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EVALUATION OF QUALITATIVE ATTRIBUTES OF THE ENTERPRISE ARCHITECTURE USING A COMBINATION OF DEMATEL AND FUZZY-ANP

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ABSTRACT

With an increase in the number of qualitative attributes that affect the enterprise architecture (EA) analysis, shareholders need an approach capable of quantitatively evaluating these attributes. Despite the development of many EA evaluation approaches, they often concentrated on an already implemented EA plan. As a result, they cannot be used for the assessment of projects underway. Moreover, some approaches do not consider the relationship between qualitative criteria and the mechanism of their effect on each other. This study proposes a new approach to assess qualitative attributes of enterprise architecture. It identifies the relationship between qualitative attributes and their effects on each other using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique. The priority criteria are then weighted using the fuzzy Analytic Network Process (ANP). Finally, the total scores of criteria are specified based on the enterprise architecture evidence and outputs. A case study is used to evaluate the proposed approach. To this end, the master plan of information and communication technology of municipalities in Iran is selected. The quality attribute of security is assessed and quantified using the proposed approach. The case study shows that the current status of the investigated enterprise fulfills 65% of the ideal qualitative attributes of security. Moreover, a comparison with previous works indicates the superiority of the proposed approach in terms of important factors in multi criteria decision making.

Keywords : enterprise architecture; enterprise architecture evaluation; qualitative attributes; DEMATEL; Fuzzy-ANP;

1. INTRODUCTION

The enterprise architecture (EA) is a framework for the development and management of enterprise information technology resources to achieve enterprise objectives [1]. Architecture at the enterprise level is called the EA, which provides a comprehensive view of the enterprise [2]. The implementation of EA provides all the required information and samples concerning the current status of the enterprise, its utilities, and transition to it. Therefore, the suitable context for informed and correct decision making is provided such that these decisions encompass the relationships between people, and enterprise technology processes and approaches [3]. As a result, among the greatest achievement of EA is that it allows for the assessment of current enterprise status, and identification, analysis, evaluation, and adoption of appropriate architecture solutions, or generally the ability to assess EA.

Regarding the high cost of enterprise decision implementation, continuous assessment of different solutions allows for the evaluation of different approaches to various dimensions based on its current status and facilitates the adoption of the best solution. Moreover, the assessment of the current status of the enterprise can provide important information about the enterprise achievements leading to the adoption of more accurate decisions in favor of the enterprise improvement.

With an increase in the number of qualitative attributes that affect the EA analysis, shareholders need an approach capable of quantitatively evaluating these attributes. There are many different EA assessment approaches with various abilities, contributing to the enterprise decision-making process. These approaches often officially investigate the EA samples and specify analysis parameters [2]. The EA assessment approaches are carried out in different phases and steps. They mainly concentrate on the identification and detection of whether the EA can bring about desirable achievements concerning qualitative attributes.

Despite the development of many EA evaluation approaches, they often concentrated on an already implemented EA plan. As a result, they cannot be used for the assessment of projects underway. Moreover, some

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approaches do not consider the relationship between qualitative criteria and the mechanism of their effect on each other.

The current study intended to determine the relationships between criteria and the way they affect each other. Moreover, an effort is made to eliminate probable human errors and output uncertainties in each implementation of the algorithm.

The second section of this paper addresses the initial concepts and definitions. The third section reviews the related works. The fourth section describes the proposed approach, in detail. It also evaluates the proposed approach via a case study. The fifth section compares the proposed approach with other quality attribute assessment techniques. The final section presents the results and future works.

2. PRELIMINARIES

The initial concepts and definitions are described in the following. They form the basis to introduce the proposed approach.

2.1 Master plan of information and communication technology

Nowadays, information and communication technology (ICT) plays an important role in almost every aspect of an organization's operations. The importance of this role is increasing, such that ICT is becoming one of the canonical points of attention, investment, and planning in the organizations. The effective use of ICT requires a master plan. Many organizations have prepared or are in the process of preparing their ICT master plan. Such plans should be technically investigated to check their consistency with the EA. In order to avoid wasting the valuable sources and preventing the monetary loss of enterprises, the ICT master plans should be revised or improved, if necessary [4].

