Group Decision Making for Hazard Analysis and Consequence Modelling Software Selection with AHP

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ABSTRACT: *Software evaluation and selection have begun to be addressed as a topic title along with the fact that microcomputers and then personal computers have become widespread and have been used in the operations of businesses. In this study, it was focused on the selection of software for identifying the physical effect distances of the explosion, fire and toxic emission, which is an important need for industrial institutions containing, using or storing hazardous chemicals. The evaluation and selection of software for the Hazard Analysis and Consequence Modeling (HACM) of potential accidents was studied at first. In means of methodology, questionnaires consisting of original questions were applied to the experts. The results obtained from questionnaires according to the Likert scale, were converted into Analytical Hierarchy Process (AHP) suggestion matrices. In this way the inconsistency problem in the pairwise comparison matrices were eliminated. As a result, evaluation and selection were made among the HACM softwares.*

KEYWORDS *Analytic hierarchy process; Group decision making; Hazard analysis and consequence modelling software; Likert scale; Software selection.*

INTRODUCTION

In today's business world, computer software is an indispensable component of decision making and application phases in that it constitutes one of the inputs of a business. Therefore, the process of evaluating and selecting the software used is an important activity. This process includes many criteria such as what is needed,

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the complexity of the need, hardware and software infrastructure to be used, user, etc. It is important to follow new technologies and trends (Industry 4.0, IoT, Big Data, BI, Smart App., etc.) and to take the related hardware and software infrastructure decisions in terms of making serious investments for the active use of software and the sustainability of the use. Thus, software selection appears to be an important decision making process. A large number of studies carried out on this subject in the literature indicate this importance.

"Software evaluation and selection" have begun to be addressed as a topic title along with the fact that microcomputers and then personal computers have become widespread and have been used in the operations of businesses. It was observed that software selection has been involved in the studies since the beginning of the 1980s. With the study presented as a report, *Zoll* (1980) indicated that there was a need for a disciplined approach in the light of criteria for the first time by stating that the software selection process was arbitrarily discussed at that time but this process should be performed in the light of certain criteria when engineering software came into question. In his study, the price, software entries, calculation aid, maintenance and update support, output options, user interaction criteria were stated to be important [1]. Five years after this study, *Dicaselli* (1985) also explained that it was important that the process of software selection was a disciplined process if the software in question was related to production such as product design, prediction, workshop management, inventory control [2]. It was observed that the number of studies on the selection of software has increased during the years following these pioneers. Until the beginning of the 90s, the studies conducted on this subject have been applied in various sectors from software used in emergency services [3] to software used in the education field [4] and, of course, software in the production field [5, 6]. These studies were based on the subjective evaluation of the selection process in terms of the compliance with the criteria in the form of checklists. Together with the study of [7], the problem of the software selection began to be regarded as a multi criteria decision making problem. As much as the fact that the software evaluation and selection problem accepted as a complicated task had a multi criteria structure, specialization of decision makers constituted an important pillar of the problem [8]. Thus, together with the basic, the basic parameters of the software selection problem were determined. There were (i) the determination of the criteria based on the administrator, user and technique, (ii) taking advantage of expert's opinions in the light of these criteria, (iii) implementing a disciplined decision making process. In the first review conducted in relation to software selection [9], these problems were evaluated bilaterally as stated above. The first one was criteria to be used for software evaluation and selection (i), another one was selection strategies (ii + iii). In this review stating the requirement to approach this process as a project, the most frequently encountered general criteria were indicated as cost, lifetime, producer, vendor, technical support, maintenance, technical properties, ease of use, interface, and integration.

It was observed in the studies conducted in the last 20 years that two trends were considered in the software selection problems. The first one was focusing on specific software selections, the second one was the increase in the use of data models and quantitative techniques in the decision making process. Upon evaluating the studies conducted, we can see that software selections were made in a quite wide spectrum. Software selection and evaluation were discussed in the fields of health [3, 10] and education [4, 11 – 14], together with concentrating especially on the field of production. Upon examining the literature in terms of evaluated and selected software types, it was observed that there were the evaluation and selection of Enterprise Resource Planning (ERP) software aiming to use various resources of the enterprises producing goods/services in a productive and integrated way [15 - 34]. It was observed that simulation software used in the analysis and evaluation of production and service systems was the second most frequently used software type [35 – 43]. The selection of Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) software used in the development and production of computer based new product designs [6, 44 - 49], the selection of project management software [50, 51], and the selection of Customer Relations Management (CRM) software [52] were the other software types used in the production sector and worked on. The studies on the evaluation and selection of building information modeling software used in the construction sector [53 - 57], GIS software used for decision making processes based on the geographical field for various purposes [58, 59], softwares used in the logistics sector [60 61], COTS, various commercial package software [62 - 66] indicate that this problem was addressed in other sectors and application fields. When the review articles related to the subject were examined [67- 69], the compilation of these studies according to the types of the software discussed indicated the effectiveness of this trend.

Upon considering in terms of the second one of the trends mentioned above (the use of quantitative techniques), *Le Blanc* and *Jelassi* (1994) used the linear weighted attribute (LWA) and multi attribute utility theory (MAUT) models in the ranking of the software alternative to each other in the selection problem and compared the results of these two methods [70]. Another pioneering study was conducted by [60]. The author, who made an application on logistics software, determined the advantages in the use of data models instead of the conventional decision making process in which large scale functional checklists were used. The author, who used the Reference Data Model, indicated with the results obtained that quantitative techniques were promising when compared to the conventional method. Together with the use of quantitative techniques, Multi Criteria Decision Making (MCDM) techniques became basic decision making processes used in the software selection problem. The first study using these techniques was the study of [71] in which the Analytical Hierarchy Process (AHP) was used for the selection problem of multimedia authorizing systems. 6 experts in software were used within the scope of the study and the results which could be completely understood, interpreted and evaluated objectively by decision makers were obtained with AHP. The authors developed their previous studies and stated with an experimental study that AHP was more convenient to establish a consensus in a group decision making process by comparing the Delphi technique [72]. In the later years, studies conducted by using the MCDM techniques have continued increasingly. One of which brought a solution for a company producing sheet metal parts by handling the CAD/CAM system selection problem with the AHP method [44], while another suggested a methodology expected to help producers and designers working on this subject by implementing the AHP technique on the selection of solid models software [73]. Data warehouse system selection for SMEs in Taiwan has been conducted by [74]. The authors stated in their studies that the software selection problem specific to the data warehouse system was a time consuming and costly task and used the AHP method by considering technical and administrative criteria which they identified to help decision making. Another study focused on the ERP software selection required in the specialization of the companies doing business in Venezuela with the same method [16]. In the following years, studies on various software selection and evaluation problem by using the AHP method alone or as a hybrid were conducted [40, 46 - 48, 58, 75, 76]. Recently, the studies of ETL software selection by [77] and selecting ERP software by [33] using the fuzzy AHP and fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) can be indicated as an example of the studies conducted with AHP. The frequency of the use in the literature indicated the validity of the AHP method both for researchers, decision makers and users. Other quantitative techniques implemented on this problem in the literature are the Analytical Neural Network (ANN) [12, 17, 23, 78], TOPSIS [30, 34, 55 – 57, 76, 77], Quality Function Deployment (QFD) [20, 25, 28, 49], Mathematical Programming [15, 20, 21, 79], and Data Envelopment Analysis (DEA) [15]. Moreover, another point we want to mention is that studies on the selection and evaluation of the appropriate software by using the questionnaires [14, 80] from experts/users in social sciences are encountered as well as in physical sciences.

