An exploratory study on the critical features of construction project planning software

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Abstract

Although planning is one of the most crucial processes of the project management process group, the significance of planning software features has not been elaborated comprehensively. The absence of this theoretical foundation causes confusion among construction practitioners when it comes to select software that meets their expectations. Therefore, in this study, it is aimed to figure out the main features of planning software along with their significance. Firstly, an in-depth literature review was conducted to detect the features of the planning software. Later, a focus group discussion (FGD) conducted with 10 experts who worked in the planning domain was organized to validate or omit the findings obtained from the literature. Next, a questionnaire survey was conducted with the same experts to score the planning features. After the Fuzzy Analytical Hierarchy Process (AHP) analysis, the ranks of the planning features were obtained. The results revealed that Cost Management, Resource Management, and Project Performance Measurement were the top three feature categories. Under each category, the following features were deemed as the most important features: Resources Allocation, Defining of Different Unit Price Types, Earned Value Analysis, Activity Code, Assigning Calendars to the Lags and Resources and Allowing Different Calendars in a Project. It is believed that the outcomes of this study provide a deep insight into the critical features that should be integrated into planning software. In other words, this study conducts a need analysis for the planning software. In this way, planning software developers focus on the most important features.

Keywords: Construction Projects; Fuzzy Analytical Hierarchy Process; Multi-Criteria Decision Making; Project Planning; Planning Software.

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1. Introduction and Literature Review

Construction projects are executed by organizations with limited resources within a defined period. Having sophisticated multidisciplinary works, planning the harmonization of all these limited resources is enormously complex, and this increase the uncertainty in the construction projects [1]. Furthermore, developments in technology upsurge the competition among the construction firms, and this increase the number of fast-track projects as well as associated risks which may eventually turn into delays. Coupled with the dynamic, turbulent environment of construction projects, time overrun is mostly unavoidable in construction projects and the majority of the construction projects fail in settling time-related disputes [2].

This paper was recommended for publication in revised form by Regional Editor Ahmet Selim Dalkilic
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To overcome this interminable issue, planning plays a crucial role. Planning is defined as a roadmap to be followed to achieve predefined goals. To adapt changing environment of the construction industry, individuals and institutions have to set goals and they can reach these goals through planning mediums [3], which is one of the most critical benefits of the project management process today [4]. If the planning is not conducted effectively, the majority of activities in the construction projects are likely not to meet their targets [5]. Schedule slippages may end up with massive cost overruns in construction projects across the globe [6], and this turn into a conflict between the contracting parties over time [6]. Conflict is an inevitable part of the construction industry, and the majority of conflicts conclude with a dispute in construction projects [7]. One of the biggest triggering factors of the dispute is project delay with a rate of 11% [6]. If the project planning is not conducted appropriately, the contractor cannot complete the project on the planned date, which may cause the contractor to pay compensation, and close relationships between the contracting parties may deteriorate. By the same token, the performance of the projects in the construction industry can be significantly enhanced by conducting a proper project planning process [8]. Therefore, researchers conducted many studies to improve the planning domain in the construction industry.

Many planning programs adopting the Gantt method, Critical Path Method (CPM), Linear Scheduling Method (LSM) and Program Evaluation and Review Technique (PERT) are actively used in the engineering practice. However, the applicability of these techniques varies according to the type and size of the project. In recent years, the technological development of planning programs has gained importance and planning techniques have begun to be used more effectively as a result of the integration of planning techniques into 4D-BIM and Enterprise Resource Planning (ERP) [7]. Despite the importance of planning in projects, few planning techniques have been developed and the effectiveness of these techniques is still a matter of debate. Therefore, planning methods such as LSM, PERT, Gantt and CPM were elaborated and their effectiveness was improved over time in the literature [9–15]. Adopting different planning methods such as Gantt, CPM, PERT and LSM, many scheduling software has been developed over the last decades. Since their effectiveness varies from project to project, the application and effectiveness of existing planning software were elaborated by various studies [16–19]. Also, planning techniques and best practices were investigated and the body of knowledge concerning the planning domain was improved by institutions such as PMI (1996) [4], which results in unity in planning practices around the world. Today, many disciplines work together in construction projects and the interfaces between these disciplines have become very complex. Thus, the developing technology has proven the need to move planning beyond stand-alone applications so that studies concerning the integration of planning medium into the BIM domain were also conducted by the researchers [20,21]. In this respect, trends have recently shifted from stand-alone planning software towards 4D-BIM. 4D-BIM software is even expected to replace all other planning software in near future. Thus, various studies were conducted to improve the effectiveness of 4D-BIM software. For instance, Chou and Yang [22] and Coyne [23] investigated the applicability of delay analysis in a BIM environment. The results revealed that most of the problems related to the delay analysis domain could be resolved by conducting delay analysis with BIM. In the past few decades, CPM and PERT - which do not consider resource constraints - were used as the top two fundamental scheduling methods in construction projects [24]. However, the availability of resources in construction projects is generally limited and the project schedule created with the help of CPM or PERT methods generally requires further optimization to also consider resource constraints. Therefore, the optimization of scheduling was also examined and improved in the literature [25]. In addition to this, without dealing with optimization, the resource levelling feature of planning was investigated and improved in the literature [26–29]. Moreover, construction safety planning was also elaborated to improve this domain [30–32]. Furthermore, the main factors affecting planning outcomes in construction projects were also detected [33].

