Analysis of Critical Success Factors of Agile Software Projects based on the Fuzzy Delphi Method

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ABSTRACT

Agile software development initiatives have gained widespread recognition both domestically and internationally, particularly in the Chinese software industry. However, traditional enterprises often face challenges, such as inadequate project management and lower success rates, which can be attributed to a limited understanding of agile methodologies and effective implementation of agile practices. To address these challenges and identify the Critical Success Factors (CSFs) in agile software projects, an extensive literature review was conducted. As a result, a CSFs model for agile projects in China was constructed. The aim of this study is to evaluate the CSFs model using the Fuzzy Delphi Method (FDM). The research involved 30 authoritative experts from the Chinese agile software development industry and academia, each with more than 10 years of relevant industry knowledge and experience. The FDM was applied to collect data through questionnaires and verify theoretical success factors and dimensions in three rounds of the survey. Finally, a total of 28 factors were analyzed and ranked to develop an optimized CSFs model that has a significant impact on agile software development in China. The research findings provide a feasible set of CSFs for the effective implementation of agile software projects in China. This CSFs model also offers valuable insights for the broader adoption of agile practices in China, with the potential to greatly improve the success rate of agile software development and implementation.

Keywords-agile software projects; China; critical success factors; expert opinion; fuzzy delphi method

I. INTRODUCTION

The 17th annual agile status report and the 2023 Chinese enterprise agile practice white paper survey data indicate that among Chinese enterprises that have already adopted agile methods, the proportion of agile teams has increased from 55% in 2022 to 63% in 2023. While agile methods have made significant progress in China, traditional enterprises still face challenges, such as insufficient agile project management, implementation difficulties, and lower success rates.

The CSFs for agile software project development exhibit distinct variations between China and other nations, primarily attributed to disparities in cultural influences, market demands, technological advancement levels, and enterprise scale across different regions [1]. These distinctions are primarily manifested in the acceptance of agile culture, the maturity of customer collaboration mechanisms, the degree of self-organizing teams, and the comprehensiveness of tools and technical support [3]. European and American countries focus on technology-driven innovation and change, with agile software development being the most advanced, combining lean thinking and being driven by an innovative culture with extensive management support, technological tools, and an open team dynamic [4]. Conversely, China's agile software development, owing to factors, such as tools, technology, and talent availability, commenced later than that of the developed nations and is relatively concentrated within internet and technology enterprises [5].

The existing literature has extensively explored the critical determinants of successful agile software initiatives. For instance, a case study uncovered seven pivotal factors, including team expertise, client engagement, iterative development, continuous enhancement, leadership backing, team communication, and team morale [6]. Similarly, a different survey and interview-based investigation identified four principal dimensions underlying agile project success: organizational culture, project management practices, team capabilities, and technical approaches [7]. Meanwhile, the human-centric CSFs in agile software development have been categorized [8]. However, the understanding of the China-based agile software sector remains limited, with a lack of systematic identification and prioritization of the CSFs being evident [9]. Furthermore, a structured model defining the CSFs for agile software development success is yet to be established [10-11].

To investigate and confirm the research gap, a comprehensive literature review was conducted, including quality evaluations of 56 relevant articles. During the evaluation process, the rationality of sample selection, scientific experimental design, correctness of data analysis, structure and expression of the articles, as well as the cited references were considered. The articles that fully aligned with the research theme were reviewed, and CSFs were summarized and screened [11].

The most important CSFs were determined and categorized into six dimensions, which include: Organization (OR) dimensions (6 CSFs), People (PE) dimensions (10 CSFs), Process (PR) dimensions (4 CSFs), Project (PO) dimensions (4 CSFs), Team (TE) dimensions (5 CSFs), and Customer (CU) dimensions (5 CSFs). The CSFs were labeled according to the dimensions observed in Table I. The codes ease the evaluation of the CSFs model using the FDM.

The FDM was selected after being compared to Factor Analysis (FA) and Analytic Hierarchy Process (AHP). The FDM has the ability to forecast the properties of developing phenomena, possesses substantial flexibility, and readily utilizes subjective expert input to accelerate predictions and reduce costs. This approach gradually converges expert opinions through iterative survey rounds, ultimately achieving consensus. It also employs the fuzzy set theory to quantify expert perspectives to determine the importance and weight of each one of CSFs [12].

TABLE I. CSFs

Dimension	CSFs	Code
OR	Management support	O1
	Team distribution/ Co-located teams	O2
	Facility with Agile style work environment	O3
	Leadership	O4
	Risk management	O5
	Culture	O6
PE	Capable and motivated team members	P1
	Knowledgeable and experienced agile coach	P2
	Managers knowing the agile process	P3
	Staff's Agile experience	P4
	Good client relationship	P5
	Customer Involvement	P6
	Training and Education	P7
	Staffing culture	P8
	Agile values	P9
	Active communication	P10
PR	Agile-oriented requirement management	R1
	Regular working schedule	R2
	Project scope is well-defined/ Project complexity	R3
PO	Budget	B1
	Plan and schedule	B2
	Project objective planning	B3
	Project change management	B4
TE	Project team skills	T1
	Project team commitment	T2
	Internal project communication and cooperation	T3
	Participation of project team	T4
	Team incentive mechanism	T5
CU	Customer involvement	C1
	Knowledgeable customer	C2
	Customer support education	C3
	Customer experience	C4
	Customer training	C5

The expert questionnaires collected in this stage are integrated with expert opinions using the double triangle fuzzy number. For each evaluation item, the most conservative and optimistic cognitive values provided by all experts are tallied separately. Extreme values beyond twice the standard deviation are removed. The minimum value among the retained most conservative cognitive values is then calculated. The specific details are summarized in Table II.

