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Abstract

Purpose – In recent years, many development projects of the medical systems encounter difficulties and eventually fail. Failure is often due to very complicated and changeable medical procedures and the inconsistent understanding between system stakeholders, especially the healthcare providers, and information technology staff. Many research results also indicate that poor communication easily results in negative consequences during the implementation of the medical information system. To effectively overcome this obstacle, the purpose of this paper is to propose an enhanced Delphi method to assist in reaching consensus during the software development with some additional steps.
Design/methodology/approach – As an alternative to the traditional way to elicit pertinent feedback from respondents, the enhanced Delphi method stresses the systematic, flexible, and cyclic stages to construct a questionnaire with viewpoints from different types of panelists and a self-assessment procedure as a validating step to measure the improvements in the system implementation.
Findings – The better communication between the members of project team does increase the comprehensive assessment of a project.
Originality/value – Based on a practical case, the enhanced Delphi method really demonstrates good performance and effectiveness.

Keywords Communication, Enhanced Delphi method, Software evaluation

Paper type Case study

1. Introduction

The medical environment is full of complexities and changes very quickly by nature, and it is difficult to completely understand and balance the user requirements from different departments. Besides, the process flexibility is strongly necessary for healthcare providers to reach the patients' maximum benefits. As a result, the negative consequences of developing the medical system occur frequently, including different opinions between active users, failure to learn from past projects, lack of integration, workflow issues, lack of user-friendliness, and so on.

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To avoid these negative consequences, effectively introducing a formal consensus development method to handle issues of communication for the implementation of a medical information system and software evaluation is important. Practitioners often need to make difficult decisions about a medical system development project. The uncertainties concerning the impacts of different options and practices vary widely. Ideally, software development guidelines would be based on the evidence derived from rigorously conducted empirical studies. However, there are few areas of healthcare in which a sufficient amount of research-based evidence exists. In these situations, the development of guidelines must inevitably be based on the opinions and experience of the practitioners that have knowledge of the medical procedure and software architecture. Hence, the formal collection and analysis of the summarized feedback is critical for the medical system development project.

In general, the Delphi method is popularly adopted by many organizations to fulfill this purpose. The domain stakeholders are requested to respond to a set of questions individually and the Delphi approach allows researchers to collect and aggregate individual responses and summarize all of the feedback from the respondents. The respondents are then able to decide whether their responses need modification. This cycle is repeated until a consensus within the respondent group is reached. However, this structured and iterative process to achieve a group consensus among a panel of stakeholders does not lend itself to sophisticated quantitative analysis (Keil *et al.*, 2002).

Rahimi and Vimarlund (2007) claimed there is still no suitable method to analyze, design, and evaluate a medical information system by eliciting users' requirements in a systematic and effective way. Besides, the Delphi method (Linstone and Turoff, 1975) does not describe how to systematically construct the questioning materials and provide a procedure to measure the improvement of the evaluation results. Thus, the traditional method may not be suitable for complicated and changeable therapeutic procedures. Hence, this study proposes an enhanced Delphi method to avoid these negative situations, which are common during the implementation of medical information systems. For performance evaluation and demonstration purpose, a case is provided herein to validate the effectiveness of our proposal. Even though the case is in medical institutes; however, we believe that the enhanced design of multiple stages and repeating cycles is also of use for any other industries in which the intensive communication between different stakeholders is the most critical factor for project success.

The organization of this paper is as follows. Section 2 explains the background of the consensus methods and describes why the Delphi method was chosen and subsequently modified. Section 3 introduces the proposed enhanced Delphi method in detail and demonstrates the adopting procedures of this enhanced Delphi method in a real case. Section 4 discusses the results of the case study. Finally, Section 5 summarizes the implications learned from this study.

2. Literature review

Practitioners in the medical industry often face the problem of trying to make decisions under many complex and changeable situations, when there is no sufficient information or an overload of information. Inconsistencies in studies, in which information is available in an appropriate form, have been resolved and summarized with statistical methods such as meta-analysis. However, some problems do not lend themselves to precise analytical techniques but can benefit from subjective judgments on a collective basis (Sasser and Bartczak, 2004). Hence, consensus methods are needed in this industry.