Although there are many studies on planning in the literature as explained above, the existing studies do not consider the adequacy of the planning features that are integrated into scheduling software such as primavera. The lack of this theoretical basis creates confusion among construction practitioners when it comes to selecting software that meets their expectations. In case the critical features and/or tools of a planning software are revealed, decision-makers could well identify software that is equipped with these features. Besides the construction practitioners, critical features are of paramount importance also for developer firms. They could integrate and/or improve the user experience of these critical features. To diminish these drawbacks as well as manage the rapid development of planning thoroughly, this study aims to determine the main features of the planning software and to determine the degree of importance of these features. For this reason, in our study, first of all, the features of the planning software were revealed by conducting an in-depth literature review. Afterwards, the findings of the literature review were further validated by conducting focus group discussions (FGD) which were organized with the participation of construction practitioners. Then, a questionnaire survey was conducted with 10 experts who worked in the field of planning for a minimum of 5 years and used at least two different planning software. The data obtained from the questionnaire were analyzed using the Fuzzy AHP (FAHP) method and the importance levels of the features that are or should be in the planning software were determined. In this way, this study will shed light on the firms developing planning software as well as practitioners selecting the most ideal planning software. Additionally, this study will fill the gap in the literature and influence the researchers focusing on the planning domain.

2. Research Methodology

This study aims to identify and prioritize the features of planning software. In this way, the firm developing and marketing planning software and construction practitioners will be provided with a deep insight into the critical features that should be integrated into planning software. In other words, this study conducts a need analysis for the planning software.

Accordingly, the research methodology given in Figure 1 was followed to achieve the objectives of this study. As depicted in Figure 1, the adopted research methodology was comprised of two stages. These stages are feature detection and verification, and assessment of the criticality of the features. In the first stage, an extensive literature review was conducted to identify the features which are available within the literature. This step was then followed by an FGD session.

In the FGD sessions, the experts assessed the validity of the features extracted from the literature and proposed additional features that are not unfolded by the existing studies. In this respect, this study makes a significant contribution to construction management literature since the theoretical knowledge of the researchers is merged with the practical experience of the construction experts. At the end of the session, the experts also categorized the features based on their similarity and relevancy. At the final stage, a questionnaire survey was conducted and the survey data was evaluated by using FAHP analysis to determine the criticality of each feature. The data reliability was verified by conducting a consistency analysis.

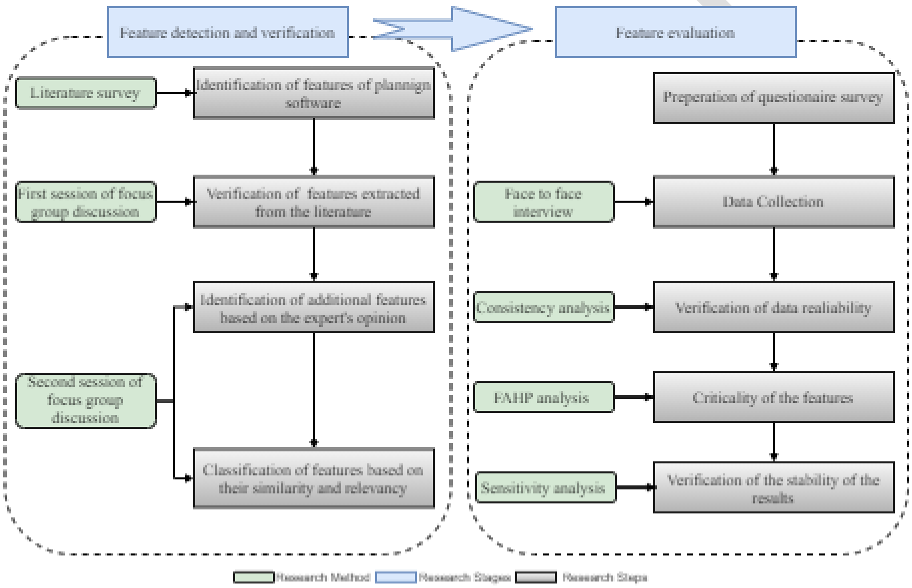

Figure 1. Implemented research methodology.