TABLE II. EXPLANATION OF FDM CODE

Symbol	Evaluation Item
C_L^i	The minimum value of the most conservative cognitive value among all expert evaluations
C_M^i	The geometric mean of the most conservative cognitive values among all expert evaluations
C_U^i	The maximum conservative cognitive value among all expert evaluations
O_L^i	The minimum value of the most optimistic cognitive value among all expert evaluations
O_M^i	The geometric mean of the most optimistic cognitive value among all expert evaluations
O_U^i	The maximum optimistic cognitive value among all expert evaluations

The formula then proceeds to determine the most conservative and optimistic cognitive triangular fuzzy numbers for each evaluation item i individually: $C^i = (C_L^i C_M^i C_U^i)$, and the most optimistic cognitive triangular fuzzy number $O^i = (O_L^i O_M^i O_U^i)$. Subsequently, the gray area test method is utilized to assess the convergence of expert opinions and the importance of consensus (G^i), which can be evaluated through three different methods [7].

The first method assumes that if there is no overlap in the fuzzy numbers of two triangles, $C_U^i \leq O_L^i$. A consensus section exists within the opinion interval values of each expert and the opinions tend to fall within this consensus section without any gray or fuzzy areas $Z^i, Z^i = C_U^i - O_L^i = 0$ or negative values. Therefore, the consensus importance of project i, G^i can be increased and set equal to the arithmetic mean of C_M^i and O_M^i, as represented by:

$$G^i = \frac{(C_M^i + O_M^i)}{2} \quad (1)$$

The second method involves the assessment of the overlap between two triangular fuzzy numbers $C_U^i > O_L^i$, that is, its gray and fuzzy zone $Z^i = C_U^i - O_L^i > 0$. If the grey fuzzy zone Z^i of the fuzzy relationship is smaller than the interval range between the geometric mean of the expert's optimistic cognition of the evaluation project and the geometric mean of the conservative cognition$M^i = O_M^i - C_M^i$, it is: $Z^i < M^i$. Even in the absence of a consensus section within the expert opinion range, experts with extreme values (the minimum value of optimistic cognition and the maximum value of conservative cognition) do not significantly differ from the opinions of other experts, leading to divergent assessments. As a result, the G^i of the evaluation project can be represented by the fuzzy set obtained through the intersection operation on the fuzzy relationship between the two triangular fuzzy numbers. The quantified score can be then calculated as the maximum membership value of this fuzzy number set. A clear formula for these calculations can be applied using the principle of similar triangles, as described in:

$$G^i = \frac{\left(C_U^i \times O_M^i\right) - \left(O_L^i \times C_M^i\right)}{\left(C_U^i - C_M^i\right) + \left(O_M^i \times C_L^i\right)} \quad (2)$$

The third method suggests that if the indicator values reach the predetermined threshold and exhibit convergence, the test values of the indicators are all greater than 0 and are in a convergent state. This implies a consistent evaluation system by experts and scholars for the CSFs, laying the groundwork for a further analysis of the G^i consensus among expert opinions.

The size of the threshold value is a crucial factor in the selection of evaluation indicators. Existing literature primarily relies on the subjective judgement of researchers based on their experience to determine this threshold value. When practical application efficiency and cost are considered, indicator projects with at least 80% expert recognition can be adopted. The authors have set the threshold value G^i of the expert consensus as $G^i \geq 7$, in line with the supporting studies. This threshold value is selected to ensure that the chosen indicators have a high level of expert consensus, which is important for ensuring the credibility and reliability of the evaluation process [13].

II. METHODOLOGY

This paper focuses on the methods deployed during the CSFs model evaluation. It involves the: Prepare Questionnaires, Identify Experts, and Conduct FDM processes, as illustrated in Figure 1.

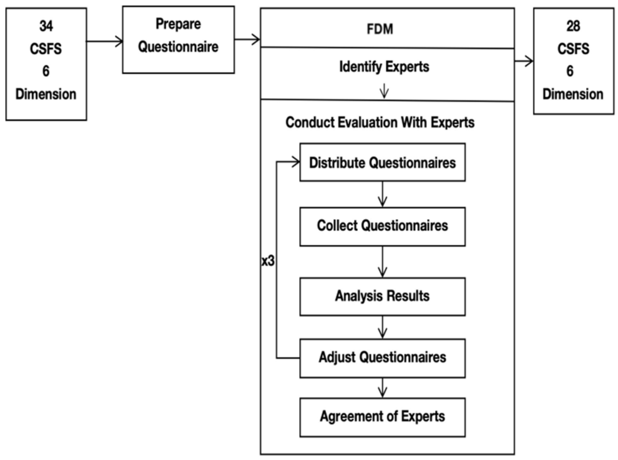

Fig. 1. Flowchart of CSFs model evaluation.

