Original Research

Unveiling Cause-and-Effect Relationships in ERP Success: An Integrated DEMATEL–FCM Analysis of Measurement Criteria

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Received: 5 February 2025 / Accepted: 8 October 2025 / Published online: 10 November 2025

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Abstract

Implementing enterprise resource planning (ERP) systems can be a complex and costly endeavour prone to failure. Hence, it is crucial to identify and manage effective measurement criteria to prevent failure and mitigate negative outcomes during implementation. This study aims to analyse the causal relationships among success measurement criteria within a company engaged in steam boiler construction and production by employing the Decision-Making Trial and Evaluation Laboratory (DEMATEL) with Fuzzy Cognitive Mapping (FCM) method. The paper integrates theoretical frameworks with practical applications. The authors extracted 15 ERP success measurement criteria through literature review, interviews, and questionnaires. DEMATEL was used to assess the interdependencies and categorize criteria into cause and effect groups, while FCM enabled the modelling of dynamic feedback relationships among them. The integrated DEMATEL–FCM framework provides a deeper understanding of how success factors interact and evolve within real organizational contexts. Factors like Enterprise Architecture Improvement, Business Process Improvement, and Employee Involvement are deemed causal, while Customer Service Improvement, Workgroup Improvement, and Competitive Model Improvement are categorized as effects. "Enterprise Architecture Improvement" emerges as the most influential criterion. This combined method not only captures the static structure of causal relationships but also allows simulation of changes in key variables, offering a more practical and adaptable tool for ERP implementers, consultants, and decision-makers.

Keywords – Success; ERP success; DEMATEL; Analysing; measurement; Fuzzy Cognitive Mapping (FCM)

INTRODUCTION

As businesses grow, managing their operations becomes increasingly complex. Effective management is essential for success, requiring managers to have accurate, up-to-date information on various aspects such as company processes and resources to make informed decisions. This information becomes even more valuable when it is organized and integrated into a cohesive system. This is where ERP systems come into play, offering numerous benefits to businesses.

An ERP system is a meticulously engineered business application designed to seamlessly unify and enhance various organizational processes and functions with meticulous attention to detail. Its primary objective is to provide a comprehensive view of a business by enabling the sharing of data and best practices in a real-time environment [1, 2]. By providing a suite of programs covering all areas of the business, ERP systems streamline internal operations [3] and provide businesses with a competitive edge, enhanced decision-making tools, and robust business analysis capabilities [4, 5, 6].

However, despite their many benefits, ERP projects often face high failure rates [7, 8, 9]. These implementations are resource-intensive and complex, requiring organizations to assess and manage their success carefully [10]. Additionally, ERP implementations often necessitate significant organizational changes [11, 12] further complicating the process and introducing inherent risks [13].

The research community emphasizes the importance of effective management in implementing ERP systems to mitigate the adverse outcomes often associated with such implementations [14]. Effectively managing ERP implementation requires a comprehensive approach to identifying and analysing the criteria for measuring ERP success [15, 16]. While numerous studies have explored these criteria, many treat them as independent factors. However, in reality, the success of ERP systems results from a combination of interconnected criteria, rather than a single element. To put it differently, the criteria for measuring ERP success constitute a complex causal structure that complicates individual analysis and prioritization.

Simply ranking these criteria without considering their interconnections fails to provide a thorough understanding of the dynamic mechanisms involved. Additionally, since each organization operates with distinct goals and strategies, requiring a customized ERP system, it becomes crucial to consider the unique characteristics and objectives of each business when identifying criteria contributing to success [17].

To better understand and manage these complexities, this study proposes an integrated approach combining DEMATEL and Fuzzy Cognitive Mapping (FCM). DEMATEL allows for identifying and visualizing the causal structure among success criteria by grouping them into cause-and-effect clusters. However, DEMATEL captures only static, unidirectional relationships. By integrating it with FCM, which models feedback loops and dynamic interactions, the approach can simulate the behavior of the system over time and analyze how changes in one factor may influence others in the network.

This integrated DEMATEL–FCM framework provides a deeper, more actionable understanding of ERP success dynamics. The proposed method was applied in a steam boiler construction and manufacturing company to identify, prioritize, and simulate the interactions among 15 key ERP success criteria. The results yield practical guidance for implementers, consultants, and decision-makers, offering a robust foundation for strategic planning and continuous ERP improvement.

The structure of this paper is organized as follows: it begins with a literature review that explores the criteria for measuring ERP success. This is followed by a detailed presentation of the theoretical foundations of the DEMATEL method. The subsequent section describes the integration of DEMATEL with Fuzzy Cognitive Mapping (FCM), outlining how this combined approach enhances the analysis of causal relationships. The methodology section then elaborates on the application of the integrated model within a real-world case study conducted in a steam boiler manufacturing company. This is followed by a comprehensive analysis and discussion of the results, evaluating the effectiveness and insights provided by the proposed approach. Finally, the paper concludes with key findings, practical recommendations, and suggestions for future research.

LITERATURE REVIEW

Numerous studies have been conducted to delineate benchmarks for measuring ERP success. Among these inquiries, the DeLone and McLean model of 1992 has garnered considerable acknowledgment and influence. This model, with over 30,000 citations, incorporates six metrics for success: system quality, information quality, use, user satisfaction [18], net benefit, and organizational impact [19]. However, in a subsequent revision of their model in 2003 [20] replaced "individual impact" and "organizational impact" with "net benefit," reflecting a refinement in their comprehension of factors contributing to ERP success.

Another esteemed model for achieving ERP success was proposed Markus and Tanis in 2000. They explored success indicators during ERP implementation, revealing that success definition and evaluation vary by perspective. Markus and Tanis emphasized that successful ERP integration is gradual and iterative. Tan and Pan (2002) later critiqued this model for insufficiently addressing non-technical causes crucial for determining ERP success, proposing an alternative model with three dimensions: infrastructure success, info structure success, and knowledge success, aiming to integrate technical and strategic aspects.

In 2003, the model presented by Gable et al, was a significant contribution to the field, widely acknowledged and substantiated in scholarly literature [21]. While building upon the DeLone and McLean model of 1992, they made adjustments. They determined that user satisfaction should not be treated as a distinct criterion and thus excluded it from their final model. Furthermore, Gable et al. noted that the focus of the DeLone and McLean model on organizational impacts predominantly cantered on financial aspects, overlooking business process enhancement and organizational transformation. In response to these shortcomings, they introduced their model featuring four substitutes: system quality, information quality, individual impact, and organizational impact. This model has laid the groundwork for subsequent research endeavours in this domain [22].

Ifinedo and Nahar (2007) expanded upon Gable et al.'s framework, incorporating workgroup impact and the quality of vendors and consultants as criteria for assessing ERP success. Given the underlying philosophy of ERP to enhance the performance of individual units, the impact on workgroups is viewed as an indicator of success. Subsequently, Ifinedo, Rapp, et al. (2010) revisited existing literature and found that the calibre of external providers (vendors and consultants) significantly affects ERP outcomes. Consequently, their model encompasses six factors: service quality, information quality, vendor quality, individual impact, workgroup impact, and organizational impact. This model has been widely adopted by numerous researchers in their studies [23].

Moalagh and Ravasan (2013) introduces a model emphasizing nonlinear relationships among ERP success criteria and organizational objectives. Utilizing the fuzzy Analytic Network Process (ANP) method, they enhance the Ifinedo and Nahar model. This approach acknowledges the complexity of ERP success factors and offers a methodological advancement for their evaluation.

Ravasan et al. (2018) expanded on Ifinedo et al.'s model [24] by integrating the factor of inter-organizational relations. They enhanced the evaluation framework by building upon Ifinedo et al.'s development model. By introducing the criterion of inter-organizational relations, Zare and Zare Ravasan broadened the model's scope to consider the impact on relationships and interactions among various suppliers involved in the ERP implementation process.

Maryam, et al. (2018) focusing on a specific case study in the Indonesian Ministry of Finance, this study evaluates ERP implementation success. It introduces new surrogates such as organizational culture and user support, which enrich the understanding of factors contributing to ERP success in diverse organizational contexts.

Mahmood et al. (2020) conducted a systematic literature review to identify challenges encountered by organizations during ERP system implementation. They analysed 53 relevant studies published between 1999 and 2018, identifying 31 factors, with the top ten including top management approach, change management, training and development, effective communication, system integration, business process reengineering, consultant/vendor selection, project management, project team formation, and data conversion/migration. The study underscores the importance of proactive planning and management capabilities in addressing these challenges, particularly in the context of cloud-based ERPs. The findings offer valuable insights for organizations to better plan and manage ERP implementation projects.