2.2 Qualitative attributes of EA

Among the major requirements in the EA process are qualitative (systemic) attributes, which should be presented through qualitative scenarios. These attributes are adopted to suit each enterprise, and every decision can result in the optimization of some of them relative to the others [5].

Utility is an attribute that should be considered by the enterprise as a long-term or short-term objective. Because enterprises are regarded as systems, attributes of complex systems are also related to complex enterprises and can be added to a definable set of utilities for each enterprise [6]. As a result, two different attributes can be considered for the enterprises:

A. Systemic attributes: these attributes have specific and standard definitions in different areas, specifically in the field of software. Some of these attributes are adopted to suit each enterprise, and every decision can result in the optimization of some of them relative to the others [5]. Some of these attributes are developability, flexibility, maintainability, security, interoperability, and stability. In some cases, these attributes are called qualitative attributes [2], which are also used in the current study.

B. Soft attributes: these attributes are specific to each enterprise system. They are considered as the human dimension of the enterprise system. Some of these attributes are trust, loyalty, and enterprise intelligence [6].

There are standard definitions of qualitative attributes in the literature [5,7], mainly in the field of software. This area uses general and concrete scenarios to define qualitative attributes [5]. With respect to enterprises, different qualitative attributes and criteria have been presented in the literature based on the standard definitions.

2.3 Enterprise information security

Today, information is the most valuable enterprise asset and can be considered as its commodity product. The development of information systems brings many benefits on one hand and may cause irreparable damages concerning information security on the other hand.

Ensuring information security in an enterprise is not possible all at once, and requires a continuous immunization cycle including planning, implementation, evaluation, and modification. As a result, supplying an information security system that covers all information-related areas is not possible. According to Kiesner's definition [4], enterprise information security architecture is an integrated security design that specifically defines the risks of an environment or scenario and describes relevant security controls and where they should be utilized.

2.4 Information security standards

There are different information and communication technology standards, which contribute to information security. However, some of these standards have not been adopted by organizations for a variety of reasons. In 2009, eleven primary control areas, called EC-11, were introduced. These controls should be implemented by

organizations to guarantee the information security. The comparison between four common standards, namely ITIL, PCI DSS, ISO27001, and COBIT, with respect to such controls shows the superiority of ISO27001 [8,9]. Thus, this standard serves as one of the basis to extract the security criteria used in this research.

2.5 Analytic network process

For the first time, Sa'ati developed the analytic network process (ANP), as one of the most applicable techniques used in multidimensional decision making [10]. In fact, the ANP is the more general form of the analytic hierarchy process (AHP) that provides a comprehensive and powerful approach for accurate decision making, using experimental information and/or personal judgments of each decision maker. It also facilitates the decision-making process by providing a structure for organizing different indices and evaluating the importance and priority of each of them to others.

The critique made of the AHP's assumptions attracted many researchers' attention to the analytic network. The estimation of the weight of each level independent of other levels, independence of each level variables from each other, the lack of relationship between them, and also the lack of feedback at different levels about each other are among the major assumptions that may be rejected under real decision-making conditions [11]. As a result, the ANP, with its specific attributes, addresses these critiques.

2.6 Decision-making trial and evaluation

The DEMATEL technique is a type of multi-dimensional decision-making technique based on pairwise comparison, used for the first time in late 1971 in the Battelle Gneeva Research Center to investigate complex international problems and use judgments of experts in scientific, political, economic, and social areas, religious leaders, and artists [12].

This technique is amongst the most applicable approaches to cope with multi-dimensional decision-making problems. The high capability of this technique has attracted much attention from scientific communities. In general, the DEMATEL technique provides a comprehensive approach based on the graph theory and allows for visual analysis of structural problems and models. Because directed graphs provide a better illustration of correlation between a system's elements, DEMATEL is based on graphs capable of dividing involved factors into the cause and effect groups and expressing the relationship between them as an understandable structural model. As a result, the causal relationships are more understandable in plotting network map [12].