In this study, the evaluation and selection of the hazard analysis and consequence modeling (HACM) software of potential industrial accidents were discussed, which have not been studied within the scope of the given literature research. Recently, the evaluation of the effects of potential industrial accidents with HACM software has become a requirement with the regulations of the state. The determination of the physical effect distances of explosion, fire and toxic emission caused by an industrial accident is very important. Because these data are so useful in order to take precaution especially emergency plan preparation and to make quantitative risk management. There have been studies conducted with the HACM software affecting technical/financial and strategic decisions on the use. The study of [81] in which evaluated the effects of the chlorine tanker accident, the studies on the development of an integrated emergency intervention model for toxic gas emission by [82], the identification of the death area at a distance of 100 m in 60 seconds for 10000 tons of methanol by using the related software by [83] and the determination of the threat zone by considering atmospheric conditions and topography in the gas pipeline by [84] were remarkable in terms of demonstrating the usage of the HACM software. While evaluating the HACM software, in the light of the basic parameters mentioned above, first the basic and sub criteria were identified (i) by using the experience of experts in this subject and common criteria in the literature. According to these criteria, the opinions of more than one decision maker/expert were obtained (ii). In the framework of the criteria determined, the opinions obtained from different experts were integrated under the concept of group decision making. Finally, the evaluation and selection process was performed by using the AHP method (iii). The questionnaire was prepared according to the basic and sub criteria determined to gather the required data in the study. The questionnaire was applied to experts in the use of the HACM software and they were asked to evaluate it according to the Likert type scale. The data processed from the questionnaire were converted into suggestion matrices according to the method in [85]. The suggested method presents the structure a decision support system because of containing data sets, analytical model, application interfaces, user and reporting system.

In the next section, information about the HACM software alternatives were discussed and the methodology of the study was described. In the third section, an AHP application was performed with the data obtained from the experts by questionnaires. The all obtained results were discussed in the fourth section.

METHODOLOGY

With the improvement of decision theory, it has been important to make decisions according to scientific approach. Decision making is a tough process especially the issue on hand is complicated and the significance of the outcome has major consequences to the stakeholders. This process has generally five steps: identification of a situation that requires a decision; identification and development of alternatives; evaluation of the alternatives due to specified criteria; choice of one of the alternatives, and implementation of the selection.

The information related to the alternatives in question was primarily given for the selection problem of the appropriate HACM software the importance of which was stated in the previous section. Here, the alternatives in question were named by being coded due to commercial rights. Then, the data acquisition from different experts and the operations of the processing and integration of these data were described under certain criteria and the information about the method used for evaluation and selection was provided.

Overview of HACM software alternatives

There are four available software packages commonly and effectively used in the determination of the physical effect distances of the explosion, fire and toxic emission occurring as a result of an industrial accident. These are the software described as A1, A2, A3, and A4. Only A1 of these software packages is presented to the user free of charge.

A1: The entry of detailed information about actual or potential accidents is provided and hazard areas for different hazards are determined in the software. Toxic gas cloud, flammable gas cloud, BLEVE, jet fires, pool fires and vapor cloud explosions can be modeled. The grid image of the two dimensional threat zone obtained as a model output can be transmitted on MARPLOT, Esri's ArcMap, Google Earth and Google Maps. The software has its own library related to the chemicals, however, it is used in pure substances and a limited number of mixture modeling. Modeling is conducted at a single point.

A2: The software estimates thermal radiation exposure and temperature rise BLEVE, jet fires, in limited and unlimited pool fires. Vapor cloud explosion is modeled with Baker-Strehlow-Tang, TNO multiple energy, TNT/HSE equivalent. In the display of the results, a 3-dimensional analyst that can be transmitted to the programs such as Google Earth is used. It has its own library related to the chemicals and can be used for mixtures. Modeling is performed at a single point.

A3: The software provides calculating and estimating the current physical effects of all kinds of accident scenarios with toxic or flammable chemicals. It includes more than fifty models on leakage, vaporization, fire, explosion, emission, and damage. It provides three dimensional images and has the transmission on maps and satellite images. It provides GIS drawings, Google Earth applications, and ESRI shape files with contours, special reports and graphic outputs on the map. It has a chemical database containing the thermodynamic characteristics of more than 2200 toxic and flammable substances. It allows for the entry of the user's own chemical. It can be implemented for mixtures. Modeling can be performed at more than one points.

A4: It is a software tool with the industrial standard for the process hazard analysis. It is used to understand the estimates and visualize the incoming effects upon the loss of integrity scenarios. It analyzes the current situations of potential hazards for life, property and the environment and evaluates their severity. It provides modeling for long and short pipeline applications, leakages, fatal tank ruptures, relief valve and disk ruptures, tank roof collapses, leakages from tank vapor spaces, leakages occurring due to the loss of integrity in closed and open areas. It conducts pool emission and vaporization, the analysis of toxic effects in closed and windy open environments, jet fires, pool fires, fireball analyses including Roberts (HSE) and TNO models, explosion models including TNT, TNO multiple energy and Baker Strehlow. It has a comprehensive chemical database and is used for mixtures and pure substances. Modeling can be performed at many points.

Data collection and pre-processing

According to the criteria identified in the suggested methodology, domain experts were asked to make an evaluation for the HACM software provided. Since the opinions of more than one decision maker were considered, the study conducted can be examined under the title of "group decision making". The survey method was used to collect data from the experts. The software was evaluated by the experts with the questionnaire prepared upon the criteria and sub criteria identified for software selection. In the questionnaire, grading was performed according to the 1-5 interval based on the Likert type Scale. The "Likert Scale" provided the ease of understanding and evaluation and an advantage with its common use.

The Likert scale introduced by [86] which was commonly known as the 5-point Likert scale. Likert developed the scale in 1932 as a part of his Ph.D. thesis as a way to identify a primarily solution of a technical problem which aroused in relation to the quantitative aspects of the study of social attitudes.

A Likert scale provides a range of responses to a given question or statement, for example: - How easy do you use Interface of Software? 1 = Very weak, 2 = Weak, 3 = Moderate, 4 = Strong, 5 = Very strong. In this example the categories need to be discrete and to exhaust the range of possible responses which respondents may wish to give. It indicates an important feature of an attitude scaling instrument, namely the assumption of unidimensionality in the scale; the scale should be measuring only one thing at a time [87, 88].

Likert scale and AHP using together need to compute the relative importance of the variables belonging to the same level, and relative to each of the associated variables. For each pair of attributes, the Expert answers question like "How much more important" in which one attribute is presented with respect to another one, using a Likert scale, or the natural 1,2,. . .,9 point scale. This scale has a semantic interpretation: 1 = equally important, 3 = weakly preferred, 5 = preferred, 7 = strongly preferred, 9 = totally preferred, with even numbers (2, 4, 6, 8) used in the case of uncertainty between two adjacent linguistic terms [89].

In the literature, the use of even number in AHP is not often used. Therefore, we decided to use 1-5 Likert scale instead of using natural point scale. The scale of relative importance is shown at Table 1.

After having the scores of the alternatives from experts, relative ratings of the options with respect to the one another should be calculated. The process of rating and then getting relative rating from experts is shown in Table 2.