Khasanah, et al. (2021) explores the relationships between project management, top management support, ERP success, and decision-making effectiveness. By employing hierarchical regression modelling, it offers empirical evidence supporting the positive influence of project management and top management support on ERP implementation success.

Butarbutar et al. (2023) conducted a systematic literature review aimed at identifying success factors for Enterprise Resource Planning (ERP) post-implementation. They utilized the Kitchenham approach, structured into planning, execution, and reporting phases. Subsequently, they identified 13 success factors within the Technology-Organization-Environment (TOE) framework, highlighting the significance of organizational factors over technical aspects. Their study underscores the importance of comprehending these factors for leaders to effectively support ERP integration after implementation.

While these studies significantly contribute to understanding ERP success, most prior models exhibit limitations in practical application. Specifically, many assess success criteria in isolation, without accounting for the complex interdependencies among them. For example, models such as those by DeLone & McLean, Gable et al., and Ifinedo et al. offer comprehensive factor sets, yet often overlook dynamic causal relationships—crucial for real-world ERP management.

Moreover, these models generally lack mechanisms to distinguish between driving and dependent factors, hindering strategic prioritization. Static evaluation frameworks further limit their utility for practitioners who must navigate evolving organizational dynamics.

To address these gaps, the present research adopts a hybrid approach by combining the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method with Fuzzy Cognitive Mapping (FCM). While DEMATEL is effective in identifying and quantifying cause-effect relationships among criteria, it may not fully capture the complexity and feedback loops often found in ERP systems. FCM complements this by providing a graphical and computational model that reflects the nonlinear, cyclical, and uncertain nature of interrelationships among success factors [25].

By integrating DEMATEL and FCM, the proposed method enables a deeper understanding of the structure and dynamics of ERP success criteria. This hybrid approach not only categorizes factors into cause-and-effect groups but also simulates potential changes in the system, offering a robust tool for strategic decision-making. Finally, the proposed model is empirically validated within a real organization, demonstrating its practical applicability and its advantages over traditional methods.

DEMATEL

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) method was first developed by the Geneva Research Centre of the Battelle Memorial Institute [26]. It serves as an effective approach for visualizing the intricate causal relationships within complex systems. DEMATEL employs matrices or digraphs to analyse cause-and-effect relationships among system components. This structural modelling technique confirms interdependencies among factors and aids in creating a map that reflects relative relationships. Researchers and practitioners have applied DEMATEL to solve complex problems across various domains, making it a valuable tool for decision-making and understanding cause-effect chains [27].

To utilize the DEMATEL method, the initial step involves defining the intricate system and subsequently identifying the factors or variables that impact the system. This can be accomplished by conducting a literature review or seeking input from experts. Furthermore, it is necessary to develop a measurement scale that can effectively depict the relationships and the strength of these relationships among the factors [28]. A scale commonly used for this purpose is from 1 to 5, representing "no impact" , "low impact", "moderate impact", "high impact," and "extreme impact" respectively. Participants were asked to rate the impact of each ERP success indicator on each other.

Braga et al suggest that researchers should undertake the following procedures when employing the DEMATEL technique [29] :

Step 1 of the DEMATEL method involves collecting the viewpoints of a group of experts (represented as $E = \{E_1, E_2, ..., E_l\}$) regarding the interrelationships among factors (represented as $F = \{F_1, F_2, ..., F_n\}$). This is done by utilizing a scaling system described earlier to create a matrix for pairwise comparisons. Each expert (*denoted as* E_k) contributes an individual matrix (denoted as Z_k) that represents the direct influence of each factor on one another $Z_k = \left[Z_{ij}^k\right]_{n\times n}$. The elements of Z_k, reflect the expert's opinion on the extent to which factor F_i influences factor F_j. The diagonal elements of Z_k have a value of zero.

In Step 2, the average matrix Z, denoted as $\left[Z_{ij}\right]_{n\times n}$., is calculated to combine the perspectives of the l experts. This is done by aggregating the individual opinion matrices to obtain a collective view.

After the average matrix Z is computed in Step 2, Step 3 involves calculating the normalized matrix X, represented as $\left[X_{ij}\right]_{n\times n}$.

$$X = \frac{z}{s} \tag{1}$$

Where

$$s = \min\left(\max_{1\le i\le n}\sum_{j=1}^{n} z_{ij} \;.\; \max_{1\le j\le n}\sum_{i=1}^{n} z_{ij}\right) \tag{2}$$

In Step 4, the total influence matrix T, denoted as $\left[t_{ij}\right]_{n\times n}$ is computed based on the normalized matrix X obtained in Step 3. Since the experts only estimated the direct influence of factors on each other, the total influence matrix T is generated by utilizing the transition theory and considering both the direct and indirect effects. This involves summing up the direct and indirect effects of factors as represented in matrix X.

$$T = X + X^2 + X^3 + \cdots + X^h = X(I - X)^{-1} \tag{3}$$

Where $h \to \infty$

The symbol I represents the identity matrix.

In Step 5, the influence relation map (IRM) is obtained by calculating two vectors, D and R. These vectors are derived by summing up the elements in each row and each column, respectively, of the total relation matrix T. The resulting vectors provide a summary of the influence relationships between the factors.

$$D = [d_i]_{n\times 1} = \left(\sum_{j=1}^{n} t_{ij}\right)_{n\times 1} \tag{4}$$

$$R = [r_i]_{1\times n} = \left(\sum_{i=1}^{n} t_{ij}\right)^{T}_{n\times 1} \tag{5}$$

The value of d_i is the sum of the ith row of matrix T. It represents all the direct and indirect effects that are dispatched from the determinant F_i to other determinants. Similarly, the value of r_j is the sum of the jth column of matrix T. It represents all the direct and indirect effects that the determinant F_j receives from the other determinants.

The diagram depicts the roles of various factors within the system. It uses a horizontal axis labelled $(D + R)$and a vertical axis labelled $(D - R)$ to illustrate these roles. The significance of a specific factor, denoted as $(d_i + r_i)$, is represented by its position on the diagram. The term $(d_i - r_i)$ refers to the net effect or importance of the factor's contribution to the system. Factors are divided into two groups: cause (driver) factors and effect (receiver) factors. A positive value of $(d_i + r_i)$ indicates that the factor $F_i$belongs to the driver factors category, meaning it influences other factors. Conversely, a negative value of $(d_i - r_i)$ indicates that the factor F_j belongs to the receiver factors category, meaning it is influenced by other factors.

DEMATEL serves as an analytical approach employed to address intricate problems by comprehending the structural dynamics of relationships among factors [30]. It addresses complex and interwoven issues, aiding in simplifying the complexity of the relationship network by presenting solutions in an illustrative manner. The reasons for choosing DEMATEL in the current study are outlined as follows:

DEMATEL establishes causal relationships among factors identified by experts within a complex system. These relationships are ascertained through mathematical conceptualization by making pairwise contextual comparisons among the identified factors [31].

DEMATEL delineates factors by offering insights into the influencing patterns among them within a systematic structure. It has been acknowledged as an effective, widely accepted, and suitable technique for addressing real-world implementations [32].

It outperforms conventional techniques such as Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), and others, as it involves establishing inter-relationships and explaining interdependence among the factors of a complex system through a causal diagram [33, 34].

DEMATEL serves as a precursor to other structural or analytical methods, such as the structural equation modelling (SEM) technique, partial least squares (PLS), and Bayesian network analysis [35].

DEMATEL has been employed as a research instrument in diverse fields such as carbon management [36], knowledge management [37], machine manufacturing units [38] , post-implementation challenges of ERP [39] and performance evaluation [40].

In the present study, DEMATEL is not used in isolation but is integrated with the Fuzzy Cognitive Mapping (FCM) method to provide a more comprehensive modeling framework. DEMATEL first identifies and quantifies the causal relationships among ERP success factors. The results—especially the total influence matrix—are then utilized to define the initial cognitive structure of the FCM model. This integration combines the strengths of both methods: DEMATEL offers a clear and structured foundation by categorizing the factors into cause-and-effect groups, while FCM incorporates fuzziness and feedback loops to simulate the nonlinear, dynamic, and uncertain nature of inter-factor relationships. As shown in recent studies, the integration of DEMATEL and FCM has proven effective in domains requiring nuanced causal reasoning and dynamic system modeling [41, 42, 43]. This hybrid approach enables a more realistic and adaptive analysis of ERP success mechanisms, enhancing the quality of decision-making for ERP stakeholders.

Integration of DEMATEL and Fuzzy Cognitive Mapping (FCM)

Fuzzy Cognitive Mapping (FCM) is a robust decision-support technique grounded in fuzzy logic and neural network theory, initially introduced by Kosko [44]. It enables the modelling of complex systems through directed graphs, wherein nodes represent concepts (e.g., success factors) and edges signify weighted causal relationships. These weights, typically ranging from −1 to 1, reflect the strength and polarity of influence among factors, thus capturing both uncertainty and ambiguity inherent in real-world decision environments [45].

