

# ERP Software Selection Criteria: A Fuzzy Analytic Hierarchy Process (FAHP) Approach

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## Abstract

This study provides a step by step guideline to develop the specific criteria and sub-criteria of Enterprise Resource Planning (ERP) software selection problem. Although the concept ERP software selection has been widely investigated in many companies, it is less investigated in manufacturing companies of developing countries. Furthermore, this problem is not sufficiently linked with real nature of decisions including Multiple-Criteria Decision Making (MCDM) and Fuzzy MCDM. To fill this gap, this research is completed in three linked phases as follows. The initial phase of this research investigates previous literature to determine potential criteria and sub-criteria of ERP software selection problem. Next, to develop fit criteria and sub-criteria of ERP software selection, the output of the first phase is rechecked by experts to determine its capability. Finally, the obtained criteria and sub-criteria of the second phase are applied to be compared and ranked by an FAHP approach. According to the obtained results, security, investment, software features, maintainability, support center, and report features are the most important criteria of ERP software selection problem.

## Keywords

ERP, ERP software selection, MCDM, Fuzzy MCDM and FAHP.

## 1. Introduction

Today's competitive markets and their fast going structure have highlighted the importance of a proper decision making (Miller and Lee, 2001). According to previous literature, there are three decision levels in any organization including strategic, tactical and operational (Galankashi and Helmi, 2016). While strategic decisions include long term activities of a company, tactical and operational decisions include medium and short term actions of an enterprise, respectively. However, short, medium and long term decisions significantly affects the performance of companies (Galankashi and Helmi, 2017). More related to this research, many companies are involved in ERP software selection

process. While the majority of companies use cost as the main criteria to select their ERP software (Haghigh and Mafi, 2010), there are many other criteria to assess and select different potential ERP software. More specifically, ERP software selection problem includes the process of criteria development, alternative assessment and finally selection. In this regard, similar to other decision making processes, there are numerous available decision making criteria to investigate and assess different ERP software. Furthermore, there are many qualitative and quantitative decision making methodologies to be applied in ERP software selection problem (Zehir et al., 2016).

Previously, there were not a variety of ERP systems to be selected by companies. In other words, the quantity of available alternatives were not very significant and companies had to choose their ERP software from a limited quantity of available alternatives. However, with the progress of computers and related tools and techniques, it is possible for manufacturing companies to be selective in their ERP software selection process. In this regard, there are many ERP systems with their specific characteristics to serve manufacturing companies. Therefore, managers can choose their ERP software among different available alternatives to address different objectives of organizations. The ERP software selection problem has been changed during recent years (Bhatt et al., 2021). In other words, different issues have been considered and investigated to enrich the problem by using numerous aspects of real world problems. According to previous studies on ERP software selection problem (Şen et al., 2009), it is necessary for all decision makers to select their ERP software using both quantitative and qualitative criteria. In other words, it is necessary to use less, applicable and fit criteria to compare different ERP systems. More specifically, ERP software selection problem should check diverse financial and non-financial issues simultaneously (Wier et al., 2007). Furthermore, there are many issues in ERP software selection decision. For example, managers should make a trade-off among quantitative issues, quality problems, security features and many other factors in the process of ERP software selection. Therefore, ERP software selection can be considered as a Multiple-Criteria Decision Making (MCDM) problem. In this regard, three major issues of developing applicable criteria, proper decision making methodology and appropriate data collection and comparison of alternatives should be handled in this problem.

ERP software selection problem has been extensively considered in previous literature (Yurtyapan and Aydemir, 2021). However, this problem is less examined in developing countries. In addition, current available studies have mostly applied MCDM approaches in ERP software selection problem. Many problems of real world can be simply considered as an MCDM problem. However, many managers, decision makers, practitioners and researcher believe that it is better to make pairwise comparisons of these decisions using linguistic terms instead of exact scalar scales (Galankashi et al., 2016). In other words, fuzzy environments are more recommended in previous literature as they can show different uncertainties and suspicions available in real world decision making processes (Rezaei et al., 2020). Therefore, as a summary of problem statement, developing the specific criteria of ERP software selection problem, investigating those using qualitative approaches and applying an appropriate Fuzzy MCDM (FMCDM) methodology to rank them is a challenge of both research and practice. In other words, although there are many criteria to be applied in ERP software selection problem (Illa et al., 2000), they are less investigated in manufacturing companies of developing countries. To be more specific, many companies have neglected to consider different criteria and sub-criteria to assess and select their ERP software and are still using cost as the main criteria of ERP software selection problem. Though, developing a step by step procedure to be applied in ERP software selection process is important as:

1. The developed methodology of this research can be applied in other ERP software selection process
2. It is possible to apply this research approach to select other manufacturing software such as maintenance, inventory, etc.