A. *Questionnaire Preparation*

Developing a fuzzy questionnaire is a crucial step in the FDM. Based on the previously constructed CSFs for agile software development in China, the aim of this study is to determine the importance rating of six dimensions and 34 CSFs that influence agile software development in the Chinese context. In the FDM, the expert panel assesses each question using a specific rating scale. The study employed the Likert 11-point scale, which ranges from 0 to 10 points and utilizes an odd number of scales to gauge the degree of importance or agreement [14]. The relationship between the numeric values and the corresponding degree is presented in Table III.

TABLE III. LIKERT 11-POINT SCALE

Values	Degree
0	Not important
1	-
2	-
3	Not important
4	-
5	Commonly
6	-
7	Important
8	-
9	-
10	Very important

The CSFs are assessed using a FDM questionnaire that incorporates primary and secondary indicators, with each question having been assigned eleven possible scores. Experts evaluate the questionnaire based on their understanding of the importance of each indicator. Table IV provides an example of the experts' responses in the questionnaire format. The questionnaire sample is portrayed in Table V, and the full questionnaire is available online [15].

TABLE IV. EXAMPLE OF FDM EXPERT QUESTIONNAIRE

Scoring the importance level of evaluation indicators		
OR		
Expert Value Filling	Most conservative cognitive value (Acceptable minimum value)	Most optimistic cognitive value (Maximum acceptable value)
	2	8

TABLE V. QUESTIONNAIRE SAMPLE

Dimension	**Importance Rating**		
OR	Management Support		
	Expert Value Filling	Most conservative cognitive value (Acceptable minimum value)	Most optimistic cognitive value (Maximum acceptable value)
	Team Distribution/ Co-located Teams		
	Expert Value Filling	Most conservative cognitive value (Acceptable minimum value)	Most optimistic cognitive value (Maximum acceptable value)
	Facility with Agile Style Work Environment		
	Expert Value Filling	Most conservative cognitive value (Acceptable minimum value)	Most optimistic cognitive value (Maximum acceptable value)
	Leadership		
	Expert Value Filling	Most conservative cognitive value (Acceptable minimum value)	Most optimistic cognitive value (Maximum acceptable value)
	Risk Management		
	Expert Value Filling	Most conservative cognitive value (Acceptable minimum value)	Most optimistic cognitive value (Maximum acceptable value)
	Culture		
	Expert Value Filling	Most conservative cognitive value (Acceptable minimum value)	Most optimistic cognitive value (Maximum acceptable value)

B. Experts' Identification

The scale and scope of the interviewed experts directly impact the accuracy and precision of FDM calculations. Existing literature suggests that a minimum of 15 experts is necessary, and the group error can be reduced as the number of expert members increases [16]. However, once the number of expert members exceeds 30, their decision-making quality no longer improves due to the increased group size. To ensure the credibility of the results, a questionnaire survey was conducted with 30 experts from the Chinese agile software development industry and academia, representing diverse regions, positions, and company scales in China, all with 10 or more years of relevant work experience.

The experts represent a diverse range of sizes, from small 10-person startups to large enterprises with up to 5,000 employees. Their roles encompass a variety of positions, including development teams, project managers, agile coaches, scrum masters, product managers, and other roles at the basic, middle, and senior levels. The sample encompasses four companies with more than 500 employees, 12 companies with 300-500 employees, and 14 companies with fewer than 300 employees. The specific details of the experts are provided in Table VI.

TABLE VI. EXPERT PROFILES

Aspect	**Description**	**Number of Experts**
Enterprise Size	>500	4
	300-500	12
	<300	14
Position	Development Teams	10
	Project Managers	7
	Agile Coach	3
	Scrum Masters	2
	Product Managers	6
	Others	2
Region	First Tier Cities	23
	Second Tier Cities	7
Job Category	Academic Expert	8
	Industry Expert	22

C. FDM Implementation

The FDM typically involves multiple rounds of questionnaire distribution and collection to gradually gather expert opinions and reach consensus. The following are the specific steps for distributing and collecting three rounds of questionnaires using the FDM. The three rounds of the questionnaire survey are shown in Figure 2.

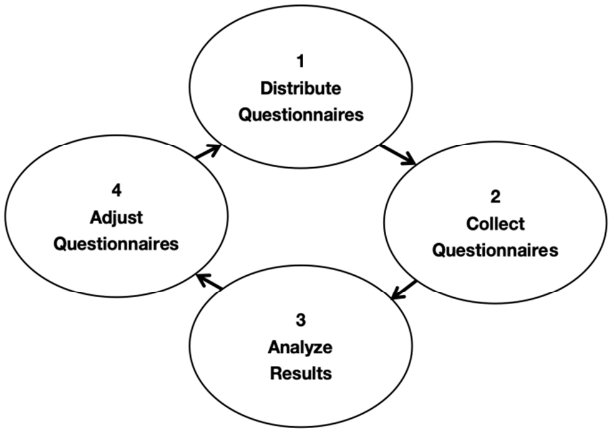

Fig. 2. Flowchart of questionnaire survey.