2.1. Feature detection and verification

As depicted in Figure 1, a comprehensive literature review was conducted to identify the critical features that were proposed by existing studies. During this literature review, the search engine Scopus was preferred since Scopus has long been known as one of the most comprehensive and effective search engines [34–36]. Firstly, the keywords that will be used in the literature review process were detected in a similar manner presented by Cevikbas and Isık [37]. Accordingly, the keywords such as “feature”, “scheduling”, “schedule”, “planning”, and “4D” were adopted to reveal the related research. It should be noted that only peer-reviewed research articles and papers presented at prestigious conferences were utilized to maximize the reliability of the literature review. Furthermore, to maximize the scope of the literature review, a snowballing approach was implemented. This approach is highly beneficial when it is complemented with a systematic literature review [38]. The snowballing approach dictates to review of the studies which are cited by the papers extracted from Scopus [39]. This step was followed by the elimination step. In this step, the titles and abstracts of the studies were deeply examined to eliminate the papers that do not focus construction industry or projects. Secondly, the papers that do not focus on planning software and their features were also eliminated. Consequently, the literature review yielded 17 features that are included or should be included in the construction planning software. These features and their sources are presented in Table 1.

Following the literature review stage, a series of FGD sessions is organized. As one of the most popular qualitative research techniques, FGD has long been implemented for researchers to collect data through dynamic and interactive group discussions [40]. In essence, the method is ideal to surface and formalize the tacit practical knowledge of the practitioners. The dynamic interactions between the participants enable to exchange of ideas, points of view, and experiences [35]. Although FGD has various promising benefits as also stated by Nyumba et al. (2018) [41], the sample size is a significant factor to materialize these benefits. However, there are no certain rules regarding the size of the focus group. The large sample of 20 and 50 is not recommended due to issues stemming from moderation. In the meantime, a sample size smaller than 5 participants should also be avoided since it reduces the reliability and prevents extracting creative ideas [42]. Thus, in this study, a group of 10 experts was determined. Experts were selected based on the judgement sampling. Accordingly, their background was deeply examined to reveal their eligibility for the research. In case the experts were deemed ideal for the study, there were invited to participate in the research. The profile of the experts were presented in Figure 2. As is illustrated in Figure 2, surveying consists of 6 civil engineers, 2 mechanical engineers and 2 architects. Their experiences in planning in the construction industry vary between 5 to 16. While a majority of the participants have bachelor’s degrees, 2 out of 10 have master’s degrees. Also, construction concerning high-rise buildings and road constitutes the majority of the experience of the experts. it can be inferred from the figure that participants' backgrounds are sufficient to reveal the importance of the planning features.

Then, the first session was conducted and experts were asked to assess the validity of the features extracted from the literature. During the session, the validity of each feature was asked in order. If the experts unanimously agreed that a particular feature is invalid, it was then eliminated. In case the experts can not reach a consensus, the final decision was made based on the opinion of the majority. As a result of the session, it was recommended to remove the features such as “Critical Path Analysis”, “Cost and Expense Control”, and “Work Breakdown Structure (WBS)” from the list since they are already included in all planning software. Additionally, experts agreed to further eliminate features such as "Detection of variances", "Record Management", "Emailing the Relevant Persons", "Comparison of Programs in terms of Revisions", and "Allowing the Production of What If Charts" due to the reasons that these features provide little benefit to a software.

In the second session, the experts were asked to propose new features. Suggestions of each expert were collected and their validity was assessed based on the similar mechanism presented above. Accordingly, features such as "Resource Leveling", "Resource Curves Entry for the Resources", "Defining of Different Unit Price Types", "Risk Analysis", and “Assigning Calendar to the Lags and Resources" were proposed by the experts. At the final part of the session, the experts categorised the attribute list under the sections of "Resource management", "Cost management", "Project Performance Measurement”, “Monitoring", "Risk Management" and "Calendar". Consequently, the final list of features is obtained and presented in Table 1.

