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An FCM-Based Dynamic Modelling of Integrated Project Delivery Implementation Challenges in Construction Projects

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Abstract

Question: What are the Integrated Project Delivery Implementation challenges in construction projects, their interrelationships and their effects on the project time, cost and quality?

Purpose: The Purpose of this study is applying an efficient method to determine the most important challenges to IPD implementation in construction industry, and also to evaluate the interrelationships among these challenges and their effects on the project time, cost, and quality.

Research Method: This study models available Integrated Project Delivery challenges using a real case data, through applying Fuzzy Cognitive Mapping technique.

Findings: Results show that contractual factors have the major influence compared with others. This shows the significance of paying attention to why project stakeholders must be integrated throughout the project life cycle since early contract documentation stage.

Limitations/Implications: This study is limited to the case selected from Tehran of Iran.

Value for authors: This study is significant due to identifying, classifying and determining the intensity of effects of IPD implementation challenges on cost, time, and quality of construction projects. It results in planning, resolving the challenges, enhancing the quality of constructions and lastly saving the construction cost and time.

Keywords: Integrated Project Delivery (IPD); Fuzzy Cognitive Map (FCM); Challenges; Construction Projects; Dynamic Modelling

Paper type: Full paper

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Introduction

One of the significant achievements in a project is its completion within predicted budget and time, and within the desired expected quality. Increased cost of project completion leads to occurrence of a loss of appropriate profitability to the beneficiary. Often, projects are not justifiable economically and technically (Lichtig, 2006) .Moreover, if project completion takes longer, there is the possibility of conducting similar projects by competitors and losing new market (Atkinson, 1999). The balance of time, cost, and quality is one of the fundamental challenges for project management. Consequently, project success heavily depends on achieving these three major factors. The type of contract adopted plays an important role in creating such balance (Eskandari and Geiger, 2008).

During recent years, depending on the type and need of projects and considering the existing rules, various executive systems and different types of contracts have been used. Besides various benefits of existing delivery systems, their disadvantages have led to lack of meeting project objectives (Sive, 2009). Based on experiences obtained from inefficient delivery systems, particularly in the multifaceted projects, project owners have decided to resolve the problems by taking advantage of integrated systems of project delivery (Nejati et al., 2014). One of these systems is Integrated Project Delivery (IPD) that its initial instructions and guidance were formulated in 2007 by American of Architects (AIA, 2007). Studies have shown that utilizing IPD has been very effective in increasing project performance, in terms of increasing control and supervision of project managers (Harrison et al., 2016).

What is observed during recent years has been applying IPD in complex construction projects (AIA, 2012), particularly hospitals and medical centers (Pikel et al., 2016). However, IPD can be used in any type of projects (Ilozor and Kelly, 2012). For example, in a study conducted by Al Subaih (2015), IPD was utilized in complex oil and gas projects (Al Subaih, 2015). One of the solutions that help IPD implementation is owner dominance (Mollaoglu-Korkmaz et al., 2014).

The need for this study has been that there is no official statistical report in IPD regard. Most of previous studies have been about introducing. Recent studies show the need for more detailed and precise design for the projects. In order to resolve the existing disadvantages, wide coordination of managers, consultants, contractors, architects, and customers is significantly required. Therefore, to implement these concepts and to quickly achieve the objectives of the project, identifying challenges is much needed (Kahvandi et al., 2017). Ghassemi and Becerik-Gerber (2011), Shahhosseini (2013), Nejati et al. (2014) have identified and categorized the IPD challenges (Ghassemi and Becerik-Gerber, 2011; Nejati et al., 2014; Shahhosseini, 2013). But none of these challenges has pointed to the relationships between the factors and also did not address the final effects of the factors on the three factors of cost, time and quality. Previous studies have identified and classified obstacles based on the research conducted by the elites through interviews and questionnaires and a review of a number of case studies. This study aims to apply a proper method to determine the severity of the impact of factors on each other. Determining the most significant challenges to IPD implementation is important due to the fact that following its determination; some proper planning can be made to resolve them, helping to enhance the quality of the construction industry (Syariazulfa, 2016).

This study uses the concept of Fuzzy Cognitive Mapping (FCM) for modeling the interrelationships amongst factors. According to Lopez and Salmeron (2012) FCMs have good features to determine the severity of the impact of factors on each other and to the same time they have no other methods limitations. FCMs enable us to represent all possible connections and this does not limit the feedback dynamics. Also, this can even be used when the information is scarce. For these reasons, it has been decided to apply the FCM technique for modeling challenges to IPD implementation. Initially, IPD has been investigated. Then the challenges of IPD and the effects of these challenges are examined. In the research method, using the FCM, data are analyzed and using the FCM static analysis and the FCM dynamic analysis. Then the impacts of the data on the three factors of time, cost, and quality are evaluated.

Next section addresses literatures on the concepts concentrated in this study.

Literature Review

In this section, the definitions and principles related to IPD are reviewed, as well as the challenges to its implementation. The importance of considering these challenges and their effects on each other are also discussed.

Integrated Project Delivery (IPD)

IPD is a contractual system for project delivery. It integrates project stakeholders throughout project life cycle. Moreover, IPD utilizes the experience of all project stakeholders to increase project value for the owner and to reduce wastes (AIA, 2007). In fact, IPD is a collaborative process, which aims to increase productivity of project lifecycle. Comprehensive definitions of IPD were offered by American Institute Architects in 2007. IPD includes presence of all key factors of the project from outset in an integrated manner, and using their experiences in a multilateral contract to have a successful project and participation in risk and reward for all stakeholders in project life cycle (AIA, 2012). Then various contracts were written to support IPD in the USA, among them is AIA E202 contract (Fish, 2011). Sometimes IPD is used as attachment to public conditions (Garcia et al., 2014). Also some owners would seek to implement Lean IPD by using a relational design-build contract with IFOA like features but most public agencies do not have legal authority to implement Lean IPD using a relational three-or-more-party agreement (Darrington, 2011).