The aim of consensus methods is to determine the extent to which experts or entities agree about a given issue. The methods provide means of synthesizing information or harnessing the insights of appropriate experts for enabling easier and precise decision making. The importance and meaning of consensus methods lies on the conditions in which agreement cannot be achieved because of a lack of scientific evidence or there is contradictory evidence on a particular issue. The Delphi process and the nominal group technique are two consensus methods commonly adopted in medical, nursing, and health services research (Jones and Hunter, 1995). Nevertheless, when groups make decisions, a few disadvantages must be overcome, e.g., an opinion dominated by one individual or by coalitions representing vested interests. In addition, some published studies have shown that the structure of the Delphi polling procedure produces predictions more accurate than those obtained from unstructured groups, i.e., group meetings, opinion polls, or focus groups (Green *et al.*, 2007). This is the reason why the Delphi method is used often by many industries.

The Delphi method is a structured process of collecting and distilling knowledge from a panel of experts with controlled opinion feedback (Adler and Ziglio, 1996). This method allows a group of experts to systematically approach a particular task or problem (Pare *et al.*, 2013). It includes the following characteristics: anonymity of respondents to reduce the effect of dominant individuals; iteration and controlled feedback through multiple rounds to reduce noise; and statistical group response to ensure that the opinion of each panelist within the group of experts is represented in the final response (Steinert, 2009). Basically, consensus resulting from panelists' responses using iterative polling over two or more rounds is more accurate than an average forecast from an individual group member (Parente and Anderson-Parente, 2011). Thus, the Delphi method represents an inductive, data-driven approach often used in exploratory studies on specific topics or research questions for which no or limited empirical evidence exists (Gupta and Clarke, 1996).

Research problems in many fields can be addressed using the Delphi method, including the physical sciences, engineering, education, public administration, biological science, healthcare, business, economics, and climatology (Okoli and Pawlowski, 2004; Linstone and Turoff, 2002; Biloslavo and Grebenc, 2012). The trend of using the Delphi method has been increasing due to its unique method of accessing knowledge embedded in years of hands-on practitioner expertise. The current industrial concerns in the IT field, such as IT outsourcing (Nakatsu and Iacovou, 2009), knowledge management systems (Nevo and Chan, 2007), business intelligence (Muller *et al.*, 2010), IT project management (Kasi *et al.*, 2008), e-business (Okoli *et al.*, 2010), and IT governance (Haes and Grembergen, 2008) have been studied using the Delphi method.

The Delphi technique has been popular in the past in raising and measuring group consensus within healthcare (Murphy *et al.*, 1998; Poon *et al.*, 2006; Snyder-Halpern, 2001). In a medical environment, it has been used to address various concerns, such as validating the features of electronic medical records (Shaw and Manwani, 2013), identifying the appropriate measures in the implementation of eHealth strategy (Iljaž *et al.*, 2011), developing and validating a taxonomy of front-end clinical decision support tools (Wright *et al.*, 2011), identifying features of e-prescribing software systems (Sweidan *et al.*, 2010), rating the framework and components of a discharge plan (Yam *et al.*, 2012), prioritizing and presenting medication alerts within computerized physician order entry systems (Riedmann *et al.*, 2011), and developing an authoritative list of IT management issues faced by public hospitals (Jaana *et al.*, 2011). Stockwell *et al.* (in press) used a two-round Delphi process which is mirrored to the method designed by Williams and Webb (1994) to elicit a final list of 51 pediatric triggers and consequently identified all-cause harm for pediatric inpatients.

For medical environment, the Delphi method is often the major choice for developing consensus (Gagnon *et al.*, 2009; van Steenkiste *et al.*, 2002; Hsu and Sandford, 2007). However, many concerns still exist regarding the methodological soundness of the Delphi approach (Pare *et al.*, 2013; Linstone and Turoff, 2011; Turoff, 2009):

- The participating entities are not easily chosen, because a software development project in a hospital usually requires participation from various stakeholders in different departments. The complicated problems and contradictions between departments are addressed using the Delphi method is a critical challenge. The problem will further influence how to establish a suitable panel size and maintain the response rate.
- Questionnaire design is an error-prone issue and easily ignored in the traditional Delphi method. Moreover, when dealing with large and very complicated problems, a systematical mechanism is needed to select items for constructing a data collection instrument for pretesting purposes.
- For comment collection, the traditional Delphi method lacks a concrete step that summarizes the heterogeneous feedback and analyzes the target problem. As a result, the presentation of findings and the utilization of results are influenced and not always optimized.
- The traditional Delphi method does not include a mechanism that addresses the self-assessment issue; thus, the past studies seldom used the method of comparing the performance between early and current projects.