Table 1. Features of Planning Software

Features Included or Should Be Included in the Planning Software	**Jamadar** [29]	**Subramani et al. [17]**	**Bhosekar et al.** [43]	**Ertaş** [44]	**Biçkes et al.** [45]	**FGD**
Resource Management						
Resource Leveling						X
Resources Allocation	X	X	X			
Financial period	X					
Resource Curves Entry for the Resources						X
Cost management						
Defining Different Unit Price Types						X
Currency Entry		X				
Project Performance Measurement						
Earned Value Analysis	X	X	X	X		
Detailing the progress steps	X					
Monitoring						
Document Control	X	X				
Activity Code					X	
Spotting future activities on Gantt Chart	X					
Risk Analysis						X
Calendar						
Assigning Calendar to the Lags and Resources						X
Allowing Different Calendars in a Project	X					

2.2. Feature Evaluation

Uncertainties in the engineering practice are one of the biggest factors that complicate the decision-making process. Therefore, many efforts have been put forward to eliminate these uncertainties in the decision-making process by developing various tools and techniques such as TOPSIS, ELECTRE, Analytical Hierarchy Process (AHP), and Analytical Network Process (ANP). AHP is one of the most preferred MCDM methods in the field of construction management [46–

48]. The method provides three critical advantages compared to other methods [49]. Firstly, the method provides a highly comprehensible procedure owing to the hierarchical representation of the research problems. Secondly, since the method is capable of identifying inconsistent data sets, it can provide a reliable result with a small sample size. Last but not least, its successful implementation in a wide range of disciplines makes it a highly reliable technique [50]. Furthermore, the method's reliability has been further maximized thanks to its integration with the fuzzy set theory [50]. Owing to the well-proven benefits of fuzzy set theory, the FAHP even outperforms the conventional AHP by further diminishing the ambiguity that exists in the nature of the decision-making [50]. Consequently, the FAHP method – which was developed by Chang [51] was implemented in this study. The following steps were carried out:

Step 1. Expert Selection and Data Collection: Similar to the FGD method, the data quality is a more significant factor than the data size. In this respect, the experts should be selected rigorously to further maximize the reliability of the FAHP analysis. In line with this principle, purposive sampling was implemented, and the background of each expert was thoroughly examined. The profile of the experts was depicted in Figure 2. Figure 2 reveals that experts have sufficient eligibility for this study. Thus, the results derived from their opinions present significant practical implications. Furthermore, the sample size of 10 experts was deemed sufficient and convenient for many studies in the literature [52–55].

The expert selection step was followed by the data collection step. The questionnaire survey included three sections. The structure of the survey is given in Appendix 1. In the first section, the experts were directed questions about their background as well as brief information about the research objectives and design. In the second session, the experts made pairwise comparisons between the categories of features. In the last section, the pairwise comparison for features within each category was made. Accordingly, a FAHP survey was designed, and the data was collected via face-to-face and/or online meetings. In this way, required assistance about the survey was provided to the participants, maximizing the reliability of the analysis. Since the linguistic variables were used in the questionnaire design, experts could reflect their answers more effectively [49].