A suggestion matrix which use relative rating as input has to be developed. The suggestion matrix can be formed by using transitivity and reciprocity rules as shown in Table 3 [85, 90 - 92]. Thus, the inconsistency and using the ranking weightages are eliminated as suggested in [85]. With the obtained suggestion matrix, evaluation phase could be started.

Evaluation with Analytic Hierarchy Process

With the end of the data collection and preprocessing process, the next stage of selecting the most appropriate software began. In this study, the AHP method was used to evaluate the criteria among themselves and their alternatives on the basis of criteria.

As being a widely used multi criteria decision making method, AHP introduced by Saaty for to determine the relative importance of a set of activities of a problem. Dealing with the activities of the problem, AHP is an effective tool for complex decision making and helps

Table 1: Likert Scale of Relative Importance.

Scale of relative importance	
Qualitative variables	Quantitative value
Not at all	1
Very little	2
A little	3
Quite a lot	4
A very great deal	5

Table 2: Likert Scale Rating for n Number of Alternatives.

Alternatives	Rating	Relative Rating (with respect to immediately previous one)
1	x_1	------
2	x_2	x_2 / x_1
3	x_3	x_3 / x_2
...	...	...
n	x_n	x_n / x_{n-1}

Table 3: Suggestion Matrix Formation Process for Diagonal Input.

Alternatives	Alt 1	Alt 2	Alt 3	⋯	Alt k	⋯	Alt n
Alt 1	1	$1 / A_{21}$	$1 / A_{31}$	⋯	$1 / A_{k1}$	⋯	$1 / A_{n1}$
Alt 2	A_{21}	1	$1 / A_{32}$	⋯	$1 / A_{k2}$	⋯	$1 / A_{n2}$
Alt 3	$A_{32}\times A_{21}$	A_{32}	1	⋯	$1 / A_{k3}$	⋯	$1 / A_{n3}$
⋮	⋮	⋮	⋮	1	⋮	⋮	⋮
Alt k	$A_{k2}\times A_{21}$	$A_{k3}\times A_{32}$	$A_{k4}\times A_{43}$	⋯	1	⋯	$1 / A_{nk}$
⋮	⋮	⋮	⋮	⋮	⋮	1	⋮
Alt n	$A_{n2}\times A_{21}$	$A_{n3}\times A_{32}$	$A_{n4}\times A_{43}$	⋯	$A_{n(k+1)}\times A_{(k+1)k}$	⋯	1

decision makers to identify the relative importance of multiple paired criteria to achieve a stated goal [93]. The AHP process makes it possible to incorporate in both judgments as intangible qualitative criteria and tangible quantitative criteria [94].

In the literature, AHP has been widely used in solving many complicated decision making problems [95 - 99]. AHP hierarchy usually consists of the following levels [100]:

- Overall objective of the decision problem - in our case the Consequence Analysis Software Selection;
- Criteria - in our study 8 groups of criteria, each of them divided into sub criteria;
- Alternatives are usually at the lowest level of the hierarchy—in our case 4 different alternative software.

In the first step, the problem is structured as a hierarchy. AHP initially breaks the problem into a hierarchy of interrelated decision elements (criteria, alternatives). A hierarchy has at least three levels: overall goal of the problem at the top, multiple criteria that define alternatives in the middle, and alternatives at the bottom [101]. The graphic structure of hierarchy is given in Fig.1. The second step is the comparison of the alternatives and the criteria. Once the hierarchy is constructed, prioritization procedure starts in order to determine the relative importance of the criteria within each level. The pairwise judgment starts from the second level and finishes in the lowest level which corresponds to alternatives. In each level, the criteria are compared as pairwise matrices according to their levels of influence and based on

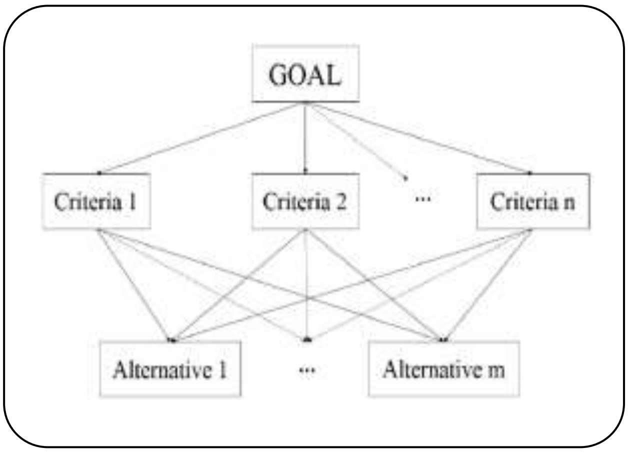

Fig. 1: Graphic Structure of Hierarchy

the specified criteria in the higher level [101]. Although, pairwise comparisons are based on a standardized comparison scale of nine levels in AHP, 1-5 point scale of relative importance has been used here according to aforementioned Likert Scale usage. The matrix format in pairwise comparisons can be described as follows. Let $C=\{C_j \mid j=1,2,\cdots,n\}$ be the set of criteria. The result of the pairwise comparison on n criteria can be summarized in ($n \times n$) evaluation matrix A in which every element $a_{ij}(i,j=1,2,\cdots,n)$ is the quotient of weights of the criteria, as shown [102]:

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

$$a_{ii}=1, a_{ji}=\frac{1}{a_{ij}}, a_{ij}\neq 0$$

At the last step, the mathematical process commences to normalize and find the relative weights for each matrix. The relative weights are given by the right eigenvector (ω) corresponding to the largest eigenvalue (λ_{max}), as

$$A_{\omega}=\lambda_{max}\times\omega \quad (2)$$

If the pairwise comparisons are completely consistent, the matrix A has rank 1 and λ_{max} = n. In this case, weights can be obtained by normalizing any of the rows or columns of A [103].

It should be noted that the quality of the output of the AHP is strictly related to the consistency of the pairwise comparison judgments. The consistency is defined by the relation between the entries of A: $a_{ij} \times a_{jk} = a_{ik}$. The consistency index (CI) is

$$CI=(\lambda_{max}-n)/(n-1) \quad (3)$$

The final consistency ratio (CR), usage of which let someone to conclude whether the evaluations are sufficiently consistent, is calculated as the ratio of the CI and the random index (RI), as indicated. In AHP, pairwise comparisons are based on a standardized comparison scale of nine levels.

$$CR=\frac{CI}{RI} \quad (4)$$

The number 0.1 is the accepted upper limit for CR. If the final consistency ratio exceeds this value, the evaluation procedure has to be repeated to improve consistency. The measurement of consistency can be used to evaluate the consistency of decision makers as well as the consistency of overall hierarchy [103]. Once again, by using suggestion matrix and Likert scale given in [85], the inconsistency was eliminated.