The scope of this research is limited to manufacturing companies of Iranian automotive industry. In other words, this study develops a methodology to prioritize criteria and sub-criteria of ERP software selection to be applied in Iranian automotive manufacturers. Though, although the scope of this research is limited to Iranian automotive industry, its framework, methodology, procedure, criteria and arrangement are appropriate to practitioners, researchers, managers and others who are interested in application of FMCDM in ERP software selection problem. So, this study contributes to develop the specific criteria and sub-criteria of ERP software selection using a fuzzy approach. Subsequently, this study develops an integrated approach for ERP software selection criteria and sub-criteria. Therefore, this research aims to investigate previous literature on ERP software selection, develop specific criteria and sub-criteria of ERP software selection and finally prioritizes ERP software selection criteria and sub-criteria by FAHP. The remainder of this study is arranged as follows. Next section reviews previous literature with a focus on specific criteria and sub-

criteria of ERP software selection. Following, different steps required to achieve the objectives of study are discussed in research methodology. Finally, the results and discussions are provided in final sections of this research.

## 2. Literature Review

Different explanations, concepts and associated subjects such as automotive industry, manufacturing companies, ERP software selection and ERP software selection criteria are discussed in Section 2. In addition, a summary of previous literature and identification of research gaps are clarified at the end of this section.

### 2.1 Automotive Industry

As an important business, automotive industry plays an important role in overall economic growth of countries. According to previous research (Galankashi et al., 2018), automotive industry includes different sections such as suppliers, manufacturing companies, distributors, retailers, maintenance plants, online call centers, research centers and many other components that are trying to convert raw materials to final products and deliver them to final customers in a desired time, quality, location, cost and other required obligations (Galankashi et al., 2020). In other words, this industry includes different supply chains to deliver final products to final customers. These supply chains address both manufacturing and service issues of this industry. This industry faces different concerns in its daily operations. However, finance, quality and service related issues are three major concerns of this industry. As an important requirement of this industry, according to previous literature, a successful automotive manufacturing company should efficiently focus on its resources to be successful in today's competitive markets (Bandara and Jayawickrama, 2021). Therefore, a proper ERP software selection process eases the process of resource planning.

### 2.2 ERP Software Selection

ERP software selection problem has been vastly investigated in previous literature (Czekster et al., 2019). However, the problem is less investigated in manufacturing companies of developing countries. According to previous literature, resource planning of manufacturing companies is very important as it affects other components of supply chain (Mabert et al., 2000). In addition, as there are numerous components in automotive industry, ERP software selection problem becomes important since these components have different resources and priorities. In other words, different components of an automotive supply chain need different resources and subsequently their required ERP software might be different compared to others. In this regard, ERP software selection problem explores and investigates available ERP software to choose from. Therefore, final prioritization of ERP software selection criteria and sub-criteria is the major output of this study.

### 2.3 ERP Software Selection Criteria

As discussed above, according to previous literature, there are numerous criteria and sub-criteria to be applied in ERP software selection process. In other words, the applied criteria of each company to select its ERP software is different as it might have different levels of income, employees, acceptable risk, and many other characteristics. In addition, the quantity and variety of these criteria might be changed as companies might make decisions in unpredictable conditions. Therefore, as mentioned, a literature review is conducted to develop the most frequently applied criteria of ERP software selection as tabulated in Table 1. As it is tabulated in the first column of this table, support center, security, software features, maintainability, report features and investment are the most frequently applied criteria of ERP software selection.

Table 1. ERP Software Selection Criteria

Criteria	Sample Reference
Support Center	Wilson and Lindo (2011)
Security	Saa et al., (2017)
Software features	Fisher et al., (2004)
Maintainability	Ekstedt et al., (2009)
Report features	Kim et al., (2013)
Investment	Wu et al., (2009)