IPD principles are divided into four groups of Organizational, Contractual, Communicative and Behavioral (Pishdad-Bozorgi and J. Beliveau, 2016). Organizational principles include 1) the presence of all stakeholders from beginning of the project, 2) common objectives, 3) participation in decision making, 4) common creativities, 5) early and careful planning, 6) participation in project control and supervision, and 7) effective communications (AIA, 2007; Pishdad-Bozorgi and J. Beliveau, 2016). Contractual principles include 1) a multilateral contract, 2) communication contract, 3) common risk and financial rewards, 4) accepting risks at the beginning of the project, and 5) delegating responsibilities to stakeholders (Pishdad-Bozorgi and J.Beliveau, 2016). Communicative principles include 1) open communications, 2) data collection, 3) sharing information (AIA, 2012; Pishdad-Bozorgi and J. Beliveau, 2016). Behavioral principles include: 1) transparent relations, 2) mutual trust and respect, 3) previous relations among some of stakeholders, 4) culture of cooperation (Pishdad-Bozorgi and J.Beliveau, 2016). One of the significant roles of IPD main team, is learning principles and then teaching them to all key stakeholders of the project and assessing and controlling the quality of its implementation (Pishdad-Bozorgi, 2016). Terminal 5 of Heathrow Airport of London is one the complex projects utilized IPD principles. It started with £4.3 billion budget and opened in 2008 (Basu et al., 2009). The success of this project was focusing on three issues of delivery system, culture, and mutual trust. In this case, project objective turned into the main objective of all stakeholders, through benefiting from teamwork (Brady and Davies, 2010; Caldwell et al., 2009). The Walter Cronkite School of Journalism project in Phoenix was contrary to state law for IPD implementation in 2006. So while maintaining the contract of Design and Construct, IPD principles were implemented and consequently the project completed with the specified budget and on time (AIA, 2012).

In 2010, the building section was consuming 41% of energy in United States, 46% of which was related to commercial buildings (Doe, 2011). In the study conducted by Lee et.al in an hospital in which IPD was implemented, it was shown that in terms of ecology and better achievement to energy risk management, IPD has been very successful (Lee et al., 2013). This matter was not just in the energy section, but it was successful in the cooperation section too. Such that, according to the studies conducted by Kraatz (2014) et.al in Australia, lack of transparent communications in projects includes 10%-50% of construction costs. Moreover, it is estimated that 60%-90% of it, is due to lack of presence of all stakeholders from beginning of the project and also changes information. Accordingly, based on the conducted studies, IPD utilization is accompanied with 9% saving (Kraatz et al., 2014). In another project, in the construction of a surgery center in California, board of directors was looking for realization of three important objectives 1) facilities had to be ready for operation until January 2013, 2) the cost didn't have to exceed $320 million, and 3) the quality of facilities had to be at the global standard level. For this purpose, an IPD Integrated Reference Agreement named as IFOA is signed by 11 stakeholders including contractors, designers, and subcontractors. Presence of the contractor in the design process caused many savings at the end of the project (Bygballe et al., 2015).

IPD has been successful comparing with other contractual systems in many projects. Bilbo et.al (2015) compared IPD projects with Construction Manager at Risk (CMR) projects. Both projects were used for hospitals. The hospital with CMR project had 96 beds and was built in 2007 with $53,655,000 budget, and the contractor saved $1,681,000 (3.13%). And in terms of scheduling, the project was delayed for 11 days. The hospital with IPD project had 103 beds and was built in 2010 with $6,187,000 (10.27%) saving and completed 81 days sooner than the determined time. Moreover, using Building Information Modeling (BIM) reduced installation problems significantly (Bilbo et al., 2015). In another hospital project in Denver, the conditions set by board of directors included: $160 million budget, a schedule of 24 months, and the highest level of quality of international standards. Consequently, during various meetings, the project was evaluated through using four types of contract system. In Design-Bid-Built (DBB) system, cost of the project was $200 million and its time period was 30 months and the quality index was 5. In CMR system, cost of the project was $175 million and its time period was 25 months and the quality index was 7. In IPD system, cost of the project was $149 million and its time period was 22 months and the quality index was 8 (Harrison et al., 2016). Consequently, according to the specified conditions by board of directors, IPD was determined as the best selection.

Next section addresses the challenges to IPD implementation.

Challenges to IPD implementation

One of the most important reasons for IPD acceptance is flexibility it provides for the project team. Project teams can face the challenges to IPD implementation based on changing circumstances and through sharing their knowledge and experience (Lee et.al 2010). Despite successful IPD implementation in few countries, this system still suffers from various obstacles. Zhang et.al (2013) in a three-year survey of a project using IPD concluded that despite employing committed people, the level of communication among people was just 14%. Given the studies conducted in the field of flexibility in executive teams, such as active social interactions and participating all stakeholders in solving problems, it can be stated that this project was not successful (Zhang et al., 2013).

Ghassemi and Gerber (2011) categorized the challenges to IPD implementation in four groups of technical, legal, financial and cultural challenges (Ghassemi and Becerik-Gerber, 2011). Nejati et.al (2014) also categorized these challenges in four similar groups. There were several challenges to projects, in which IPD has been used completely or partly. In a tripartite agreement among representative of the owner, architectural company, and a main contractor, IPD was used for building a surgery center. The trend was such that the architect and the contractor were selected separately through negotiations. The challenge to representative of the employer was lack of experience of the contractor for early presence in the project beside the architect and the maintenance contractor. In fact, lack of familiarity of contractors of this project with IPD and their tendency to use conventional contractual methods were the most significant challenges in this project. Representative of the employer resolved the challenge by holding numerous justification sessions and allocating more than 3% of the budget to encouraging the contractor to cooperate (Bygballe et al., 2015). In IPD, the owner, designer, and contractor sign a multilateral contract, and all three manage the risks involved.

Besides, IPD-oriented contracts can either be a multilateral contract (Rahim et al., 2015), or several bilateral contracts. For example, in a hospital project with 447 beds in the United States with $385 million facilities budget and $276 million budget for construction, the owner believed that through IPD implementation, they will achieve a very better quality, less wastes, more safety, and increased investment return. However, all stakeholders were not present from beginning of the project, so the team couldn't properly define the project scope to make the contract. Thus, sub-contracts were used beside the main IPD team, which included representatives of the owner, the engineers, and the architects. Due to lack of integration of a part of the contract, there were some issues not covered by insurance. Accordingly, the IPD team decided to use incentive option to solve this problem. In addition, in a medical center project with an area of 600,000 and $250 million and 34 months period, there were two owners. They faced the challenge of lack of motivation of investors to use modern contracts such as IPD and lack of sufficient knowledge and familiarity of them with IPD. IPD proposed by a contractor who had the experience of working with it and a tripartite contract. The stakeholders were looking for legal advisor for drafting the contract, then IPD agreement was applied as a communication bridge and several bilateral contracts were set in the project (Pishdad-Bozorgi, 2016). In the Cathedral Hill Hospital project in San Francisco, the existing challenges were the challenge of selecting the compensator for financial losses and lack of mutual trust among project key stakeholders in financial and management issues. These problems were resolved by allocating additional budget to gain project stakeholders confidence (AIA, 2012). Governments have some legal challenges that have specific methods to select the contractors and contracts (Collins and Parrish, 2014). As the result, resolving them to implement IPD depends on governmental decisions.

