



Challenges to agile project management during COVID-19 pandemic: an emerging economy perspective

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Abstract

Globally, COVID-19 pandemic has affected more than 214 countries across the world, creating uncertainty and affecting every institution and individual. The organisations recognise the need of agile projects that may offer several benefits including faster deployments, adaptability and best fit alignment to fulfill the customer needs. Implementing agile projects is the key to survive in the post pandemic situation, but emerging economies have limited scope for implementation. The present study determines the critical factors that restricts implementation of agile projects in emerging economies. The critical factors are identified from literature and validated by experts. The validated critical factors are further assessed to identify the cause-and-effect relationship using Fuzzy Decision-Making Trial and Laboratory (F-DEMATEL) method. The results of the study posit ‘Skepticism towards the new way of working’ is the most significant causal factor affecting other factors. This study is an attempt to help project managers to consider the significant factors for agile project implementation in post pandemic situation. The project managers may be benefitted from this study by considering these factors to manage challenges for agile project implementation in emerging economies. This study contributes to assess the influencing and the influenced challenging factors for agile project implementation.

Keywords Project management · Agile transformation · COVID-19 · Emerging economies · Industry 4.0 technologies

1 Introduction

COVID-19 has caused a substantial disruption in the firms functioning and their transactions with government, health, monetary and other businesses (Ivanov 2021). Researchers

in the area of agile transformation know the significance and the need of it for the firms during this pandemic. The scope of agile projects become prominent due to inevitable disruption caused by the COVID-19 (Batra 2020). Agile project management has gained popularity for last two decades as a substitute of traditional methods such as waterfall that covered only the core value and ability to respond promptly to the dynamic business requirements, processes, technologies and conditions (Fernandez and Fernandez 2008; Ciric et al. 2019). These projects emphasise on the collaborative, people-oriented approach towards software development (Cooper and Sommer 2018). The manager’s role in the scrum master on agile projects is to facilitate adaptive leadership, processes, remove obstacles, and develop motivation for their teams. This has the changed the role of command-and-control style of the manager in the agile settings (Nerur et al. 2005). However, agile project teams advocate self-organising teams displaying high levels of autonomy, but Several challenges emerge when these self-organising teams closely work with routinized activities of projects such as estimation, planning and elicitation (Venkatesh et al. 2020). Several benefits are offered by the agile projects including

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faster deployments, adaptability and best fit alignment with the firm's and customer needs, but still the adoption and implementation of these projects is challenging (Hoda and Murugesan 2016; Sjödin et al. 2020).

The situation during COVID-19 has generated extreme uncertainty across the globe affecting every institution and individual (Dohaney et al. 2020; Ivanov 2021). Now, the firms look for technologies and systems that may strengthen their capabilities to tackle the uncertainty. The inclusion of artificial intelligence, data analytics and other industry 4.0 technologies has transformed the existing systems and opens the door for agility (Holden et al. 2021). During disruption, the resources need to be optimised for developing capabilities and building agility (Blome et al. 2013; Sharma and Joshi 2021; Sharma et al. 2021c; Nandi et al. 2021). But what are the challenges faced by the firms to adopt and manage agile projects in emerging economies where the resources are scarce and industry 4.0 implementation is in nascent phase? The present research aims to evaluate the challenges using F-DEMATEL analysis that restrict implementation of agile project during COVID-19. This study tries to demonstrate relationship among challenging factors that offers opportunities to decide how these agile projects could benefit firms to address pandemic situation in future. Hence, this study establishes objectives to delineate set of challenging factors that can help the project managers and can contribute to existing theory for understanding the challenges to agile project implementation. Based on this discussion, the present study focuses on the following research objectives:

RO1: Identifying challenging factors to agile project implementation during COVID-19 in emerging economies like India?

RO2: Modeling factors for investigating interrelationship and building hierarchy for the same.

RO3: Suggesting measures for agile transformation in projects to address the disruption in future.

The outcomes of the study will facilitate the project managers and decision makers to implement agile projects for handling disruptive environment. The research study presents a distinct contribution in the direction of project management in context to COVID-19. A literature review is conducted to identify the challenging factors to agile project implementation during pandemic situation. The methodological procedure employed three phases- systematic literature review was conducted in phase I followed by the assessment of factors using F-DEMATEL in phase II. In phase III the discussion and implications are discussed for project managers.

The organisation of this research paper is as: Sect. 2 captures the various challenging factors based on literature review and experts' validation. Section 3 describes the research methodology undertaken in the study. Section 3.2 elaborates application of methods cause and effect

interrelationship computations. Section 4 presents the discussion of findings of the study. Section 5 concludes with limitations and future research directions.

2 Literature review

Through literature review the published literature on project management implementation, agile transformation and challenges was searched using "Scopus" and "Web of Science (WoS)" databases. The search terms such as "project management implementation", "agile transformation" "Implementation of agile project implementation", "Agile projects during COVID-19" were used to search the pertinent articles. The research is limited to for last five years. A total of 45 articles were found relevant for the study.

2.1 Agile project management implementation

With Industry 4.0 revolution, the emerging economies are transforming their manufacturing sector (Ding et al. 2021; Sharma et al. 2021a, b). The most important challenge in manufacturing industry is to develop the resilience across the value chain. Automation provides a time-saving and efficient approach towards executing manual tasks, but India has slow rate of automation (Sharma et al. 2021a, b). Agility not only limited to competitiveness but also brings innovation and improves adoption for the change to the system and consequently. Previous research described agility led to reduce cost and improve efficiency (Orłowski et al. 2017). Few research studies also showed that agile projects are implemented across industries where methods such as Scrum and Kanban do not focus on comprehensive advanced planning and execution, rather develop a solution step by step and coordinates respective interim results in short cycles (Conforto et al. 2014; Lei et al. 2017; Saragih et al. 2021). Flexibility is facilitated with agile projects, and thereby enabling companies to take actions with dynamic customer needs (Persson et al. 2012; Koch and Schermuly 2021). The research gap may be summarised as there is no study that has analysed the challenging factors to agile project implementation in emerging economies. Accordingly, the research questions are addressed.

The successful execution of the projects depends on different project types, and models. A procedural model organises the methods into phases in standardised way. Procedural models are categorised into two methods: 1) plan-driven methods that follows classical waterfall model 2) agile methods following test driven approach (Lei et al. 2017). Hybrid approaches combine the advantage of both the models to enrich the plan-driven process model with agile principles (Patanakul and Rufo-McCarron 2018). The selection of a model is quite challenging. Based on the literature, following

are the challenging factors to agile project implementation are listed below in the Table 1.

3 Proposed research framework

The current study has conducted a three-phase study shown in Fig. 1 demonstrating the proposed framework adopted for conducting the study.

During first phase, the challenges to agile project implementation during COVID-19 were identified through literature review. F-DEMATEL method was applied to examine the cause-and-effect among the challenging factors identified in the second phase. F-DEMATEL is one of the widely used methods in several disciplines (Kumar et al. 2018; Luthra et al. 2016). In the third phase a discussion and implication are discussed for effective project implementation for the future research work. This research focuses on presenting information by the means of experiences of the experts who were contacted to participate in the study. This study attempted to analyse and investigate the challenges that are crucial for organisations for implementing agile project implementation. The factors that were analysed and investigated were largely challenging to get a deeper understanding of the problem statement. Initially, the challenges were identified from literature and validated from the experts. The establishment of the relations between the cause and effect of the identified factors was also evident while investigating and validating these factors. The following sub-sections explain all the adopted steps in the research methodology undertaken.

3.1 Data collection

A questionnaire was used to receive the response of the experts. The experts validated the identified challenging factors from the literature. A total of 15 experts were undertaken from the manufacturing industries including automotive, electronics, software etc. All the experts undertaken had prior knowledge about agile project implementation. The experience of the experts was 5+ years and were designated at the managerial positions.

