{c}}=\begin{cases}\langle(\frac{b_1}{c_3},\frac{b_2}{c_2},\frac{b_3}{c_1});\alpha_{\tilde{b}}\wedge\alpha_{\tilde{c}},\theta_{\tilde{b}}\vee\theta_{\tilde{c}},\beta_{\tilde{b}}\vee\beta_{\tilde{c}}\rangle if\,(b_3>0,c_3>0)\\ \langle(\frac{b_3}{c_3},\frac{b_2}{c_2},\frac{b_1}{c_1});\alpha_{\tilde{b}}\wedge\alpha_{\tilde{c}},\theta_{\tilde{b}}\vee\theta_{\tilde{c}},\beta_{\tilde{b}}\vee\beta_{\tilde{c}}\rangle if\,(b_3<0,c_3>0)\\ \langle(\frac{b_3}{c_1},\frac{b_2}{c_2},\frac{b_1}{c_3});\alpha_{\tilde{b}}\wedge\alpha_{\tilde{c}},\theta_{\tilde{b}}\vee\theta_{\tilde{c}},\beta_{\tilde{b}}\vee\beta_{\tilde{c}}\rangle if\,(b_3<0,c_3<0)\end{cases} \tag{13}$$

Score function ($S_b$) for a single-valued triangular neutrosophic numbe b = ($b_1$, $b_2$, $b_3$) can be found as follows [54].

$$S_b=(1+b_1-2*b_2-b_3)/2 \tag{14}$$

where $S_b\in[-1,1]$

## Neutrosophic DEMATEL

DEMATEL method developed by Geneva Research Center as a structural method was formed for presenting causal relationships between examined factors in complex and intertwined problems. Components of the system can be visualized via directed graph diagram and associated matrices are used for showing direct and indirect influences. An intelligible structural model can be constructed via using relationship between the cause and effect factors. One of the advantages of Neutrosophic DEMATEL is its ability to explicitly present the views of the DMs in an uncertain and vague environment by considering the truthiness, indeterminacy, and falsity of the decision-making situations and showing the disagreements between the DMs. The steps of neutrosophic DEMATEL can be summarized as below [55,56]:

1-Decision goals are determined, DMs are chosen and criteria are identified.

2-Pairwise comparison matrices $(\tilde{E})$ for criteria ($C_1$, $C_2$, …, $C_n$) are formed. Components of the matrices are written by triangular neutrosophic numbers ($l_{nn}$, $m_{nn}$, $u_{nn}$) provided by DMs seen as Eq. (15).

$$\tilde{E}=\begin{bmatrix}(l_{11},m_{11},u_{11}) & (l_{12},m_{12},u_{12}) & \cdots & (l_{1n},m_{1n},u_{1n})\\ \vdots & \vdots & & \vdots \quad \vdots\\ (l_{n1},m_{n1},u_{n1}) & (l_{n2},m_{n2},u_{n2}) & \cdots & (l_{nn},m_{nn},u_{nn})\end{bmatrix} \tag{15}$$

3-Maximum truth membership degree (α), minimum indeterminacy membership degree (β), and minimum falsity membership degree (θ) of single-valued triangular neutrosophic numbers are determined by the DMs as a pairwise comparison matrix seen as $(\tilde{F})$ Eq. (16).

$$\tilde{F}=\begin{bmatrix}(l_{11},m_{11},u_{11};\alpha,\beta,\theta) & (l_{12},m_{12},u_{12};\alpha,\beta,\theta) & \cdots & (l_{1n},m_{1n},u_{1n};\alpha,\beta,\theta)\\ \vdots & \vdots & \vdots & \vdots\\ (l_{n1},m_{n1},u_{n1};\alpha,\beta,\theta) & (l_{n2},m_{n2},u_{n2};\alpha,\beta,\theta) & \cdots & (l_{nn},m_{nn},u_{nn};\alpha,\beta,\theta)\end{bmatrix} \quad (16)$$

4-Neutrosophic pairwise comparison matrix is transformed into a deterministic pairwise comparison matrix (E) following Eq.(17) below

$$E=\begin{bmatrix}e_{11} & e_{12} & \cdots & e_{1n}\\ \vdots & \vdots & \vdots & \vdots\\ e_{n1} & e_{n2} & \cdots & e_{nn}\end{bmatrix} \quad (17)$$

let $\tilde{d}_{ij}=\left\langle (d_1,e_1,f_1),\alpha_{\tilde{d}},\theta_{\tilde{d}},\beta_{\tilde{d}}\right\rangle$ be a single-valued neutrosophic number, the score and accuracy degrees related to $\tilde{d}_{ij}$ are obtained as below:

$$S(\tilde{d}_{ij})=\frac{1}{16}\left[d_1+e_1+f_1\right]x(2+\alpha_{\tilde{d}}-\theta_{\tilde{d}}-\beta_{\tilde{d}}) \quad (18)$$

$$A(\tilde{d}_{ij})=\frac{1}{16}\left[d_1+e_1+f_1\right]x(2+\alpha_{\tilde{d}}-\theta_{\tilde{d}}+\beta_{\tilde{d}}) \quad (19)$$