In this study a comprehensive list of IPD implementation drawbacks is prepared through a questionnaire survey. For that, an in-depth literature review of the IPD concept is done and various case studies applying the IPD system is reviewed. Then employers, project managers, consultants, and contractors active in the field of construction have been investigated. The obtained results were analyzed using Exploratory Factor Analysis (EFA) method. Among 44 probable IPD implementation challenges that were questioned, 22 challenges in the construction industry were considered. The challenges to implementing IPD are listed below and an ID is allocated for each. The relevant references for each challenge are shown in the Appendix 1.

- A1: Lack of coordination for the compensator for financial losses in this project.
- A2: Lack of coordination in managing in this project.
- A3: The effect of weak matrix structure in this project.
- A4: Lack of sufficient knowledge and familiarity of investors of this project with modern successful contractual systems in the world.
- A5: Lack of training courses about defining and stating the advantages of modern successful contractual systems of the world for investors of this project.
- A6: Lack of motivation of investors to use modern contracts such as IPD approach.
- A7: Lack of proficiency and strong management of the employer.
- A8: Lack of appropriate orientation for future and inattention to the future development.
- A9: Lack of familiarity of contractors of this project with IPD approach.
- A10: Lack of existence of conditions to assign insurance to whole of the project, considering using modern contractual systems.
- A11: Lack of existence of conditions to assign the liability insurance to the contractor, considering using modern contractual systems.
- A12: Lack of participation of government agencies in the construction of this project, considering the rules governing the government contracts.
- A13: Lack of mutual trust among project key stakeholders about financial and management issues.
- A14: Poor data transfer among different phases of a project.
- A15: Lack of homologous contracts among sub-contractors, such as IPD approach.
- A16: The tendency to use conventional contractual methods and resistance against new ideas.
- A17: Lack of proper definition of responsibilities of each party to the contract in this project.
- A18: Lack of proper definition of the culture of teamwork among project key stakeholders.
- A19: Lack of appropriate policies and strategies for the present construction contracts.
- A20: Lack of sufficient knowledge about design and construction and maintenance among representatives of the employer.
- A21: Lack of using BIM as a suitable tool for IPD implementation.
- A22: Lack of integrated of key stakeholders.

These challenges have had different effects and these effects have been collected from different sources, as shown in the table. In his article, Shahhosseini (2013) indicated some of the challenges' effects, increase of redo, reduction of project performance, lack of meeting the objectives of the project and reduction of proper financial confrontation among the employer, the advisor, and the contractor (Shahhosseini, 2013). Also by literature reviews, reduction of motivation is one of important effects of challenges and following that reduction of the sense of cooperation among various working groups and reduction of mutual trust among stakeholders are important as well. For example, the lack of mutual trust among project key stakeholders about financial and management issues leads to increase of changes and increase of disputes and claims that both will have additional costs for the projects (Pishdad-Bozorgi and J. Beliveau, 2016). Lack of integrated interoperability of key stakeholders due to lack of the required technology leads to increase of complexity of the performing project (Nejati et al., 2014). In the Table 1, the challenges effects are identified. Then, 10 challenges' effects are determined as more effective ones. These challenges' effects are reviewed in 4 general areas of technical-executive, economical-financial, contractual-legal, and environmental-cultural.

Table 1: IPD implementation Challenges' effects

ID	Challenges' effects	References
E1	Reduction of motivation	(Ghassemi and Becerik-Gerber, 2011; Mollaoglu-Korkmaz et al., 2014; Zhang and Li, 2014)
E2	Reduction of proper financial confrontation among the employer, the advisor, and the contractor	(Collins and Parrish, 2014; Shahhosseini, 2013; Shahhosseini, Shakeri, et al., 2014)
E3	Increase of changes	(Hampson and Kraatz, 2013; Nejati et al., 2014; Pishdad-Bozorgi and J.Beliveau, 2016)
E4	Increase of disputes and claims	(Pishdad-Bozorgi, 2016; Pishdad-Bozorgi and J.Beliveau, 2016)
E5	Reduction of project performance	(Shahhosseini, 2013; Zhang and Li, 2014)
E6	Reduction of mutual trust among stakeholders	(Mollaoglu-Korkmaz et al., 2014; Pishdad-Bozorgi and J. Beliveau, 2016)
E7	Lack of meeting the objectives of the project	(Collins and Parrish, 2014; Shahhosseini, 2013; Shahhosseini, Hajarolasvadi, et al., 2014)
E8	Increase of complexity of the performing project	(Hampson and Kraatz, 2013; Nejati et al., 2014)
E9	Increase of redo	(Nejati et al., 2014; Shahhosseini, 2013)
E10	Reduction of the sense of cooperation among various working groups	(El Asmar et al., 2015; Lee, 2013)

In the data analysis section, the effect of these factors on the challenges to IPD implementation and also their effect on three factors of time, cost, and quality are reviewed. These challenges' affect and exacerbate each other. It also influences the main goals of the project and causes the lack of satisfaction of the stakeholders.

Next section addresses research method adopted.

Research Method

The purpose of this study was to identify the most important IPD projects' challenges in the literature and then investigate available interrelationships among these factors. To achieve this goal, we utilized a research structure based on literature review, real case data and cognitive mapping as the data analysis procedure. The research steps includes identifying IPD projects' challenges, effects and failure modes, selecting IPD experts, creating interconnection dependency among challenges and constructing FCM model, analyzing resulted FCM statistically, applying the proposed model for simulation of five scenarios, and finally interpreting and discussing the results. Figures 1 depicts the research steps.

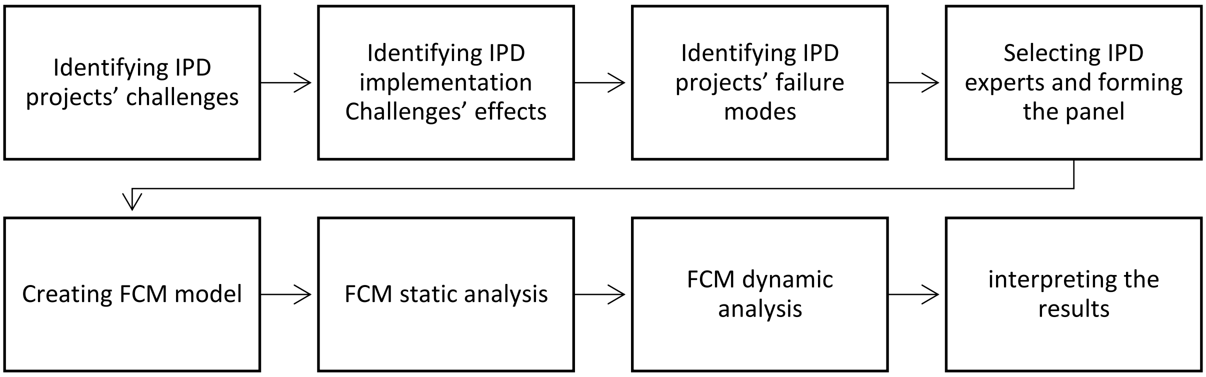

Figure 1. The research steps

Next section addresses fuzzy cognitive mapping (FCM) adopted.