3.2 Determining causal relationships between challenging factors

F-DEMATEL method is used in the current study to determine the interrelationship among the challenging factors. It is the most suitable method to observe the inter-relationship among the factors (Si et al. 2018). Also, F-DEMATEL can address the biases and vagueness in human judgments (Farooque et al. 2020). All the variables were assessed based on linguistic scale mentioned in Table 2.

3.2.1 Step 1: Developing a fuzzy direct relation matrix

The experts were asked to evaluate the impact of factor i on factor j using a linguistic scale shown in Table 2. Triangular fuzzy numbers (TFNs) were used for capturing the fuzziness in the judgments (Seçme et al. 2009). Table 2 exhibits the fuzzy linguistic scale (Venkatesh et al. 2017) to convert impact scores to triangular fuzzy numbers.

The fuzzy direct relation matrix $Z = [Z_{ij}]_{n \times n}$ is obtained through Eqs. 1–3

$$xl_{ij}^k = (l_{ij}^k - \min l_{ij}^k) / \Delta_{min}^{max} \quad (1)$$

$$xm_{ij}^k = (m_{ij}^k - \min l_{ij}^k) / \Delta_{min}^{max} \quad (2)$$

$$xr_{ij}^k = (r_{ij}^k - \min l_{ij}^k) / \Delta_{min}^{max} \quad (3)$$

$$\text{where } \Delta_{min}^{max} = \max r_{ij}^k - \min l_{ij}^k$$

3.2.2 Step 2: Constructing the normalised direct relation matrix using Eq. 4

$$m = \min \left[\frac{1}{\max \sum_{j=1}^n |a_{ij}|}, \frac{1}{\max \sum_{j=1}^n |a_{ij}|} \right] \quad (4)$$

Integrating crisp value through

$$Z_{ij} = \frac{1}{p} (z_{ij}^1 + Z_{ij}^2 + Z_{ij}^p) \quad (5)$$

3.2.3 Step 3: Developing total relation matrix using Eq. 6

$$T = N(I - N)^{-1} \quad (6)$$

3.2.4 Step 4: Calculating the sum of rows (D) and the sum of columns (R) using Eqs. (7) and (8)

$$D = \left[\sum_{j=1}^n t_{ij} \right]_{n \times 1} \quad (7)$$

$$R = \left[\sum_{i=1}^n t_{ij} \right]_{1 \times n} \quad (8)$$

3.2.5 Step 5: Creating the cause-effect diagram

Based on the values of $D + R$ and $D - R$, a cause-effect diagram (Fig. 2) is drawn using. $(D + R)$ presents horizontal axis that determines the prominence of a factor, signifying its total effects in terms of influenced and influential power. $(D - R)$ presents vertical axis that describes the causal-effect relationship between the challenging factors. A factor is categorised in cause group when $(D - R)$ value is more than

Table 1 Challenging factors to agile project implementation during COVID-19 in emerging Economies

| Code | Variables | Implied Meaning | References |
|------|---|---|--|
| F1 | Investment decisions require up-front certainty | Organisations must realise the changing need where stakeholders should be encouraged to take upfront certainty and stop watching investments as iterative test-and-learn cycle | Djödin et al. 2020; Sharma and Joshi 2020; Tsoy and Staples 2020 |
| F2 | Third party involvement | The challenge is to manage with the partners or third parties those are not able to adapt agile transformations | Holden and Azar 2021; Shastri et al. 2021 |
| F3 | Loss of control | Due to agile projects, the control is distributed among the team which may annoy the stakeholders to reassert controls and governance that no longer apply | Lill and Wald 2021 |
| F4 | Automation landscape insufficiently mature | Agile project implementation creates challenges that can be solved with the automation. But, due to lack of automation adopted by the organisation creates struggle to cope with the agile transformation | Baham and Hirschheim 2021; Scholz et al. 2020 |
| F5 | Less motivation and enthusiasm due to COVID-19 impact | COVID-19 negatively affects budget, hence affects value generation adversely creating less motivation and enthusiasm | Koch and Schermuly 2021; Malik et al. 2021 |
| F6 | Projects take too long to get going | Agile project implementation is hampered by indecision and also inability of organisation to take prompt decision | Ragas and Ragas 2021 |
| F7 | Slow Governance processes | Agile project implementation will lead into conflicts with existing systems and processes leading into slow governance | Sjödin et al.2020; Ragas and Ragas 2021 |
| F8 | Non- availability of skilled people | The emerging economies like India are lacking in skilled staff. Thus, agile project implementation is difficult if the manpower is non-skilled | Koch and Schermuly 2021; Niederman 2021 |
| F9 | Risk mitigation | Agile is more active in risk management as compared to waterfall model | Sithambaram et al. 2021 |
| F10 | Structural impediments | A set of exiting conditions may thwart the agile project management implementation | Narkhede et al. 2020 |
| F11 | Lack of clarity around roles | Agile project focuses on team roles that may create ambiguity in the job roles | Malik et al. 2021 |
| F12 | Resistance to Change | Challenges are faced when exposed to the other parts of the organisation for adopting the agile projects | Sithambaram et al. 2021 |
| F13 | Lack of shared value | Challenge to agile projects implementation is the shared value that occurs due to multiple teams | Hoda and Murugesan 2016; Baham and Hirschheim 2021 |
| F14 | Skepticism towards the new way of working | Skepticism is the common problem in the agile project implementation. At one hand there are benefits of agility, but on the other hand opposition to implement it | Zasa et al. 2020; Baham and Hirschheim 2021 |
| F15 | Lack of investment | The lack of funding may hamper to implement agile projects | Joshi et al. 2020; Holden et al. 2021 |
| F16 | Misunderstanding agile concepts | Agile Projects needs to be implemented with concepts and planning but due to lack of clarity it sometimes misleads the project managers | Sithambaram et al. 2021 |
| F17 | Lack of coordination in multi-team environment | There are challenges of coordination among the team members which restricts to implement agile projects | Hoda and Murugesan 2016 |

Table 1 (continued)

| Code | Variables | Implied Meaning | References |
|------|---|--|---------------------|
| F 18 | Requirement’s ambiguity affects quality | In context to requirements engineering, agile projects may need to extend to accommodate additional testing activities. The inability to extend the testing may create problems for agile project implementation | Rindell et al. 2021 |

zero. On the contrary, a factor is categorised in effect group when $(D - R)$ value is less than zero. The normalised direct relation matrix and total relation matrix using Eqs. 4, 5, and 6 are shown in Table 3 and 4.

From step 4, using Eq. 7 and 8, $(D + R)$ and $(D - R)$ values are computed and shown in Table 5.

Based on the values of $D + R$ and $D - R$, the impact results are shown in Table 6. The challenging factors are categorised into cause-and-effect groups.

The cause-effect diagram is presented to plot the cause and effect challenging factors shown in Fig. 2.

4 Discussion of findings

The F-DEMATEL results in the causal and effect factors categorisation. Based on the $D - R$ values, the categorisation is done. The factors F1, F2, F4, F5, F10, F13, F14, F15 and F16 are cause group factors as they have positive $D - R$ values. This shows that these factors influence the other

factors and are critical for the organisations to take care of. The challenging factors- investment decisions require up-front certainty (F1), third party involvement (F2), automation landscape insufficiently mature (F4), non- availability of skilled people (F8), structural impediments (F10), lack of shared value (F13), skepticism towards the new way of working (F14), lack of investment (F15), misunderstanding agile concepts (F16) are categorised as causal group factors.

The readiness of the organisation is significant in adopting agile transformation. The organisations should avoid waste including investments on new projects that has uncertainty and non-guaranteed ROI. With the agile project implementation organisations take this uncertainty as an opportunity to experiment and bring change reduced cost. Investment decisions require up-front certainty (F1) is in line with the previous research that suggests companies are reluctant towards agile project implementation as it may not bring returns or unexpected results (Djödin et al. 2020; Tsoy and Staples 2020). Many companies lock their structure into fixed-price or fixed-outcome contracts and thus working with stakeholders who can’t or won’t adapt agile projects will jeopardise its success (Holden et al. 2021; Shastri et al. 2021).