5-Average views of all DMs related to each criterion are integrated into one matrix using Eq. (20):

$$e_{11}=\frac{e_{11}d_1+e_{11}d_2+\cdots+e_{11}d_n}{d} \quad (20)$$

where $d$ represents the number of DMs.

6-Initial direct relation matrix A is an nxn matrix acquired via pair-wise comparisons, $A = [a_{ij}]_{nxn}$ where $a_{ij}$ is shown as the degree to which criterion $i$ has an effect on the criterion $j$.

7-Normalized direct-relation matrix (X) is computed via Eqs. (21) and (22). All principal diagonal elements are equal to zero for that.

$$X = K.A \quad (21)$$

$$K=\frac{1}{Max_{1\le i\le n}\sum_{j=1}^{n}a_{ij}} \quad i,j = 1,2,\ldots,n \quad (22)$$

8-Total-relation matrix (T) is obtained via Eq. (23), where the I is shown as the identity matrix.

$$T = X(1-X)^{-1} \quad (23)$$

9-The sum of rows and columns is used to obtain vector S and vector R within the total relation matrix T indicated via Eqs. (24), (25), and (26) respectively. After that, the horizontal axis vector (S+R) namely "Prominence", is generated by adding R to S , denoting the level of importance of the criterion. Accordingly, the vertical axis (S-R) namely "Relation", is created by subtracting R from S, allocating criteria into cause and effect groups. If the value of (S-R) is positive, the criterion belongs to the cause group; otherwise, it is allocated to the effect group.

$$T = [t_{ij}]_{nxn} \quad i,j=1,2,\ldots,n \quad (24)$$

$$S=\left[\sum_{j=1}^{n}t_{ij}\right]_{nx1} \quad (25)$$

$$R=\left[\sum_{i=1}^{n}t_{ij}\right]_{1xn} \quad (26)$$

where vectors S and R indicate the sum of rows and columns from the total-relation matrix $T = [t_{ij}]_{nxn}$ respectively.

**Table 2.** Critical success factors of ERP

| Critical Success Factors | Explanation | Source |
|---|---|---|
| C1 | Appropriate software selection | [57] |
| C2 | Supplier selection | [58] |
| C3 | Top management support | [1] |
| C4 | Project and change management | [59] |
| C5 | Measurement of determined vision, goals and performance | [60] |
| C6 | Redesign/management of business processes | [41] |
| C7 | Resource allocation | [1] |
| C8 | Data reliability | [27] |
| C9 | Interdepartmental communication/ coordination | [61] |
| C10 | Troubleshooting degree and software test | [1] |

## Analysis

In order to apply the DEMATEL method under a neutrosophic environment for evaluating the ERP critical success factors in manufacturing firms employing more than people, a survey consisting of the critical success factors was designed following an in-depth literature review. The factors determined used in the survey are shown in Table 2.

The survey inquired about the level of importance of the ERP critical success factors based on a five-point neutrosophic scale converting DEMATEL comparison scale to triangular neutrosophic numbers. The DEMATEL technique was selected for weighting the ERP critical success factors having inter-influenced and interdependent elements. Neutrosophic sets were preferred because they are better at presenting the vague, inconsistent, and indeterminate judgments of the experts than fuzzy, intuitionistic, and hesitant sets.

The survey was administered to 10 DMs in Ordu with expertise in ERP. Information and details related to DMs are given in Table 3.

All the experts were assigned equal weights, and the geometric mean was applied to integrate the experts' views.

Then a direct relationship matrix consisting of crisp values was formed as shown in Table 4.

From the direct relationship matrix, the normalized direct relation matrix was formed via Eqs. (21) and (22), and then the total relation matrix T, shown in Table 5, was acquired via Eq.(23).

Lastly, prominence (horizontal) and relation (vertical) axes indicated by (S+R) and (S-R) were calculated to get the causal diagram. Computations for these axes are presented in Table 6.

As per the views of DMs, criterion 4, *project and change management,* was considered the most important cause criterion with a prominence value of 23.745. On the other hand, criterion 6, r*edesign/management of business processes*, was the most important effect criterion with a relation value of -1.632. Criterion 9, *interdepartmental communication/coordination*, was considered the least important cause criterion.