APPLICATION OF HACM SOFTWARE SELECTION

In this section, the application of HACM software selection was performed with the AHP method of which methodology had been previously described. It was previously stated that various software packages were used to be aware of the effects of the accident before it occurred to prevent industrial accidents causing a serious loss of life and property and environmental effects and to prepare emergency plans for these. It is very important for institutions in the sector to select the most appropriate software. Rules and regulations including serious liabilities force the related institutions (metal industry, fuel companies, cement industry, SMEs, etc. including public and autonomous institutions) to use these software packages. Thus, this problem concerns a wide range of industrial sectors and the requirement to use these software packages is continuous. In other words, there is no such thing as the end of the need for the use of software after a certain period. The selection process of the appropriate software for the user among the available software used for the relevant purpose is a strategic decision. These decisions to be made are under the authority of the senior

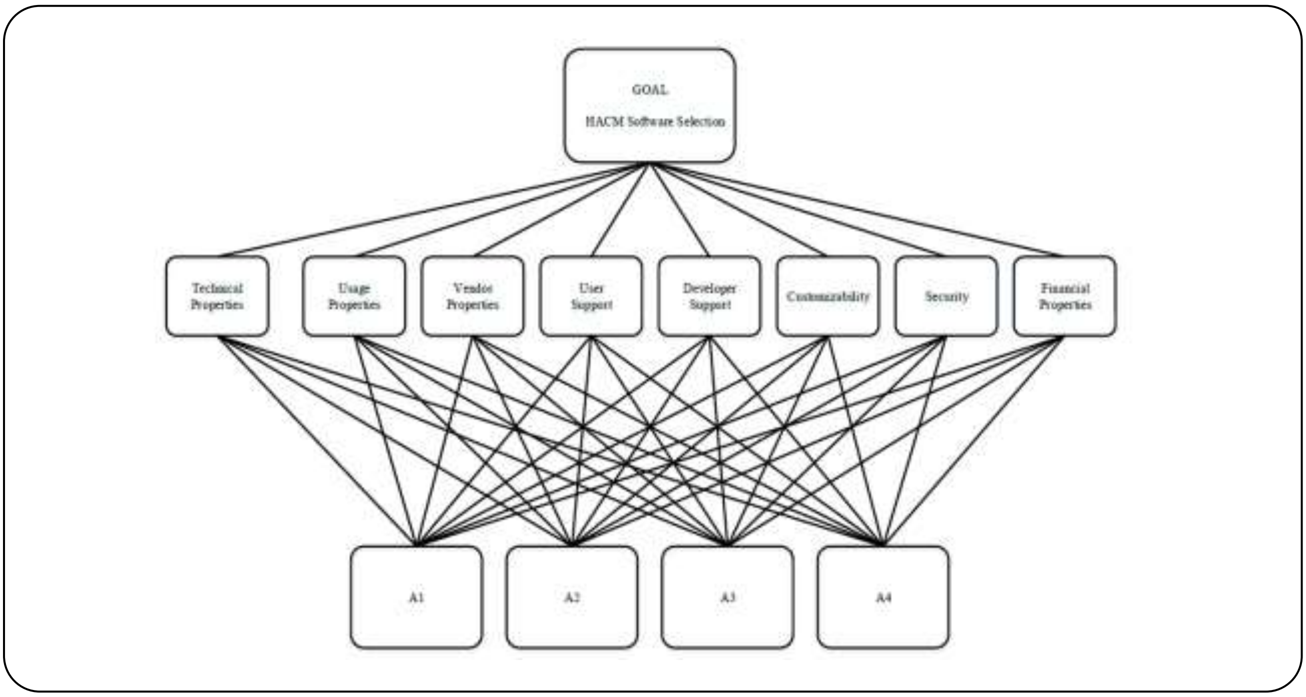

Fig. 2: The Decision Hierarchy of HACM Software Selection.

management of a high budget and generally public or private sector. This HACM software selection problem with high uncertainty has been indicated as an analytical solution method in which the opinions of experts are used and the user is supported and its application has been performed. The application can also provide service as Group DSS when its compounds are considered.

Criteria and sub criteria

The structure of the application consisted of 8 main criteria, 34 sub criteria and 4 alternatives. The criteria to be considered in the selection of software were determined by the literature review. Structured decision hierarchy with alternative and criteria is provided in Fig. 2. Also detailed criteria and sub criteria are provided in Fig. 3.

There exist three levels in the decision hierarchy structured for the problem. The overall goal of the decision process determined as “HACM Software selection” at the first level of the hierarchy. The criteria are on the second level and alternative software are on the third level of the hierarchy. Considering such a structure like Fig. 2 and Fig. 3, it was possible to face with challenges and negative impact on application of the questionnaire. In order to minimize such bothers in the problem, especially designed Likert Scale questionnaire was conducted.

Evaluation of alternatives and criteria with part of proposed method

At this stage of the decision procedure, the questionnaire results received from experts have been investigated and combined for the evaluation process. As being widely used, geometric mean method was used in the combining process. The pairwise comparison matrices used in the selection process were formed according to the details given in Sect. 2.2. All the criteria and sub criteria calculations has been done for all alternatives. In order to obtain more objective and comprehensive results in the evaluation phase, sub criteria were evaluated under each main criteria. Because of having numerous sub criteria and the structure of the AHP method, sub criteria cannot be used directly for the solution process. In this sense, consistency of each sub criteria depending on each main criterion was also calculated. Likert scale rating for alternatives is shown in Table 4.

After getting the relative rating of alternatives (Table 4), we had to place these rating in to the comparison matrix with using rule of reciprocity and transitivity. Obtained alternatives consensus pairwise comparison matrix under Likert scale is shown in Table 5. Similar calculations were made for the other seven criteria among alternatives.