One of the primary advantages of FCM lies in its capability to simulate feedback loops and dynamic behavior within systems. This is particularly valuable for analyzing multifaceted phenomena such as ERP success, where interdependencies and evolving interactions among factors are prevalent. Compared to conventional modeling approaches, FCM provides greater adaptability, scalability, and interpretability in modeling human expert knowledge and cognitive structures [46].

In the present study, FCM is employed in conjunction with the DEMATEL method to enhance the validity and depth of the causal model. Initially, DEMATEL is used to determine the causal intensity among ERP success factors and to construct a total influence matrix. To operationalize this matrix within the FCM framework, a threshold is established to eliminate negligible relationships. The refined matrix is then used as the adjacency matrix for the cognitive map.

The analytical process continues with the use of FCMapper, which facilitates the extraction of key network indicators such as indegree, outdegree, centrality, and density. These indicators provide a quantitative perspective on the structural roles of the variables within the ERP system, helping to identify influential factors and their interconnections. The extracted data is then used to visually represent the system's cognitive structure. The resulting map not only illustrates the relationships between the variables but also enables the development of various scenarios.

This integrative methodology combines DEMATEL's strength in uncovering structured causal hierarchies with FCM's dynamic modeling capabilities, yielding a comprehensive and adaptive framework for evaluating and improving ERP success.

Research Methodology

The implementation of enterprise resource planning (ERP) systems often presents complex and costly challenges, frequently leading to failure. Therefore, it is crucial to identify and manage effective evaluation criteria to prevent setbacks and reduce negative outcomes during deployment. This study aims to examine the causal relationships among successful evaluation criteria in a company specializing in steam boiler construction and manufacturing. The analysis employs the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method with Fuzzy Cognitive Mapping (FCM) to uncover these relationships.

The interaction of various indicators affecting ERP success often involves complex, nonlinear relationships that amplify the impact of different factors. By integrating FCM with DEMATEL, the interconnected nature of these factors can be better captured, allowing for the identification of the most significant criteria for ERP success.

The development and confirmation of the DEMATEL-FCM model to examine the elements influencing ERP success adhere to the modelling-validation method outlined in Figure 1. This integrated approach enables a more comprehensive analysis and prioritization of ERP success criteria, combining the strengths of both methods.

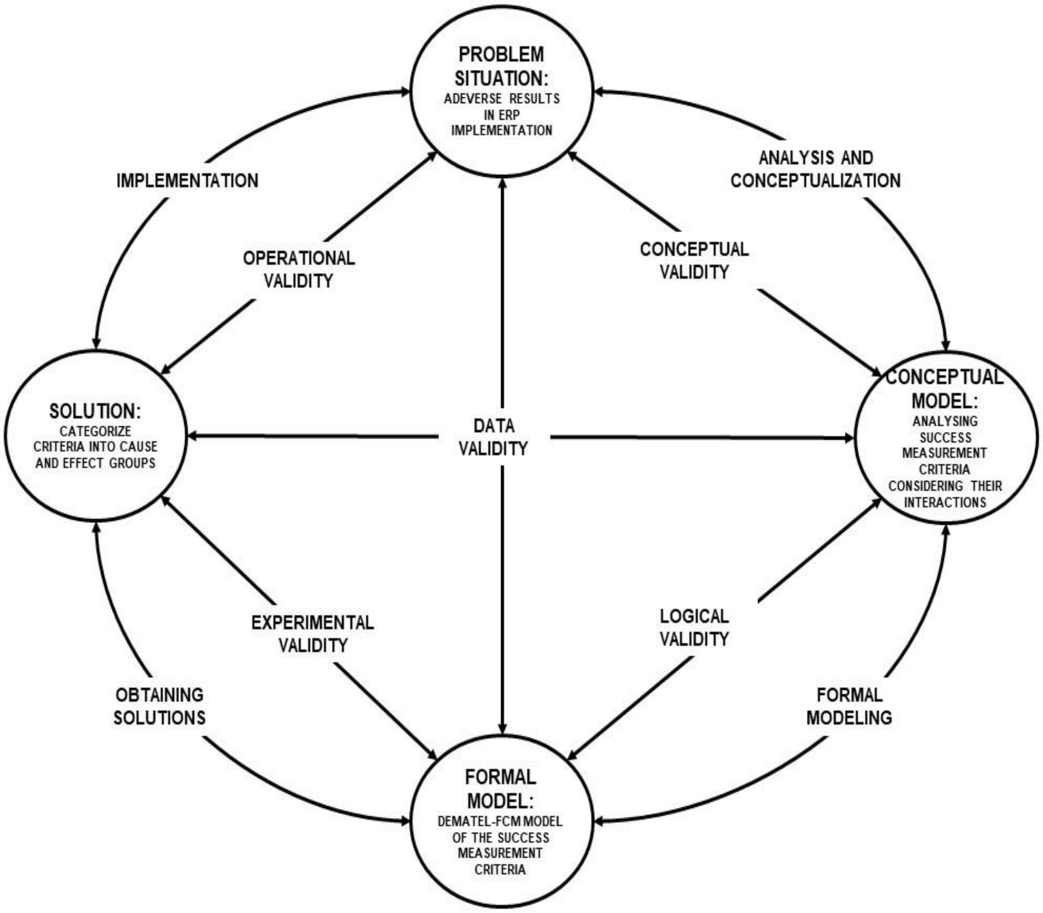


FIGURE 1
MODELLING- VALIDATION PROCESS MODIFIED FROM [47]

I. Modelling- Validation Process

It's customary to combine modelling and validation into a unified task termed the modelling-validation process [47]. This process involves interconnected and iterative phases, as illustrated in Figure 1 [48]. Typically, the modelling-validation process commences with a problem situation (Figure 1), denoting any dissatisfaction with a system or the identification of underlying factors causing an issue [48]. The conceptual model portrays a cohesive "mental image" of the problem situation, shaped by the perspectives and knowledge of the modellers. Subsequently, the formal model translates this conceptual model into mathematical symbols, computer languages, or a blend of both, facilitating problem examination and solution derivation. The outcome of the modelling-validation process constitutes the solution, forming the foundation for recommendations aimed at addressing the problem [48].

Models form the cornerstone for decision-making and resource allocation, underscoring the paramount importance of their validity to both creators and users [49]. Validation holds immense importance as it evaluates the alignment of the model with the actual system. Within the modelling-validation process, various validation tasks should be performed, encompassing conceptual, logical, experimental, and operational validation. [48].

Conceptual validity primarily focuses on evaluating the pertinence and accuracy of the information, theories, and scope underlying the conceptual model of the problem scenario. Achieving an adequate level of validity may require decision-makers and modellers to iteratively revisit the problem scenario until it is reached. This iterative approach is applicable to all types of validity. Logical validation, on the other hand, revolves around ensuring the formal model's capacity to accurately represent the problem scenario, addressing the potential elimination of any relevant variables or relationships from the formal model. Experimental validity, subsequently, concerns the precision and adequacy of the obtained solution. Finally, operational validation aids decision-makers in assessing the quality and applicability of solutions and recommendations regarding problem scenarios.

II. Data collection and construction of DEMATEL-FCM model of ERP success measurement criteria

The success of a DEMATEL-FCM model hinges on its construction and data quality. Since expert knowledge forms the foundation, gathering it effectively depends on the research field. This study leveraged literature review, interviews, and questionnaires to build and validate a DEMATEL-FCM model for ERP success measurement criteria. The construction and validation of the DEMATEL-FCM model involved the participation of three expert panels.

Stage 1: Expert Questionnaire Design (Validation Planning):

Five academic ERP researchers were recruited to design a comprehensive questionnaire. (Table I)

The questionnaire assessed the model's validity in three dimensions: conceptual, experimental, and operational, ensuring its reliability.

Questions built upon existing research (references [50] and [47] to maintain consistency.

Stage 2: Internal Assessment (Model Building & Conceptual/Experimental Validation):

A team of ten internal specialists (managers, engineers, and procurement professionals) with at least 5 years of experience was formed.

This team built the model and evaluated its conceptual and experimental validity.

Diverse expertise ensured a well-rounded perspective.

Stage 3: External Assessment (Operational Validation):

Ten external experts, averaging 20 years of ERP project oversight, were invited.

Their role was solely focused on assessing the model's effectiveness in real-world applications (operational validity).

Overall, the validation process involved three stages, each with a distinct purpose and group of experts.