The first round of the questionnaire survey begins with the distribution of questionnaires. To ensure that experts could fully comprehend and respond to the questions, the provided materials included project background information, detailed questionnaires, scoring examples, factor descriptions, CSFs descriptions, and open-ended question descriptions. The experts were encouraged to submit their opinions anonymously within one week to mitigate the impact of social pressure and personal bias, thereby ensuring the authenticity and objectivity of the feedback. After one week, all experts' responses were received, and the response rate was 100%.

After gathering experts' responses, the collected issues are classified and summarized, and the main perspectives, areas of consensus, and disagreements are identified. The quantifiable opinions are then statistically analyzed. The quality of expert opinions, including their relevance, accuracy, comprehensiveness, and consistency, is evaluated. Opinions with evident errors or deviations should be approached cautiously, and the potential reasons considered. For each evaluation item, the most conservative and optimistic cognitive values provided by all experts are counted, and the extreme values beyond the 2-fold standard deviation are eliminated. All values, as seen in Table II, are calculated to understand the overall distribution and dispersion of expert opinions. Subsequently, the grey zone test method is employed to assess the convergence of expert opinion and determine the consensus value G^i.

Questions with differences or disputes can be addressed through in-depth discussions and exchanges via email and online platforms. By engaging in such discussions, experts can clarify their viewpoints, supplement missing information, or refine their positions. Furthermore, analyzing the open opinions of experts can help confirm whether to add, delete, or modify certain questions. In the initial round, experts provided open opinions on a flexible work environment and team member capabilities. After repeated discussions with experts and FDM verification, CSFs were eliminated. The final step of the first round is to adjust the results. The findings from the initial survey were disseminated anonymously to all experts. The feedback content encompasses summarized expert opinions, calibrated statistical metrics, and potential trend analysis.

The second round of the questionnaire survey is initiated by incorporating feedback from the first round. After receiving the initial feedback, experts will reference the opinions of their peers and their own preliminary assessments to modify and enhance the responses provided in the first iteration. They may adjust their perspectives, supplement missing information, or introduce new arguments. Subsequently, the revised opinions of the second round of experts are collected, and an in-depth analysis is conducted. Comparisons are made between the changes in the results of the two rounds, new trends in expert opinions are identified, and consensus points are reinforced. Finally, the results of the second round of analysis and the emerging trends in expert opinions are anonymously shared with all experts. Experts are encouraged to further contemplate and discuss in order to articulate their views more accurately in the next round. This survey questionnaire still prompts experts to submit their views anonymously within an one-week timeframe, and subsequently receive responses from all experts, achieving a 100% response rate. Then, based on the expert opinions gathered in this round and the analysis of the FDM results, two CSFs pertaining to customer relationships and customer training have been removed.

After receiving the second round of feedback, experts will engage in deeper discussions and reflections, initiating the third round. They may provide more specific arguments or reasons to support their viewpoint or adjust their position regarding the remaining points of disagreement. Next, the final opinions from the third round of experts will be collected, and a comprehensive analysis and summary using FDM will be conducted. The consistency and reliability of expert opinions will be evaluated to determine whether there are clear consensus points or issues requiring further exploration. Through three iterative rounds of investigation and feedback, the opinions of experts will gradually converge. Ultimately, a comprehensive conclusion or recommendation will be formed, reflecting the consensus opinions of experts and a deep understanding of the research problem.

The third round of survey questionnaire still received responses from all experts within a week, with a response rate of 100%. Based on the expert opinions of this round and the analysis of the FDM results, there are no modified opinions in this round. The expert opinions have reached a consensus, and the investigation is concluded.

D. CSFs Finalization

The gathered survey responses were combined, with double triangle fuzzy numbers being utilized for expert judgments. For each assessment criterion, the most cautious and sanguine cognitive values provided by all experts were tallied individually, and outliers exceeding twice the standard deviation were excluded.

The study first established the most conservative and optimistic cognitive triangular fuzzy numbers for each evaluation item. Then, it employed the grey zone test method to assess the convergence of expert opinions and the significance of consensus. The consensus degree was calculated using the corresponding formulas for fuzzy numbers with and without overlapping. If the consensus of the indicators reached the threshold value and was in a convergent state, it indicated that the evaluation system of CSFs by experts and scholars was generally consistent. Based on the predetermined consensus threshold, CSFs with a commonality of less than 7 were identified. Subsequently, the importance, adaptability, and the need to remove the evaluation indicators were discussed through an online collective discussion. Ultimately, the four evaluation indicators below the threshold set in the first round and the two evaluation indicators in the second round were eliminated due to the agreement of all experts. The study expanded on these findings by conducting further analysis and providing additional insights to enhance the understanding of the critical success factors in the evaluation system.

III. RESULTS AND DISCUSSION

This study administered 90 questionnaires through email and received 90 completed responses over three rounds. After the performed review, all responses were deemed valid, achieving a 100% response rate. As outlined in the FDM process, the authors utilized Microsoft Excel software to test the consistency of CSFs. Specifically, the steps entailed converting the fuzzy data into a quantifiable format and then employing Excel's functionality to analyze and confirm the validity and consistency of these data. The FDM calculation flow chart is presented in Figure 3.