Fuzzy Cognitive Maps (FCMs)

The FCMs are combination of Fuzzy Logic and Neural Networks (Kosko, 1986). Rather, FCMs model a system as a one-layer network, where through this network there are some concept nodes (C_i) which represent key factors and characteristics of the modeled complex system, and some weighted arcs (W_{ij}) connecting these nodes, represent the casual relationship that exists among them. On the whole, the relationship between two concepts have three possible types; 1) positive causality ($W_{ij} > 0$), 2) negative causality ($W_{ij} < 0$), and 3) no relationship ($W_{ij} = 0$). Moreover, the values of W_{ij} indicate how strongly concept C_i effect concept C_j. To construct FCMs, more simply to extract a symmetric weight matrix which represent mentioned weighted arcs; after identifying the constitutive concepts, some domain experts draw aforementioned relationship among the concepts. Afterwards, they estimate the strength of them (Papageorgiou, 2010). Meanwhile, all the suggested values by experts are considered as linguistic variables, and overall linguistic weight is obtained, which transformed to a numerical weight with the defuzzification method of Centre of Gravity (Papageorgiou, 2011). Accordingly, in the result model there are three types of concepts, 1) input concepts which have more overall effects on other ones, 2) intermediate concepts in which the input and output weights are approximately the same, 3) output concepts which are more affected by other concepts (Kosko, 1986).

In addition, there are two type of analyses for interpreting the FCM output models; static and dynamic analysis (Kosko, 1986). Static analysis displays the overall effects of the extracted model, that is to say, total influences of the input and intermediate concepts on the output ones using a cause and effective path analysis. To implement such analysis, at first, a casual path from some concept node C_i to concept node C_j, say C_i --~ C_{k1}, C_{k1}--~…

C_{kn}, C_{kn}---C_j can be indicated by sequence (i, k, …., kn,j).Then the indirect effect of C_i on C_j is the causality C~I impart to C_j via the path (i, kl….kn,j). The total effect of C_i on C_j is the composite of all indirect effect causalities C~ imparts to C_j (Kosko, 1986). A simple fuzzy causal algebra is created by interpreting the indirect effect operator I as the minimum operator, (or t-norm) and the total effect operator T as the maximum operator (or s-norm) on the partially ordered set P of causal values (Pelaez and Bowles, 1996). Formally let ~ be a causal concept space, and let e: ~ x ~ P be a fuzzy causal edge function, and assume that there are m-many causal path from C_i to C_j: (i, k~….k~, j) for 1 ~< r ~< m. Then let Ir (C_i, C_j) denote the indirect effect of concept C_i on concept C_j via the r^{th} causal path, and let T (i, C_j) denote the total effect of C_i on C_j over all m causal path. Then:

I~(Ci,Cj)=min(w(Cp,Cp+,): (p,p+1) ~ (i, k~…..k,~j)) (1)

T(Ci,Cj)=max(Ir(Ci, Cj)), where l< ~r<~m (2)

Where p and p+1 are contiguous left to right path indices (Papageorgiou, 2010).

On the other hand, dynamic analysis starts with an extracted model as mentioned above, and an initial state of the corresponding system which are represented weight matrix W and initial vector A^0 respectively. The latter, depicts the existing states of each concept in the modeled system; beside, the ultimate goal of dynamic analysis is estimation of final state of these concepts under causal and effective relationships of the model. Thus, in order to reach this goal, an iterative process commence and at each step for calculating the new value of concepts the equation 3 is used (Groumpos, 2010).

$$A_i^t = f\left(\sum_{\substack{j=1 \\ j\neq i}}^{n} A_j^{t-1} W_{ji} + A_i^{t-1}\right) \qquad (3)$$

A_i^t is the value of concept Ci at time t, A_i^{t-1} the value of concept Ci at time t-1, A_j^{t-1} the value of concept Cj at time t-1, and the weight W_{ji} of the interconnection from concept Cj to concept Ci. The function f is a threshold function and to squash the result in the interval [0, 1]. This value indicates at which level this concept will be activated. Actually, this activation level can be interpreted as relative abundance (Hobbs et al., 2002). More rigorously, the activation level can represent membership in fuzzy set describing linguistic measures of relative abundance (e.g., low, average, and high) (Kosko, 1986). Due to the inherent limitations of the sigmoid function, we used the transformed version of equation 1 as illustrated in equation 4 (Papageorgiou, 2011).

$$A_i^t = f\left(\sum_{\substack{j=1 \\ j\neq i}}^{n} (2A_j^{t-1} - 1)\, W_{ji} + 2A_i^{t-1} - 1\right) \qquad (4)$$

Furthermore, the uni-polar sigmoid function is used to activate any concept's value, where $\omega > 0$ determines the steepness of the continuous function f as equation 5:

$$f(x) = \frac{1}{1 + e^{-\omega(x)}} \qquad (5)$$

Finally, this process keeps repeating till converging to a steady state point in which, almost all concepts plateau. The equation 6 checks the stopping condition, of this process. in this equation, the second norm between old and new state vector is examined according to a fractional threshold:

$$\|A^t - A^{t-1}\|^2 \leq \varepsilon \qquad (6)$$

The purpose of this study is to identify the most important IPD projects' challenges in the literature and then investigate available interrelationships among these challenges. To achieve this goal, we utilized a research structure based on a real case data and cognitive mapping as the data analysis procedure.

Selecting IPD Experts and forming the panel

FCM technique is highly dependent on the data source. To improve the reliability and consistency of the FCM graphs, using a panel of experts is recommended (Zare Ravasan and Mansouri, 2014). A heterogeneous panel is used here, which is a group of people with the same knowledge but on a different social or professional scale.