3. RELATED WORKS

The field of EA includes a set of different evaluation of contexts. This section tried to present some of the most important approaches and their major characteristics. Although the quality of products is always considered by EA developers, the qualitative attributes of the products and outputs of the enterprise are less addressed. Despite the fact that achieving some qualitative attributes, such as security, is among the factors considered in most enterprises, their implementation and execution in EA have been remained as a great challenge to major organizations.

There are many studies into the analysis and evaluation of EA. Some of them are based on a specific framework, and some are independent of such frameworks and are based on the concepts of EA. A group of these approaches is more concentrated on an implemented EA plan [13], while another group of them contains mostly qualitative criteria [14]. Some of these approaches have been developed in industry [15,16], and some other approaches are presented in academia [17,18]. Some well-known approaches concentrate on the evaluation of the current status of EA in an enterprise [15].

A number of studies are technically concentrated on the analysis and evaluation of an EA plan. These approaches are associated with two major defects in terms of the evaluation approach. First, they are concentrated on the evaluation of an EA plan, and thus, cannot be used to evaluate ongoing plans and reduce the risks of EA projects [18]. Second, the majority of criteria are qualitative and not capable of quantitative evaluation. As a result, an appropriate criterion is not created for enterprise analysis and the enterprise cannot identify the improvement approaches [17].

In some approaches, there are uncertainties in the human selection and decision-making mechanisms [19,20,21]. On the other hand, another shortcoming of some approaches is their output uncertainties in each execution of the evaluation algorithm [19,20].

The Fuzzy AHP-based approach in [2] presents a quantitative assessment method of EA quality attribute achievement for different EA scenarios, based on the enterprise's situation. This method can be used to indicate the architecture candidates that best suits the quality attributes of a given EA. This approach is automated by a software which facilitates knowledge management and decision making in the enterprise. However, a major disadvantage of this work is that it does not consider the relationship between criteria and sub-criteria.

Similar to the previous work, an approach is proposed in [21] that evaluates the quality attributes using ANP. For each attribute, criteria and sub-criteria are defined and then, their relationships are constructed in the form a network model based on the opinions of the EA experts. This approach does not determine the mutual effect and interaction of criteria and sub-criteria of each quality attribute. As a result, the evaluated weights may be unreal. Based on the works proposed in [2,21], this paper suggests a new approach to evaluate qualitative attributes of enterprise architecture, eliminating the shortcomings of these approaches.

4. PROPOSED APPROACH FOR EVALUATION OF EA ATTRIBUTES

In the proposed approach, the analytic network process, as a multi-dimensional decision-making approach, along with the fuzzy logic, is used to prioritize the elements. To make a decision about the optimal solution, in addition to defining and identifying the appropriate criteria for data analysis and obtaining desirable results, the DEMATEL technique is used to determine the relationship between the criteria and the way they affect each other, based on the opinion of experts. The process of the proposed approach is presented in Figure 1.