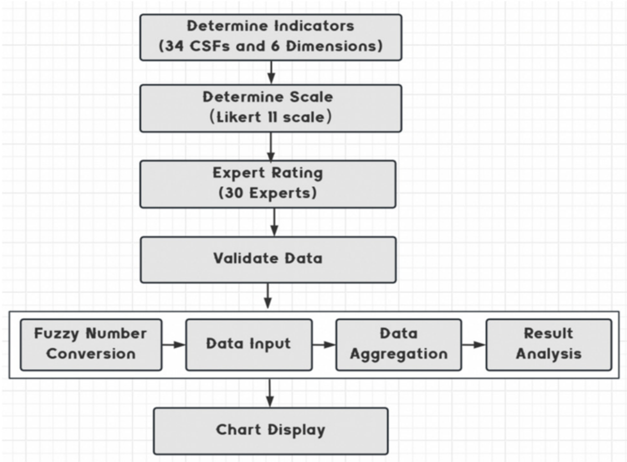

Fig. 3. Flowchart of FDM calculation.

1. Fuzzy Number Conversion: The fuzzy evaluations provided by experts are converted into specific double triangular fuzzy numbers, with extreme values falling outside twice the standard deviation being removed.
2. Data Input: A Microsoft Excel worksheet is created for inputting the converted fuzzy number data. Each expert's evaluation of each indicator is entered as a data point into the corresponding cell.
3. Data Aggregation: All experts' fuzzy evaluations are converted into fuzzy numbers, and aggregation processing is performed. The non-eliminated values, as seen in Table II, are included in the calculations, and the G^i is determined.
4. Result Analysis: The results of the fuzzy operations are analyzed to evaluate the consistency and reliability of the expert opinions. These statistics can serve as the basis for decision analysis.
5. Chart Display: Using the chart function of Microsoft Excel, the results of the fuzzy number operations are displayed in the form of tables and line charts, facilitating an intuitive understanding of the distribution and trends of the expert opinions.

Based on the above analysis steps, the first round results suggest that the analysis of Table VII reveals that the consensus values for the four CSFs: O3, P1, P3 and T2 are below the established threshold of 7, indicating a lack of convergence. Based on the consistency test results of the FDM, the number of influencing factors was reduced from 34 to 30 by eliminating the four aforementioned factors.

The second round results indicate that after conducting the initial data collection and analysis, revised FDM questionnaires were administered to the same group of subject matter experts, processing their responses through the established methodology. As shown in Table VIII, the CSFs P5 and C5 failed to reach a consensus among the experts. With no additional suggestions having been provided for modification, the consistency test outcomes of the FDM prompted adjustments to the indicator system. As a result, the number of influencing factors was scaled down from 30 to 28, which was achieved by eliminating the P5 and C5 factors, and the indicators were then reset.

The third round of FDM questionnaires were administered to the same panel of experts. The data collected were then processed using the established methodology, and the findings are presented in Table IX and Figure 4.

The data evidenced in Table IX reveal that the most conservative and optimistic cognitive values of the five CSFs within the organization dimension, including management support, team distribution/co-located teams, leadership, risk management, and culture, are all aligned. Furthermore, the consensus values of these five CSFs in Table IX further corroborate their convergence, suggesting that all CSFs should be retained and none of them requires removal. The most conservative and optimistic perspectives regarding the seven CSFs in the people dimension are aligned. These CSFs include: knowledgeable and experienced agile coach, staff's agile experience, customer involvement, training and education, Staffing culture, agile values, and active communication. Furthermore, the consensus values of these five CSFs presented in Table IX reinforce the convergence, suggesting that all CSFs can be retained and none needs to be removed from the people dimension. The most conservative and optimistic cognitive values of the four CSFs in the process dimension encompass the following convergent elements: agile-oriented requirement management, regular working schedule, well-defined project scope/complexity, and regular software delivery. When combined with the consensus values of these four CSFs presented in Table IX, it can be concluded that they all converge, demonstrating that all CSFs can be retained and there is no need to remove any CSFs in the process dimension.

The six dimensions of agile software projects have been ranked in ascending order of importance based on a consensus from the third round of evaluation. According to the China expert's perspective, the project dimension is the most crucial, as it encompasses key factors, such as project scope, timeline, and resource allocation. This is followed by the people dimension, which emphasizes the importance of skilled and collaborative team members, and the organization dimension, which considers the influence of organizational structures and processes on project success. The ranking of these six dimensions is presented in Table X.

TABLE VII. ANALYSIS RESULTS OF THE FIRST ROUND OF SURVEY QUESTIONNAIRE DATA

Code	C_L^i	C_M^i	C_U^i	O_L^i	O_M^i	O_U^i	Z^i	M^i	$M^i - Z^i$	G^i	Astringent
O3	1	4.53	7	4	8.10	10	3	3.57	0.57	6.32	NO
P1	1	4.90	7	5	8.73	10	2	3.83	1.83	6.82	NO
P3	1	4.23	6	3	8.60	10	3	4.37	1.37	6.42	NO
T2	1	4.97	7	5	8.43	10	2	3.47	1.47	6.70	NO