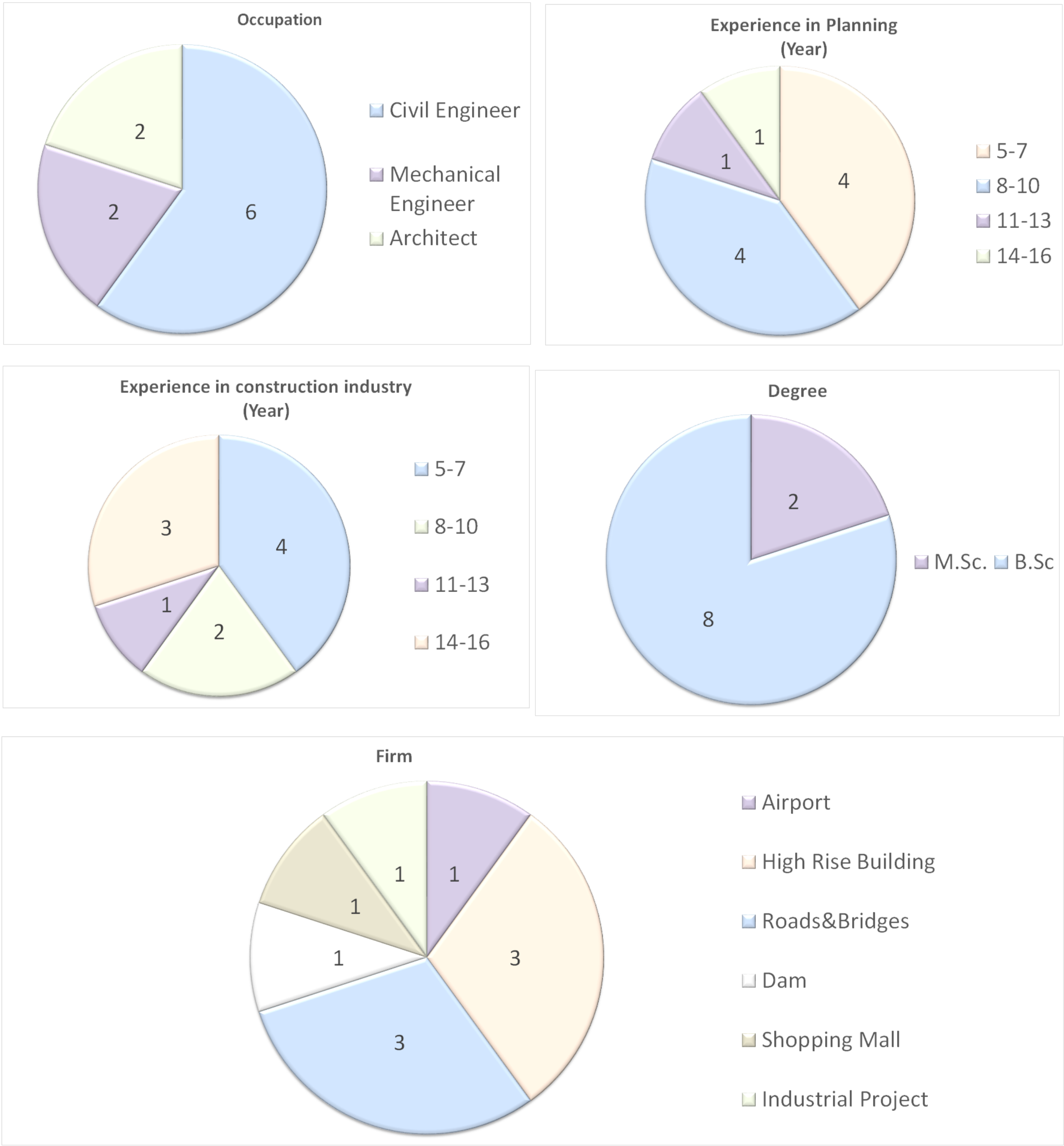

Figure 2. Profile of the experts participating in the study.

Step 2. Consistency check: The consistency check was one of the most critical steps of the study. At this step, the consistency of each matrix completed by each expert was checked. In case a particular matrix was found to be inconsistent, it was rechecked by the corresponding participant. The consistency check was performed by following the procedure proposed by Saaty (1980) [56]. Accordingly, the CR of each matrix should be less than 10% to be considered consistent. It should be noted that the λ_{max}, RI, CI, and n are called as the maximum eigenvalue of the corresponding matrix, the random index, the consistency index and the number of criteria of the corresponding matrix, respectively.

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{1}$$

$$CR = \frac{CI}{RI} \tag{2}$$

Step 3. Aggregation of decision matrices: At this step, the judgments of the participants were merged to obtain aggregation decision matrices. Accordingly, the following formula is performed to obtain aggregated decision matrices [49,57]. It should be noted that, as also presented in Eq. 3, the geometric mean should be used for each component of the triangular fuzzy numbers.

$$l_{ij} = \left(\prod_{k=1}^{K} l_{ijk}\right)^{1/K}, \quad m_{ij} = \left(\prod_{k=1}^{K} m_{ijk}\right)^{1/K}, \quad u_{ij} = \left(\prod_{k=1}^{K} u_{ijk}\right)^{1/K} \tag{3}$$

where K is the total number of respondents.

Step 4. Application of Chang's extent analysis: Let $X = \{x_1, x_2, x_3, \dots \dots \dots, x_n\}$, and $U = \{u_1, u_2, u_3, \dots \dots \dots u_m\}$ are object and goal sets respectively.

Step 4.1 Calculate fuzzy synthetic extent value: Accordingly, the fuzzy synthetic extent value for *i^th^* object was calculated by performing the following formulas.