As illustrated in Figure 1, the process of modelling and validating begins with identifying a problem situation. In this research, the identified problem situation pertains to the negative outcomes observed after the implementation of ERP systems. Subsequently, a conceptual framework was formulated to address this problem situation. The rationale behind this was to deduce that an analysis of the criteria used to measure ERP success could aid project managers in averting failures and mitigating adverse outcomes after implementation.

However, it became evident that these measurement criteria possess a complex structure, posing challenges in independently analysing and prioritizing them. Consequently, a decision was made to develop an efficient approach for scrutinizing ERP success criteria. At this juncture, the validity of the conceptual model for the identified problem situation was evaluated to ascertain whether the assumptions and theories underpinning the framework are pertinent and accurate enough to diminish negative outcomes during ERP implementation.

To achieve this, a panel of experts was solicited to respond to two specific questions designed to gauge their level of agreement with the conceptual validity of the model (see Table I). For each question, experts were required to rate their agreement on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The average agreement level of the experts for each question determined the final value of their agreement with the conceptual validity of the model, as indicated in the third column of Table I. The overall agreement of the experts with the model's validity is presented in the fourth column. The results in Table I reveal that the final value of the experts' agreement with the conceptual validity of the model is 4.5 out of 5, suggesting that the majority of experts hold a positive view regarding the validity of the conceptual framework.

TABLE I
DESIGNED QUESTIONS FOR THE MODEL VALIDATION

Validation	Questions	The average degree of the experts' agreement	The final value for the model's validity
Conceptual validity	Have the main criteria for evaluating ERP success and their interconnected relationships been accurately recognized?	4.61	4.5
	Does the conceptual framework encompass all essential elements that will mitigate negative consequences in forthcoming ERP implementations?	4.40	
Experimental validity	Are the conclusions drawn from the study sufficiently effective and precise?	4.56	4.63
		4.51	

	Do the outcomes of the dynamic analysis correspond to the observations made? Does addressing the identified root causes of ERP success reduce adverse outcomes in subsequent ERP implementations?	4.82	
Operational validity	What is the effectiveness and applicability of the proposed model in mitigating negative outcomes in future ERP implementations?	4.71	4.71

A similar methodology was employed to ascertain the experimental and operational validity of the model, consistent with a prior study [47].

Following this, to examine the identified problem situation and devise potential solutions, the conceptual framework is transformed into a formal model, as depicted in Figure1. This involves the construction of the model tailored for evaluating the criteria used to measure the success of ERP systems.

To build the DEMATEL-FCM model, it was essential to identify the criteria used to measure the success of ERP systems and understand the relationships between them. Through an extensive review of the literature, it became evident that numerous prior researchers had identified identical or similar criteria for assessing ERP success. Consequently, deliberate efforts were made to identify and eliminate duplicates, leading to the creation of an initial list of criteria for evaluating ERP success.

Following that, in-depth interviews were carried out with a second group of experts to identify the criteria for assessing ERP success and to understand the causal relationships among them. These interviews were conducted individually, with each expert spending an average of approximately 3 hours sharing their insights. The interviews were recorded and subsequently transcribed verbatim. The anecdotal data gathered from these interviews served as a valuable resource for analysing the findings of the study.

In the interviews, the initial list served as a reference for experts to pinpoint the factors essential for gauging ERP success. Experts had the flexibility to include or exclude criteria from the preliminary list based on their appropriateness. Ultimately, a total of 15 criteria were established to measure ERP success, as detailed in Table II.

TABLE II
IDENTIFIED ERP SUCCESS MEASUREMENT CRITERIA

Label	ERP success measurement criteria	Description
S1	Enterprise Architecture Improvement	With the implementation of ERP, there should be improvements in the enterprise architecture.
S2	Business Process Improvement	The implementation of ERP will lead to improvement in the model of the business processes.
S3	Employee Involvement Improvement	The level of Employee Involvement should improve significantly.
S4	Legacy System Replacement	The amount of engagement with an ERP system should be greater than with legacy systems.
S5	E-business and E-Commerce Enhancement	With the establishment of ERP, the e-commerce and e-business models of the organization should be improved.
S6	Cost Reduction Enhancement	The cost of products and services should be reduced significantly as waste is reduced.
S7	Customer Service Improvement (Service Quality)	The level of customer service and data analysis related to each customer should improve significantly.
S8	Information Management & Quality Improvement (Information Quality)	Due to the nature of integration in the ERP model, data quality must be significantly improved in terms of accuracy, completeness, and up-to-dateness.
S9	Workgroup Improvement (Workgroup impact)	Due to the establishment of the process model instead of the tasks of the organizational units, the communication between the interdepartmental employees improves.

S10	Management Report Quality and Business Intelligence Improvement	With the establishment of ERP, the quality of management reports will be significantly improved in terms of the power of analysis and the speed of its delivery.
S11	Competitive Model Improvement	The competitiveness of the organization will increase because its requirements have already been provided.
S12	Earnings Per Share (EPS) Improvement	Due to the value of the ERP system and its results will greatly increase the value of the organization's intangible assets. Therefore, with the establishment of ERP, the value of the shareholders will be more valued.
S13	Key Performance Indicators (KPI) Measurement Improvement	By using extensive data and information and the ability to combine them in a calculation engine, the ability to define more realistic, accurate, and up-to-date KPIs is provided.
S14	Decision-Making Model Improvement	To improve decision-making models, the definition engine of formulas and the definition of complex queries are necessary, which are prepared by establishing a suitable ERP.
S15	Knowledge Management Improvement	With the establishment of ERP, the background for better knowledge management at the enterprise level will be provided.

These criteria are categorized into seven groups, encompassing strategic, human resources, information technology, commercial, financial, customer relationship, and management aspects (refer to Table III).

TABLE III
CATEGORIZE OF ERP SUCCESS MEASUREMENT CRITERIA

Label	**ERP success measurement criteria**	**Classification**
S1	Enterprise Architecture Improvement	Strategic
S2	Business Process Improvement	Strategic
S3	Employee Involvement Improvement	Human Resources (HR)
S4	Legacy System Replacement	Information Technology (IT)
S5	E-business and E-Commerce Enhancement	Commercial
S6	Cost Reduction Enhancement	Financial
S7	Customer Service Improvement (Service Quality)	Customer Relationship Management (CRM)
S8	Information Management & Quality Improvement (Information Quality)	Information Technology (IT)
S9	Workgroup Improvement (Workgroup impact)	Human Resources (HR)
S10	Management Report Quality and Business Intelligence Improvement	Information Technology (IT)
S11	Competitive Model Improvement	Strategic
S12	Earnings Per Share (EPS) Improvement	Financial
S13	KPI Measurement Improvement	Management
S14	Decision-Making Model Improvement	Management
S15	Knowledge Management Improvement	Management

The experts in the second panel were tasked with assessing the extent of causal connections among various concepts. This assessment was conducted linguistically, utilizing five specified linguistic variables illustrated in Figure 2. The aggregation of experts' ideas was accomplished by employing the Mamdani fuzzy inference method and a summation operator. Subsequently, the fuzzy outputs obtained were subjected to defuzzification using the centre of gravity (COG) method.

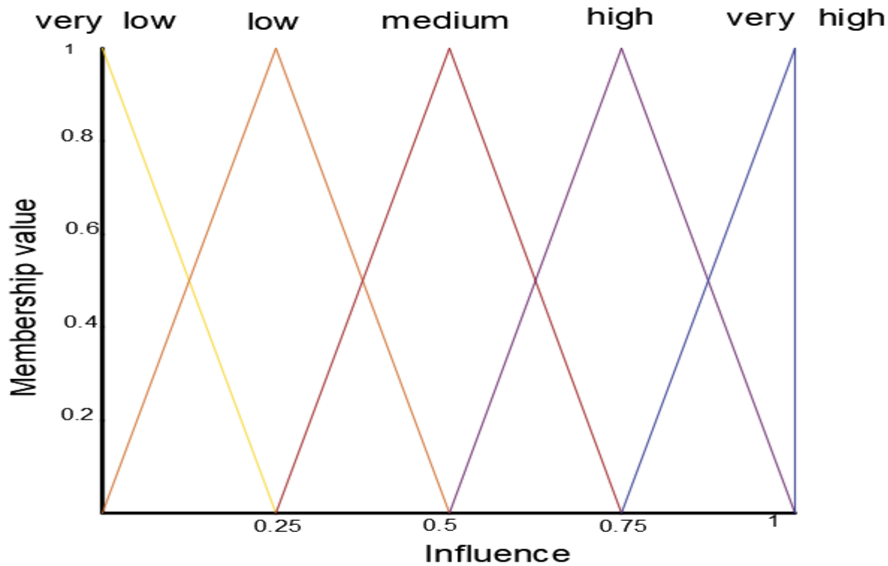


FIGURE 2
GRAPHS OF THE MEMBERSHIP FUNCTION USED FOR THE FIVE LINGUISTIC VARIABLES

The process of consolidating the experts' opinions to determine the weight of the interrelationship between two concept nodes is detailed below. Let's consider A and B as two criteria for measuring ERP success, and 10 experts were tasked with determining the weight of the interrelationship between A and B. Among the experts, two chose 'very high,' four chose 'high,' and four chose 'medium.' The weight associated with each linguistic variable is calculated by dividing the count of each linguistic variable by the total number of experts. Fuzzy IF-THEN rules are then employed to express the experts' opinions. The resulting three IF-THEN rules are as follows:

IF (Criteria A is activated), THEN (Criteria B is classified as Very High) with a weight of 0.2.