Agile project implementation needs automation. But lack of automation adopted by the Indian organisations create struggle to cope with the agile transformation. However, understandably, no organisations anticipated or planned for a crisis with the broad scale operational impact of COVID-19 (Koch and Schermuly 2021; Malik et al. 2021). This has created the negative impact on the mental state of the employee and lower down their motivation and morale. The agile project implementation is not limited to the technical transformation but a cultural adaptation too. It requires a

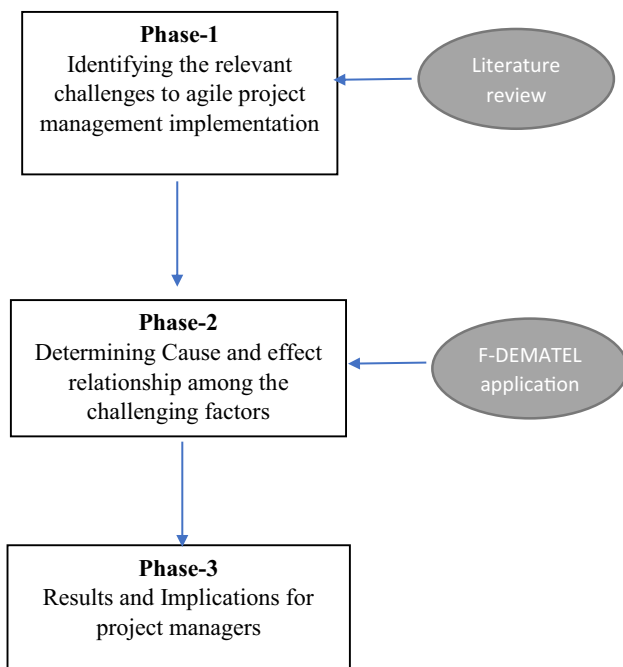


Fig. 1 Proposed research framework

Table 2 Linguistic labels

| Linguistic terms | Triangular fuzzy numbers |
|------------------|--------------------------|
| Very High (VH) | (0.9, 1.0, 1.0) |
| High (H) | (0.7, 0.9, 1.0) |
| Medium High (MH) | (0.5, 0.7, 0.9) |
| Medium (M) | (0.3, 0.5, 0.7) |
| Medium low (ML) | (0.1, 0.3, 0.5) |
| Low (L) | (0, 0.1, 0.3) |
| Very Low (VL) | (0, 0, 0.1) |

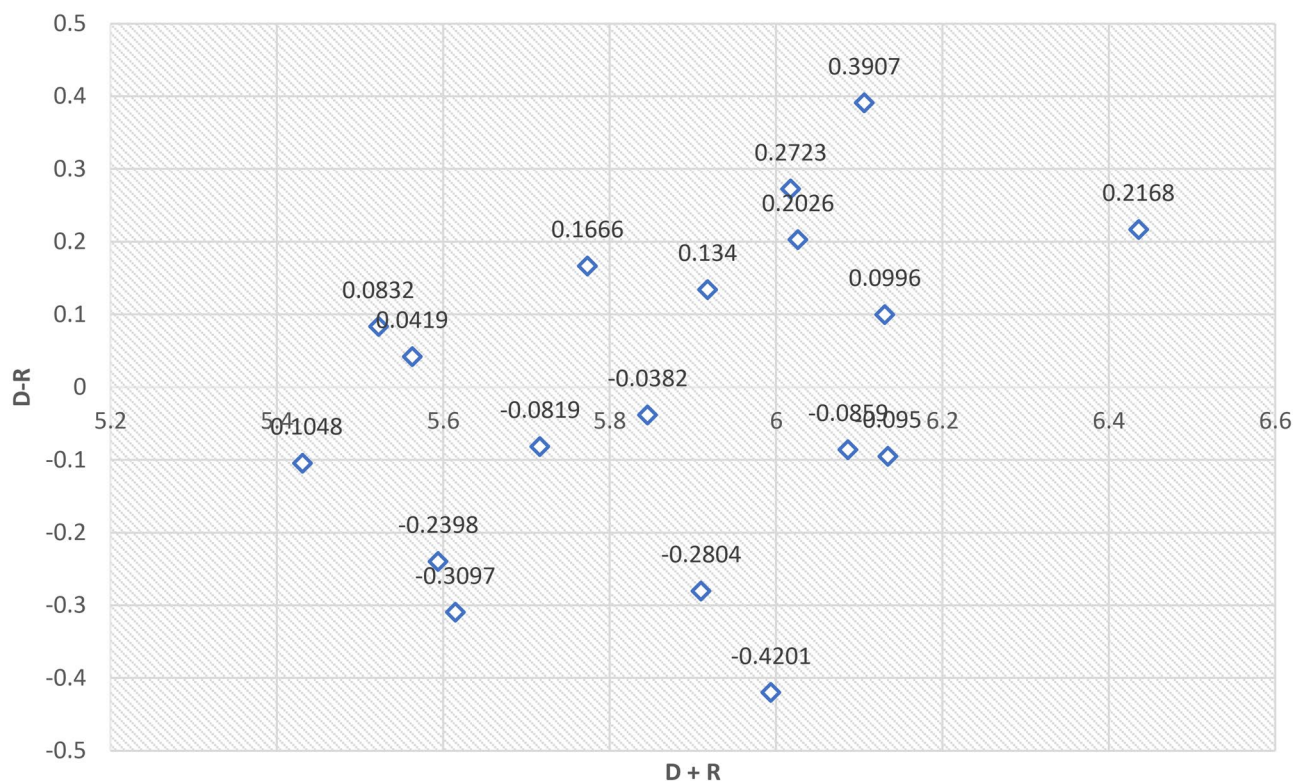


Fig. 2 Cause and effect diagram

change whereby organisations open their doors for adoption new skills, processes and technologies. If the organisation becomes rigid with the culture, roles and traditional approach for working, it may not allow the agile team which has the capability to solve a problem (Cavaleri et al. 2012, Koch and Schermuly 2021; Niederman 2021). Several pre-existing conditions hinder the implementation of agile projects (Lee and Yong 2010; Narkhede et al. 2020).

The most significant causal factor is skepticism towards the new way of working (F14) that has highest value (0.3907). Management acknowledges the benefits of agility but opposes its implementation. This aligns with the previous research where skepticism had raised due to misconceptions, including that agile does not work for complex products (Zasa et al. 2020). This reluctant perception keeps the firms and employees to adopt the transformation.

Based on the impact results, negative values of D-R, loss of control (F3), less motivation and enthusiasm due to COVID-19 impact (F5), projects take too long to get going (F6), governance processes remain slow (F7), risks are not actively mitigated (F9), Lack of clarity around roles (F11), change resistance (F12), coordination challenges in multi-team environment (F17), requirement's ambiguity affects quality (F18) are categorised as effect group factors. These factors get influenced by the casual group factors.

Due to agile projects, the control is distributed among the team which may annoy the stakeholders (Lill and Wald

2021). The influence of the causal group factors may create the feeling of loss of control as the challenge to avoid implementation of agile projects. Several aspects of agile transformation may develop challenges that can't be resolved by conventional means (Nuottila et al. 2016).

Agile project implementation is hampered by indecision and inability of organisation to take prompt decision (Ragas and Ragas 2021). Agile requires far more active risk management as compared to the traditional models, a risk log and monthly meetings were set up to review risks and take actions for mitigating the most urgent ones. Agile project focuses on team roles that may create ambiguity in the job roles. These projects need to be implemented with concepts and planning but due to lack of clarity it sometimes misleads the project managers. Many examples of problems had been seen by misconceptions related to agile software development. Generally, the agile manifesto is not properly understood and practices were conducted without understanding the real purpose (Sithambaram et al. 2021). There are challenges of coordination among the team members which restricts to implement agile projects (Hoda and Murugesan 2016). In context to requirements engineering, agile projects may need to be extended to accommodate additional testing activities. The inability to extend the testing may create problems for agile project implementation (Rindell et al. 2021).