The commercial project case studied in this study is amongst the greatest commercial complexes in the Middle East. Its area is about 1,700,000 square meters in west of Tehran, capital of Iran. Its construction has been started since 2011 and it will continue until 2018. This complex includes commercial section, two office towers, parking, two five-star hotels, an artificial lake, and catering halls. This project is constructing in two phases with 1,100,000 square meters and 600,000 square meters area. This project is one of the pioneer projects using BIM technology in Iran. Because of its large area, various contractors have been employed in it with different types of contracts that some of them follow IPD system. However, due to the existing challenges mentioned in this study, IPD has not been implemented completely. As this project is the first project in Iran using both BIM technology and IPD principles, the authors decided to take advantage of the experience of stakeholders of this project through questionnaire and interview.

Here, the participants belong to different professional scales in this project (IPD and project managers, employers, consultants and contractors who have more than five years of experience in the field). This team composition guarantees that the participants who were finally selected have a profound knowledge of IPD projects. In reaching out to the target sample, four steps were followed. At first, the first contact has been conducted as a pre-notice, which briefly introduced the research goal to the respondents and notified them that they would be requested within a few days to attend in a panel. The main request cover letter indicating exact time and place of the panel was sent out within a day after the pre-notice. The cover letter explained the purpose of the research and assuring respondents that answers would remain confidential. We also indicated in the cover letter and highlighted in the panel that we would provide a summary of the results in exchange for participation. In total, 10 out of 15 invited experts were participated in the panel. We thus achieved the making up of a heterogeneous panel of experts, 10 is a good size which is similar to that of the other FCM studies (Lopez and Salmeron, 2012; Papageorgiou et al., 2009).

Creating an FCM Model for Analyzing IPD projects' Challenges

The purpose of this study is to apply the FCM technique for modeling IPD projects' challenges interrelationships. To this end, as a first step, IPD projects' challenges are identified through literature review as depicted in section 2.2. Also, for creating the research model, we use the challenges' effects and three-level classification of projects failure modes as time, cost, and quality. Therefore, the proposed model of the paper can be depicted as Figure 2. That Figure is a partial representation because it does not include the interactions existing among the challenges, challenges' effects and failure modes.

Modelling Interdependencies

For modelling interdependencies, at first, IPD experts in a panel were asked to represent the interactions that exist between IPD projects' challenges, effects, and project failure modes.

Table 2 represents the relationship between numbers and linguistic variables. Note that the relations are positive, i.e., changes in the level of the factors exposure provoke changes in their effect factors in the same direction. In a similar vein, all direct connections from IPD projects' challenges to effects and also from effects to failure modes are positive. Therefore, an increase in the level of one challenge makes the project failure more likely.

Table 2: Linguistic values and mean of fuzzy numbers

Linguistic values	The mean of fuzzy numbers
Very high (VH)	1.00
High (H)	0.70
Medium (M)	0.50
Low (L)	0.30
Very low (VL)	0.10

Figure 2 shows the proposed model of the paper. This figure shows that we use the Challenges' effects and three-level classification of projects failure modes as time, cost, and quality.

Results

As discussed before, in FCMs, there are two types of analysis, while static analysis depicts the overall effects of each concept to output ones, dynamic analyses acts as an estimator of final state of system. Moreover, it allows investigating "what-if" scenarios by performing simulations of a given model from different initial state vectors (Stach et al., 2010) which is provided in the following.

Static Analysis

Based on the augmented adjacency matrix among IPD projects' challenges (Di), challenges' effects (Ei) and project failure modes (Fi) (see Table 3, 4, and 5), and the equations 4-5, the path effect from challenges to challenges' effects (Di~Ej) and from challenges' effects to project failure modes (Ei~Fj) can be calculated. The result of the calculations is depicted in Table 6

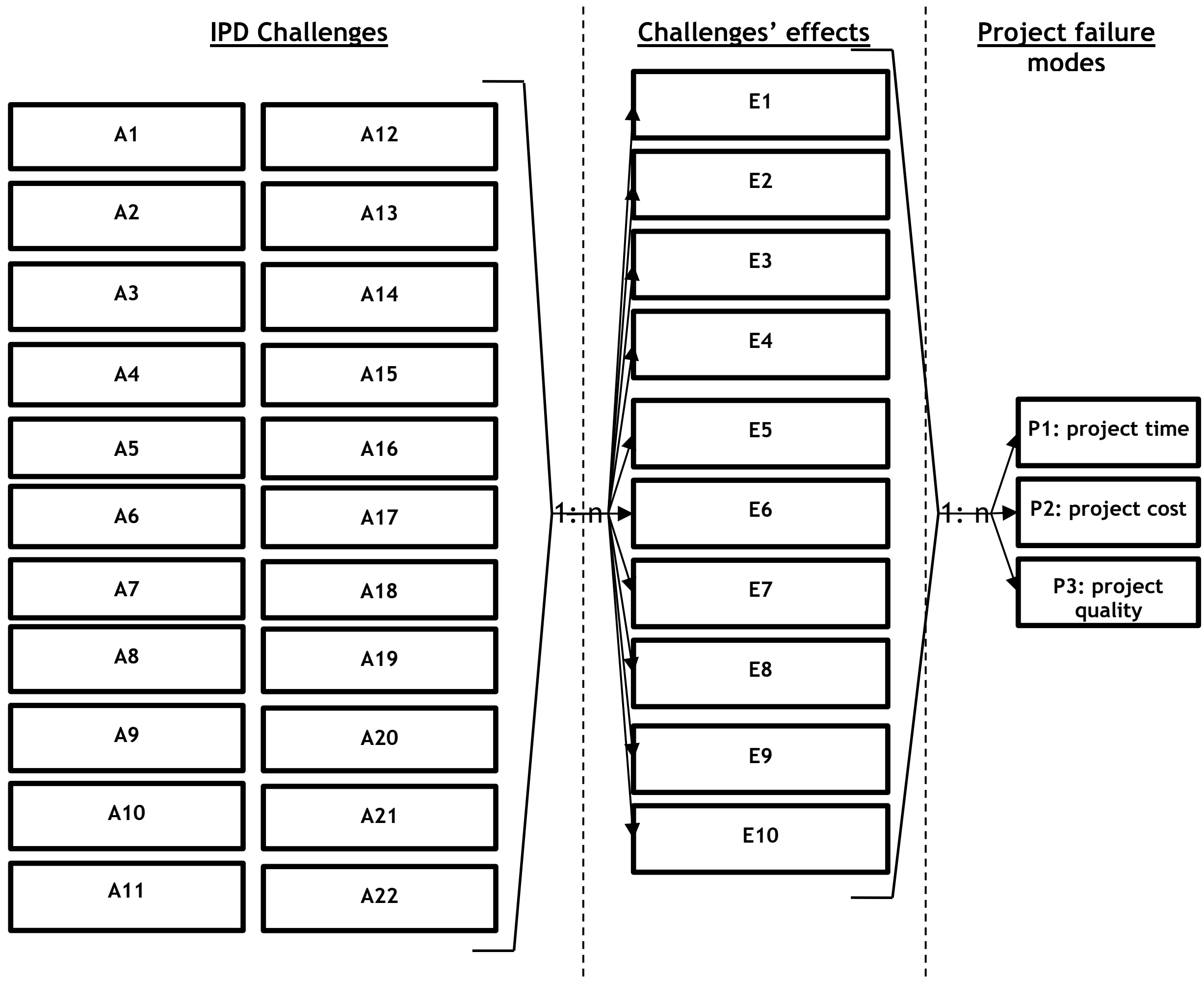

Figure 2. Challenges, effects and project failure modes

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Table 3: The effect among IPD projects' challenges and challenges' effects (initial data)