In view of the above-mentioned issues, an enhanced method supporting continuous planning processes is proposed for reaching consensus for software development and evaluation in the medical environment.

3. The enhanced Delphi method and case study

In this paper, several techniques of improvement, including questionnaire construction with a cyclic pretest, a repeating process to reach consensus, and a self-assessment are adopted to address the above-mentioned problems. There are five stages within the enhanced Delphi method: the development of the questionnaire, the refinement of the questionnaire, the collection of comments, the analysis of comments, and the validation. These stages are organized within three cycles. The first and second stages are grouped as cycle 1 for constructing and pretesting the questionnaire for use in the next cycle. Cycle 2 consisting of the third and fourth stages are used to reach consensus. The fifth stage, i.e., cycle 3, is used to validate the results from the different stakeholders' perspective; the objective of which is to examine the improvement. These three cycles stop only after the respondents' comments almost converge. In comparison to the traditional Delphi method, our method adopts an additional pretest cycle for better questionnaire construction and an extra validation cycle for further self-assessment.

The proposed method is practiced within the implementation project of the Advanced Hand-Drafting and Picture Management (AHDP) system at the Shinying and Chiayi hospitals supervised by the Department of Health, Executive Yuan, Taiwan, ROC. By integrating the Hand-Drafting and Picture Management (HDP) system (Yang *et al.*, 2012) with Hospital Information System and the Picture Archiving and Communication System in the distributed software architecture and sharing resources between hospitals via a common cloud interface, the AHDP system provides the hand-writing and hand-drawing function to physicians to assist in the form-signing and form-editing work, supplies version control and reference mechanisms to record subjective data, objective data, assessments of the patient's status, and plans for patient care (SOAP) information as well as defines the XML format for transmitting medical information across multiple hospital systems.

For simplicity and easy-to-observe, we adopt the enhanced Delphi method as shown in Figure 1 to build the guideline of software evaluation for the above-mentioned project. Actually, we think this five-stage enhanced Delphi method could also be used to reach consensus for any other parts of software project as long as the complex and changeable details are involved and the intensive communication is needed. Moreover, it can applies well to the projects with the similar above characteristics in other industries too.