IF (Criteria A is activated), THEN (Criteria B is classified as High) with a weight of 0.4.

IF (Criteria A is activated), THEN (Criteria B is classified as Medium) with a weight of 0.4.

The term ON, in linguistic terms, is a binary variable that signifies the existence of the node.

Figure 3 to 6 depict the procedure of consolidating diverse perspectives from various experts. The aggregated fuzzy number representing experts' opinions, as depicted in Figure 6, is ultimately subjected to defuzzification using the centre of gravity method. This process determines the weight of the interrelationship between factors A and B.

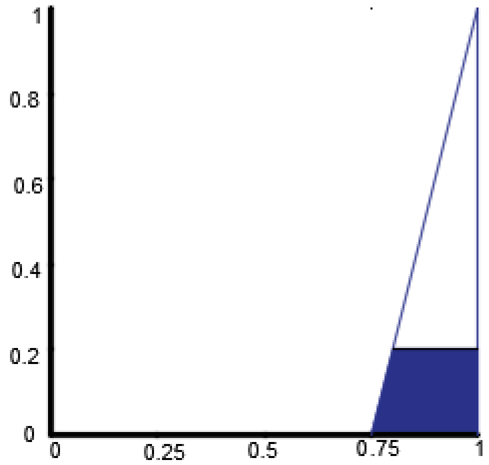


FIGURE 3
THE FUZZY OUTPUT GENERATED FROM THE INITIAL RULE.

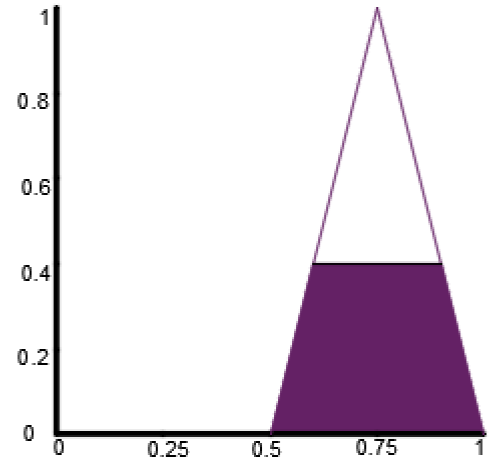


FIGURE 4
THE FUZZY OUTPUT OBTAINED FROM THE SECOND RULE.

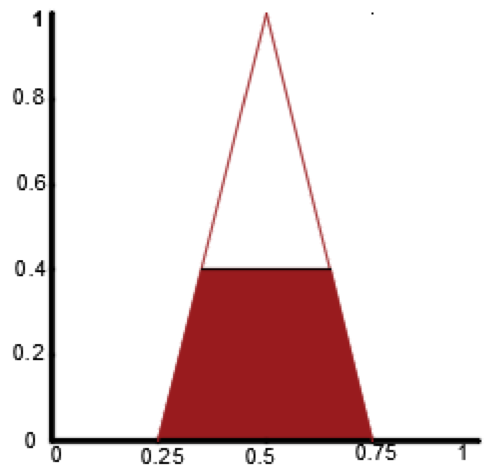


FIGURE 5
THE FUZZY OUTPUT RESULTING FROM THE THIRD RULE

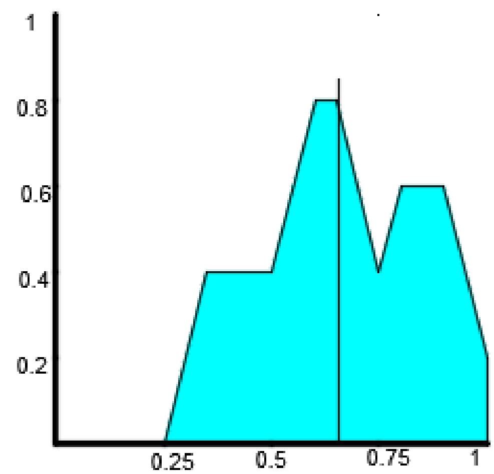


FIGURE 6
THE AGGREGATED FUZZY NUMBER RESULTING FROM THE EXPERTS' OPINIONS

The approach described above was employed to ultimately ascertain the weights of the interrelationships among various concepts. Table IV displays the initial direct relation matrix, indicating the respective weights of the relationships between different concepts.

TABLE IV
DIRECT RELATION MATRIX

Si	**S**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**
S1	0	0.70	0	0	0	0	0	0.54	0	0	0	0	0	0	0
S2	0	0	0.75	0	0.81	0.25	0	0	0	0	0	0	0	0	0
S3	0	0	0	0.31	0	0	0.42	0	0.78	0	0	0	0	0	0
S4	0	0	0	0	0	0	0	0.40	0	0	0	0	0	0	0
S5	0	0	0	0	0	0	0	0	0	0	0.85	0	0	0	0
S6	0	0	0	0	0	0	0	0	0	0	0.71	0	0	0	0
S7	0	0	0	0	0	0	0	0	0	0	0.66	0	0	0	0
S8	0	0	0	0	0	0	0	0	0.29	0.31	0	0	0.36	0	0

S9	0	0	0	0	0	0	0.31	0	0	0	0	0	0	0	0.25
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.61	0.55
S1	0	0	0	0	0	0	0	0	0	0	0	0.85	0	0	0
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.57	0
S1	0	0	0	0	0	0	0	0	0	0	0.44	0	0	0	0
S1	0	0	0	0	0	0	0	0	0	0	0.56	0	0	0	0

In the subsequent phase, the normalized direct-relation matrix (Table V) was derived from the original direct-relation matrix. Following that, the total-relation matrix (see Table VI) was obtained.

TABLE V
NORMALIZED DIRECT-RELATION MATRIX

X	**S**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**
S1	0	0.38	0	0	0	0	0	0.29	0	0	0	0	0	0	0
S2	0	0	0.41	0	0.44	0.14	0	0	0	0	0	0	0	0	0
S3	0	0	0	0.17	0	0	0.23	0	0.42	0	0	0	0	0	0
S4	0	0	0	0	0	0	0	0.22	0	0	0	0	0	0	0
S5	0	0	0	0	0	0	0	0	0	0	0.46	0	0	0	0
S6	0	0	0	0	0	0	0	0	0	0	0.39	0	0	0	0
S7	0	0	0	0	0	0	0	0	0	0	0.36	0	0	0	0
S8	0	0	0	0	0	0	0	0	0.15	0.17	0	0	0.19	0	0
S9	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0.14
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.30
S1	0	0	0	0	0	0	0	0	0	0	0	0.46	0	0	0
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.31	0
S1	0	0	0	0	0	0	0	0	0	0	0.24	0	0	0	0
S1	0	0	0	0	0	0	0	0	0	0	0.30	0	0	0	0

TABLE VI
TOTAL-RELATION MATRIX

T	**S**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**
S1	0	0.38	0.15	0.02	0.17	0.05	0.05	0.30	0.11	0.05	0.14	0.06	0.06	0.03	0.03
S2	0	0	0.41	0.07	0.44	0.14	0.12	0.01	0.18	0.00	0.31	0.14	0.00	0.00	0.02
S3	0	0	0	0.17	0	0	0.30	0.03	0.43	0.00	0.13	0.06	0.00	0.00	0.06
S4	0	0	0	0	0	0	0.00	0.22	0.03	0.03	0.01	0.00	0.04	0.02	0.01
S5	0	0	0	0	0	0	0	0	0	0	0.46	0.21	0	0	0
S6	0	0	0	0	0	0	0	0	0	0	0.39	0.18	0	0	0
S7	0	0	0	0	0	0	0	0	0	0	0.36	0.16	0	0	0
S8	0	0	0	0	0	0	0.02	0	0.15	0.17	0.06	0.02	0.19	0.12	0.07
S9	0	0	0	0	0	0	0.17	0	0	0	0.10	0.04	0	0	0.14
S1	0	0	0	0	0	0	0	0	0	0	0.17	0.08	0	0.33	0.30
S1	0	0	0	0	0	0	0	0	0	0	0	0.46	0	0	0
S1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0	0	0	0	0	0	0	0	0	0	0.07	0.03	0	0.31	0
S1	0	0	0	0	0	0	0	0	0	0	0.24	0.11	0	0	0
S1	0	0	0	0	0	0	0	0	0	0	0.30	0.14	0	0	0

The total correlation matrix (T), presented in Table VII, served as the input correlation matrix for the FCMapper software. All matrix elements were constrained to the interval [-1, 1], representing the standardized strength of pairwise relationships between factors. To enhance interpretability and focus on statistically meaningful interactions, a thresholding procedure was implemented. The threshold value was operationally defined as the arithmetic mean (0.048) of all matrix T elements [51]. Correlation values below this critical threshold were nullified ($|r| < 0.048 \rightarrow 0$), effectively generating a refined adjacency matrix that preserves only the most substantive relationships while eliminating negligible effects. Figure7 shows the FCM model of the ERP success criteria.