Codes	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
A1	0	0	0	0.3	0	0.1	0	0.3	0	0.5	0.5	0.1	0.5	0.5	0.3	0	0.3	0	0	0	0	0	0.1	0.3	0.3	0.3	0	0.3	0	0.1	0.3	0
A2	0	0	0	0.1	0	0.1	0.3	0	0	0	0	0	0	0	0.3	0.1	0	0.3	0	0	0	0.1	0.1	0	0	0	0	0.3	0.1	0	0	0.1
A3	0	0	0	0	0	0	0.3	0	0	0	0	0	0.3	0	0.1	0.3	0.5	0	0	0	0	0.3	0	0	0	0	0	0.3	0.1	0	0	0
A4	0.3	0	0	0	0.1	0.3	0	0	0	0	0	0	0.3	0.5	0.5	0.1	0.3	0	0	0.1	0	0	0	0	0.3	0	0.1	0.3	0.1	0.3	0.3	0.1
A5	0	0	0	0	0	0	0	0.1	0	0	0	0	0.3	0.5	0.3	0	0	0.3	0	0	0	0	0	0	0.1	0	0	0	0	0	0.1	0
A6	0	0	0	0	0.3	0	0.1	0	0	0	0	0	0	0.1	0	0.1	0	0	0.3	0	0	0	0	0	0	0	0	0	0.3	0	0	0.3
A7	0.1	0.3	0.1	0.3	0	0.1	0	0.3	0	0	0	0	0	0	0	0	0.1	0.3	0	0	0	0.3	0.3	0.3	0	0.3	0	0	0.1	0.1	0.3	0
A8	0	0	0	0.1	0	0	0.1	0	0	0	0	0	0	0.3	0	0	0	0	0.1	0	0	0	0	0	0	0.3	0	0	0.1	0	0.1	0
A9	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0.3	0	0	0	0.3	0	0	0	0	0	0	0.3	0.1	0	0	0	0.3	0	0
A10	0.1	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0.1	0.3	0	0	0	0	0	0	0.3	0.1	0	0.1	0.3	0.3	0	0	0	0.3
A11	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0.3	0.1	0	0	0	0	0	0.3	0.3	0	0.3	0	0.1	0.3	0.1	0	0.3
A12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0.5	0	0	0	0	0.1	0.3	0.3	0.3	0.1	0	0.3	0	0.3	0.3
A13	0	0.3	0	0	0	0.1	0.1	0	0	0	0	0.1	0	0.1	0	0	0	0.1	0	0.1	0	0	0.3	0.3	0.3	0.3	0	0.3	0.3	0	0.3	0.3
A14	0	0	0	0.3	0	0.3	0	0.1	0	0.3	0.1	0.3	0	0	0.1	0	0	0.3	0	0	0	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.3	0	0.1	0.1
A15	0.3	0	0.3	0	0.3	0	0.3	0	0	0	0	0	0	0	0	0	0.3	0	0	0.3	0	0	0	0	0.3	0	0	0	0	0	0	0
A16	0	0.3	0	0.1	0	0.1	0.3	0.3	0	0.1	0	0	0.3	0	0	0	0	0.1	0.1	0	0	0.1	0	0	0	0	0.3	0.3	0	0	0	0
A17	0.1	0	0	0	0.5	0	0	0	0.1	0.1	0.1	0	0	0.3	0	0	0	0.3	0	0	0	0.3	0	0	0	0.3	0.3	0.3	0	0.3	0	0
A18	0	0.1	0	0	0.1	0	0	0	0	0	0	0	0.3	0	0	0.3	0.1	0	0	0	0	0	0.1	0	0	0.3	0.3	0.3	0	0.3	0	0.1
A19	0	0	0	0.3	0.3	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.1	0.1	0	0.3	0	0.3	0	0.3	0	0.3	0.3	0	0
A20	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0.1	0.1	0	0	0	0.1	0.3	0.3
A21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0.3	0	0.1	0.1	0.1	0	0.1	0.1	0.1
A22	0	0.1	0	0	0	0	0	0.3	0.1	0	0	0.3	0	0.1	0	0	0	0	0	0	0	0	0	0.1	0.3	0.3	0.1	0.1	0	0	0.3	0.3

Table 4: The link among challenges' effects (Ei) and project failure modes (Fi) (initial data)

	Time	Cost	Quality
E1	0.1	0.3	0.1
E2	0.3	0	0.1
E3	0.3	0.1	0
E4	0	0.3	0.3
E5	0	0	0
E6	0.1	0.1	0
E7	0.3	0	0.1
E8	0.1	0.1	0.3
E9	0.3	0.1	0

According to the average (initial effects) values, A13 (Lack of mutual trust among project key stakeholders about financial and management issues) is the most effective challenge on challenge effects. However, based on the FCM augmentation relations, A3 (The effect of weak matrix structure in this project), A5 (Lack of training courses about defining and stating the advantages of modern successful contractual systems of the world for investors of this project), and A15 (Lack of homologous contracts among sub-contractors, such as IPD approach) are the most augmented challenges which mean that these challenges are the most affecting challenges in the network of relations in our FCM model. Meanwhile, these challenges should be considered seriously in IPD projects to prevent project failure. The point is that mentioned challenges are the root challenges which not only have effects on final project failure but also, affect other challenges and strengthen them.

Dynamic Analysis

It is possible to develop what-if analysis (scenarios) using different initial vector states. With the intention of observing the evolution of several initial scenarios, each analysis begins with the definition of an initial vector, which represents a proposed initial situation or scenario (Zare Ravasan and Mansouri, 2014).