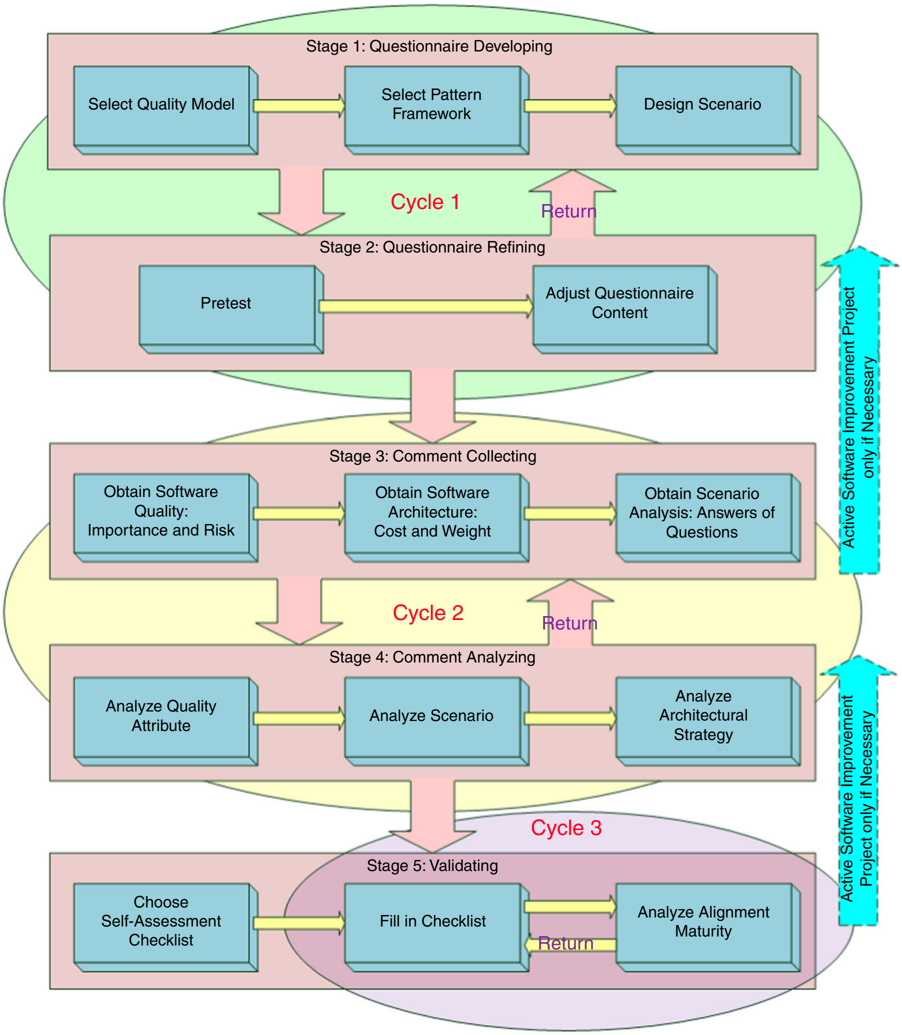

Figure 1.
The framework of enhanced Delphi method

3.1 Questionnaire development stage

For software evaluation, software quality and software architecture are two important issues to consider. To design a questionnaire to measure these two factors, suitable software architecture analysis methods should be carefully selected. Before conducting an evaluation, the software components should first be examined in detail. The major purpose of this step is to analyze the software architecture by examining whether the quality requirements have been addressed and whether the architectural strategies adopted in the system satisfy these quality requirements. Four important items need to be considered in this stage: the quality model, architectural strategy, pattern language, and scenario type. To design the questionnaire of architectural strategy analysis, we integrate the methods of ATAM (Kazman *et al.*, 2000), CBAM (Kazman *et al.*, 2002), and a pattern language of Buschmann *et al.*, (2007). The ISO (2001) (ISO/IEC 9126-1) is selected as the quality model and also used for the basis of scenario analysis. However, the choice of methods is really up to users because different industries or different parts of project may prefer to different standards or best practices. After the important standards are decided, the related primary attributes and sub-attributes could be embedded into the questionnaire. According to the planned software architecture, the adopted architectural patterns and design patterns of the referred pattern language is examined in detail and enclosed in the questionnaire as well. The necessary scenarios are derived in accordance with the architectural strategies and quality model.

3.2 Questionnaire refinement stage

After choosing seven physicians and one software developer as the pretest participants, a draft questionnaire obtained in the first stage is sent to them for review. In addition to the questions developed in the previous stage, each pretest participant is asked to provide feedback about any ambiguity in the questionnaire. Once the collection of responses is completed, the questionnaire is modified based on the suggestion of the pretest participants. If the revision is significant, we will return to the first stage to check the compatibility with standards. This cycle 1 between the first and second stages is repeated until the questionnaire causes little to no confusion.

3.3 Comment collection stage

The finished questionnaire is then e-mailed to 70 randomly chosen physicians at two hospitals and three IT technicians of the software development team. This structured questionnaire consists of two parts. The first part concentrates on evaluating the software quality. For each attribute of the quality model, two important parameters should be evaluated: the importance of successfully achieving a software quality goal and the risk of achieving a software quality goal. The second part focusses on evaluating the architectural strategies through scenario analysis. For each architectural strategy, the cost should be determined after comparing all the possible architectural strategies. Based on these architectural strategies, the scenario analysis is performed by using the related scenarios. The relationships between the scenarios and architectural strategies are especially emphasized to the panelists. For each scenario, the following factors are addressed: the importance of this scenario, the completeness of the system either with or without the inclusion of this scenario, the influence on the primary attributes of the quality model, and the risk of this scenario.

3.4 Comment analysis stage

After obtaining the comments from the previous stage, the results are summarized and analyzed. The following software evaluation results should be elicited: first, the quality analysis report of the quality model that includes the importance and risk of successfully achieving a software quality goal; second, the impacts of each of the quality model's primary attributes and scenarios; third, the potential risk points, quality sensitivity points, and tradeoff points through scenario analysis; fourth, the architectural strategies with use case scenarios, current utilities, and expected utilities; fifth, the architectural strategy benefits; and sixth, the rank of return on investment for architectural strategies. We then judge if a consensus is reached. If not, we will return to the third stage again providing the analytic results and anonymous comments for these 73 panelists to review. This cycle 2 between the third and fourth stages is repeated until the comments of these panelists almost reach a consensus.