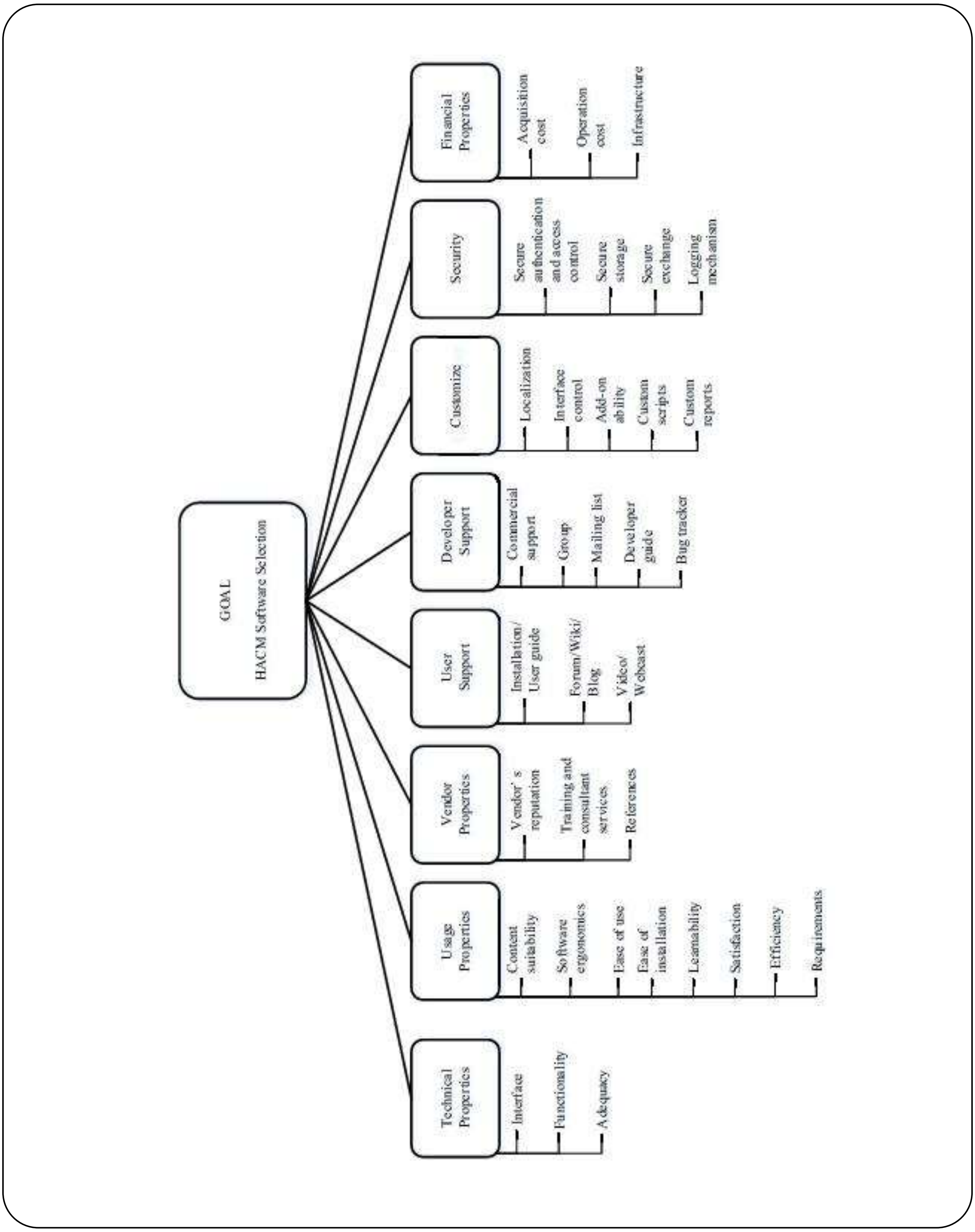

Fig. 3: Sub criteria for Software Evaluation.

Table 4: Likert Scale Rating of Alternatives.

3	Rating	Relative Rating (with respect to immediately previous one)
A1	1.698	-----
A2	4.704	2.770
A3	4.081	0.867
A4	3.732	0.915

Table 5: Pairwise Comparison Matrix of Alternatives according to Security Criteria.

	A1	A2	A3	A4	Weight	CI, RI, CR
A1	1.000	0.361	0.416	0.455	0.119	$\lambda_{max} = 4$
A2	2.770	1.000	1.153	1.261	0.331	CI = 0.0
A3	2.403	0.867	1.000	1.903	0.287	RI = 0.9
A4	2.198	0.793	0.915	1.000	0.263	CR = 0.0

Table 6: Matrix of Criteria with respect to Alternatives.

	Security	Technical Properties	Usage Properties	Vendor Properties	User Support	Developer Support	Customize	Financial Properties
A1	0.119	0.184	0.222	0.187	0.187	0.183	0.143	0.214
A2	0.331	0.311	0.309	0.307	0.295	0.303	0.331	0.253
A3	0.287	0.257	0.231	0.268	0.288	0.262	0.267	0.267
A4	0.263	0.248	0.237	0.239	0.230	0.253	0.259	0.267

After getting for all of the criteria (like Table 5) a new matrix was formed to use for finding the rank of alternatives with respect to each criteria (Table 6). Same procedure like Table 6, was made for the criteria which is shown in Table 7. The weights of the criteria to be used in evaluation process were calculated by using AHP method.

In addition, Super Decisions software was used every stage to control of results obtained from our calculations of AHP. In Fig. 4, it was showed the input of pairwise comparison matrix of criteria via the software as an example. With the calculations done in Table 7, the results obtained from the computations based on the pairwise comparison matrix provided in Table 8.

The C4, C7 and C5 were determined as the three most important criteria in the selection process. Consistency ratio of the pairwise comparison matrix was calculated as $0.0 < 0.1$. So the weights were shown to be consistent and suitable for using in the selection process. After getting the weights of criteria, multiplying them with the alternatives weight the results of AHP are summarized in Table 9. Based on weight values, the ranking of the alternatives in descending order are A2, A3, A4 and A1. Proposed model results indicate that A2 is the best alternative with value of 0.305.

CONCLUSIONS

In this study, it was aimed to select the most suitable HACM software using commonly in industrial establishments. The expert opinions were used in the selection process of determining criteria and a larger criteria set was obtained when compared to the ones in the literature. The opinions of more than one expert were acquired by means of the questionnaires. The questionnaires were conducted and evaluated by using the Likert type scale. The Likert type scale values obtained from the questionnaires were converted into the AHP suggestion matrices and evaluated. The most appropriate software ranking was proposed on the basis of the criteria determined according to the results obtained. Accordingly, the values of A1=0.1798, A2=0.3051, A3=0.2676 and A4=0.2474 were taken from the alternatives. Therefore, the ranking was performed as A2, A3, A4 and A1.

Table 7: Pairwise Comparison Matrix of Criteria.

	Security	Technical Properties	Usage Properties	Vendor Properties	User Support	Developer Support	Customize	Financial Properties
Security (C1)	1.000	1.968	0.866	0.310	0.500	0.537	0.485	0.783
Technical Properties (C2)	0.508	1.000	0.440	0.158	0.254	0.273	0.247	0.398
Usage Properties (C3)	1.155	2.272	1.000	0.358	0.577	0.620	0.561	0.904
Vendor Properties (C4)	3.224	6.344	2.792	1.000	1.612	1.732	1.565	2.523
User Support (C5)	2.000	3.936	1.732	0.620	1.000	1.075	0.971	1.565
Developer Support (C6)	1.861	3.663	1.612	0.577	0.931	1.000	0.904	1.456
Customize (C7)	2.060	4.054	1.784	0.639	1.030	1.107	1.000	1.612
Financial Properties (C8)	1.278	2.515	1.107	0.396	0.639	0.687	0.620	1.000

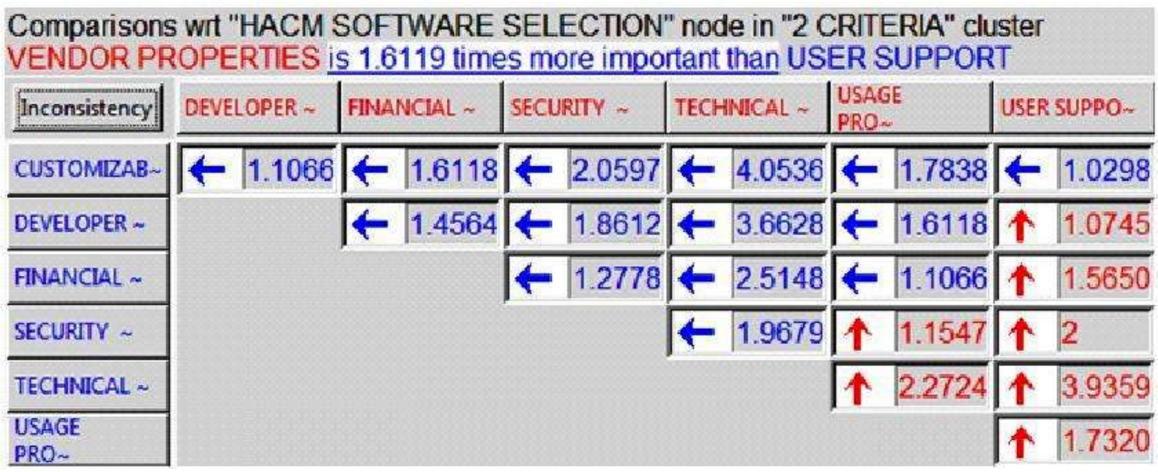

Fig. 4: Pairwise Comparison Matrix of Criteria from Super Decisions Software.