In this experiment the authors used five initial vectors state (scenario), each one have some challenges activated. Scenarios describe events and situations that would be occurred in the future real-world. Scenario 1 is related to the condition that just managerial challenges are contributing in the model, scenarios 2-4 are respectively related to environmental, contractual, and technical source of challenges. Finally, scenario 5 is conducted using a real case data.

Table 6 illustrates initial condition of each scenario with their value in equilibrium point.

Table 5: Indirect effects (based on FCM Max of Mins relations)

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	Average* (indirect effects)	Average** (Initial effects)	FCM augmentation***
A1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.17**	**0.13**
A2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.06**	**0.24**
A3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.04**	**0.26**
A4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.15**	**0.15**
A5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.02**	**0.28**
A6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.06**	**0.24**
A7	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.14**	**0.16**
A8	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.05**	**0.25**
A9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.07**	**0.23**
A10	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.14**	**0.16**
A11	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.17**	**0.13**
A12	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.20**	**0.10**
A13	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.24**	**0.06**
A14	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.13**	**0.17**
A15	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.03**	**0.27**
A16	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.06**	**0.24**
A17	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.12**	**0.18**
A18	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.14**	**0.16**
A19	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.15**	**0.15**
A20	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3	**0.14**	**0.09**	**0.05**
A21	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	**0.12**	**0.09**	**0.03**
A22	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	**0.30**	**0.15**	**0.15**

* Average based on indirect effects (based on FCM Max of Mins relations)

** Average based on Initial effects (direct relations, Table 3)

*** FCM augmentation= Average (indirect effects) – Average (Initial effects)

	Scenario#1 Managerial	Final State	Scenario#2 Environmental	Final State	Scenario#3 Contractual	Final State	Scenario#4 Technical	Final State	Scenario#5 our case	Final State
A1	**1**	0.81	0	0.75	0	0.78	0	0.53	**0.6**	0.79
A2	**1**	0.85	0	0.76	0	0.84	0	0.53	**0.4**	0.83
A3	**1**	0.67	0	0.62	0	0.63	0	0.00	0.0	0.65
A4	**1**	0.85	0	0.89	0	0.89	0	0.64	**0.3**	0.90
A5	**1**	0.91	0	0.88	0	0.91	0	0.66	**0.3**	0.92
A6	0	0.83	**1**	0.81	0	0.84	0	0.61	**0.7**	0.84
A7	0	0.82	**1**	0.86	0	0.89	0	0.61	0.0	0.89
A8	0	0.88	**1**	0.87	0	0.91	0	0.63	**0.1**	0.91
A9	0	0.58	**1**	0.56	0	0.57	0	0.53	**0.2**	0.57
A10	0	0.84	**1**	0.81	0	0.82	0	0.61	**0.3**	0.83
A11	0	0.76	**1**	0.73	0	0.75	0	0.55	**0.5**	0.76
A12	0	0.79	**1**	0.73	0	0.76	0	0.58	**0.2**	0.76
A13	0	0.91	0	0.94	**1**	0.95	0	0.66	**0.4**	0.94
A14	0	0.96	0	0.95	**1**	0.98	0	0.83	**0.4**	0.98
A15	0	0.86	0	0.91	**1**	0.95	0	0.71	**0.6**	0.93
A16	0	0.84	0	0.87	**1**	0.90	0	0.61	**0.5**	0.89
A17	0	0.86	0	0.89	**1**	0.92	0	0.53	**0.3**	0.91
A18	0	0.95	0	0.89	**1**	0.98	0	0.91	0.0	0.97
A19	0	0.67	0	0.66	**1**	0.67	0	0.53	0.0	0.67
A20	0	0.71	0	0.65	0	0.69	**1**	0.00	**0.1**	0.71
A21	0	0.00	0	0.53	0	0.53	**1**	0.00	**0.1**	0.53
A22	0	0.79	0	0.82	0	0.85	**1**	0.63	0.0	0.84
E1	-	0.92	-	0.88	-	0.94	-	0.61	-	0.95
E2	-	0.93	-	0.81	-	0.95	-	0.62	-	0.93
E3	-	0.97	-	0.93	-	0.98	-	0.76	-	0.98
E4	-	0.99	-	0.96	-	0.99	-	0.84	-	0.99

E5	-	0.92	-	0.93	-	0.94	-	0.71	-	0.94
E6	-	0.98	-	0.97	-	0.99	-	0.75	-	0.99
E7	-	0.94	-	0.90	-	0.96	-	0.72	-	0.96
E8	-	0.88	-	0.89	-	0.94	-	0.73	-	0.93
E9	-	0.97	-	0.88	-	0.98	-	0.68	-	0.96
E10	-	0.97	-	0.88	-	0.98	-	0.67	-	0.97
Time	-	**0.89**	-	**0.93**	-	**0.92**	-	**0.88**	-	**0.91**
Cost	-	**0.78**	-	**0.84**	-	**0.83**	-	**0.78**	-	**0.82**
Quality	-	**0.78**	-	**0.80**	-	**0.81**	-	**0.77**	-	**0.79**

Table 6: Simulation results of five scenarios

All the challenges (nodes) in the initial vector are not activated at the initial time in the scenario 1, but A1 to A5. As can be seen from Table 6, the stable vector shows as the initial activated challenges have a strong influence over the remainder challenges. Findings confirm the critical role of managerial challenges in IPD projects. Higher effects are got over A14 (0.96), A18 (0.95), A5 (0.91), A13 (0.91), respectively. The most affected challenges' effects in this scenario are E4 (0.99), and E6 (0.98). All the activated challenges contributed to failure modes as time (0.89), cost (0.78), and quality (0.78).

In implementation of IPD, integrated communication and effective behavior of director of the project organization are so significant. A14 "poor data transfer among different phases of the project", using conventional contracts will result in lack of coordination in project phases and reduction of control of project managers. A18 "lack of a proper definition of the culture of teamwork among project key stakeholders" and A13 "lack of mutual trust among project key stakeholders about financial and management issues", trust and the culture of teamwork have been defined in IPD in a way beyond all project management discussions proposed till now (Pishdad-Bozorgi and J.Beliveau, 2016). It can be stated that IPD contractual principles include delegation of responsibilities by project manager and sharing risks and rewards and several financial shares with stakeholders will be performed based on mutual trust and respect (AIA, 2010). The culture of teamwork is one of the issues should be taught to each member (Pishdad-Bozorgi and J. Beliveau, 2016). In a project in the United States with $11.7 million budget, project stakeholders were more than 100 people. This project was the first experience of team members with IPD approach, so holding training sessions was necessary. During these sessions, the culture of teamwork and mutual communications were addressed besides IPD procedure. Holding these sessions was one of the factors of project success (Garcia et al., 2014). Management issues were most influenced by E4 "increased disputes and claims" and E6 "reduced mutual trust among stakeholders". The most important part of the project coordinator, is strong and efficient management. However, inefficiency of this part will naturally have negative effects on the mutual trust among stakeholders and will result in conflicts among them. As a result, sometimes these conflicts will result in duplications or project pause, these in turn will affect time and cost and quality of the project.