3.5 Validation stage

In the fifth stage, we select the self-assessment checklist revised from Luftman (2003) to assess the alignment maturity of the AHDP systems implemented at these two hospitals. However, as emphasized before, the choice of checklist could be left to users. In this case, the evaluation categories include communications, competency/value, governance, partnership, technology scope, and skills. In each category, many corresponding practices are used to construct the detailed items as shown in Table I to examine the maturity level of the architecture alignment. The same physicians and IT technicians that participate in the comment collecting and analyzing stages of second cycle are invited as panelists to assist in the assessment process. All of them answered the checklist in a five-point Likert scale and these data are summarized and returned to them for further consideration. This cycle 3 is stopped when the assessments from the respondents almost converge. The average results of 73 panelists regarding AHDP project is demonstrated with circle (○) in Table I. This 100 percent perfect response rate can be attributed to the strong support from the top management of hospitals. Furthermore, the assessment document leaves space for comments and some of them provided text feedback. After finishing this self-assessment stage, the software architecture alignment of the project could be elicited, and the related recommendations are also retrieved.

In addition to the above procedures, two extra reverse flows from cycle 3 back to cycle 2 and from cycle 2 back to cycle 1 are supplemented in the enhanced Delphi method. These two backward streams are not routines and they will be activated only if the thorough revision of projects is inevitable. Therefore, in Figure 1, we use the dash-lined arrows on the right-hand side to indicate this irregularity.

By utilizing this enhanced Delphi method, the user is capable of systematically handling the implementation issues as well as software evaluation for medical information systems. The major objectives are as follows:

- ensure the software architecture is built with consistent standards, thereby enabling future interoperability within and across hospitals and simplifying the exchange of medical resources;
- serve as a framework for new infrastructure developments and ensure software quality by flexibly constructing software architecture;
- eliminate redundancy and duplicative efforts in medical systems design, vendor negotiations, etc.; and
- reduce long-term costs and software implementation time by leveraging existing knowledge assets.

Practice category	Practice	Assessment 1	2	3	4	5
Communications	1. Understanding of business by IT			×	○	
	2. Understanding of IT by business			×	○	
	3. Organizational learning			×	○	
	4. Style and ease of access			×	○	
	5. Leveraging intellectual assets			×	○	
	6. IT – business liaison staff			×	○	
Competency/value measurements	7. IT metrics		×		○	
	8. Business metrics			×	○	
	9. Link between IT and business metrics			×	○	
	10. Service level agreements		×		○	
	11. Benchmarking		×		○	
	12. Formally assess IT investments		×		○	
	13. Continuous improvement practices	×			○	
Governance	14. Formal business strategy planning			×	○	
	15. Formal IT strategy planning			×	○	
	16. Organizational structure			×	○	
	17. Reporting relationships			×	○	
	18. How IT is budgeted		×		○	
	19. Rationale for IT spending		×		○	
	20. Senior-level IT steering committee			×	○	
	21. How projects are prioritized		×		○	
Partnership	22. Business perception of IT			×	○	
	23. IT's role in strategic business planning		×		○	
	24. Shared risks and rewards	×			○	
	25. Managing the IT – business relationship			×	○	
	26. Relationship and trust style			×	○	
	27. Business sponsors and champions		×		○	
Technology scope	28. Primary systems			×	○	
	29. Standards			×	○	
	30. Architectural integration		×		○	
	31. How IT infrastructure is perceived			×	○	
Skills	32. Innovative, entrepreneurial environment		×	○		
	33. Key IT HR decisions made by:		×	○		
	34. Change readiness			×	○	
	35. Career cross-over opportunities			×	○	
	36. Cross-functional training and job rotation			×	○	
	37. Social interaction		×	○		
	38. Attract and retain top talent		×	○		

Notes: 1 = very bad; 2 = bad; 3 = general; 4 = good; 5 = very good

Table I.
Average alignment assessment of the first year of HDP project (×) and AHDP project (○)

4. Results and discussion

Traditionally, the primary obstacle of software development is that it lacks a feasible method to enhance the mutual understanding and communication between users and IT staff. By implementing this enhanced Delphi method in conjunction with software architecture analysis methods, these difficulties can be reduced to a minimum. During the implementation of the AHDP project, we also collect the critical comments from the project participants, which are recorded as follows.

The questionnaire construction procedure of our proposal is flexible because the questionnaire designer is able to adjust the adopted quality model and pattern language. In this way, the applicability of the software evaluation procedure is enhanced. Because the architectural strategy is mapped to the architectural pattern, the related design patterns could be effectively categorized. Based on the analyzed architectural strategies, the elicited scenarios are able to faithfully describe the operational mechanisms of the developing system.