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \times \left[\sum_{j=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \tag{4}$$

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \tag{5}$$

$$\left[\sum_{j=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right] = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \tag{6}$$

$$\left[\sum_{j=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{j=1}^{n} u_i}, \frac{1}{\sum_{j=1}^{n} um_i}, \frac{1}{\sum_{j=1}^{n} l_i}\right) \tag{7}$$

Step 4.2 Calculate the degree of possibility: The degree of possibility was computed by using a fuzzy synthetic extent value. Equations 8 and 9 were implemented to determine the degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$. $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are expressed as triangular fuzzy numbers.

$$V(M_2 \geq M_1) = \sup_{y \geq x}\left[\min\left(\mu_{M1}(x), \mu_{M2}(y)\right)\right] \tag{8}$$

$$V(M_2 \geq M_1) = htg(M_1 \cap M_2) = \begin{Bmatrix} 1 & if\ m_2 \geq m_1 \\ 0 & if\ l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{Bmatrix} \tag{9}$$

M_2 and M_1 are compared by considering two cases of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$.

Step 4.3 Calculate the degree of possibility for a convex fuzzy number: The following equation was then utilized

$$V(M \geq M_1, M_2, \dots, M_k) = V[(M \geq M_1),(M \geq M_2),\dots,(M \geq M_k)] = minV(M \geq M_i) \quad (10)$$

where $i = 1, 2, 3, \dots \dots \dots, k$.

Step 4.4 Calculate the weights: Considering that $d'(A_i) = \min\ V(S_i \geq S_k)$ for k =1, 2, …, n; k ≠ I; weights of each criterion were computed as follows.

$$W' = (d'(A_1), d'(A_2), \dots, d'(A_n))^T \quad (11)$$

where $A_i(i = 1, 2, 3, \dots \dots \dots, n)$ are n elements.

Step 4.5 Calculate the normalized weights: The normalized weights were obtained for each problem as shown below:

$$W = \left(d(A_1), d(A_2), \dots, d(A_n)\right)^T \quad (12)$$

Consequently, the results obtained from FAHP analysis are presented in normalized weights provided in Table 2.

Step 5 Sensitivity analysis: As the last step of the analysis, sensitivity analysis was conducted to validate the stability of the results. In essence, the sensitivity analysis aims to reveal the change in the results with the variations in the input data (Kamvysi et al. 2014). In case such changes are marginal, the analysis results are deemed stable and reliable. The sensitivity analysis is performed by reiterating the same fuzzy AHP analysis with various degrees of fuzziness which had initially been taken as 0.5. In this study, the analysis was conducted by taking the degree of fuzziness as 0.4 and 0.6. The results of the sensitivity analysis are presented in Figure 3.

3. Results and discussion

As is identified in the analysis, the cost management feature far outweighed the other features. Ending up with rapid environmental changes, construction projects upsurge the pressure on project management in terms of time and cost which are affecting the project's success [58]. Nominately, Larsen et al. [59] also pinpointed that cost overrun is deemed a global phenomenon in construction projects. Since cost is one of the most crucial success criteria in construction projects, monitoring and controlling are needed. Additionally, time is one of the critical factors affecting cost management, and integration of the cost into time allows the project manager to manage the cash flow of the projects. This integration could maximize the resilience of the construction projects since, as also highlighted by Viles et al [60], the majority of the administrative problems stem from poor cash flow management. One of the breakdowns of the cost management option is “Allowing the Defining of Different Unit Price Types”. Projects may have more than one contractor having a different agreement in terms of payment. Therefore, planning software enabling to generate different unit price types is believed to increase its practicality. Additionally, currency entry is another breakdown of the cost management option of the planning software. Commonly, the rapid development of the construction industry and globalization trigger the use of different currencies in projects. Project stakeholders such as owners, contractors, subcontractors, suppliers, consultants, service providers, etc. may have contracts signed among them in a different currency. Therefore, cost management gains further importance in projects using more than one currency, and the availability of currency entry is believed to improve the usability of planning software.

Resource management option in planning software – which constitutes “Resource Leveling”, “Resources Allocation”, “Financial period” and “Resource Curves Entry for the Resources” - is the second important factor. Distribution of resources such as materials, labor, machinery & equipment and their timely use affect the profitability of the projects. While resource management with planning software increases the productivity of resources, it reduces slippage of the resources by enabling resource levelling as well as resource allocation. More than a few current conventional resource management methods such as resource levelling and resource allocation are adopted to overcome the efficiency of resource utilization; however, they are not comprehensive options to resolve the existing problems in the construction industry. Because various studies such as Huynh and Lucko [61] state to the importance of resource management particularly for large-scale construction projects, the resource management domain should be improved in accordance with the expectation of the construction industry.