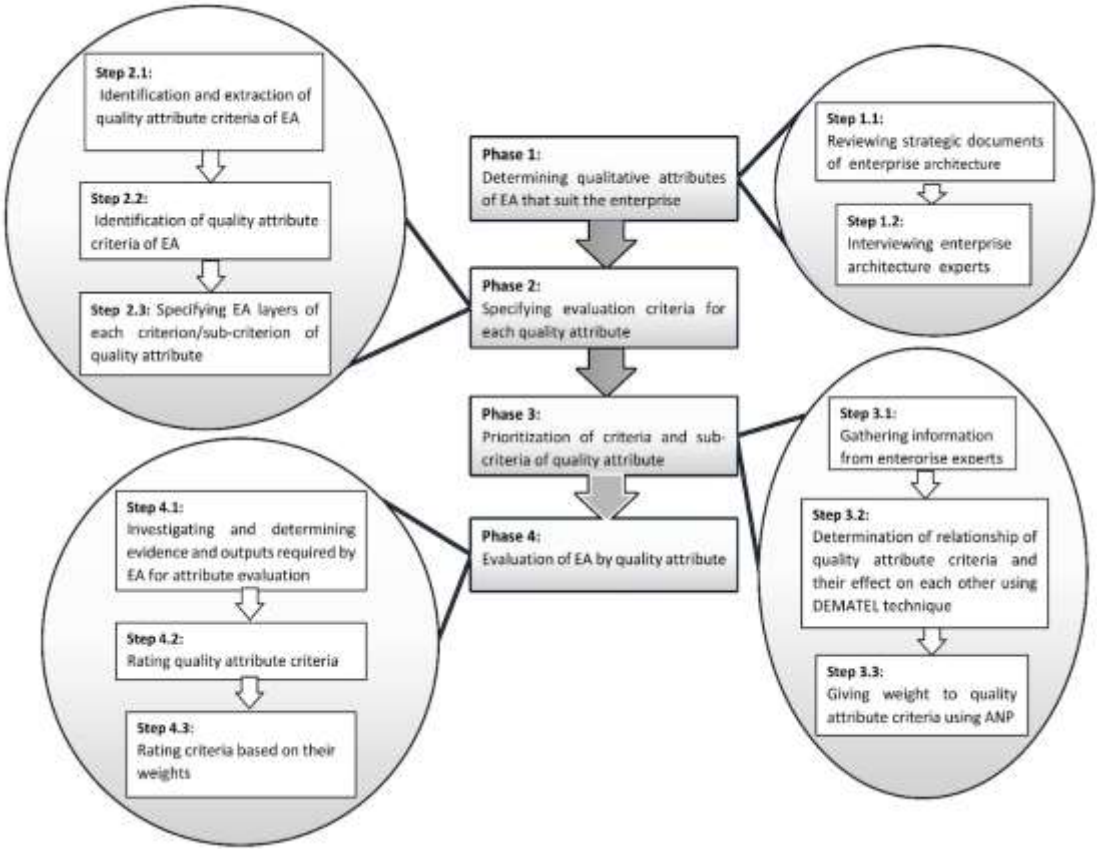

Figure. 1 Proposed approach for evaluation of qualitative attributes of EA

4.1 Phases of the Proposed Approach

In the following, the phases of the proposed approach and their related steps are described. Moreover, the ICT master plan of a municipality in Iran has been selected as a case study. This municipality belongs to one the largest cities in the country that has implemented an EA, however, for security purposes, it remains anonymous. To evaluate the proposed approach, such phases are applied to this case study.

Phase 1: Determining qualitative attributes of EA that suit the enterprise

In this phase, the senior managers and experts specify qualitative attributes that desirably fit the enterprise. Specification of these attributes in different enterprises varies based on the maturity of the EA. At this point, the desirable qualitative attributes of the enterprise should be specified by collecting information from its senior managers and enterprise experts and then organizing the obtained information. In fact, this phase specifies desirable qualitative attributes of the enterprise.

The desirable qualitative attributes of the enterprise are specified through reviewing the strategic documents of EA and interviewing the enterprise experts. For simplicity, only one quality attribute (i.e. security) has been considered in this research.

Phase 2: Specifying evaluation criteria for each quality attribute

Each quality criterion of the EA is determined using specific criteria and sub-criteria. Although these criteria and sub-criteria can be derived using the standards pertaining to qualitative attributes, such as software quality management ISO/IEC 25000, their inability to cover EA layers makes them inefficient. As a result, considering the EA layers, the relationship between layers and their effect on achieving the objectives of qualitative attributes are taken into consideration.

Regarding the lack of a specific basis to rate criteria pertaining to each quality attribute and to prevent hotchpotch of rating by the experts, a set of criteria are provided for regulation and more precise evaluation processes. These sub-criteria have no role in between-criterion relationships and interactions.

In the following, three steps of this phase are explained:

Step 2.1: Identification and extraction of quality attribute criteria of EA

This step specifies the criteria affecting the quality attribute of security. Diversity of security standards, approaches, and frameworks in different areas of EA has made the selection of a suitable approach and framework problematic for companies and enterprises.

Regarding the diversity of enterprises, different criteria have been developed for the evaluation of EA outputs. Based on the literature, studies into EA security [26,27], and opinions of the experts in this field, effective criteria have been developed to evaluate information security in EA. Such criteria are depicted in Table 1.

Step 2.2: Identification of quality attribute criteria of EA

This step investigates and specifies the sub-criteria of the quality attribute security. Such sub-criteria are developed with the help of specialists and experts in the field of EA.