TABLE VIII. ANALYSIS RESULTS OF THE SECOND ROUND OF SURVEY QUESTIONNAIRE DATA

Code	C_L^i	C_M^i	C_U^i	O_L^i	O_M^i	O_U^i	Z^i	M^i	$M^i - Z^i$	G^i	Astringent
P5	1	4.73	7	5	8.83	10	2	4.10	2.10	6.78	NO
C5	1	4.63	7	4	9.13	10	3	4.50	1.50	6.88	NO

TABLE IX. ANALYSIS RESULTS OF THE THIRD ROUND OF SURVEY QUESTIONNAIRE DATA

Code	C_L^i	C_M^i	C_U^i	O_L^i	O_M^i	O_U^i	Z^i	M^i	$M^i - Z^i$	G^i	Astringent
OR	1	5.77	8	6	9.63	10	2	3.87	1.87	7.70	YES
PE	2	6.20	8	6	9.33	10	2	3.13	1.13	7.77	YES
PR	1	5.67	8	6	9.73	10	2	4.07	2.07	7.70	YES
PO	1	6.10	8	6	9.60	10	2	3.50	1.50	7.85	YES
TE	1	5.23	9	7	9.37	10	2	4.13	2.13	7.30	YES
CU	2	5.83	8	5	9.33	10	3	3.50	0.50	7.58	YES
O1	2	5.83	8	7	9.67	10	1	3.83	2.83	7.75	YES
O2	1	5.30	8	7	9.73	10	1	4.43	3.43	7.52	YES
O4	1	5.17	8	6	9.53	10	2	4.37	2.37	7.35	YES
O5	1	6.10	8	6	9.50	10	2	3.40	1.40	7.80	YES
O6	2	5.80	8	7	9.63	10	1	3.83	2.83	7.72	YES
P2	1	4.77	8	6	9.60	10	2	4.83	2.83	7.18	YES
P4	2	5.93	8	6	9.60	10	2	3.67	1.67	7.77	YES
P6	2	5.93	8	6	9.47	10	2	3.53	1.53	7.70	YES
P7	3	5.53	7	7	9.50	10	0	3.97	3.97	7.52	YES
P8	2	5.70	8	5	9.40	10	3	3.70	0.70	7.55	YES
P9	3	5.63	8	6	9.57	10	2	3.93	1.93	7.60	YES
P10	1	5.33	8	7	9.57	10	1	4.23	3.23	7.45	YES
R1	3	5.70	8	5	9.50	10	3	3.80	0.80	7.60	YES
R2	2	5.87	8	7	9.53	10	1	3.67	2.67	7.70	YES
R3	3	6.23	8	6	9.53	10	2	3.30	1.30	7.88	YES
R4	2	5.40	8	5	9.40	10	3	4.00	1.00	7.40	YES
B1	2	6.40	8	5	9.37	10	3	2.97	0.03	7.88	YES
B2	2	6.23	8	6	9.60	10	2	3.37	1.37	7.92	YES
B3	2	5.03	7	7	9.57	10	0	4.53	4.53	7.30	YES
B4	2	5.87	8	5	9.47	10	3	3.60	0.60	7.67	YES
T1	2	5.27	7	5	9.30	10	2	4.03	2.03	7.28	YES
T3	1	5.97	8	7	9.53	10	1	3.57	2.57	7.75	YES
T4	3	6.10	8	6	9.50	10	2	3.40	1.40	7.80	YES
T5	3	6.20	8	7	9.70	10	1	3.50	2.50	7.95	YES
C1	1	5.40	8	6	9.63	10	2	4.23	2.23	7.52	YES
C2	3	5.63	8	6	9.60	10	2	3.97	1.97	7.62	YES
C3	2	5.83	8	7	9.50	10	1	3.67	2.67	7.67	YES
C4	3	5.37	8	6	9.43	10	2	4.07	2.07	7.40	YES

The top nine CSFs are outlined in Table XI.

- The most significant factor is T5, which is instrumental to the successful implementation of agile software projects. Human elements have a paramount impact on project execution, so motivating team members to contribute to project success is a top priority [17, 18].
- B2 - A comprehensive project plan with clear milestones and timelines is crucial. Effective resource and task organization, feasible schedules, and robust time management strategies underpin successful project execution and implementation [19].
- Effective budget management, referring to B1, is essential for project success. It enables organizations to oversee projects efficiently, enhance decision-making, and thoroughly manage expenditures. This mitigates cost overruns and resource waste, while helping formulate realistic plans and objectives based on project budgets [20, 21].
- The R3 factor encompasses well-defined project scope and complexity. Effective scope management is critical, as the project scope directly impacts time and cost. Defining clear requirements and managing the scope ensures consistent expectations among teams and stakeholders. Project complexity arises from technical, requirement, and data aspects. When faced with complexity, it is important to develop a reasonable response plan to simplify the problem, facilitating smooth project implementation [17, 22].
- O6 is significant for the successful implementation and sustainable development of agile software projects. Potential risks may arise from diverse factors, which can expose the project to uncertainties and challenges if not managed properly [19].
- T4 including resource sharing, code sharing, mutual support, reducing individual dominance, and minimizing risks, can enhance project success rates. However, in China, many companies failed during their initial agile transformation because they believed agile development was only for the

development team. The management teams assumed training and supporting developers would be enough, without considering the impact of agile on other departments like sales and finance [23, 24].