The suggested structure was studied under the title of multi criteria group decision making and decision support was provided to users/administrators at the stage of decision making. Information technology deeply affecting our life in every aspect and its environment continuously develop and change. Solution methods, specialization areas and expert groups are updated depending on this change and new evaluation applications are required in the long term.

With the correct selection and use of the appropriate HACM software, the effectiveness, continuity and reliability of institutions will increase. Software selection is a long term and strategic decision. The investment will be made in relation to the hardware infrastructure, database management infrastructure, the adaptability to innovative technologies scale and technical staff for data acquisition and preparation in the appropriate way for the software and application modules. The development of the model by making the updates in question in the future studies and the creation of a framework for the field in which the problem is being studied are the points on which we are focusing for the future. This is one of the contributions of the study.

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Table 8: Criteria Weights Obtained with AHP.

Criteria	Weight	CI, RI, CR
C1	0.076	$\lambda_{max} = 8$
C2	0.039	
C3	0.088	CI = 0.0
C4	0.246	
C5	0.153	RI = 1.4
C6	0.142	
C7	0.157	CR = 0.0
C8	0.068	

Table 9: Weights and Rank of Alternatives.

Alternatives	Weight	Rank
A1	0.180	4
A2	0.305	1
A3	0.268	2
A4	0.247	3

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REFERENCES

[1] Zoll P.F., Engineering Software Selection Criteria, *Proc. Int. Conf. Fire Saf.*, 67–71 (1980).

[2] Dicaselli R.. How to Select Manufacturing Software, *Mod. Mach. Shop*, **58**(4): 60–63 (1985).

[3] Clochesy J., Henker R., Selecting Computer Software Applications in Critical Care, *Dimensions of Critical Care Nursing*, **5**(3): 171–177 (1986).

[4] Butler D., Selection of Software in the Instructional Laboratory, *Behavior Research Methods, Instruments and Computers*, **20**(2): 175–177 (1988).

[5] Mahmoud E., Malhotra N., Decision Making Process of Small Business for Microcomputers and Software Selection and Usage, *INFOR: Information Systems and Operational Research*, **24**(2): 116–133 (1986).

[6] Masud A., Kolarik B., A Microcomputer Based Knowledge System for CAD Software Selection, *Computers and Industrial Engineering*, **13**(1-4): 26–28 (1987).

[7] Le Blanc L., Tawfik Jelassi M., DSS Software Selection: A Multiple Criteria Decision Methodology, *Information and Management*, **17**(1): 49–65 (1989).

[8] Galletta D., King R.C., Rateb D., The Effect of Expertise on Software Selection, *ACM SIGMIS Database*, **24**(2): 7–20 (1993).

[9] Rowley J., Selection and Evaluation of Software, *Aslib Proc.*, **45**(3): 77–81 (1993).

[10] Andersen C., Emery L., Guidelines for Selection of Health Information Management Software in Outpatient Practice, *Occupational Therapy in Health Care*, **24**(2): 147–158 (2010).

[11] Frank H., Some Considerations when Selecting Digital Library Software, *OCLC Systems and Services*, **22**(2): 107–110 (2006)

[12] Etaati L., Sadi-Nezhad S., Makue A., Using Fuzzy Group Analytical Network Process and ISO 9126 Quality Model in Software Selection: A Case Study in e-learning Systems, *J. Appl. Sci.*, **11**(1): 96–103 (2011).

[13] Kaygısız Ertuğ Z., Girginer N., A Multi Criteria Approach for Statistical Software Selection in Education, *Hacettepe University Journal of Education*, **29**(2): 129–143 (2014).

[14] Iroaganachi, Mercy A., Iwu-James J. and Esse, U.C., Software Selection and Deployment for Library Cooperation and Resource Sharing Among Academic Libraries in South-West Nigeria, *DESIDOC Journal of Library and Information Technology*, **35**(1): 3–8 (2015)

[15] Bernroider E, Stix V., Profile Distance Method-A Multi Attribute Decision Making Approach for Information System Investments, *Decision Support Systems*; **42**(2): 988–998 (2006)

[16] Natalia C, Ana Marîa B, Nancy B, Simôn R., Model for the Selection of ERP Software: The Venezuelan Case, *Revista de la Facultad de Ingenieria*, **21**(1): 125–137 (2006)

[17] Ayağ Z, Özdemir RG., An Intelligent Approach to ERP Software Selection Through Fuzzy ANP, *Int. J. Prod. Res.*, **45**(10): 2169–2194 (2007)

[18] Al-Mashari M, Ghani S, Al-Braithen M., The Enterprise Resource Planning (ERP) Selection Process: Case Analysis and Proposed Framework, *International Journal of Business Information Systems*, **3**(2): 120–139 (2008)

[19] Deep A, Guttridge P, Dani S, Burns N., Investigating Factors Affecting ERP Selection in Made-To-Order SME Sector, *Journal of Manufacturing Technology Management*, **19**(4): 430–446 (2008).

[20] Karsak E., Özoğul C., An Integrated Decision Making Approach for ERP System Selection, *Expert Systems with Applications*, **36**(1): 660–667 (2009)

[21] Şen C.G., Baraçlı H., Şen S., Başlıgil H., An Integrated Decision Support System Dealing with Qualitative and Quantitative Objectives for Enterprise Software Selection, *Expert Systems with Applications*, **36**(3): 5272–5283 (2009b).

[22] Karaarslan N., Gündoğar E., An Application for Modular Capability Based ERP Software Selection Using AHP Method, *International Journal of Advanced Manufacturing Technology*, **42**(9-10): 1025–1033 (2009).

[23] Yazgan HR, Boran S, Göztepe, K. An ERP Software Selection Process with Using Artificial Neural Network Based on Analytic Network Process Approach, *Expert Systems with Applications*, **36**(5): 9214–9222 (2009).

[24] Kutlu B., Akpınar E., ERP Software Selection Using Fuzzy Methodology: A Case Study, *Journal of Applied Sciences*, **9**(18):3378–3384 (2009).

[25] Şen C.G., Baraçlı H., Fuzzy Quality Function Deployment Based Methodology for Acquiring Enterprise Software Selection Requirements, *Expert Systems with Applications*, **37**(4): 3415–3426 (2010).

[26] Parkhill R., Belton V., Bititci U., Roberts A., Smith M., Using Multiple Criteria Decision Analysis to Aid The Selection of Enterprise Resource Planning Software: A Case Study, *Smart Innovation, Systems and Technologies*, **5**: 39-49 (2010).

[27] Onut S., Efendigil T., A Theorical Model Design for ERP Software Selection Process under the Constraints of Cost and Quality: A Fuzzy Approach, *Journal of Intelligent and Fuzzy Systems*, **21**(6): 365–378 (2010).

[28] Zahedi M., Yousefi S., Cheshmberah M., A Fuzzy Quality Function Deployment Approach to Enterprise Resource Planning Software Selection, *Asian Journal of Scientific Research*, **4**(2): 114–128 (2011).

[29] Benlian A., Hess T., Comparing the Relative Importance of Evaluation Criteria in Proprietary and Open Source Enterprise Application Software Selection - A Conjoint Study of ERP and Office Systems, *Information Systems Journal*, **21**(6): 503–25 (2011).

[30] Huiqun H., Guang S., ERP Software Selection Using the Rough Set and TOPSIS Methods Under Fuzzy Environment, *Advances in Information Sciences and Service Sciences*, **4**(3): 111–118 (2012).