## 2.4 Related Studies

ERP software selection problem has been investigated in previous literature. More specifically, this problem has been investigated in the presence of numerous issues such as group decision making, uncertain decision making, fuzzy logic, size of companies, MCDM, fuzzy MCDM and many others. As an example of size related concerns of ERP software selection, Bernroider and Koch (2001) investigated the problem in medium and large size organizations. The criteria, their weights and the developed research methodology are the main output of this research. In a MCDM related study, Wei et al., (2005) applied an AHP in the ERP selection problem. This research developed criteria, methodology and a real case study to apply AHP in ERP software selection problem. Ziaee et al., (2006) applied a modular approach in ERP system selection. More specifically, this research developed a two-phase approach to choose an ERP vendor and a suitable ERP software. According to this research, the developed methodology and outputs are applicable to be used by Small Manufacturing Enterprises (SMEs). As an example of fuzzy MCDM approaches, Ayağ and Özdemir (2007) applied a Fuzzy Analytic Network Process (FANP) approach in ERP software selection problem. According to this research, FANP approaches are more recommended comparing to ANP as they deal with uncertain and imprecise judgments of human comparisons. In addition to fuzzy logic, ANP has been integrated with other approaches such as Artificial Neural Network (ANN). As an example, Yazgan et al., (2009) integrated ANN and ANP in the process of ERP software selection process. According to this study, the developed model is applicable to predict software priorities using the ANN model. As an example of integrated decision making tools, Karsak and Özogul (2009) developed an integrated decision making approach for ERP system selection. This research applied a novel decision making framework for ERP software selection using zero-one goal programming, Quality Function Deployment (QFD) and fuzzy linear regression. In another example of integrated modular capability-based ERP software selection, Karaarslan and Gundogar (2009) applied an AHP in the problem of ERP software selection. This research has assisted a company to investigate two elected candidates using an AHP. In another example of fuzzy approaches, Onut and Efendigil (2010) considered different constraints of cost and quality in a fuzzy model to provide a beneficial structure to the managers for use in ERP software vendor selection process. In another example of integrated MCDM techniques in ERP software selection problem, Kazancoglu and Burmaoglu (2013) investigated ERP software selection process of a steel forming and hot dip-galvanizing firm. In another example of integrated fuzzy MCDM approaches, Tolga (2018) applied a fuzzy AHP in ERP software selection problem. This study integrated TODIM and fuzzy AHP approaches to evaluate and prioritize different ERP software. Finally, in a recent research, Arya and Kumar (2021) applied an integrated entropy weighting and q-rung fuzzy TODIM in ERP software selection problem. A numerical example is applied to solve a real problems to illustrate the applicability of the developed model.

## 2.5 Identification of research gap

As a summary of discussed literature, a step by step and applicable methodology to develop both criteria and sub-criteria of ERP software selection is less investigated in previous studies, principally in developing countries. Additionally, supporting the major concern of the previous literature, as there are numerous criteria and sub-criteria to compare and select ERP software, it is necessary to investigate them based on both qualitative and quantitative approaches. Finally, many practitioners, managers, decision makers and companies prefer to express their judgments in fuzzy environments as it is possible to reflect uncertainties (Hashemzahi et al., 2020; Galankashi et al., 2020). Therefore, to address the gaps of previous literature on ERP software selection, this research provides a step by step approach to develop ERP software selection criteria and sub-criteria, investigate them using the comments of experts and finally prioritize them by an FAHP approach.

## 3. Research Methodology

This section discusses the developed research methodology to illuminate different steps required to achieve the main objectives of this research. As discussed in introduction section, this research aims to investigate previous literature on ERP software selection, develop the specific criteria and sub-criteria of ERP software selection and finally prioritize ERP software selection criteria and sub-criteria by FAHP. Therefore, each objective has been translated as a research phase to be discussed based on its required steps. According to Figure 1, this study has been completed in three linked phases as follows. Firstly, a literature review is conducted to develop potential criteria of ERP software selection. Next, the second phase applies an expert based investigation to recheck all developed criteria and sub-criteria of previous phase. Finally, the third phase applies a FAHP to rank criteria and sub-criteria of ERP software selection problem. Therefore, figure 1 displays a summary of research methodology by focusing different steps required to complete each phase. In addition to this Figure, different steps required to achieve the objectives of this research are discussed in next sections as follows.