Step 2.3: Specifying EA layers of each criterion/sub-criterion of quality attribute

This step addresses the determination of the EA dimensions (layers) of each criterion/sub-criterion of quality attribute, using the enterprise experts.

Table. 1 Dimensions, criteria, and sub-criteria of quality attribute of EA security

Dimensions	Criteria	Sub-criteria
Organization Strategy	Objectives and strategies of enterprise information security (C1)	- Traceability, transparency, and comprehensiveness of security policies and its effect on enterprise components - Investigating information security policymaking in all areas of information and communication technology according to the type and degree of risks
	- Legal requirements of information security (setting regulation) (C2)	- Traceability, transparency, and comprehensiveness of security policies and its effect on enterprise components - Considering high-level evidence pertaining to information security at the national level - Using the latest revision of BSI standards in exploitation of information security management system
	Enterprise Information Security Policies (C3)	- Traceability, transparency, and comprehensiveness of information security policies and their effects on enterprise components - Investigating general and consultative security policies and confidential agreements - Specifying general objectives, as well as the importance and domain of security in information sharing mechanism
	Enterprise structure of security (C4)	- Investigating enterprise security structures and its compatibility with security standards - Effect of objectives, strategies, legal requirements, and policies of information security on enterprise security structure

Business Process		- User awareness and education (identifying enterprise security levels, increasing security skills, holding information security training courses, managing user performance, establishing secure communication with clients, and managing negligence)
	Security processes (C5)	Compatibility and effectiveness of objectives, strategies, legal requirements, and policies of information security concerning enterprise security structure Investigating the inclusion of enterprise security processes in common enterprise processes - Investigating the security role and responsibilities, as well as achievement in enterprise security objectives - Investigating the coverage of business processes in identification of information security risks
	Security roles and responsibilities (C6)	- investigating the identification of enterprise security levels, as well as enterprise role, responsibilities, and structures - Effectiveness of objectives, strategies, legal requirements, and policies of enterprise information security policies on security roles and responsibilities
	Business security standards (C7)	- Investigating compatibility of business security standards with legal objectives, strategies, requirements, and policies of enterprise information security - Traceability of security standards and investigating effects of security standard on enterprise components
User	Service security requirements (C8)	- Investigating enterprise service security levels - Investigating compatibility of service security standards with strategies, legal requirements, and security policies of enterprise information - Investigating role of service in enterprise mission and its sensitivity - Investigating security requirement implementation
	Security levels of data flow (C9)	- Investigating security levels of data flow in enterprise processes - Investigating data flows between enterprise units - Investigating unallowable data flows
	Security processes (C10)	- Investigating security of all relationships between services and processes - Investigating data exchange security levels - Investigating security roles and access permissions
	Data security architecture (C11)	- Compatibility of database security approaches and data warehouse with enterprise security policies and regulations - Investigating data security levels and integration of data security approaches - Investigating data access permissions - Investigating security considerations pertaining to data carriers - Investigating database and data warehouse security
		- Compatibility of software security approaches with enterprise security policies and regulations

Data	Software security architecture (C12)	- Investigating achievement of enterprise software security requirements - Investigating software security components and modules - Investigating data level of data generated, processes or stored by software
	Service security architecture (C13)	- Investigating enterprise service security levels - Investigating essential requirements of service security - Investigating security components of services and their compatibility with enterprise security policies - Investigating enterprise charts, and roles and responsibilities
Infrastructure	Network security architecture (C14)	-Effects of objectives, strategies, legal requirements, and policies of enterprise information security on network security architecture - Compatibility of network security architecture approaches with strategies, legal requirements, and regulations of enterprise security Integration of network security architecture approaches Investigating network management procedures and access permission to network resources - Investigating Intra- and inter-enterprise communications
	Security of operating systems (C15)	- Effects of objectives, strategies, legal requirements, and policies of enterprise information security on operating system security approaches - Compatibility of operating system security approaches with strategies, legal requirements, and regulations of enterprise security - Integration of operating system security approaches - Investigating network software and hardware security
	Security of middleware and service providers (C16)	- Effects of objectives, strategies, legal requirements, and policies of enterprise information security on security of middleware and service providers - Compatibility of middleware and service providers' security approaches with strategies, legal requirements, and regulations of enterprise security - Integration of middleware and service providers security approaches

Phase 3: Prioritization of criteria and sub-criteria of quality attribute

This study uses the hybrid fuzzy multi-criteria decision making ANP-DEMATEL in the third phase. In this phase, the decision subject is discussed by decision makers and the general result is obtained. Therefore, aggregation of individual judgments (AIJ) with geometric mean are used and there is no need to evaluate the opinion of each decision maker separately [23,24,25].