Table 3 Normalised Tables for all three fuzzy values l, m, u

Total Normalised Direct-Relation Matrix for l, m, u

| | | | | | | | | | | | | | | | | | | | |
|-----|-----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| (l) | F1 | 0 | 0.0229 | 0.0190 | 0.0336 | 0.0301 | 0.0477 | 0.0349 | 0.0349 | 0.0200 | 0.0189 | 0.0126 | 0.0222 | 0.0371 | 0.0339 | 0.0233 | 0.0243 | 0.0148 | 0.0169 |
| | F2 | 0.0332 | 0 | 0.0335 | 0.0462 | 0.0315 | 0.0010 | 0.0403 | 0.042 | 0.0403 | 0.0010 | 0.0361 | 0.0307 | 0.0296 | 0.0307 | 0.0223 | 0.0127 | 0.0445 | 0.0338 |
| | F3 | 0.0319 | 0.0305 | 0 | 0.0158 | 0.0116 | 0.0169 | 0.0063 | 0.019 | 0.0148 | 0.0169 | 0.0158 | 0.0189 | 0.0243 | 0.0137 | 0.0147 | 0.0211 | 0.0169 | 0.0317 |
| | F4 | 0.0213 | 0.0211 | 0.0254 | 0 | 0.0485 | 0.0169 | 0.0403 | 0.0232 | 0.0371 | 0.0201 | 0.0180 | 0.0308 | 0.0275 | 0.0349 | 0.0328 | 0.0211 | 0.0329 | 0.0361 |
| | F5 | 0.0239 | 0.0080 | 0.0356 | 0.0050 | 0 | 0.0010 | 0.0275 | 0.0328 | 0.0062 | 0.0158 | 0.0211 | 0.0339 | 0.0243 | 0.0413 | 0.0169 | 0.0148 | 0.0328 | 0.0307 |
| | F6 | 0.0393 | 0.0200 | 0.0041 | 0.0010 | 0.0169 | 0 | 0.0169 | 0.0265 | 0.0168 | 0.0222 | 0.0371 | 0.0296 | 0.0232 | 0.0360 | 0.0307 | 0.0106 | 0.0074 | 0.0169 |
| | F7 | 0.0104 | 0.0200 | 0.0211 | 0.0276 | 0.0328 | 0.0169 | 0 | 0.0382 | 0.0328 | 0.0222 | 0.0211 | 0.0169 | 0.0349 | 0.0296 | 0.0285 | 0.0285 | 0.0338 | 0.0169 |
| | F8 | 0.0200 | 0.0242 | 0.0231 | 0.0434 | 0.0487 | 0.0487 | 0.0169 | 0 | 0.0487 | 0.0168 | 0.0381 | 0.0264 | 0.0370 | 0.0265 | 0.0296 | 0.0295 | 0.0339 | 0.0487 |
| | F9 | 0.0180 | 0.0243 | 0.0306 | 0.0253 | 0.0190 | 0.0273 | 0.0243 | 0.0190 | 0 | 0.0169 | 0.0307 | 0.0212 | 0.0275 | 0.0243 | 0.0242 | 0.0264 | 0.0253 | 0.0444 |
| | F10 | 0.0276 | 0.0254 | 0.0190 | 0.0221 | 0.0199 | 0.0178 | 0.0371 | 0.0265 | 0.0010 | 0 | 0.0169 | 0.0308 | 0.0318 | 0.0180 | 0.0190 | 0.0051 | 0.0434 | 0.0253 |
| | F11 | 0.0372 | 0.0233 | 0.0349 | 0.0231 | 0.0242 | 0.0274 | 0.0211 | 0.0349 | 0.0265 | 0.0169 | 0 | 0.0169 | 0.0041 | 0.0052 | 0.0073 | 0.0402 | 0.0328 | 0.0042 |
| | F12 | 0.0116 | 0.0265 | 0.0340 | 0.0224 | 0.0169 | 0.0361 | 0.0402 | 0.0190 | 0.0179 | 0.0179 | 0.0169 | 0 | 0.0169 | 0.0042 | 0.0073 | 0.0116 | 0.0041 | 0.0423 |
| | F13 | 0.0350 | 0.0190 | 0.0190 | 0.0254 | 0.0210 | 0.0189 | 0.0307 | 0.0340 | 0.0210 | 0.0466 | 0.0223 | 0.0169 | 0 | 0.0328 | 0.0328 | 0.0423 | 0.0190 | 0.0423 |
| | F14 | 0.0275 | 0.0306 | 0.0284 | 0.0295 | 0.0273 | 0.0221 | 0.0114 | 0.0307 | 0.0444 | 0.0423 | 0.0318 | 0.0179 | 0.0487 | 0 | 0.0328 | 0.0423 | 0.0328 | 0.0380 |
| | F15 | 0.0201 | 0.0243 | 0.0253 | 0.0348 | 0.0233 | 0.0380 | 0.0391 | 0.0148 | 0.0487 | 0.0168 | 0.0328 | 0.0169 | 0.0010 | 0.0010 | 0 | 0.0010 | 0.0169 | 0.0381 |
| | F16 | 0.0318 | 0.0254 | 0.0222 | 0.0232 | 0.0348 | 0.0316 | 0.0339 | 0.0297 | 0.0487 | 0.0456 | 0.0223 | 0.0169 | 0.0169 | 0.0010 | 0.0010 | 0 | 0.0169 | 0.0328 |
| | F17 | 0.0211 | 0.0233 | 0.0253 | 0.0232 | 0.0391 | 0.0254 | 0.0307 | 0.0328 | 0.0328 | 0.0169 | 0.0169 | 0.0169 | 0.0169 | 0.0169 | 0.0169 | 0.0169 | 0 | 0.0179 |
| | F18 | 0.0021 | 0.0201 | 0.0287 | 0.0255 | 0.0435 | 0.0296 | 0.0255 | 0.0073 | 0.0265 | 0.0222 | 0.0072 | 0.0040 | 0.0339 | 0.0329 | 0.0062 | 0.0329 | 0.0062 | 0 |
| (m) | F1 | 0 | 0.0372 | 0.0337 | 0.0483 | 0.0448 | 0.0626 | 0.0498 | 0.0498 | 0.0349 | 0.0338 | 0.0254 | 0.0371 | 0.0520 | 0.0488 | 0.0382 | 0.0392 | 0.0297 | 0.0318 |
| | F2 | 0.0458 | 0 | 0.0478 | 0.0604 | 0.0415 | 0.0159 | 0.0552 | 0.0573 | 0.0552 | 0.0159 | 0.0510 | 0.0456 | 0.0445 | 0.0456 | 0.0372 | 0.0276 | 0.0594 | 0.0487 |
| | F3 | 0.0466 | 0.0452 | 0 | 0.0301 | 0.0262 | 0.0318 | 0.0212 | 0.0339 | 0.0297 | 0.0318 | 0.0307 | 0.0285 | 0.0392 | 0.0286 | 0.0296 | 0.0360 | 0.0318 | 0.0466 |
| | F4 | 0.0360 | 0.0358 | 0.0397 | 0 | 0.0632 | 0.0318 | 0.0552 | 0.0381 | 0.0521 | 0.0350 | 0.0329 | 0.0457 | 0.0424 | 0.0498 | 0.0477 | 0.0360 | 0.0478 | 0.0510 |
| | F5 | 0.0382 | 0.0223 | 0.0498 | 0.0197 | 0 | 0.0159 | 0.0424 | 0.0477 | 0.0211 | 0.0286 | 0.0360 | 0.0488 | 0.0392 | 0.0562 | 0.0318 | 0.0297 | 0.0477 | 0.0456 |
| | F6 | 0.0542 | 0.0349 | 0.0190 | 0.0021 | 0.0318 | 0 | 0.0318 | 0.0414 | 0.0232 | 0.0371 | 0.0520 | 0.0445 | 0.0381 | 0.0509 | 0.0457 | 0.0255 | 0.0223 | 0.0318 |
| | F7 | 0.0253 | 0.0349 | 0.0360 | 0.0425 | 0.0477 | 0.0318 | 0 | 0.0531 | 0.0477 | 0.0371 | 0.0360 | 0.0318 | 0.0498 | 0.0434 | 0.0434 | 0.0434 | 0.0487 | 0.0318 |
| | F8 | 0.0349 | 0.0391 | 0.0380 | 0.0583 | 0.0636 | 0.0636 | 0.0318 | 0 | 0.0636 | 0.0317 | 0.0530 | 0.0413 | 0.0519 | 0.0414 | 0.0445 | 0.0444 | 0.0488 | 0.0636 |
| | F9 | 0.0329 | 0.0392 | 0.0455 | 0.0402 | 0.0339 | 0.0422 | 0.0392 | 0.0339 | 0 | 0.0318 | 0.0456 | 0.0361 | 0.0424 | 0.0392 | 0.0391 | 0.0413 | 0.0402 | 0.0593 |
| | F10 | 0.0415 | 0.0403 | 0.0339 | 0.0370 | 0.0295 | 0.0327 | 0.0520 | 0.0414 | 0.0159 | 0 | 0.0318 | 0.0457 | 0.0467 | 0.0329 | 0.0339 | 0.0104 | 0.0583 | 0.0402 |
| | F11 | 0.0521 | 0.0382 | 0.0498 | 0.0380 | 0.0391 | 0.0423 | 0.0360 | 0.0498 | 0.0414 | 0.0318 | 0 | 0.0318 | 0.0190 | 0.0201 | 0.0200 | 0.0551 | 0.0477 | 0.0180 |
| | F12 | 0.0265 | 0.0404 | 0.0489 | 0.0341 | 0.0318 | 0.0510 | 0.0551 | 0.0339 | 0.0328 | 0.0328 | 0.0318 | 0 | 0.0318 | 0.0191 | 0.0222 | 0.0265 | 0.0190 | 0.0572 |
| | F13 | 0.0499 | 0.0339 | 0.0328 | 0.0403 | 0.0359 | 0.0338 | 0.0456 | 0.0489 | 0.0359 | 0.0615 | 0.0372 | 0.0318 | 0 | 0.0477 | 0.0477 | 0.0572 | 0.0339 | 0.0572 |
| | F14 | 0.0424 | 0.0444 | 0.0412 | 0.0444 | 0.0422 | 0.0370 | 0.0241 | 0.0456 | 0.0593 | 0.0572 | 0.0467 | 0.0328 | 0.0636 | 0 | 0.0477 | 0.0572 | 0.0477 | 0.0508 |
| | F15 | 0.0350 | 0.0392 | 0.0402 | 0.0497 | 0.0371 | 0.0529 | 0.0540 | 0.0297 | 0.0636 | 0.0222 | 0.0477 | 0.0318 | 0.0159 | 0.0159 | 0 | 0.0159 | 0.0318 | 0.0530 |