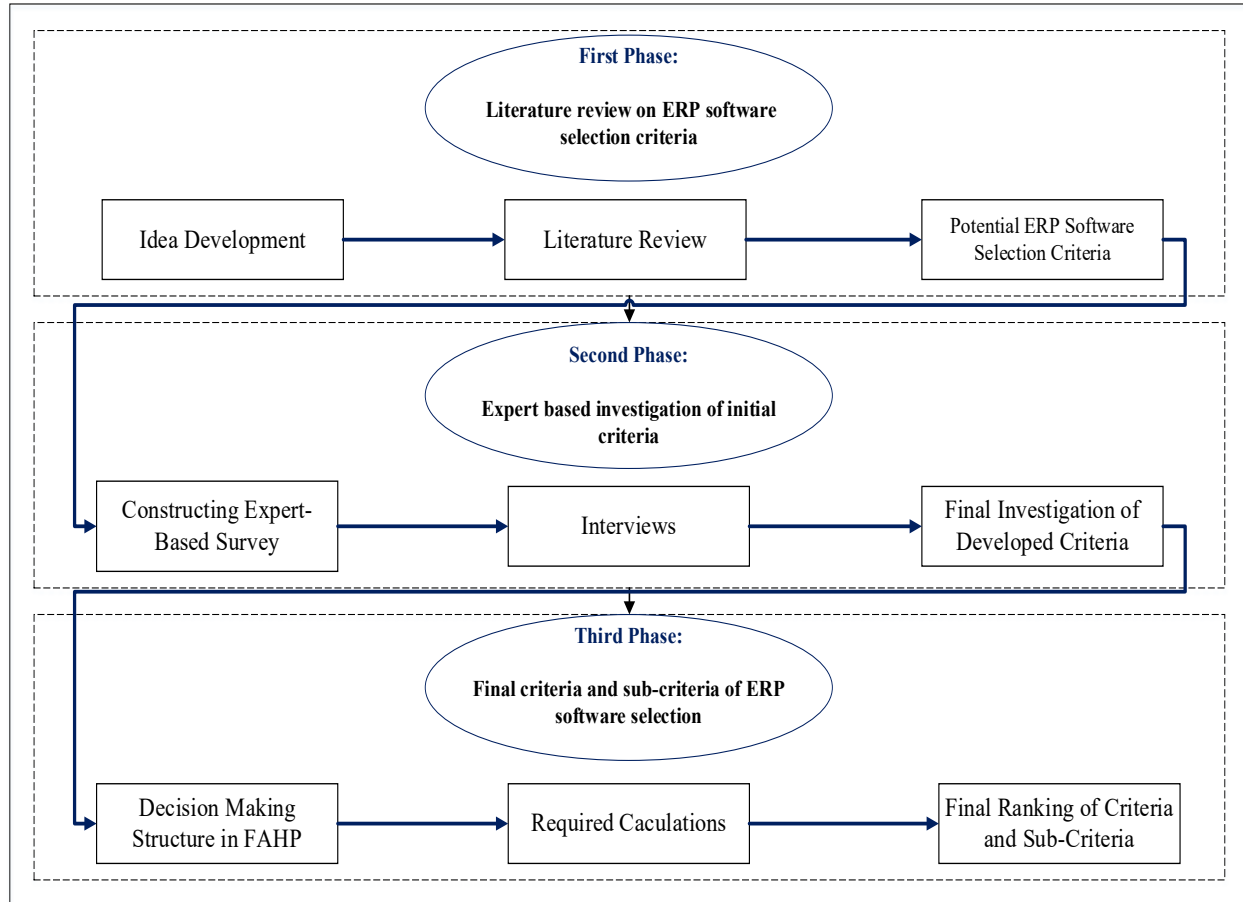


Figure 1. Research Steps

### 3.1 First Phase: Literature review on ERP software selection criteria

As discussed in previous sections, potential ERP software selection criteria of previous literature are developed in this phase. A literature review has been completed to finalize this phase. The output of this phase are more investigated in the next phase.

### 3.2 Second Phase: Expert based investigation of initial ERP software selection criteria and sub-criteria

There are different criteria and sub-criteria to be applied in ERP software selection process. Furthermore, according to aforementioned discussions, the quantity of these criteria might be variable as decision makers make their decision with regard to varying conditions of real world problems including industry, budget, risk and many other factors. In this regard, an expert based investigation of initial criteria and sub-criteria has been completed in this phase.

### 3.3 Third Phase: Final criteria and sub-criteria of ERP software selection

Finally, the outputs of previous phases are ranked in this phase. More specifically, the developed criteria and sub-criteria of previous phases are compared to determine their score. In other words, this phase applies an FAHP to determine the score of each criteria and sub-criteria. Consequently, final ranking of ERP software selection criteria and sub-criteria is the main output of this phase.