Table 2. Weights and Ranks of features

Features	Weights	Normalized Weights	Ranks
Resource Management	***0.772***	***0.226***	***2***
Resource Leveling	0.169	0.072	4
Resources Allocation	1.000	0.430	1
Financial period	0.629	0.267	2
Resource Curves Entry for the Resources	0.533	0.229	3
Cost Management	***1.000***	***0.292***	***1***
Defining of Different Unit Price Types	1.000	0.621	1
Currency Entry	0.610	0.379	2
Project Performance Measurement	***0.577***	***0.169***	***4***
Earned Value Analysis	1.000	0.556	1
Detailing the progress steps	0.798	0.444	2
Monitoring	***0.667***	***0.195***	***3***
Document Control	0.546	0.205	3
Activity Code	1.000	0.375	1
Spotting future activities on Gantt Chart	0.431	0.162	4
Risk Analysis	0.691	0.259	2
Calendar	***0.4025***	***0.121***	***5***
Assigning Calendar to the Lags and Resources	1.000	0.500	1
Allowing Different Calendar in a Project	1.000	0.500	1

Project Performance Measurement which constitutes the attributes such as “Earned Value Analysis” and “Detailing the Progress Steps” is a key medium in terms of monitoring the project. It is claimed that many factors have a significant effect on the performance of construction projects [58]. Since the project performance measurement tool is a very vital aspect of the project management process, planning software enabling the project performance measurement attributes will highly contribute to the success of the projects.

The study conducted by Vacanas and Danezis [62] highlighted that the project should be continuously monitored in accordance with the plan. Being a significant aspect of the project management process, monitoring process tools enabled by planning software will highly contribute to the success of a project. Since “Document Control”, “Activity Code”, and “Spotting future activities on Gantt Chart” are of paramount importance, planning software should more focus on these features to satisfy the expectation of the construction industry. Document control - which is one of the most crucial medium of the monitoring process – enables the project to look at the planning from a different perspective. Therefore, improving the activity code domain in the planning software is believed to lead to more comprehensive monitoring of construction projects. Under the monitoring tool, risk management is one of the most significant medium of planning software; however, many of them disregard the concept of risk management. A holistic examination of uncertainty and an integrated risk management tool is mandatory to rise the success of a construction project schedule [63]. However, quantitative risk analysis techniques such as Monte Carlo Analysis are mostly provided as different stand-alone software. Since risks are very common and affect the works carried out on-site, it is believed that the integration of qualitative and quantitative risk analysis into planning software will improve the success of construction projects.

Although the calendar has been adopted by planning software for a long time, “Assigning Calendar to the Lags and Resources” and “Allowing Different Calendar in a Project” have been overlooked [64]. Since activity duration and lag change according to the assigned calendar which may affect the longest path of the projects, planning software enabling the calendar to be assigned to the activity duration, lag and resources are very crucial. Additionally, allowing different calendar improves the reliability of schedules by assigning different working calendars to the resources as well as work activities. In such cases, as also stated by Cevikbas and Isık [7], the same path may include activities having different total floats according to their distinct calendar. This also complicates the definition of the critical path; therefore, developing a planning software tool clarifying this vagueness may improve the use of planning mediums.

Besides results of the sensitivity analysis reveals that rankings of the planning features do not vary concerning the degree of fuzziness so that the analysis was deemed reliable.