During the refinement stage, any unnecessary or unsuitable information responses from the pretest participants are summarized, and the questionnaire is then revised based on the received feedback. Thus, the structure and content of the questionnaire can be easily understood even for any non-IT staff. Due to the efforts of the pretest, the efficiency and effectiveness of the questionnaire answering stage are improved. One of the panelist remembers that most project members from different departments are able to follow the steps of the questionnaire without difficulty and do not struggle with technical jargon.

The questionnaire is designed based on carefully chosen software architecture analysis methods, the distributed pattern language and the ISO 9126-1 quality model; thus, the software quality and software architecture is completely examined in detail. The first cycle is an important pretest mechanism for designing the software evaluation questionnaire under formal and rational organization. The referenced quality model and pattern language are then flexibly adjusted to fit the AHDP project. Moreover, the pretest mechanism is used to formally filter out inappropriate items in the questionnaire until consensus is achieved; thus, the produced questionnaire is suitable and useful. One of the questionnaire respondent states that because the produced software evaluation questionnaire is consolidated by reaching consensus from the pretest participants, the meaningful and understandable contents of questionnaire's items are presented to most of the project members in a clear way. Due to this reason, the response rate improves. Furthermore, the corresponding comments of any item in the questionnaire are attached for reference purposes and then the results are recollected. Thus, the final answers are summarized without ambiguity. Because feedback is submitted to the panelists between rounds, the answers from the second cycle are considered more rigorously, and the consensus concerning the software evaluation outputs in the second cycle are also more precise.

After receiving the feedback from the panelists during the second cycle, the evaluation results regarding the software quality and architectural strategy are then briefed. One of the system developer thinks that the elicited recommendations improve the design issues of the business and IT strategy planning and are also retained as important knowledge assets for further software improvement or future maintenance. Because the evaluation results include a software quality attribute analysis, scenario analysis, and architectural strategy analysis, the diversity of the software evaluation is also enhanced. These benefits are achieved by carefully selecting the suitable software architecture analysis methods for cycle 1.

In addition to the summarized qualitative statements, we also analyze the quantitative measurement. Generally, the cycle 3 is designed to assess the alignment maturity of the medical system. Aside from the direct benefits of evaluating the system, the enhanced Delphi method can further provide a chance to assess the improvement, i.e., to validate the improved alignment maturity of the current project by comparison with the previous project. As described in preceding section, we employ the validation stage, i.e. cycle 3, in the AHDP project to investigate the effectiveness of the enhanced Delphi method too. To compare with the current AHDP project, the first year of HDP project that used the traditional Delphi method is chosen as the comparative target. We recall three participants to join this assessment cycle. The average results of assessment for the first year of HDP project and AHDP project are shown with cross (×) and circle (○) in Table I, respectively. As demonstrated in this table, the software architecture alignment is enhanced, on average, by one point in a five-point Likert scale because the communication channel between project participants is tremendously improved. Furthermore, from the assessment results, the categories of communications, competency/value, governance, partnership, technology scope, and skills are all advanced. These results directly support the effectiveness of our enhanced Delphi method. Actually, this study is also a sound way to solidify the baseline measurements for monitoring the project performance and provide the foundation for internal benchmarking.

5. Conclusions

Medical system development projects are often influenced by individuals from different departments with different viewpoints. A critical factor for information system success is to ensure that the software quality and the designed software architecture of a medical system meet the expectations of the healthcare personnel. This objective is not easy to fulfill due to the especially complicated and changeable characteristic for the medical procedures. Due to this reason, we propose an enhanced Delphi method to assist in the communication between all of the stakeholders, especially the healthcare staff and IT staff. In addition to the traditional Delphi method, two extra cycles are proposed to increase the effectiveness and efficiency of the questionnaire construction and self-assessment procedures. Hence, the applicability of our method has been improved due to the reduced misunderstanding and better communication quality between stakeholders. In this enhanced Delphi method, the software performance is enhanced using better communication channel, full integration and favorable workflow. Moreover, it also encourages the user-involvement culture, which reduces the failure rate of medical system projects.

This study uses a real case to demonstrate the proposed enhanced Delphi method. In this case, the adopting procedures are shown, and the related benefits are discussed. By introducing the enhanced Delphi method into the medical system project, the gap between staffs from different units is reduced. Even if the medical environment is complicated and diversified by nature, our proposed method not only helps execute the medical system implementation project in a more efficient and systematic way but also reduces the possible negative consequences.

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