TABLE VII
FCM CORRELATION MATRIX

T	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
S1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	0
S2	0	0	1	1	1	1	1	0	1	0	1	1	0	0	0
S3	0	0	0	1	0	0	1	0	1	0	1	1	0	0	1
S4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
S5	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
S6	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
S7	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
S8	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1
S9	0	0	0	0	0	0	1	0	0	0	1	1	0	0	1
S10	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
S11	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
S12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S13	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
S14	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
S15	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0

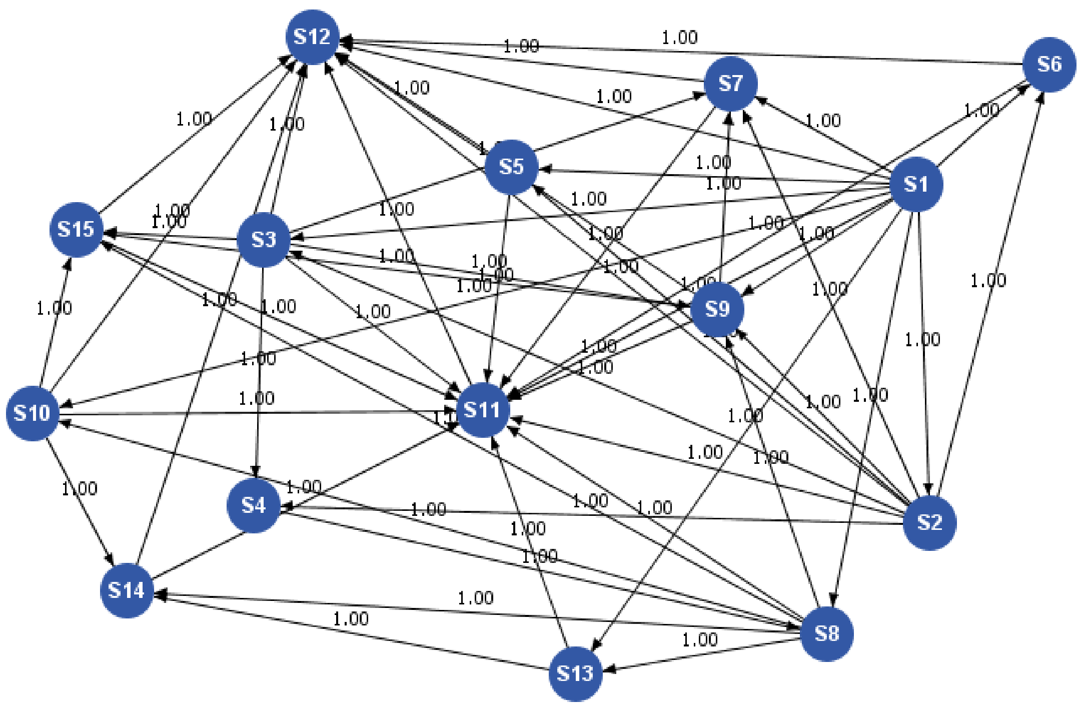
Table VIII outlines the structural details of the FCM model, which comprises 15 ERP success measurement criteria linked by 53 causal relationships. Of these criteria:

- 13 functions as standard nodes with bidirectional influences (receiving and exerting impacts).
- 1 criterion operates as a transmitter node, acting as an independent driver that influences others without being affected by external factors.
- 1 serves as a receiver node, solely receiving influences from the network without propagating.

TABLE VIII
GENERAL INFORMATION OF THE FCM MODEL

Ordinary connections	**Number of receivers**	**Number of transmitters**	**The total amount of connections**	**Number of Criteria**	**Density**
13	1	1	53	15	0.24

III. Overview of the Proposed Method



FIGUR 7
FCM MODEL OF THE ERP SUCCESS CRITERIA

To provide a clear understanding of the implementation process, the proposed hybrid DEMATEL-FCM methodology is structured into a sequence of interconnected steps. These steps guide the transition from the identification of ERP success criteria to expert evaluation, causal analysis, dynamic modelling, and scenario simulation. By systematically integrating qualitative expert knowledge with quantitative modelling tools, the approach facilitates both structural insight and predictive capability. The following flowchart (Figure 8) illustrates the overall procedure followed in this study.

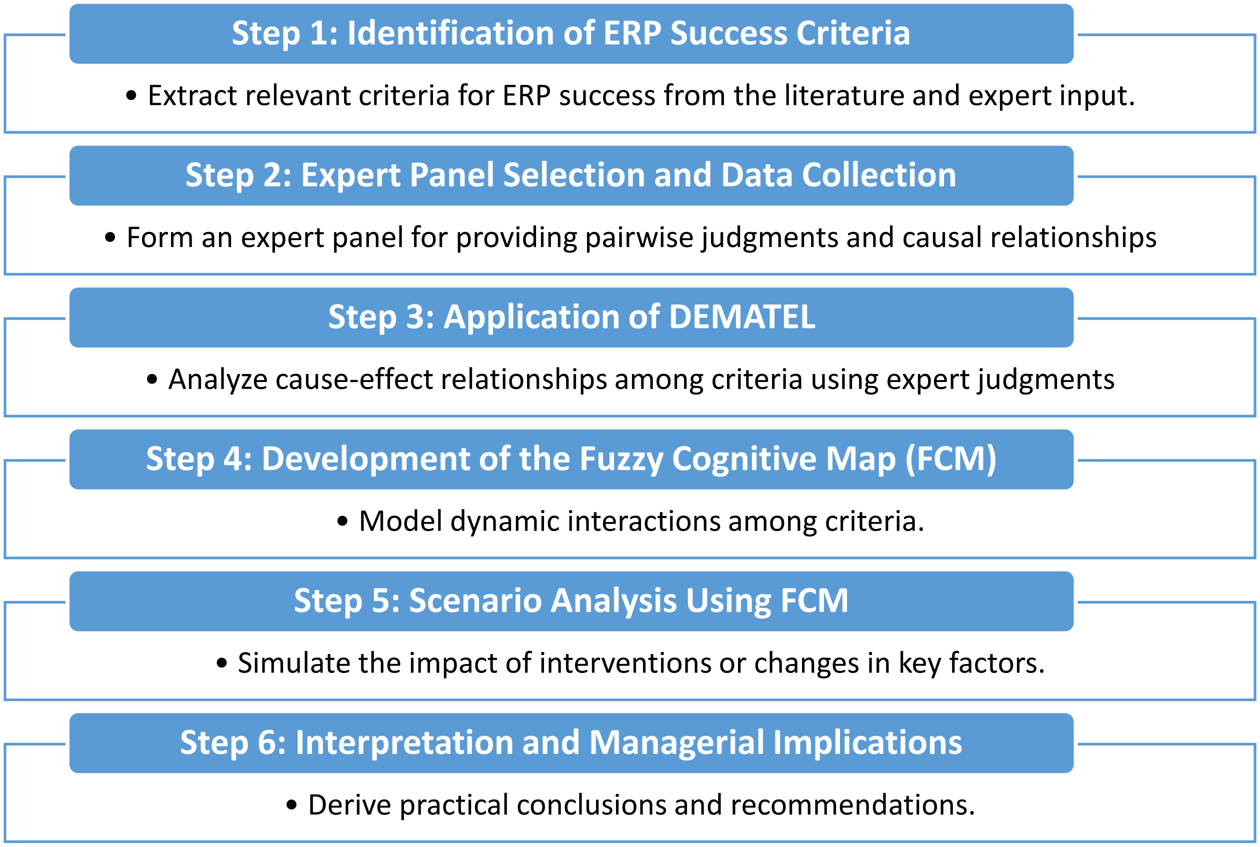


FIGURE 8
FLOWCHART OF THE PROPOSED DEMATEL-FCM METHODOLOGY FOR ERP SUCCESS EVALUATION

The following sections give the results of the dynamic analysis. Also, the experimental and operational validity evaluation of the model is explained.