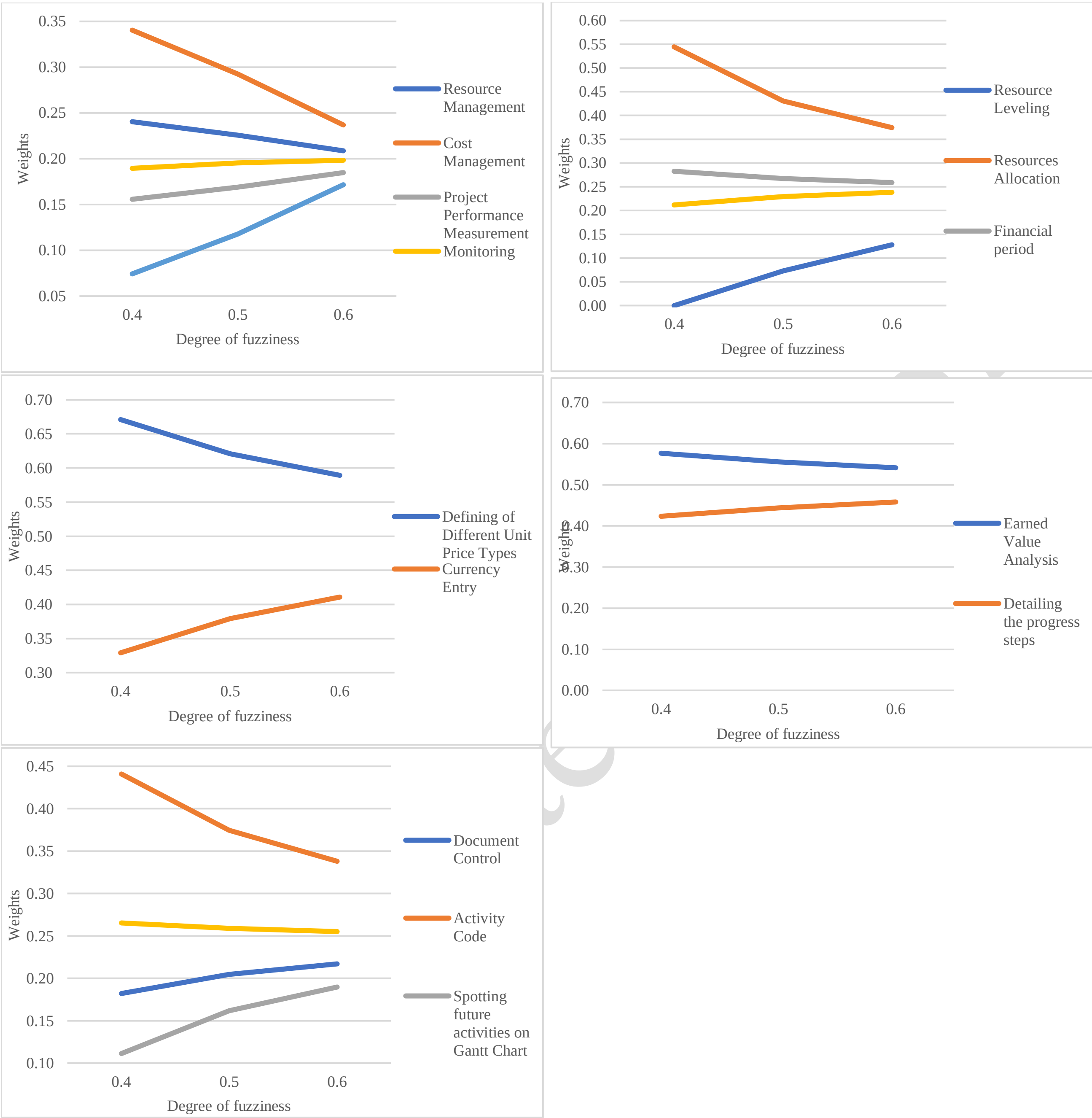

Figure 3. Results of the sensitivity analysis

4. Conclusion

Generating construction planning entails considerable experience and practical knowledge as well as planning software that has sufficient tools. The effectiveness of planning software relies on its capabilities. Notwithstanding the contributions of the studies concerning the planning domain, there is no study investigating the significance of the features of planning software. This study aims to detect the basic features of planning software, and then reveal the significance levels of the determined features. First of all, a comprehensive literature review was conducted to determine the features of the planning software. Afterwards, an FGD session was conducted with 10 experts working in the field of planning to confirm the findings or remove them from the list. Then, a survey was conducted with the same experts to score the planning features, and the information obtained was analyzed via the FAHP method to reveal the importance of the planning features.

Planning is one of the very important Project Management Process Group having very critical roles in 13 knowledge areas defined by the Project Management Institute (PMI) [65]. Since planning software plays a crucial role in the construction industry, it should satisfy the demands of the practitioners taking part in construction projects. The main contribution of this study is to reveal all the required functions as well as their significance for planning software. As is illustrated in the results and discussion section, the categorization of planning feature, namely Cost management received the highest score. It was followed by other categorizations such as Resource Management, Project Performance Measurement, Monitoring and Calendar respectively. Under each category, the following features are deemed as the most important features: Resources Allocation, Defining of Different Unit Price Types, Earned Value Analysis, Activity Code, Assigning Calendars to the Lags and Resources and Allowing Different Calendars in a Project. It is highly believed that these outcomes allow planning software developers to improve the most important features of planning software. Furthermore, construction companies can choose planning software that meets the expectations of the construction industry with the help of the outputs obtained from this study.

This study was conducted mainly on Turkish experts. However, the results may vary concerning country-specific conditions. Thus, further studies could focus on other countries and/or regions. Furthermore, by using the same feature list presented in this study, the variations between the expert's preferences could also be examined. Lastly, the effectiveness of various planning software in terms of offering these features could be tested and validated in future studies.

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