Table 4 Total-Relation matrix T
Total-Relation matrix T of fuzzy number (l, m, u)

| | | | | | | | | | | | | | | | | | | | |
|-----|-----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| (l) | F1 | 0.0186 | 0.0396 | 0.0373 | 0.0514 | 0.0513 | 0.0648 | 0.0547 | 0.0549 | 0.0414 | 0.0361 | 0.0310 | 0.0386 | 0.0562 | 0.0513 | 0.0394 | 0.0412 | 0.0332 | 0.0401 |
| | F2 | 0.0521 | 0.0197 | 0.0552 | 0.0669 | 0.0565 | 0.0232 | 0.0627 | 0.0645 | 0.0642 | 0.0201 | 0.0548 | 0.0482 | 0.0514 | 0.0501 | 0.0398 | 0.0334 | 0.0643 | 0.0593 |
| | F3 | 0.0442 | 0.0422 | 0.0138 | 0.0297 | 0.0275 | 0.0305 | 0.0219 | 0.0335 | 0.0301 | 0.0287 | 0.0281 | 0.0303 | 0.0381 | 0.0264 | 0.0255 | 0.0332 | 0.0296 | 0.0474 |
| | F4 | 0.0398 | 0.0391 | 0.0460 | 0.0203 | 0.0704 | 0.0365 | 0.0616 | 0.0448 | 0.0590 | 0.0379 | 0.0366 | 0.0474 | 0.0482 | 0.0531 | 0.0487 | 0.0394 | 0.0519 | 0.0601 |
| | F5 | 0.0379 | 0.0228 | 0.0507 | 0.0214 | 0.0183 | 0.0176 | 0.0435 | 0.0489 | 0.0244 | 0.0300 | 0.0348 | 0.0458 | 0.0405 | 0.0540 | 0.0293 | 0.0298 | 0.0469 | 0.0491 |
| | F6 | 0.0529 | 0.0336 | 0.0198 | 0.0173 | 0.0337 | 0.0161 | 0.0335 | 0.0426 | 0.0338 | 0.0352 | 0.0505 | 0.0418 | 0.0384 | 0.0485 | 0.0425 | 0.0248 | 0.0223 | 0.0348 |
| | F7 | 0.0282 | 0.0363 | 0.0394 | 0.0454 | 0.0534 | 0.0348 | 0.0203 | 0.0571 | 0.0532 | 0.0384 | 0.0382 | 0.0326 | 0.0528 | 0.0456 | 0.0432 | 0.0448 | 0.0513 | 0.0397 |
| | F8 | 0.0421 | 0.0445 | 0.0463 | 0.0644 | 0.0740 | 0.0698 | 0.0425 | 0.0250 | 0.0730 | 0.0373 | 0.0587 | 0.0459 | 0.0595 | 0.0480 | 0.0479 | 0.0502 | 0.0550 | 0.0752 |
| | F9 | 0.0349 | 0.0402 | 0.0480 | 0.0426 | 0.0395 | 0.0444 | 0.0434 | 0.0380 | 0.0205 | 0.0328 | 0.0464 | 0.0358 | 0.0453 | 0.0402 | 0.0381 | 0.0425 | 0.0418 | 0.0644 |
| | F10 | 0.0422 | 0.0396 | 0.0351 | 0.0383 | 0.0390 | 0.0338 | 0.0545 | 0.0441 | 0.0199 | 0.0142 | 0.0315 | 0.0440 | 0.0480 | 0.0332 | 0.0324 | 0.0202 | 0.0580 | 0.0442 |
| | F11 | 0.0519 | 0.0375 | 0.0498 | 0.0386 | 0.0424 | 0.0431 | 0.0383 | 0.0518 | 0.0441 | 0.0303 | 0.0151 | 0.0310 | 0.0210 | 0.0201 | 0.0203 | 0.0531 | 0.0476 | 0.0236 |
| | F12 | 0.0251 | 0.0389 | 0.0473 | 0.0360 | 0.0333 | 0.0488 | 0.0545 | 0.0341 | 0.0333 | 0.0300 | 0.0299 | 0.0124 | 0.0320 | 0.0186 | 0.0193 | 0.0247 | 0.0182 | 0.0581 |
| | F13 | 0.0531 | 0.0372 | 0.0388 | 0.0455 | 0.0445 | 0.0393 | 0.0525 | 0.0548 | 0.0438 | 0.0636 | 0.0404 | 0.0339 | 0.0215 | 0.0503 | 0.0483 | 0.0594 | 0.0386 | 0.0653 |
| | F14 | 0.0489 | 0.0504 | 0.0506 | 0.0516 | 0.0528 | 0.0441 | 0.0369 | 0.0543 | 0.0684 | 0.0616 | 0.0519 | 0.0370 | 0.0701 | 0.0206 | 0.0502 | 0.0617 | 0.0540 | 0.0647 |
| | F15 | 0.0348 | 0.0384 | 0.0413 | 0.0497 | 0.0416 | 0.0527 | 0.0558 | 0.0320 | 0.0649 | 0.0296 | 0.0471 | 0.0309 | 0.0182 | 0.0173 | 0.0135 | 0.0160 | 0.0325 | 0.0559 |
| | F16 | 0.0482 | 0.0411 | 0.0399 | 0.0405 | 0.0548 | 0.0485 | 0.0531 | 0.0488 | 0.0661 | 0.0596 | 0.0385 | 0.0329 | 0.0362 | 0.0193 | 0.0163 | 0.0164 | 0.0349 | 0.0535 |
| | F17 | 0.0364 | 0.0376 | 0.0414 | 0.0390 | 0.0570 | 0.0409 | 0.0478 | 0.0500 | 0.0503 | 0.0308 | 0.0323 | 0.0313 | 0.0340 | 0.0325 | 0.0305 | 0.0316 | 0.0165 | 0.0378 |
| | F18 | 0.0174 | 0.0331 | 0.0430 | 0.0389 | 0.0591 | 0.0421 | 0.0410 | 0.0241 | 0.0423 | 0.0361 | 0.0215 | 0.0175 | 0.0492 | 0.0467 | 0.0191 | 0.0460 | 0.0215 | 0.0187 |
| (m) | F1 | 0.0793 | 0.1125 | 0.1135 | 0.1254 | 0.1311 | 0.1407 | 0.1343 | 0.1345 | 0.1211 | 0.1080 | 0.1037 | 0.1104 | 0.1335 | 0.1249 | 0.1100 | 0.1140 | 0.1093 | 0.1233 |
| | F2 | 0.1283 | 0.0831 | 0.1346 | 0.1447 | 0.1362 | 0.1044 | 0.1463 | 0.1481 | 0.1481 | 0.0964 | 0.1328 | 0.1235 | 0.1329 | 0.1276 | 0.1141 | 0.1105 | 0.1436 | 0.1463 |
| | F3 | 0.1093 | 0.1062 | 0.0666 | 0.0949 | 0.0979 | 0.0976 | 0.0923 | 0.1037 | 0.1004 | 0.0919 | 0.0935 | 0.0883 | 0.1061 | 0.0915 | 0.0876 | 0.0970 | 0.0963 | 0.1198 |
| | F4 | 0.1171 | 0.1152 | 0.1244 | 0.0839 | 0.1527 | 0.1160 | 0.1440 | 0.1277 | 0.1415 | 0.1123 | 0.1139 | 0.1217 | 0.1286 | 0.1294 | 0.1216 | 0.1150 | 0.1303 | 0.1458 |
| | F5 | 0.1066 | 0.0906 | 0.1205 | 0.0912 | 0.0786 | 0.0891 | 0.1174 | 0.1226 | 0.0990 | 0.0948 | 0.1038 | 0.1120 | 0.1124 | 0.1220 | 0.0948 | 0.0975 | 0.1168 | 0.1257 |
| | F6 | 0.1186 | 0.0987 | 0.0878 | 0.0710 | 0.1045 | 0.0697 | 0.1041 | 0.1133 | 0.0965 | 0.0988 | 0.1159 | 0.1052 | 0.1070 | 0.1134 | 0.1045 | 0.0894 | 0.0897 | 0.1080 |
| | F7 | 0.1025 | 0.1092 | 0.1150 | 0.1194 | 0.1325 | 0.1107 | 0.0854 | 0.1358 | 0.1320 | 0.1094 | 0.1119 | 0.1039 | 0.1294 | 0.1176 | 0.1129 | 0.1166 | 0.1261 | 0.1220 |
| | F8 | 0.1246 | 0.1256 | 0.1305 | 0.1461 | 0.1618 | 0.1535 | 0.1308 | 0.0992 | 0.1603 | 0.1166 | 0.1404 | 0.1251 | 0.1449 | 0.1295 | 0.1255 | 0.1303 | 0.1385 | 0.1661 |
| | F9 | 0.1084 | 0.1124 | 0.1228 | 0.1160 | 0.1185 | 0.1194 | 0.1219 | 0.1167 | 0.0849 | 0.1035 | 0.1193 | 0.1064 | 0.1215 | 0.1128 | 0.1074 | 0.1140 | 0.1163 | 0.1454 |
| | F10 | 0.1101 | 0.1075 | 0.1057 | 0.1075 | 0.1080 | 0.1045 | 0.1278 | 0.1177 | 0.0941 | 0.0664 | 0.1004 | 0.1102 | 0.1196 | 0.1016 | 0.0979 | 0.0790 | 0.1275 | 0.1207 |
| | F11 | 0.1215 | 0.1062 | 0.1210 | 0.1084 | 0.1174 | 0.1145 | 0.1131 | 0.1262 | 0.1186 | 0.0979 | 0.0706 | 0.0983 | 0.0942 | 0.0898 | 0.0848 | 0.1207 | 0.1183 | 0.1008 |
| | F12 | 0.0925 | 0.1038 | 0.1156 | 0.0999 | 0.1054 | 0.1170 | 0.1257 | 0.1060 | 0.1050 | 0.0947 | 0.0968 | 0.0627 | 0.1019 | 0.0854 | 0.0829 | 0.0904 | 0.0867 | 0.1320 |
| | F13 | 0.1298 | 0.1131 | 0.1167 | 0.1227 | 0.1272 | 0.1183 | 0.1347 | 0.1370 | 0.1262 | 0.1370 | 0.1171 | 0.1082 | 0.0876 | 0.1263 | 0.1208 | 0.1337 | 0.1170 | 0.1504 |
| | F14 | 0.1292 | 0.1284 | 0.1306 | 0.1319 | 0.1388 | 0.1266 | 0.1212 | 0.1403 | 0.1538 | 0.1383 | 0.1318 | 0.1146 | 0.1531 | 0.0862 | 0.1260 | 0.1394 | 0.1355 | 0.1516 |
| | F15 | 0.1045 | 0.1068 | 0.1125 | 0.1189 | 0.1154 | 0.1236 | 0.1297 | 0.1067 | 0.1387 | 0.0878 | 0.1162 | 0.0978 | 0.0911 | 0.0867 | 0.0652 | 0.0846 | 0.1032 | 0.1328 |

Table 4 (continued)
Total-Relation matrix T of fuzzy number (l, m, u)