**Table 3.** Detailed information related to DMs

| DMs | Duty | Graduate | Experience (years) |
|---|---|---|---|
| **DM1** | Operation Manager | Operation Engineering | 11 |
| **DM2** | Warehouse and Operation Manager | Industrial Engineering | 12 |
| **DM3** | Quality Business Development Manager | Environmental Engineering | 10 |
| **DM4** | Quality Business Development Manager | Business Administration | 8 |
| **DM5** | Quality Business Development Manager | Business Administration | 10 |
| **DM6** | Operation Manager | Business Administration | 18 |
| **DM7** | Operation Manager | Environmental Engineering/ Business Administration | 13 |
| **DM8** | Business Manager | Business Administration | 18 |
| **DM9** | Process Engineer | Operation Engineering | 15 |
| **DM10** | Operation Manager | Business Administration | 9 |

**Table 4.** Direct relationship matrix

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **C1** | 0.000 | 0.556 | 0.479 | 0.399 | 0.358 | 0.548 | 0.472 | 0.448 | 0.616 | 0.515 |
| **C2** | 0.564 | 0.000 | 0.541 | 0.428 | 0.427 | 0.386 | 0.439 | 0.533 | 0.473 | 0.488 |
| **C3** | 0.589 | 0.409 | 0.000 | 0.519 | 0.338 | 0.595 | 0.529 | 0.485 | 0.500 | 0.511 |
| **C4** | 0.543 | 0.474 | 0.497 | 0.000 | 0.442 | 0.561 | 0.521 | 0.560 | 0.541 | 0.526 |
| **C5** | 0.618 | 0.617 | 0.600 | 0.449 | 0.000 | 0.369 | 0.454 | 0.560 | 0.504 | 0.522 |
| **C6** | 0.525 | 0.526 | 0.463 | 0.450 | 0.715 | 0.000 | 0.552 | 0.557 | 0.523 | 0.564 |
| **C7** | 0.643 | 0.714 | 0.688 | 0.639 | 0.665 | 0.639 | 0.000 | 0.586 | 0.530 | 0.552 |
| **C8** | 0.527 | 0.557 | 0.519 | 0.537 | 0.538 | 0.557 | 0.545 | 0.000 | 0.459 | 0.496 |
| **C9** | 0.519 | 0.500 | 0.485 | 0.556 | 0.538 | 0.527 | 0.509 | 0.500 | 0.000 | 0.496 |
| **C10** | 0.519 | 0.560 | 0.526 | 0.583 | 0.549 | 0.605 | 0.597 | 0.546 | 0.583 | 0.000 |

**Table 5.** Total relation matrix

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **C1** | 2.214 | 2.217 | 2.192 | 1.945 | 1.953 | 2.141 | 0.603 | 0.600 | 0.618 | 0.600 |
| **C2** | 2.387 | 2.043 | 2.207 | 1.951 | 1.966 | 2.097 | 0.554 | 0.562 | 0.558 | 0.553 |
| **C3** | 2.484 | 2.262 | 2.123 | 2.052 | 2.024 | 2.237 | 0.611 | 0.606 | 0.610 | 0.603 |
| **C4** | 2.528 | 2.330 | 2.330 | 1.934 | 2.096 | 2.274 | 0.608 | 0.612 | 0.611 | 0.602 |
| **C5** | 2.638 | 2.450 | 2.442 | 2.151 | 2.022 | 2.302 | 0.619 | 0.628 | 0.624 | 0.618 |
| **C6** | 2.656 | 2.468 | 2.446 | 2.186 | 2.277 | 2.214 | 0.635 | 0.635 | 0.633 | 0.630 |
| **C7** | 0.710 | 0.753 | 0.743 | 0.739 | 0.718 | 0.694 | 0.610 | 0.670 | 0.666 | 0.660 |
| **C8** | 0.643 | 0.678 | 0.668 | 0.671 | 0.649 | 0.631 | 0.614 | 0.557 | 0.606 | 0.602 |
| **C9** | 0.618 | 0.648 | 0.640 | 0.648 | 0.626 | 0.605 | 0.588 | 0.586 | 0.536 | 0.580 |
| **C10** | 0.632 | 0.668 | 0.658 | 0.665 | 0.640 | 0.626 | 0.609 | 0.604 | 0.609 | 0.541 |

**Table 6.** Prominence and relation axes for causal diagram

| Criteria | S+R | S-R |
|---|---|---|
| **C1** | 22.954 | 0.427 |
| **C2** | 21.712 | 0.241 |
| **C3** | 23.538 | 0.445 |
| **C4** | 23.745 | 0.578 |
| **C5** | 19.168 | -0.967 |
| **C6** | 21.492 | -1.632 |
| **C7** | 20.238 | -1.257 |
| **C8** | 22.648 | 1.633 |
| **C9** | 20.837 | 0.516 |
| **C10** | 21.349 | 1.563 |

The overall ranking of the ERP critical success factors in terms of their level of importance was C4 > C3 > C1 > C8> C2 > C10 > C9.