- Experienced staff, referring to P4, familiar with daily work methods can identify problems and effective practices, providing the team with knowledge to evaluate the company's needs. While some staff members have basic agile understanding, insufficient proficiency hinders agile implementation. Employing inexperienced staff extends the program's duration or complexity and jeopardizes successful task completion [23].
- O1 is crucial for successful project implementation. It is vital for both enterprise managers and project leaders to clearly define objectives, provide resource support, and oversee the project's development. Management support is a pivotal factor in the successful execution of a project [17, 19].
- Effective collaboration, open communication, and cohesive teamwork, referring to T3, are critical for the success of an agile software development project. Such constructive cooperation can enhance productivity, mitigate conflicts, and foster knowledge exchange and innovative problem-solving, ultimately strengthening the project team's capabilities and competitiveness [18].

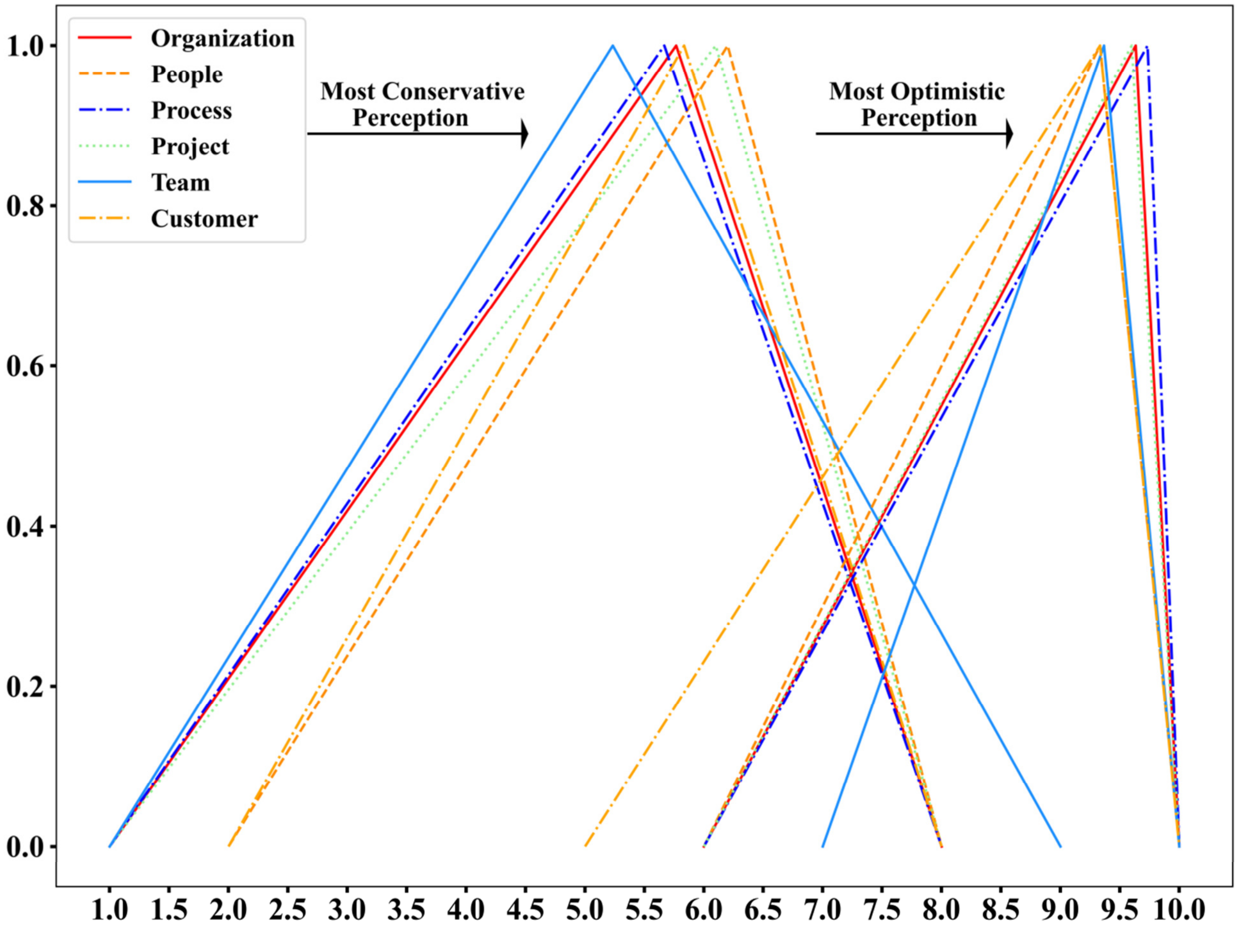

Fig. 4. Visualization results of the third round of six dimensions.