| | | | | | | | | | | | | | | | | | | | |
|-----|-----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| (l) | F16 | 0.1218 | 0.1137 | 0.1154 | 0.1144 | 0.1336 | 0.1238 | 0.1318 | 0.1277 | 0.1443 | 0.1301 | 0.1120 | 0.1040 | 0.1131 | 0.0929 | 0.0866 | 0.0740 | 0.1100 | 0.1353 |
| | F17 | 0.1074 | 0.1074 | 0.1139 | 0.1100 | 0.1328 | 0.1134 | 0.1235 | 0.1256 | 0.1259 | 0.0992 | 0.1031 | 0.0996 | 0.1079 | 0.1028 | 0.0977 | 0.1009 | 0.0744 | 0.1167 |
| | F18 | 0.0844 | 0.1004 | 0.1126 | 0.1083 | 0.1320 | 0.1119 | 0.1140 | 0.1006 | 0.1153 | 0.1019 | 0.0901 | 0.0838 | 0.1200 | 0.1141 | 0.0822 | 0.1123 | 0.0915 | 0.0806 |
| (u) | F1 | 0.3836 | 0.4358 | 0.4465 | 0.4431 | 0.4604 | 0.4448 | 0.4735 | 0.4668 | 0.4452 | 0.4158 | 0.4356 | 0.4228 | 0.4548 | 0.4316 | 0.4193 | 0.4216 | 0.4396 | 0.4654 |
| | F2 | 0.4341 | 0.3882 | 0.4514 | 0.4440 | 0.4500 | 0.4174 | 0.4715 | 0.4663 | 0.4605 | 0.4009 | 0.4551 | 0.4326 | 0.4493 | 0.4289 | 0.4213 | 0.4146 | 0.4547 | 0.4802 |
| | F3 | 0.4069 | 0.4090 | 0.3627 | 0.3923 | 0.4044 | 0.3952 | 0.4116 | 0.4183 | 0.4083 | 0.3797 | 0.4005 | 0.3810 | 0.4131 | 0.3861 | 0.3777 | 0.3855 | 0.4045 | 0.4400 |
| | F4 | 0.4354 | 0.4393 | 0.4554 | 0.3874 | 0.4671 | 0.4343 | 0.4749 | 0.4611 | 0.4600 | 0.4195 | 0.4460 | 0.4321 | 0.4586 | 0.4351 | 0.4264 | 0.4235 | 0.4512 | 0.4782 |
| | F5 | 0.4126 | 0.4034 | 0.4391 | 0.3980 | 0.3824 | 0.3966 | 0.4468 | 0.4472 | 0.4171 | 0.3928 | 0.4229 | 0.4093 | 0.4291 | 0.4181 | 0.3956 | 0.3933 | 0.4343 | 0.4557 |
| | F6 | 0.4013 | 0.3940 | 0.3905 | 0.3619 | 0.4059 | 0.3447 | 0.4155 | 0.4201 | 0.3950 | 0.3806 | 0.4141 | 0.3859 | 0.4083 | 0.3930 | 0.3817 | 0.3699 | 0.3893 | 0.4205 |
| | F7 | 0.4249 | 0.4374 | 0.4510 | 0.4421 | 0.4667 | 0.4339 | 0.4176 | 0.4675 | 0.4654 | 0.4228 | 0.4478 | 0.4252 | 0.4579 | 0.4296 | 0.4279 | 0.4306 | 0.4597 | 0.4693 |
| | F8 | 0.4558 | 0.4609 | 0.4741 | 0.4650 | 0.4892 | 0.4701 | 0.4861 | 0.4351 | 0.4877 | 0.4339 | 0.4812 | 0.4545 | 0.4809 | 0.4547 | 0.4511 | 0.4506 | 0.4811 | 0.5066 |
| | F9 | 0.4327 | 0.4406 | 0.4566 | 0.4356 | 0.4514 | 0.4381 | 0.4687 | 0.4579 | 0.4047 | 0.4175 | 0.4553 | 0.4269 | 0.4571 | 0.4326 | 0.4239 | 0.4292 | 0.4516 | 0.4804 |
| | F10 | 0.4124 | 0.4192 | 0.4250 | 0.4081 | 0.4216 | 0.4064 | 0.4470 | 0.4395 | 0.4108 | 0.3486 | 0.4189 | 0.4134 | 0.4364 | 0.4038 | 0.3966 | 0.3778 | 0.4338 | 0.4494 |
| | F11 | 0.4199 | 0.4166 | 0.4355 | 0.4106 | 0.4293 | 0.4143 | 0.4392 | 0.4465 | 0.4337 | 0.3941 | 0.3737 | 0.4012 | 0.4104 | 0.3909 | 0.3836 | 0.4076 | 0.4342 | 0.4286 |
| | F12 | 0.3809 | 0.3922 | 0.4096 | 0.3825 | 0.4030 | 0.3986 | 0.4248 | 0.4099 | 0.4034 | 0.3750 | 0.3973 | 0.3345 | 0.4012 | 0.3706 | 0.3652 | 0.3700 | 0.3849 | 0.4303 |
| | F13 | 0.4442 | 0.4408 | 0.4512 | 0.4419 | 0.4566 | 0.4346 | 0.4760 | 0.4687 | 0.4563 | 0.4347 | 0.4528 | 0.4281 | 0.4063 | 0.4441 | 0.4366 | 0.4356 | 0.4494 | 0.4839 |
| | F14 | 0.4518 | 0.4577 | 0.4705 | 0.4526 | 0.4717 | 0.4484 | 0.4697 | 0.4788 | 0.4801 | 0.4451 | 0.4728 | 0.4399 | 0.4773 | 0.3950 | 0.4471 | 0.4462 | 0.4741 | 0.4913 |
| | F15 | 0.4073 | 0.4150 | 0.4286 | 0.4157 | 0.4280 | 0.4206 | 0.4473 | 0.4254 | 0.4371 | 0.3781 | 0.4312 | 0.3985 | 0.4060 | 0.3862 | 0.3473 | 0.3809 | 0.4170 | 0.4534 |