The criteria were divided into two groups made up of the cause criteria which affect the ERP critical success factors (C1, C2, C3, C4, C8, C9, C10) and effect criteria which were affected by the ERP critical success factors (C5, C6, C7).

## Discussion

The Conducted analysis revealed that the most important factor in ERP implementations in production companies is "Project and Change Management". The results obtained support the studies by [62], [63], and [27]. In today's changing competitive conditions, ERP systems can achieve success by integrating with project systems with different business models. Therefore, an advanced ERP system regarding the development of projects can play an effective role in enterprises. In order to ensure the effectiveness of ERP and competitiveness, emphasis should put on integrating project management practices with enterprise goals and strategies, which can be considered a critical indicator.

The other factor identified by the study as significant is "*Top management support*". The results are consistent with the studies of [64], [65], and [41]. It is the responsibility of top management to take over the project, if necessary in writing, for the innovation to spread throughout the organization's all units. The study finds and emphasizes that there is no factor more important than top management support in the project life cycle. The top management should understand the feasibility and rationale of ERP applications correctly from a business perspective and present them successfully to all employees. The top management can demonstrate its active support for ERP applications in two ways; as the sponsors of the project, they provide decision-making and budget support to the project team in key business areas. As project leaders, they can support the project team as ordinary members or a top executive who plays a key role in change.

## Conclusion

It is vitally important for businesses to move towards more modern technological strategies grounded in the desire for sustainable production and market. The proper implementation of ERP while remaining faithful to its critical success factors puts the organization on an express lane to overall sustainability. A properly running ERP software will confer on the organization benefits ranging from cost advantage, and improved service quality, to customer satisfaction, and all-around efficiency and effectiveness. Proper implementation of ERP is often subject to a fitting integration with the ERP-related technology and well as a firm adherence to the critical success factors which this study sought to demonstrate.

This study determined and examined the cause-and-effect criteria groups for critical success factors of ERP. *Project and change management, top management support*, and *appropriate software selection* were found as the most important three criteria affecting critical success factors of ERP respectively. On the other hand, *measurement of determined vision, goals, and performance, redesign/ management of business processes*, and *resource allocation* were the criteria that were affected by the critical success factors of ERP. These results are a powerful tool in the decision-making process in ERP implementation.

As has been observed in the literature review, DMs and practitioners in ERP have a lot of critical success factors to consider, often in an environment of uncertainty with its share of complexities. Choosing the most appropriate factors and sorting them through often contradictory qualitative and quantitative criteria is no mean task. The installation, modification, or complete overhaul of an ERP system, often leads to challenges regarding cost, marketing, resource management, performance, energy, and environmental impact among others. This study simply offers a roadmap that promises to help overcome most of these challenges. The model proposed in this study takes into account the requirements and motivations of different DMs. We predict many valuable theoretical contributions of the proposed Neutrosophic DEMATEL methodology. SVNS are considered for explaining DMs' judgments efficiently as compared to fuzzy, type 2 fuzzy, and intuitionistic sets.

One of the main limitations of the study is the number of expert groups interviewed which could not be increased due to time constraints. Similarly, the study was done with a focus only on the manufacturing sector in Ordu province of Turkey, limiting its scope. Another limitation of the study is that focusing on ERP success factors has led to insufficient examination of other studies on ERP and applications. In addition, the grouping of topics in the studies may carry subjectivity at some points. Furthermore, no criterion set was found in both the opinions of the expert group and the literature review on the theme of factors affecting ERP success.

The scope is further limited by the fact that the study considered ERP critical success factors, ignoring other aspects of ERP studies.

Future studies could be built on the limitations highlighted here including by considering other sectors, regions, and aspects of the ERP. Different hybrid techniques in different environments (picture fuzzy sets, orthopair fuzzy sets, fermatean fuzzy sets, spherical fuzzy sets) could also be used to evaluate the phenomenon.

There are many studies in the literature on ERP critical factors, and ours finds room among them by first bringing a different methodological approach and providing a point of comparison.

## Authors' contributions

Each author has participated and contributed sufficiently to take public responsibility for appropriate portions of the content.

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