### 3.4 Data Collection

As discussed above, this research has been completed in three linked phases. In this regard, it is necessary to collect the required data of each phase separately. There were three issues linked with data collection process as it was necessary to complete each phase before starting the next phase. The first phase of this research provided a literature review on ERP software selection criteria. In this regard, the data collection process of this phase is completed based on previous related literature on the topic. Next, the second phase of this research focused on an expert based

investigation of initial ERP software selection criteria and sub-criteria. In other words, the investigated criteria and sub-criteria of the previous phase were investigated by the experts to be prioritized. As discussed, it is necessary to develop fit and applicable criteria for the process of ERP software selection. In this regard, the outputs of the second phases are further investigated using a fuzzy MCDM technique. In this regard, a FAHP questionnaire is designed based on its different steps. In other words, the designed questionnaire follows different steps of FAHP to ease its final calculation. Following, the designed questionnaire is distributed among different experts to collect their judgments and pairwise comparison matrices. Therefore, as different experts have contributed to fill this questionnaire, the obtained outputs are completely reliable.

#### 4. Results

This section provides the obtained results of this research. As discussed in research methodology section, this study has been completed in three linked phases. Therefore, to ease the tracking process of results, the outputs of this research has been arranged according to different phases discussed in research methodology. The first phase of this research investigates previous studies to develop potential criteria and sub-criteria of ERP software selection. As a reminder, the main output of this phase is tabulated in Table 1. Following, the developed criteria and sub-criteria of first phase were more investigated by the experts of company. As an important output of this phase, all aforementioned criteria and sub-criteria were approved by experts. Finally, as the output of third phase, an FAHP is applied to prioritize the criteria and sub-criteria of ERP software selection. To do so, an interview was conducted with three experts of an Iranian automotive manufacturer to collect the required data of FAHP calculations. The final weights of each criteria are calculated according to the judgments of each expert and are tabulated in Table 2. As it is clear in this table, the first columns shows the criteria, the second column applies a parameter as the representative of each criteria, the third column shows the obtained weight and finally the last column displays the final ranking of all criteria. A simple average is applied to calculate final weight of each criteria. Similarly, final weights of all sub-criteria are calculated and tabulated in Table 3. This table includes three columns. The first column of this table shows the criteria and their obtained weights, the second column shows the sub-criteria and finally the third column shows the weight of each sub-criteria. Similar to main criteria, a simple average is applied to integrate different scores of all experts.

Table 2. Final weights of ERP software selection criteria

Criteria	Applied Parameter	Obtained Weight	Ranking
Support Center	C1	0.087	5
Security	C2	0.274	1
Software features	C3	0.230	3
Maintainability	C4	0.144	4
Report features	C5	0.01	6
Investment	C6	0.26	2

Table 3. Final weights of ERP software selection sub-criteria

Criteria	Sub-Criteria	Weight
Support Center (0.087)	Communication skills	0.074
	Availability	0.52
	Learning skills	0.407
Security (0.274)	Accuracy	0.165
	Error free	0.509
	Reliability	0.325
Software Features (0.230)	Overall performance	0.302
	Aggregation capability	0.208
	Mechanism	0.209
	Integrity	0.281
Maintainability (0.144)	Maintenance guidelines	0.2
	Maintenance methods	0.541
	Usability	0.259
Report Feature (0.01)	Data clearance	0.424
	Flexibility	0.332
	Online reports	0.144
	Multiple reports	0.100
Investment (0.26)	Rate of Return (ROR)	0.307

Therefore, final phase of this research showed that security, investment, software features, maintainability, support center, and report features are the main criteria of ERP software selection, respectively. These criteria can be applied to compare and rank potential ERP software of manufacturing companies.

## 5. Conclusion

This research suggested a procedure to develop the specific criteria of ERP software selection problem. To do so, three linked phases were completed to achieve the objectives of this research. The first phase analyzed previous literature to determine potential criteria and sub-criteria of ERP software selection problem. Next, the output of the first phase was reinvestigated by experts to determine its capability in ERP software selection problem. Lastly, the finalized criteria and sub-criteria of the second phase were compared and ranked by an FAHP approach. The obtained results showed that security, investment, software features, maintainability, support center, and report features are the most important criteria of ERP software selection problem. Although the developed research methodology and applied procedure have been applied in automotive industry, it is possible to apply it in other industries including healthcare, electrical appliances, etc. In other words, the developed methodology of this research can be applied in ERP software selection of other industries. In addition, it can be applied in any software selection process. Furthermore, other FMCDM approaches can be applied instead of FAHP.

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