| | F16 | 0.4299 | 0.4339 | 0.4420 | 0.4269 | 0.4511 | 0.4312 | 0.4656 | 0.4502 | 0.4540 | 0.4208 | 0.4386 | 0.4152 | 0.4385 | 0.4031 | 0.3947 | 0.3658 | 0.4345 | 0.4721 |
| | F17 | 0.4284 | 0.4351 | 0.4492 | 0.4310 | 0.4604 | 0.4356 | 0.4687 | 0.4659 | 0.4588 | 0.4121 | 0.4387 | 0.4193 | 0.4424 | 0.4213 | 0.4136 | 0.4153 | 0.3935 | 0.4634 |
| | F18 | 0.3921 | 0.4127 | 0.4327 | 0.4131 | 0.4386 | 0.4191 | 0.4427 | 0.4230 | 0.4325 | 0.3991 | 0.4080 | 0.3875 | 0.4371 | 0.4168 | 0.3824 | 0.4111 | 0.4083 | 0.3961 |

Table 5 Values for the causal diagram

| | Di | | | Ri | | | Di + Ri | | | Di - Ri | | | Crisp Di + Ri | Crisp Di - Ri |
|-----|--------|--------|--------|--------|--------|--------|---------|--------|---------|---------|---------|--------|---------------|---------------|
| | l | m | u | l | m | U | l | m | u | l | m | u | | |
| F1 | 0.7811 | 2.1296 | 7.9062 | 0.7088 | 1.9961 | 7.5541 | 1.4899 | 4.1257 | 15.4603 | -6.7730 | 0.1335 | 7.1974 | 5.9178 | 0.1340 |
| F2 | 0.8864 | 2.3014 | 7.9212 | 0.6719 | 1.9408 | 7.6318 | 1.5583 | 4.2422 | 15.5530 | -6.7454 | 0.3606 | 7.2493 | 6.0176 | 0.2723 |
| F3 | 0.5606 | 1.7409 | 7.1769 | 0.7438 | 2.0599 | 7.8718 | 1.3044 | 3.8007 | 15.0487 | -7.3112 | -0.3190 | 6.4331 | 5.6146 | -0.3097 |
| F4 | 0.8407 | 2.2413 | 7.9854 | 0.7374 | 2.0143 | 7.5519 | 1.5782 | 4.2556 | 15.5373 | -6.7112 | 0.2269 | 7.2479 | 6.0264 | 0.2026 |
| F5 | 0.6457 | 1.8954 | 7.4943 | 0.8490 | 2.2242 | 7.9377 | 1.4947 | 4.1196 | 15.4319 | -7.2919 | -0.3288 | 6.6453 | 5.9100 | -0.2804 |
| F6 | 0.6221 | 1.7961 | 7.0721 | 0.7309 | 2.0546 | 7.5840 | 1.3530 | 3.8507 | 14.6561 | -6.9619 | -0.2586 | 6.3412 | 5.5939 | -0.2398 |
| F7 | 0.7547 | 2.0921 | 7.9773 | 0.8186 | 2.1982 | 8.1473 | 1.5733 | 4.2904 | 16.1246 | -7.3926 | -0.1061 | 7.1587 | 6.1346 | -0.0950 |
| F8 | 0.9592 | 2.4491 | 8.4188 | 0.8032 | 2.1893 | 8.0482 | 1.7624 | 4.6385 | 16.4670 | -7.0890 | 0.2598 | 7.6156 | 6.4358 | 0.2168 |
| F9 | 0.7386 | 2.0675 | 7.9608 | 0.8327 | 2.2058 | 7.9105 | 1.5713 | 4.2733 | 15.8713 | -7.1719 | -0.1383 | 7.1281 | 6.0865 | -0.0859 |
| F10 | 0.6724 | 1.9062 | 7.4687 | 0.6522 | 1.8851 | 7.2711 | 1.3246 | 3.7912 | 14.7398 | -6.5987 | 0.0211 | 6.8165 | 5.5628 | 0.0419 |
| F11 | 0.6597 | 1.9221 | 7.4700 | 0.6875 | 1.9734 | 7.7905 | 1.3472 | 3.8955 | 15.2604 | -7.1307 | -0.0513 | 6.7825 | 5.7162 | -0.0819 |
| F12 | 0.5947 | 1.8043 | 7.0338 | 0.6375 | 1.8757 | 7.4082 | 1.2322 | 3.6801 | 14.4420 | -6.8134 | -0.0714 | 6.3963 | 5.4307 | -0.1048 |
| F13 | 0.8308 | 2.2238 | 8.0419 | 0.7605 | 2.1047 | 7.8646 | 1.5913 | 4.3285 | 15.9065 | -7.0338 | 0.1191 | 7.2814 | 6.1309 | 0.0996 |
| F14 | 0.9299 | 2.3773 | 8.2702 | 0.6758 | 1.9543 | 7.4415 | 1.6057 | 4.3317 | 15.7117 | -6.5116 | 0.4230 | 7.5944 | 6.1062 | 0.3907 |
| F15 | 0.6721 | 1.9222 | 7.4236 | 0.6045 | 1.8224 | 7.2919 | 1.2766 | 3.7445 | 14.7156 | -6.6198 | 0.0998 | 6.8191 | 5.5221 | 0.0832 |
| F16 | 0.7488 | 2.0847 | 7.7681 | 0.6683 | 1.9194 | 7.3291 | 1.4171 | 4.0042 | 15.0973 | -6.5804 | 0.1653 | 7.0998 | 5.7733 | 0.1666 |
| F17 | 0.6778 | 1.9623 | 7.8530 | 0.7179 | 2.0308 | 7.7959 | 1.3958 | 3.9930 | 15.6489 | -7.1181 | -0.0685 | 7.1351 | 5.8456 | -0.0382 |
| F18 | 0.6173 | 1.8559 | 7.4528 | 0.8920 | 2.3231 | 8.2649 | 1.5093 | 4.1790 | 15.7176 | -7.6476 | -0.4672 | 6.5608 | 5.9939 | -0.4201 |