[31] Kazancoğlu Y., Burmaoğlu S., ERP Software Selection with MCDM: Application of TODIM Method. International, *Journal of Business Information Systems*, **13**(4): 435–452 (2013).

[32] Fulmer B., Gerard G., Selecting an Enterprise Resource Planning System: An Active Learning Simulation, *Journal of Emerging Technologies in Accounting*, **11**(1): 71–82 (2014).

[33] Efe B., An Integrated Fuzzy Multi Criteria Group Decision Making Approach for ERP System Selection, *Applied Soft Computing*, **38**:106–117 (2016).

[34] Çakır S., Selecting Appropriate ERP Software Using Integrated Fuzzy Linguistic Preference Relations – Fuzzy TOPSIS Method, *International Journal of Computational Intelligence Systems*, **9**(3): 433–449 (2016).

[35] Hlupic V., Paul R., Methodological Approach to Manufacturing Simulation Software Selection, *Computer Integrated Manufacturing Systems*, **9**(1): 49–55 (1996).

[36] Hlupic V., Simulation Software Selection Using Simselect, *Simulation*, **69**(4): 231–239 (1997).

[37] Mchaney R., White D., Discrete Event Simulation Software Selection: An Empirical Framework. Simulation and Gaming, **29**(2): 193–215 (1998).

[38] Nikoukaran J., Hlupic V., Paul R., Hierarchical Framework for Evaluating Simulation Software, *Simulation Practice and Theory*, **7**(3): 219–31 (1999).

[39] Tewoldeberhan T., Verbraeck A., Hlupic V., Implementing A Discrete Event Simulation Software Selection Methodology for Supporting Decision Making at Accenture, *Journal of the Operational Research Society*, **21**(10): 1446– 58 (2010).

[40] Zakria G., Guan Z., Shao X., Riaz Y., Hameed U., Selection of Simulation Software for Manufacturing System: Application of Analytical Hierarchy Approach In Multi Criteria Decision Making, *Advanced Science Letters*, **4**(6-7): 2152–2158 (2011).

[41] Hincu D., Andreica M., The Evaluation and Selecting Process for Simulation Software Using Fuzzy Sets, *Metalurgia International*, **17**(3): 141–144 (2012).

[42] Baykasoğlu A., "Graph Theory" And "Matrix Method" Based Approach for Business Process Modeling/Simulation Software Selection, *Journal of the Faculty of Engineering and Architecture of Gazi University*, **28**(3): 555– 566 (2013).

[43] Bo S., Yanming L., Establishment on Evaluation Indicator System for Power System Simulation Software, *Open Electrical and Electronic Engineering Journal*, **8**(1): 372–378 (2014).

[44] Öztürk N., Çelikliay G., Öztürk F., Software Selection Management in Sheet Metal Fabrication Industry, *Metall*, **59**(6): 382–387 (2005).

[45] Allcock A., Easy Software Selection, *Machinery*, **166**(4157): 18–9 (2008).

[46] Zakria G., Guan Z., Riaz Y., Jahanzaib M., Khan A., Selecting and Prioritizing Key Factors for CAD/CAM Software in Small and Medium Sized Enterprises Using AHP, *Frontiers of Mechanical Engineering in China*, **5**(2): 1571-64 (2010).

[47] Ayağ Z., A Combined Fuzzy AHP-Simulation Approach to CAD Software Selection, *International Journal of General Systems*, **39**(7): 731–756 (2010).

[48] Roshanaei V., Vahdani B., Mousavi S.M., Mousakhani M., Zhang G., CAD/CAM System Selection: A Multi Component Hybrid Fuzzy MCDM Model, *Arabian Journal for Science and Engineering*, **38**(9): 2579–2594 (2013).

[49] Prasad K., Chakraborty S., A QFD-Based Decision Making Model For Computer Aided Design Software Selection, *International Journal of Industrial Engineering and Management*, **7**(2): 49–58 (2016).

[50] Liberatore M., Pollack-Johnson B., Factors Influencing the Usage and Selection of Project Management Software, *IEEE Transactions on Engineering Management*, **50**(2): 164–72 (2003).

[51] Fu C., Yang S.L., The Group Consensus Based Evidential Reasoning Approach for Multiple Attributive Group Decision Analysis, *European Journal of Operational Research*, **206**(3): 601–608 (2010).

[52] Lee Y.C., Tang N.H., Sugumaran V., Open Source CRM Software Selection Using the Analytic Hierarchy Process, *Information Systems Management*, **31**(1): 2–20 (2014).

[53] Omar M.F., Nursal A.T., Nawi M.N.M., Haron A.T., Goh K.C., A Preliminary Requirement of Decision Support System for Building Information Modelling Software Selection, *Malaysian Construction Research Journal*, **15**(2): 11–28 (2014).

[54] Nursal A., Omar Mohd M., Nawi M., Case Study Methodology of DSS Development for BIM Software Selection in Construction Industry, *American-Eurasian Journal of Sustainable Agriculture*, **8**(3): 81–5 (2014).

[55] Nursal A., Omar M., Nawi M., Decision Support Evaluation for Building Information Modeling Software Selection, *Jurnal Teknologi*, **75**(9): 117-122 (2015a).

[56] Nursal A.T., Omar M.F., Nawi M.N.M., The Design of Topsis4bim Decision Support for Building Information Modeling Software Selection, *Jurnal Teknologi*, **77**(5): 1–7 (2015b).

[57] Nursal A., Omar M., Nawi M., Asri M., Adoption of Cloud Based Decision Support System for Building Information Modeling Software Selection, *Advanced Science Letters*, **22**(5-6): 1310–1313 (2016).

[58] Eldrandaly K., GIS Software Selection: A Multi Criteria Decision Making Approach, *Applied GIS*, **3**(5):1-17 (2007).

[59] Eldrandaly K., Naguib S., A Knowledge-Based System for GIS Software Selection, *International Arab Journal of Information Technology*, **10**(2): 152–159 (2013).

[60] De Heij J., The Use of Data Models for Assessing Standard Logistics Software, *Computers in Industry*, **25**(2): 211–216 (1994).

[61] Sahay B., Gupta A., Development of Software Selection Criteria for Supply Chain Solutions, *Industrial Management and Data Systems*, **103**(1- 2): 97–110 (2003).

[62] Ncube C., Maiden N., "Guiding Parallel Requirements Acquisition and COTS Software Selection" In: *Proceedings of the IEEE International Conference on Requirements Engineering*, 133–140 (1999).

[63] Kunda D., STACE: "Social Technical Approach to COTS Software Evaluation", Springer; Volume 2693 of Lecture Notes in Computer Science, 64–84 (2003).

[64] Brooks L., Kunda D., Social-Technical COTS Development: The STACE Contribution, *Journal of Intelligent Systems*, **15**(1-4): 177–202 (2006).

[65] Ahmad N., Laplante P., Using the Analytical Hierarchy Process in Selecting Commercial Real Time Operating Systems, *International Journal of Information Technology and Decision Making*, **8**(1): 151–168 (2009).

[66] Wybo M., Robert J., L´Eger P.M., Using Search Theory to Determine an Applications Selection Strategy, *Information and Management*, **46**(5): 285–93 (2009).

[67] Nikoukaran J., Paul R., Software Selection for Simulation in Manufacturing: A Review, *Simulation Practice and Theory*, **7**(1): 1–14 (1999).