TABLE X. RANKING OF SIX DIMENSIONS

Code	C_L^i	C_M^i	C_U^i	O_L^i	O_M^i	O_U^i	Z^i	M^i	$M^i - Z^i$	G^i	Astringent
PO	1	6.10	8	6	9.60	10	2	3.50	1.50	7.85	YES
PE	2	6.20	8	6	9.33	10	2	3.13	1.13	7.77	YES
OR	1	5.77	8	6	9.63	10	2	3.87	1.87	7.70	YES
PR	1	5.67	8	6	9.73	10	2	4.07	2.07	7.70	YES
CU	2	5.83	8	5	9.33	10	3	3.50	0.50	7.58	YES
TE	1	5.23	9	7	9.37	10	2	4.13	2.13	7.30	YES

TABLE XI. RANKING OF THE TOP NINE CSFs

Code	C_L^i	C_M^i	C_U^i	O_L^i	O_M^i	O_U^i	Z^i	M^i	$M^i - Z^i$	G^i	Astringent
T5	3	6.20	8	7	9.70	10	1	3.50	2.50	7.95	YES
B2	2	6.23	8	6	9.60	10	2	3.37	1.37	7.92	YES
B1	2	6.40	8	5	9.37	10	3	2.97	0.03	7.88	YES
R3	3	6.23	8	6	9.53	10	2	3.30	1.30	7.88	YES
O5	1	6.10	8	6	9.50	10	2	3.40	1.40	7.80	YES
T4	3	6.10	8	6	9.50	10	2	3.40	1.40	7.80	YES
P4	2	5.93	8	6	9.60	10	2	3.67	1.67	7.77	YES
O1	2	5.83	8	7	9.67	10	1	3.83	2.83	7.75	YES
T3	1	5.97	8	7	9.53	10	1	3.57	2.57	7.75	YES

The three-round FDM consistency test results verified the CSFs and dimensions, highlighting 28 key factors with a very significant impact on the agile software development in China. This analysis led to the finalization of an optimized CSFs model, presented in ranked order of importance in Table XII. The fuzzy evaluation, conducted using the FDM method and fuzzy weight calculations, reordered the CSFs based on their relative importance, which is displayed from the highest to the lowest.

TABLE XII. OPTIMIZED CSFS MODEL IN CHINA

Dimension	CSFs
Project	Plan and Schedule
	Budget
	Project change managementt
	Project objective planning
People	Staffs' Agile Experience
	Customer involvement
	Agile values
	Staffing culture
	Training and education
	Active communication
	Knowledgeable and experienced agile coach
Organization	Risk Management
	Management Support
	Culture
	Team Distribution/ Co-located Teams
	Leadership
Process	Project scope is well-defined/ Project complexity
	Regular working schedule
	Agile-oriented requirement management
	Regular delivery of software
Customer	Customer Support Education
	Knowledgeable Customer
	Customer involvement
	Customer Experience
Team	Team incentive mechanism
	Participation of project team
	Internal project communication and cooperation
	Project team skills

IV. CONCLUSION

This paper develops a Critical Success Factor (CSF) model for agile projects in China and employs the Fuzzy Delphi Method (FDM) to analyze the CSFs influencing agile software projects. The fuzzy evaluation results were obtained through fuzzy clustering of expert opinions and calculation of fuzzy weights. Decision-making and optimization were conducted based on 34 CSFs, and it was ultimately concluded that 28 CSFs have a substantial impact on agile software development in China. These 28 CSFs were ranked according to their fuzzy weights. By acknowledging and addressing these CSFs, Chinese agile teams can enhance their efficiency and achieve higher success rates in agile software development. More importantly, the nine most influential CSFs among the 28 were identified, including T5, B2, B1, R3, O6, T4, P4, O1, and T3.

The study suggests that implementing the following strategies can provide a systematic approach to applying CSFs in agile software development projects in China during project execution. Establishing effective incentive mechanisms, such as material or intangible rewards, as well as providing training and promotion opportunities, can enhance employee motivation. Additionally, adopting an iterative planning approach, which involves developing plans at varying levels of detail and flexibility to adjust development tasks and objectives, can ensure the project progresses according to predetermined goals. Furthermore, utilizing budget tracking software to monitor expenses at all times and allocating funds based on different stages of iteration or project progress can ensure the reasonable distribution of resources across various development cycles.

Regularly conducting budget review meetings enables adjusting the budget based on evolving demand, which ensures the continuous development of the project. Establishing a robust risk identification mechanism facilitates the prompt recognition, evaluation, and mitigation of potential risks, a particularly crucial aspect in agile projects prone to frequent requirement changes. Encouraging open feedback channels and cross-functional team formation with diverse skill sets promotes project improvement through active member participation. Organizing regular experience-sharing sessions fosters employee learning and the exchange of agile practices. Providing professional training on agile methods and tools, as well as employing agile coaches to offer guidance, can help teams adapt to agile approaches efficiently. Maintaining effective communication between management and the project team, understanding progress and requirements, and promptly allocating necessary resources are also important. Introducing team collaboration tools like JIRA and Trello can improve communication within the team. Establishing an internal knowledge-sharing platform can facilitate members' access to relevant documents and information, reducing duplicate communication and information loss.

The developed CSFs model will also serve as a valuable reference for implementing agile practices in China, significantly enhancing the success rate of agile software development and implementation in the country. Compared to prior research, the primary contribution of this paper lies in its utilization of the FDM to collect highly representative expert opinions from China, which were then employed to rank CSFs and assign weights. After a thorough analysis, the most innovative and applicable CSF model for the Chinese agile software development market was derived, and the influence of the nine most CSFs on agile software development projects in China was examined.

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