After determining the criteria/sub-criteria of quality attribute in the previous phase, they should be prioritized, based on the opinions of enterprise experts and conditions and attributes, to be used in the assessment of EA. In this way, the importance of each criterion to the enterprise is explained and the rate of each criterion given by the experts are customized to suit the enterprise.

In the following, three steps of this phase are explained:

Step 3.1: Gathering information from enterprise experts

The research items are divided into two categories presented by two questionnaires.

In the first questionnaire, the identified criteria in five dimensions are delivered to the EA experts to obtain their opinions concerning the accuracy of categories considering the concepts. Then, the required modifications

are made based on their opinions. In the second questionnaire, opinions of the experts concerning the importance of a criterion and its effect on another criterion are gathered using a fuzzy technique.

After collecting the opinions of the experts within the second questionnaire, results are integrated using the arithmetic mean and then the mean matrix is obtained.

Step 3.2: Determination of relationship of quality attribute criteria and their effect on each other using DEMATEL technique

In this step, due to the uncertainties in the relationship between criteria and sub-criteria among the experts, the DEMATEL technique is used to specify such relationships. In addition, the experts' opinions are applied to the mean matrix.

Figure 2 presents the cause and effect diagram between security criteria by illustrating the significant relationships between them.

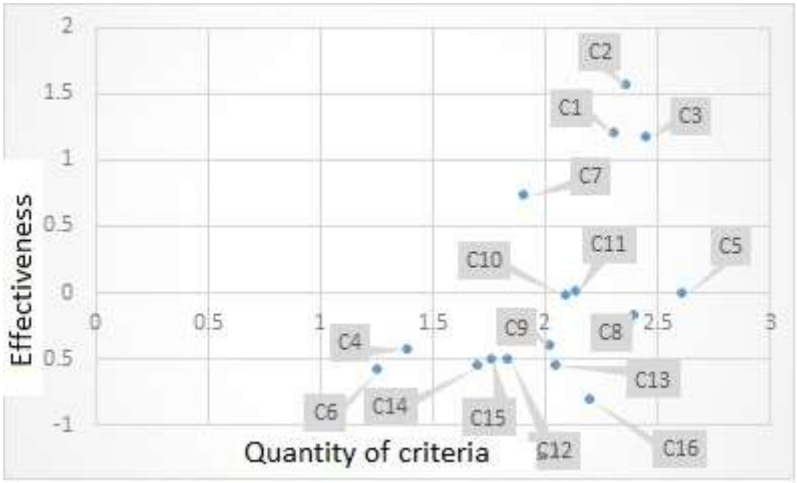

Figure. 2 Cause and Effect diagram and relationship between security criteria

According to Figure 2, among the main factors, the C1, C2, C3, C7, and C11 security criteria were undoubtedly the effective ones, which is due to the positive value of the C-R index. On the other hand, other criteria are affected, due to the negative value of the C-R index. Moreover, the C1, C2, C3, C5, and C8 security criteria are more important than other criteria, given the x-axis (C+R value).

Step 3.3: Giving weight to quality attribute criteria using ANP

This step used the output of the previous step (significant relationships between quality attribute criteria) as the input of ANP to weight criteria and their importance. Further, three stages of ANP are presented:

Stage A. Formation of network structure (explanation of relationship model of quality attribute criteria)

After collecting the experts' opinions concerning the relationship between criteria and then specifying those relationships, a model that presented these relationships is developed with a network structure.

The model proposed by the experts for security is implemented in Super Decisions software (Figure 3).