RESULTS AND DISCUSSION

This section provides a comprehensive explanation of the analysis conducted on the criteria for measuring the success of ERP along with a discussion of the obtained results.

Table IX displays the resultant values of "D + R" and "D - R" for different factors. Additionally, the identified influential factors are ranked and examined through a two-dimensional grid of "D + R" and "D-R," depicted in Figure9. The calculated "D + R" values for these factors vary between 0.67 and 3.25. A higher value indicates more pronounced interactions with other factors in the system, thereby highlighting the relative significance of each criterion. Notably, Competitive Model Improvement attains the highest "D + R" value of 3.25, indicating its significant interactions with other factors affecting ERP success. Based on the findings, the top five crucial factors comprise Competitive Model Improvement, Business Process Improvement, Employee Involvement Improvement, Earnings Per Share (EPS) Improvement, and Enterprise Architecture Improvement.

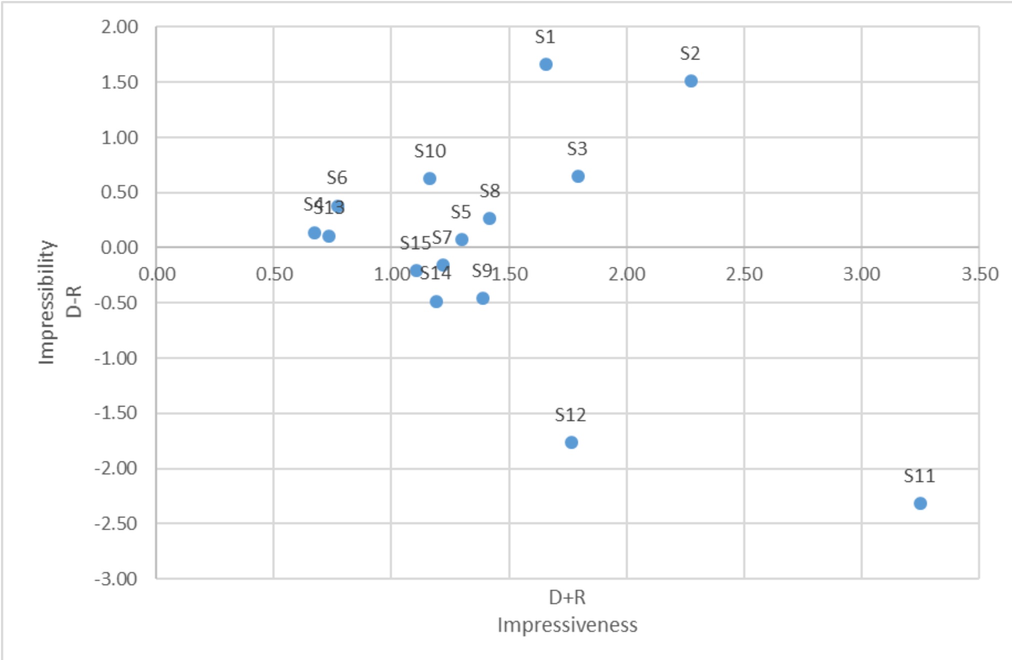


FIGURE 9
THE GRID OF D + R AND D-R (THE INFLUENCE RELATION MAP (IRM)) IN A TWO-DIMENSIONAL LAYOUT DEPICTING THE ERP SUCCESS MEASUREMENT CRITERIA.

TABLE IX
RANKING OF ERP SUCCESS MEASUREMENT CRITERIA BASED ON DEMATEL ANALYSIS RESULTS

No.	Factor description	Rank	D	Rank	R	Rank	D+R	Rank	D-R
1	Enterprise Architecture Improvement	2	1.66	15	0.00	5	1.66	1	1.66
2	Business Process Improvement	1	1.89	10	0.38	2	2.27	2	1.51
3	Employee Involvement Improvement	3	1.22	9	0.57	3	1.79	3	0.64
4	Legacy System Replacement	13	0.41	12	0.27	15	0.67	7	0.14
5	E-business and E-Commerce Enhancement	6	0.68	7	0.61	8	1.30	9	0.07
6	Cost Reduction Enhancement	7	0.58	14	0.20	13	0.77	5	0.38
7	Customer Service Improvement	8	0.53	5	0.69	9	1.22	10	-0.16
8	Information Management & Quality Improvement	5	0.84	8	0.58	6	1.42	6	0.26
9	Workgroup Improvement	9	0.47	3	0.93	7	1.39	12	-0.46
10	Management Report Quality and Business Intelligence Improvement	4	0.89	13	0.27	11	1.16	4	0.62
11	Competitive Model Improvement	10	0.47	1	2.78	1	3.25	15	-2.32
12	Earnings Per Share (EPS) Improvement	15	0.00	2	1.77	4	1.77	14	-1.77
13	Key Performance Indicators (KPI) Measurement Improvement	12	0.42	11	0.31	14	0.74	8	0.11
14	Decision-Making Model Improvement	14	0.35	4	0.84	10	1.19	13	-0.48
15	Knowledge Management Improvement	11	0.45	6	0.66	12	1.11	11	-0.21

Table IX also showcases the values of "D-R," which signify the potency of each factor's effect. A higher "D-R" value indicates that the factor holds greater sway over other factors than the influence it receives from them. These calculated "D-R" values aid in categorizing the influencing factors into cause-and-effect groups. A positive "D-R" value indicates the cause group, while a negative value indicates the effect group, as illustrated in Table X. The factor with the highest "D-R" value holds the most significant direct impact on the others [52].

TABLE X
SORTING THE CRITERIA INTO CATEGORIES OF CAUSAL AND EFFECT GROUPS DEPENDING ON THE "D-R" VALUE

Cause group (D-R>0)	Effect group (D-R<0)
Enterprise Architecture Improvement	Customer Service Improvement
Business Process Improvement	Workgroup Improvement
Employee Involvement Improvement	Competitive Model Improvement
Legacy System Replacement	Earnings Per Share (EPS) Improvement
E-business and E-Commerce Enhancement	Decision-Making Model Improvement
Cost Reduction Enhancement	Knowledge Management Improvement
Information Management & Quality Improvement	
Management Report Quality and Business Intelligence Improvement	
Key Performance Indicators (KPI) Measurement Improvement	

According to the obtained findings, Enterprise Architecture Improvement, Business Process Improvement and Employee Involvement Improvement have the highest D-R values of 1.66, 1.51, and 0.64, respectively. This indicates that these factors exert the most significant influence on ERP success. These factors are identified as root causes and wield considerable impact on other success-related variables. Consequently, it's imperative for project managers to prioritize addressing these root causes, as they are more manageable. The results highlight that enhancing Enterprise Architecture Improvement and Business Process Improvement stands out as one of the most effective strategies for improving ERP success.

In contrast, factors displaying a negative "D-R" value are primarily shaped by external influences, as the total effect they exert on other factors (D) is lesser than the impact they receive from external factors (R). In the present study, as illustrated in Figure9, the "Competitive Model Improvement" exhibits the lowest "D-R" value, standing at -2.32. This implies that this factor is an impressible factor and highly susceptible to external influences and isn't easily manageable or improvable independently. The rationale behind this is that Competitive Model Improvement underlying root causes such as Enterprise Architecture Improvement, Business Process Improvement, and so forth.

Following the identification and causal analysis of ERP success factors using the DEMATEL method, which effectively reveals the direction and strength of influence among variables, the next phase of the study employed Fuzzy Cognitive Mapping (FCM) to simulate and evaluate the dynamic behavior of the system. As shown in Table XI, the FCM results highlight the outdegree, indegree, and centrality values for each concept. Notably, factors such as S1 (Enterprise Architecture Improvement) (Outdegree = 11.00, Indegree = 0.00) and S2 (Business Process Improvement) (Outdegree = 8.00, Indegree = 1.00) emerged as dominant causal drivers, consistent with their classification as root causes in the DEMATEL framework. Conversely, elements like S11 (Competitive Model Improvement) and S12 (Earnings Per Share (EPS) Improvement) exhibited the highest indegree values (12.00 and 11.00, respectively), suggesting their role as outcome variables highly influenced by upstream components in the system.

The consistency between the DEMATEL and FCM analyses reinforces the structural integrity of the proposed ERP success model. Moreover, this combined approach provides a robust foundation for scenario-based analysis. By strategically altering the activation levels of high-outdegree nodes (e.g., S1, S2), or simulating interventions on feedback-sensitive nodes (e.g., S11, S12), multiple policy scenarios can be developed. These scenarios enable the evaluation of potential improvements, risk mitigations, or investment priorities under different decision contexts. The following such simulation scenarios, designed to examine how changes in key causal variables influence overall system outcomes and the success trajectory of ERP implementation and maintenance efforts.