[68] Şen C., Baraçlı H., Şen S., A Literature Review and Classification of Enterprise Software Selection Approaches, *International Journal of Information Technology and Decision Making*, **8**(2): 217–238 (2009a).

[69] Al-Arfaj A., Al-Mudimigh A., Enterprise Software Selection Methodologies - A Brief Review, *Information*, **15**(11B): 4813–4832 (2012).

[70] Le Blanc L., Jelassi T., An Empirical Assessment of Choice Models for Software Selection: A Comparison of The LWA and MAUT Techniques, *Journal of Decision Systems*, **3**(2): 115–126 (1994).

[71] Lai V., Trueblood R., Wong B., Software Selection: A Case Study of the Application of the Analytical Hierarchical Process to the Selection of a Multimedia Authoring System, *Information and Management*, **36**(4): 221–232 (1999).

[72] Lai V.S., Wong B.K., Cheung W., Group Decision Making in a Multiple Criteria Environment: A Case Using the AHP in Software Selection, *European Journal of Operational Research*, **137**(1): 134–144 (2002).

[73] Okudan G., A Multi Criteria Decision Making Methodology for Optimum Selection of a Solid Modeler for Design Teaching and Practice, *Journal of Engineering Design*, **17**(2): 159–175 (2006).

[74] Lin H.Y., Hsu P.Y., Yeh Y.T., Application of the AHP In Data Warehouse System Selection Decisions for Smes in Taiwan, *International Journal of Management and Enterprise Development*, **3**(6): 599–617 (2006).

[75] Assadi P., Sowlati T., Design and Manufacturing Software Selection in the Wood Industry Using Analytic Hierarchy Process, *International Journal of Business Innovation and Research*, **3**(2): 182–198 (2009).

[76] Kara S., Cheikhrouhou N., A Multi Criteria Group Decision Making Approach for Collaborative Software Selection Problem, *Journal of Intelligent And Fuzzy Systems*, **26**(1): 37–47 (2014).

[77] Hanine M., Boutkhoum O., Tikniouine A., Agouti T., Application of an Integrated Multi-Criteria Decision Making AHP-TOPSIS Methodology for ETL Software Selection, *Springer Plus*, **5**(1):1-17 (2016).

[78] Mulebeke J., Zheng L., Analytical Network Process for Software Selection in Product Development: a Case Study, *Journal of Engineering and Technology Management*, **23**(4): 337–352 (2006).

[79] Li X., Zhu D., Object Technology Software Selection: A Case Study, *Annals of Operations Research*, **185**(1): 5–24 (2011).

[80] Kemp E., Phillips C., Pringle D., Hedderley D., Dickson B., Chan M., Software Selection for the Management and Prevention of RSI in a Diverse User Community, *International Journal of Industrial Ergonomics*, **29**(1): 1–14 (2002).

[81] Brzozowska L., Computer Simulation of Impacts of a Chlorine Tanker Truck Accident, *Transportation Research Part D: Transport and Environment*, **43**:107–122 (2016).

[82] Cao H., Li T., Li S., Fan T., An Integrated Emergency Response Model for Toxic Gas Release Accidents Based on Cellular Automata, *Annals of Operations Research*, **255**: 617-638 (2017).

[83] Xing Z., Wang Y., Safety Assessment and Fire Design of the Synthesis and Refining Unit for Annual 10000t Methanol, *Journal of Safety and Environment*, **3** (2015).

[84] Norhamimi M.H., Libriati Z., Nordin Y., Norhazilan M.N., Environmental Loss Assessment for Gas Pipeline Failure by Considering Localize Factors Using Fuzzy Based Approach, *Applied Mechanics and Materials*, **735**:163–167 (2015).

[85] Hossain M.F., Adnan Z.H, Hasin M.A.A., Improvement in Weighting Assignment Process in Analytic Hierarchy Process by Introducing Suggestion Matrix And Likert Scale, *International Journal of Supply Chain Management*, **3**(4): 91–95 (2014).

[86] Likert R., A Technique for the Measurement of Attitudes, *Archives of Psychology*, **140**:1–55 (1932).

[87] Oppenheim A.N., "Questionnaire Design, Interviewing and Attitude Measurement", Pinter, London (1992).

[88] Cohen L., Manion L., Morrison K., "Research Methods in Education", 6th ed. Routledge, London (2007).

[89] Marcomini A., Suter II G.W., Critto A., "Decision Support Systems for Risk Based Management of Contaminated Sites", Springer Science and Business Media, New York (2008).

[90] Ishizaka A., Lusti M., An Expert Module To Improve The Consistency of AHP Matrices, International *Transactions in Operational Research*, **11**: 97-105 (2004).

[91] Yucheng W., Baoguo M., Zhaohan S., Ranking Method for the Reciprocal Judgment Matrix Based on the Unascertained Three Valued Judgments, *Journal of Systems Engineering And Electronics*, **17**:115–120 (2006).

[92] Gass S.I., Standard S.M., Characteristics of Positive Reciprocal Matrices in the Analytic Hierarchy Process, *Journal of the Operational Research Society*, **53**(12): 1385-1389 (2002).

[93] Carr M., Zwick P., Smart Land-Use Analysis: The LUCIS Model. Redlands: ESRI Press (2007).

[94] Badri M.A., A Combined AHP-GP Model for Quality Control Systems, *International Journal of Production Economics*, **72**: 27–40 (2001).

[95] Lv J., Peng Q., Chen X., Sun Z., A Multi Objective Heuristic Algorithm for Gene Expression Microarray Data Classification, *Expert Systems with Applications*, **59**:13–19 (2016).

[96] Petrillo A., De Felice F., Jannelli E., Autorino C., Minutillo M., Lavadera A.L., Life Cycle Assessment (LCA) And Life Cycle Cost (LCC) Analysis Model for a Stand-Alone Hybrid Renewable Energy System, *Renewable Energy*, **95**: 337-355 (2016).

[97] Çevik Onar S., Büyüközkan G., Öztayşi B., Kahraman C., A New Hesitant Fuzzy QFD Approach: An Application To Computer Workstation Selection, *Applied Soft Computing Journal*, **46**:1–16 (2016).

[98] Dede G., Kamalakis T., Sphicopoulos T., Theoretical Estimation of the Probability of Weight Rank Reversal in Pairwise Comparisons, *European Journal of Operational Research*, **252**(2): 587–600 (2016).

[99] Hassanzadeh R., Nedovic-Budic Z., Where to Go First: Prioritization of Damaged Areas for Allocation of Urban Search and Rescue (USAR) Operations (PI-USAR Model). Geomatics, *Natural Hazards and Risk*, **7**(4): 1337– 1366 (2016).

[100] Kramulova J., Jablonsky J., AHP Model for Competitiveness Analysis of Selected Countries, *Central European Journal of Operations Research* **24**(2): 335–351 (2016).

[101] Albayrak E., Erensal Y.C., Using Analytic Hierarchy Process (AHP) to Improve Human Performance. an Application of Multiple Criteria Decision Making Problem, *Journal of Intelligent Manufacturing*, **15**: 491–503 (2004).

[102] Dağdeviren M., Yavuz S., Kılınç N., Weapon Selection Using the AHP and TOPSIS Methods Under Fuzzy Environment, *Expert Systems with Applications*, **36**: 8143–8151 (2009).

[103] Wang J.J., Yang D.L., Using A Hybrid Multi Criteria Decision Aid Method for Information Systems Outsourcing, *Computers and Operation Research*, **34**: 3691–700 (2007).