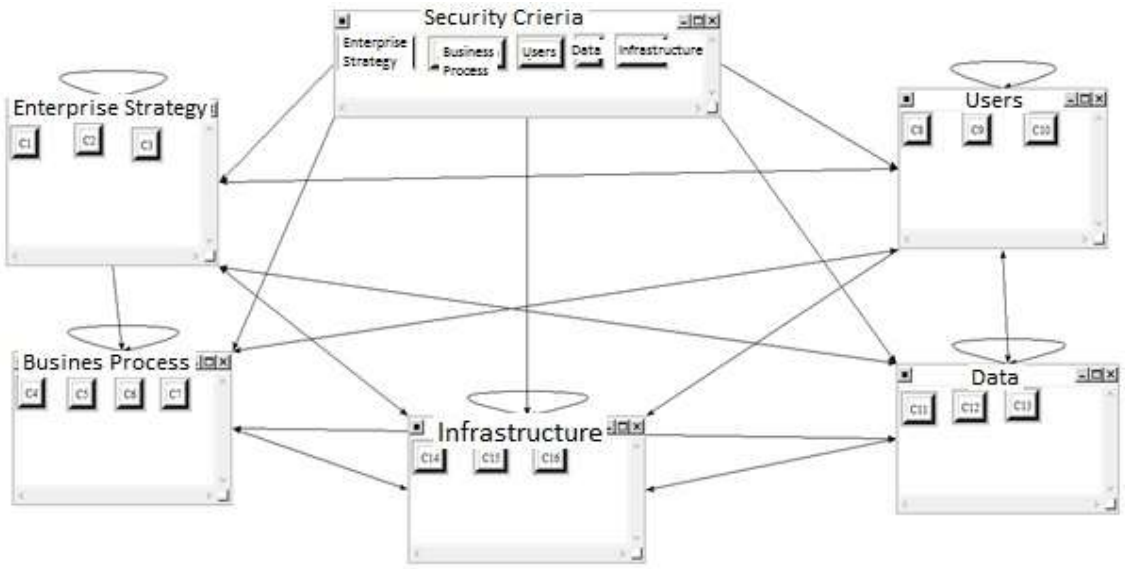

Figure. 3 Network structure of the model proposed by experts for EA security

Stage B. Collecting experts' opinions on prioritization of criteria

To prioritize the criteria of qualitative attributes, using the ANP, a questionnaire is made by means of the model proposed by the experts.

To prioritize the criteria, the pairwise comparison inventory pertaining to each internal relationship is first made. The aim is to determine the preference of criteria based on the opinions of the experts. The respective software conducted the given pairwise comparisons using the model of network structure which was developed in the previous stage. After the preparation of the pairwise comparison inventory, the experts are asked to complete it. Then, the completed questionnaires are introduced to the software to evaluate and calculate the internal weight of the main criteria.

The introduction of values to the software continued as long as the incompatibility of the pairwise comparison matrix of criteria is at an allowable level (less than 0.1); otherwise, the pairwise comparison inventories are returned to the experts for revision.

Stage C. Prioritization and weighting of criteria

In this stage, the unweighted super-matrix, weighted super-matrix, and limited super-matrix are calculated using the ANP in Super Decisions. Then, the limited super-matrix is used to evaluate and prioritize criteria.

Regarding the use of experts' opinions in this stage, prioritization is based on the current status and conditions of the enterprise. As a result, the enterprise conditions are very effective in prioritization. Table 2 presents the mean of the final weight of security criteria from the experts' viewpoints.

Table. 2 Final weight of security criteria

Dimensions	Weight of dimensions	Criterion	Normalized by cluster	Limiting
Strategy	0.12814	C1	0.33071	0.04262
		C2	0.14675	0.01875
		C3	0.52254	0.06677
Business process	0.27528	C4	0.12466	0.03432
		C5	0.38313	0.1055
		C6	0.23555	0.06486
		C7	0.25666	0.0706
User	0.20084	C8	0.27737	0.05574

		C9	0.34603	0.0695
		C10	0.37661	0.0756
Data	0.19266	C11	0.22306	0.04299
		C12	0.20320	0.03917
		C13	0.57374	0.1105
Infrastructure	0.20308	C14	0.48749	0.099
		C15	0.38885	0.07897
		C16	0.12366	0.02511

Phase 4: Evaluation of EA by quality attribute

Regarding the prioritized security criteria in the previous phase, the achievability of this quality attribute in the enterprise is investigated and assessed based on the experts' opinions. In fact, qualitative evaluation of the EA is quantified in this phase. Considering that the criteria and sub-criteria of quality attribute are determined based on EA dimensions, the enterprise is able to compare the dimensions of EA based on the given quality attribute.