TABLE XI
FCM RESULTS

SYMBOLS	OUTDEGREE	INDEGREE	CENTRALITY
S1	11.00	0.00	11.00
S2	8.00	1.00	9.00
S3	6.00	2.00	8.00
S4	1.00	2.00	3.00
S5	2.00	2.00	4.00
S6	2.00	2.00	4.00
S7	2.00	4.00	6.00
S8	6.00	2.00	8.00
S9	4.00	4.00	8.00
S10	4.00	2.00	6.00
S11	1.00	12.00	13.00
S12	0.00	11.00	11.00
S13	2.00	2.00	4.00
S14	2.00	3.00	5.00
S15	2.00	4.00	6.00

Scenario Analysis: Impact of Deactivating Primary Driving Factors

To further validate the insights derived from the DEMATEL analysis, a scenario-based simulation was conducted using Fuzzy Cognitive Mapping (FCM). In this scenario, two of the most influential driving factors identified earlier—Enterprise Architecture Improvement (S1) and Business Process Improvement (S2)—were deliberately deactivated (i.e., their initial activation values were set to zero). The goal was to investigate the system's dynamic behaviour in the absence of these key enablers and assess the subsequent impact on the overall ERP success indicators.

The simulation results are summarized in Table XII, comparing the steady-state activation levels of all factors before and after the deactivation of S1 and S2. As evident from the results, the exclusion of these two root-cause factors resulted in a considerable drop in the activation values of multiple dependent criteria, especially those located in the intermediate and output layers of the cognitive map.

For instance, the values for S3 (Employee Involvement Improvement), S4 (Legacy System Replacement), S5 (E-business and E-Commerce Enhancement), and S6 (Cost Reduction Enhancement) dropped from approximately 0.91 to around 0.65. Likewise, indicators such as S7 (Information Management Improvement) and S9 (Decision-Making Model Improvement) experienced significant reductions in their steady-state outputs. In contrast, the effect on terminal output factors—such as S11 (Customer Service Improvement), S12 (EPS Improvement), S14 (KPI Measurement Improvement), and S15 (Management Report Quality)—was less pronounced, although still noticeable.

These results reinforce the central role of S1 and S2 as foundational drivers in the ERP success ecosystem. Their absence not only weakens the performance of directly connected criteria but also propagates diminishing effects throughout the network due to the interconnected nature of the system.

From a managerial perspective, this scenario illustrates that insufficient focus on enterprise architecture and process redesign can compromise the entire ERP success trajectory. Therefore, sustained investment in architectural improvements and business process alignment should be prioritized to secure long-term performance gains in ERP implementation projects.

TABLE XII
THE SIMULATION RESULTS

Node	**Scenario 1**	**Results of Scenario 1**	**Scenario 2**	**Results of Scenario 2**
S1	1.00	0.65905	0	0.00
S2	1.00	0.813434061	0	0
S3	1.00	0.915940008	1.00	0.659046068

S4	1.00	0.934884383	1.00	0.813434061
S5	1.00	0.915940008	1.00	0.659046068
S6	1.00	0.915940008	1.00	0.659046068
S7	1.00	0.98741337	1.00	0.924236357
S8	1.00	0.925492	1.00	0.839254
S9	1.00	0.986620	1.00	0.918067
S10	1.00	0.924793	1.00	0.843234
S11	1.00	0.999993	1.00	0.999909
S12	1.00	0.999985	1.00	0.999819
S13	1.00	0.924793	1.00	0.843234
S14	1.00	0.977071	1.00	0.970582
S15	1.00	0.991373	1.00	0.985873

It is to be noted that previous studies [53, 54, 55] considered Business Process Improvement (S2 in our notation) as the only factor affecting ERP success implementation but the present study elaborates the interaction among BPR and a comprehensive set of affecting factors as summarized in Table II.

To assess the model's experimental validity, the second group of experts responded to the questions outlined in Table I, resulting in a final score of 4.4 out of 5. This score indicates strong affirmation among most experts regarding the model's experimental validation. Moving forward in the modelling-validation process, the operational validity of the proposed model was evaluated. The third group of experts answered designated questions aimed at assessing operational validity, yielding a final score of 4.5 out of 5, indicating a high level of agreement among experts regarding the model's practicality for managing ERP success.

Upon analysis of the findings, it becomes evident that the intricate interdependencies among the various factors influencing ERP success necessitate a structured approach for understanding their roles and impacts. The DEMATEL method provides a systematic framework to uncover the causal relationships and prioritize the criteria based on their degree of influence and dependence. However, while DEMATEL is highly effective in identifying and structuring these cause-effect relationships, it does not capture the dynamic behavior of the system over time. To address this limitation, Fuzzy Cognitive Mapping (FCM) is incorporated to simulate how changes in key influencing factors propagate through the network and impact the overall system outcomes. The integration of DEMATEL and FCM enables both a qualitative understanding of interrelationships and a quantitative assessment of potential future scenarios, offering a more comprehensive tool for evaluating ERP success under dynamic conditions.

The proposed DEMATEL-FCM method offers significant improvements over traditional methods such as AHP, ANP, or fuzzy TOPSIS for ERP success evaluation. Unlike these methods, which focus on linear relationships or pairwise comparisons, the integration of FCM with DEMATEL enables a more dynamic representation of complex, non-linear interactions among ERP success criteria [41].This method not only identifies the direct and indirect relationships between criteria but also accounts for their varying degrees of influence, which enhances the precision of the analysis [56].Moreover, the fuzzy approach incorporated into FCM allows for handling uncertainty and imprecision in expert judgments, which is a common challenge in ERP evaluations [43].This combination provides a more holistic and robust framework for understanding ERP success factors, offering valuable insights for both theoretical and practical applications.

CONCLUSION AND REMARKS

The research community emphasizes the necessity of effective management in overcoming the challenges inherent to ERP implementation. Achieving success in such projects requires a comprehensive understanding of the factors influencing ERP outcomes, not as isolated elements, but as an interconnected network with dynamic interdependencies. Traditional studies often overlook these relationships, treating success criteria as standalone metrics. This study addressed this limitation by adopting an integrated analytical framework that combines the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method with Fuzzy Cognitive Mapping (FCM), thereby capturing both structural and dynamic aspects of ERP success.

Initially, fifteen ERP success criteria were identified through a systematic literature review and expert interviews. Using the DEMATEL method, the interrelationships among these criteria were mapped and analysed. The model was validated through conceptual, experimental, and operational stages. The results revealed that Enterprise Architecture Improvement, Business

Process Improvement, and Employee Involvement Improvement had the highest "D-R" values, positioning them as root causes with strong influence over the ERP success system. In contrast, Competitive Model Improvement and EPS Improvement appeared as highly dependent outcomes with low "D-R" values, suggesting their limited manageability without addressing upstream factors.

While DEMATEL provided insight into the causal structure, it lacked the ability to simulate system dynamics under varying conditions. To address this, Fuzzy Cognitive Mapping (FCM) was employed. The FCM results, consistent with DEMATEL findings, highlighted Enterprise Architecture Improvement (S1) and Business Process Improvement (S2) as dominant drivers with the highest outdegree values. Conversely, Competitive Model Improvement (S11) and EPS Improvement (S12) emerged as outcome variables, having the highest indegree values.

To explore the implications of these relationships, scenario-based simulations were conducted by altering or deactivating key drivers. For instance, in one scenario, deactivating S1 and S2 led to a significant drop in activation levels across multiple downstream factors, demonstrating their foundational role in the ERP success architecture.

This integrated DEMATEL-FCM approach allows decision-makers to both prioritize interventions based on structural influence and simulate their effects under different operational scenarios. It empowers managers with a more systemic and dynamic understanding of ERP success, moving beyond static ranking of factors.

The main limitation of this study lies in its reliance on expert judgment, which introduces a degree of subjectivity to the analysis. Although consistency checks and expert diversity were employed to mitigate this issue, future research could incorporate larger datasets and real-time system data to enhance robustness. Additionally, while the model was tested in a single manufacturing firm, the methodology is transferable and can be applied across different industries with proper contextual adjustments.

From a scientific and practical perspective, this research contributes by:

(i) Identifying and structuring ERP success criteria through the DEMATEL method;

(ii) Simulating their systemic interactions using FCM to reveal dynamic behaviours; and

(iii) Demonstrating the feasibility and value of the combined approach in a real-world ERP context.

Ultimately, this study advocates for a shift toward holistic and adaptive success management in ERP projects—where cause-effect structures are not only understood but actively leveraged for informed, strategic decision-making.

DECLARATIONS

Conflict of interest: Both the authors declare that they have no known conflicts of interest.

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