4.1 Theoretical contributions

This study contributes to agile project implementation and impact of several challenging factors.

Table 6 Impact results of factors

| Factors | D + R | D - R | Impact |
|---------|--------|---------|--------|
| F1 | 5.9178 | 0.1340 | Cause |
| F2 | 6.0176 | 0.2723 | Cause |
| F3 | 5.6146 | -0.3097 | Effect |
| F4 | 6.0264 | 0.2026 | Cause |
| F5 | 5.9100 | -0.2804 | Effect |
| F6 | 5.5939 | -0.2398 | Effect |
| F7 | 6.1346 | -0.0950 | Effect |
| F8 | 6.4358 | 0.2168 | Cause |
| F9 | 6.0865 | -0.0859 | Effect |
| F10 | 5.5628 | 0.0419 | Cause |
| F11 | 5.7162 | -0.0819 | Effect |
| F12 | 5.4307 | -0.1048 | Effect |
| F13 | 6.1309 | 0.0996 | Cause |
| F14 | 6.1062 | 0.3907 | Cause |
| F15 | 5.5221 | 0.0832 | Cause |
| F16 | 5.7733 | 0.1666 | Cause |
| F17 | 5.8456 | -0.0382 | Effect |
| F18 | 5.9939 | -0.4201 | Effect |

In contingency theory view, no generalised path is towards success or failure. This study is appropriate in elaborating that several challenging factors are responsible for agile project implementation. Firstly, it makes an understanding of the agile project implementation challenges existing in emerging economies. However, the initiatives for inclusion of industry 4.0 technologies undertaken by the government of India but still the implementation is very low due to several challenges like—skepticism towards the new way of working, non-availability of skilled people, third party involvement, automation landscape insufficiently mature, misunderstanding agile concepts etc. There is limited research on agile project implementation and its challenges in context to India. The exploration of these challenging factors will support researchers to understand the key issues affecting the implementation of project. Secondly no study has categorised the challenging factors into causal and effect to explore its nature. By F-DEMATEL method, the study has grouped the challenging factors into cause and effect. Furthermore, each factor influence is calculated and its interrelationship with other factors. Finally, this study fills the gap on limited research on agile project implementation. This study provides insights for managers and policymakers to plan strategic actions for agile project implementation in emerging economy like India. The study acts as a steppingstone in the theoretical development of agile project implementation for future cross-sectional research.

4.2 Managerial implications

The current study determines the cause-and-effect relationship among the challenging factors, and therefore provides opportunities for the project management teams to improve their current systems. It also helps policy-makers and the decision makers to take initiatives for developing the agile projects. As per the findings the influential causal factors are—Investment decisions require up-front certainty (F1), third party involvement (F2), automation landscape insufficiently mature (F4), less motivation and enthusiasm due to COVID-19 impact (F5), non-availability of skilled people (F8), structural impediments (F10), lack of shared value (F13), skepticism towards the new way of working (F14), lack of investment (F15), and misunderstanding agile concepts (F16). These factors have high influence on all other factors and thus project managers must focus on these to implement agile projects successfully. The managers may be benefitted from this study to consider these factors and make efforts to get rid of these challenges for agile project implementation in emerging economies like India. Thus, this study contributes to assess the influencing and the influenced factors for agile project implementation.

For majority of the organisations, the question for adopting digital development for enhancing the quality is not to be raised but how and to which extent needs to be planned. Agility is one of the key enablers for keeping the pace and customer centricity and means of fundamental shift. The transformation ranges from structural changes, governance to capabilities, technological transformation, sourcing, people, culture, and performance. These areas are optimised to enhance focus, speed, and flexibility, transparency, predictability and control, with reduction in the cost.

This study suggests that the skepticism among the employees is the main challenging factor that inhibits agile project implementation. Project manager must consider formalising specialised roles, such as testing manager to drive rigor and alignment for test plans, tools, and data; build master; or even a traditional project manager to avoid the challenges reacted to job role, shared values, Project managers should also focus on training to enhance the skills of the team members and increasing the adaptability for the future. The skepticism for the adaptability must be taken care of urgently as most of the organisations are struggling with the disruptive environment and need to shift to the automation, agility to survive in the post pandemic situation.

5 Conclusions, limitations and future research

The situation during COVID-19 has created disruptive environment across the globe affecting every institution and individual. The inclusion of artificial intelligence, data science and other industry 4.0 technologies have transformed the existing systems and demonstrated the need of agility. During disruption, the resources need to be optimised for developing capabilities and building agility. This study aimed at identifying challenges faced by the firms to adopt and manage agile projects in emerging economies where the resources are limited. The present research evaluates the challenges to agile project management during COVID-19 and establish relationship among those factors using F-DEMATEL. This study offers opportunities for managers to decide how agile projects could benefit firms to deal pandemic situation in future.

The lessons from the COVID-19 enable the organisations to realise the need of preparedness for a ‘new normal’ situation. With the help from this paper, the critical factors are explored that must be considered for enhancing agility in the project management implementation during pandemic. This research approach is certainly in line with the increasing trend towards pandemic and new normal situation. The results of this study show skepticism towards the new way of working (F14) and third-party involvement (F2) are the most critical factors that must be considered to improve the agility in the projects.

This research study has few limitations that are required to be highlighted for future similar studies to consider. The identification and finalisation of factors is very challenging. The dynamic environment will develop more factors to be considered in near future. Thus, the study has identified 18 critical factors which may increase in future. The study has assessed the factors based on expert from one country and thus the study may be replicated to the other countries with the similar conditions. The study has investigated cause-and-effect group analysis using F-DEMATEL which may be further assessed through empirical analysis.

Declarations

Competing interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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