In the following, three steps of this phase are explained:

Step 4.1. Investigating and determining evidence and outputs required by EA for attribute evaluation

To evaluate the quality attribute criteria, those evidence and outputs of the EA which may contain relevant information should be investigated. To this end, a set of the EA evidence and outputs, which may contain criteria-related information, are investigated and extracted with the help and guidance of the enterprise specialists and experts.

Step 4.2. Rating quality attribute criteria

To rate the set of quality attribute criteria, sub-criteria should be rated by the enterprise experts based on their achievability and results, considering the EA evidence and outputs. Finally, the overall score of each criterion is calculated.

Step 4.3. Rating criteria based on their weights

In this step, the final scores of criteria are calculated based on their weights; in addition, the overall score of each quality attribute criterion is obtained. To obtain the final score of each criterion, its score should be multiplied by its weight (significance level).

With the introduction of security evaluation approach to the current status of the enterprise, it is found that it fulfilled 65.64% of its ideal conditions (scored 65.64 out of 100).

5. COMPARISON OF PROPOSED APPROACH WITH OTHER QUALITY ATTRIBUTE EVALUATION APPROACHES

This section compared the proposed approach with other evaluation approaches of quality attribute. Some of these approaches are introduced and investigated in literature review. The approaches proposed in [2] and [21] are selected as the comparison references. This is because both references are based on multi-criteria decision-making approaches. In this study, the multi-criteria evaluation approaches are used. Parameters used for this comparison are those required for the assessment of evaluation. Table 3 presents the required evaluation parameters and evaluation realities.

Table. 3 Comparison of proposed approach with other quality attribute evaluation approaches

Comparison parameter	[2]	[21]	The Proposed Approach
Assess-ability of quality attribute in different enterprise conditions	✓	✓	✓
Applicability in real environment	✓	✓	✓
Independence of EA frameworks	×	✓	✓

Reduction in human error pertaining to experts' opinions (ambiguity and uncertainty in judgments of decision makers)	×	×	✓
Independence of software architecture evaluation models	×	✓	✓
Supporting EA layers	×	✓	✓
Considering prioritization criteria based on opinions of enterprise experts	✓	✓	✓
Considering mutual effect and interaction of criteria and sub-criteria of each quality attribute	×	×	✓
Compatibility of criteria rating during their changes	×	×	✓

6. RESULTS AND FUTURE WORKS

The EA evaluation approaches intend to specify the distance between the current status and a feasible ideal status of an enterprise from different views, such as EA traits and quality of known EA components. They also try to determine the shortcomings and problems to be addressed to bridge this distance rapidly and more accurately. Using individuals involved in enterprise activities is among the most effective approaches for evaluating the enterprise and identifying shortcomings and defects. This is because specific attributes and dimensions of the enterprise are important to each group of stakeholders, and provide a more accurate and complete knowledge of the enterprise weaknesses and strengths. In this way, the enterprise is investigated from different viewpoints.

The basis of the proposed approach is the hybrid fuzzy multi-criteria decision-making technique (ANP-DEMATEL). After specifying the qualitative characteristics of organizational architecture with the help of experts, criteria and sub-criteria of each characteristic, along with its pertinent organizational architecture layers were specified. Then, the relationship of criteria for qualitative attributes and the way they affect each other were identified using DEMATEL technique and according to the experts' opinions. Further, the ANP was employed to weight the significance of qualitative criteria. Ultimately, the total scores of criteria were specified based on evidence and outputs of organizational architecture. The final score of each qualitative characteristic was obtained by multiplying the score of each criterion by its significance level.

For further studies, the TOPSIS technique or the combination of ANP-BOCR can be investigated to rate qualitative attributes. Moreover, other qualitative attributes of the enterprise can be studied and evaluated.

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