In scenario 2 environmental challenges (nodes) in the initial vector are activated which are A6 to A12. With regard to Table 6, initial activated challenges have a strong influence over the remainder challenges. Higher effects are got over A14 (0.95), A13 (0.94), A15 (0.91), respectively. The most affected challenges' effects in this scenario are E6 (0.97), and E4 (0.96). All the activated challenges contributed to failure modes as time (0.93), cost (0.84), and quality (0.80).

A14 "poor data transfer among different phases of the project" and A13 "lack of mutual trust among project key stakeholders about financial and management issues" and A15 "lack of homologous contracts among sub-contractors, such as IPD approach" are factors influenced by environmental factors. Insurance companies' support for IPD contracts is one of the factors provide a basis for trust. Moreover, lack of government support for IPD in some countries, will affect lack of homologous contracts among sub-contractors (Pishdad-Bozorgi and J.Beliveau, 2016). In an IPD contract, stakeholders are not allowed to abuse the terms. This matter will result in mutual trust and subsequently problem solving (AIA, 2007). Consequently, when there is mutual trust in a project, common risks will be acceptable by all stakeholders of the project (Pishdad-Bozorgi and J. Beliveau, 2016). Environmental factors will be most vulnerable to the effects of E4 "increased disputes and claims" and E6 "reduced mutual trust among stakeholders". Motivation of investors for using IPD and then support and strong management of the employer and familiarity of the contractor with IPD are among significant factors led to failure of IPD. Lack of strong management will result in emergence of disputes and reduced mutual trust among stakeholders (Pishdad-Bozorgi, 2016). On the other hand, findings show that the effects of these effects on time, cost, and quality are more prominent in environmental factors than other ones.

All the challenges (nodes) in the initial vector are not activated at the initial time in the scenario 3 (Contractual Challenges), but A13 to A19. As can be seen from Table 6, the stable vector shows as the initial activated challenges have a strong influence over the remainder challenges. Higher effects are got over A14 (0.98), A18 (0.98), A15 (0.95), A13 (0.95), respectively. The most affected challenges' effects in this scenario are E4 (0.99), E6 (0.99), E3 (0.98), E9 (0.98), and E10 (0.98). All the activated challenges contributed to failure modes as time (0.92), cost (0.83), and quality (0.81).

Building trust through using contracts is very effective on flexibility of team when solving problems and savings (Pishdad-Bozorgi and J.Beliveau, 2016). In a health care project in San Francisco, through implementing IPD and in fact changing the type of contract, the contractor of maintenance section was added to the project as an advisor from beginning of the designing stage. As a result, in the electrical equipment section alone, it was saved about $ 1million and in the mechanical section, about $5 million (AIA, 2012). Reasonable contracts, in which the interests of all parties are met, will lead to mutual trust of parties (Garcia et al., 2014). Type of contracts can affect improvement of communications and creating common objectives, and they can also enhance the culture of teamwork (Zhang et al., 2013). Proper and timely sharing and transfer of information is so significant in building trust. Not following it, will result in defensive and aggressive behaviors of individuals and disruption in the project progress, which is not in favor of the project at all (Ashcraft, 2014; Fish and Keen, 2011). Contractual factors will be most vulnerable to the effects of E4 "increased disputes and claims", E6 "reduced mutual trust among stakeholders", E9 "increased duplications", E3 "increased changes" and E10 "reduction of the spirit of cooperation among different working groups". Poor data transfer between different phases of the project will result in duplications and increased changes; and this is inevitable. Lack of mutual trust among project key stakeholders about financial and management issues, and lack of proper definition of the culture of teamwork among project key stakeholders will affect the reduction of the spirit of cooperation among various working groups (Pishdad-Bozorgi, 2016).

In scenario 4 environmental challenges (nodes) in the initial vector are activated which are A20 to A22. With regard to Table 6, initial activated challenges have a strong influence over the remainder challenges. Higher effects are got over A18 (0.91), A14 (0.83), A15 (0.71), respectively. The most affected challenges' effects in this scenario are E4 (0.84), and E6 (0.75). All the activated challenges contributed to failure modes as time (0.88), cost (0.78), and quality (0.77).

Applying BIM requires a high level of mutual cooperation among people in different phases of a project. Trust-based relations will make the job easier for BIM team (Thomassen, 2011). On the other hand, poor data transfer among different phases of the project and lack of proper definition of the culture of teamwork among project key stakeholders, create some problems for applying BIM and reduce its efficiency (Kraatz et al., 2014). Technical factors will be most vulnerable to the effects of E4 "increased disputes and claims" and E6 "reduced mutual trust among stakeholders". The disputes and claims affect integrated cooperation of key stakeholders. Consequently, it will result in increased time and cost.

In our case scenario, all the challenges (nodes) in the initial vector are activated to some degree, at the initial time, but A3, A7, A18, A19, A22. As can be seen from Table 6, the stable vector shows as the initial activated challenges have a strong influence over the remainder challenges. Higher effects in this scenario are got over A14 (0.98), A18 (0.97), A13 (0.94), respectively. The most affected challenges' effects in this scenario are E4 (0.99), E6 (0.99), and E3 (0.98). All the activated challenges contributed to failure modes as time (0.91), cost (0.82), and quality (0.79).

In the case study reviewed in this study, project managers controlled factors such as proper definition of the culture of teamwork among project key stakeholders and the existence of appropriate policies and contractual strategies and integrated interoperability of key stakeholders and strong management of the employer and reinforced matrix structure of the organization. However, due to less attention to the factors such as lack of mutual trust among project key stakeholders about financial and management issues and poor data transfer among different phases of the project, the project was influenced by them and faced several problems in different phases. Mutual trust was a factor created serious problems for the contractors of this project. It was because their funding has been delayed for several times, and they themselves had to compensate some of the losses. People should focus on the project outcomes to create a trust-based cooperation not their individual objectives (Briscoe and Dainty, 2005; Ve et al., n.d.). In IPD-oriented projects, focus on the individual goals makes achieving the success impossible (Garcia et al., 2014). The factors available in the case study performed are most vulnerable to the effects of E4 "increased disputes and claims" and E6 "reduced mutual trust among stakeholders" and E3 "increased changes". Type of contracts and lack of coordination among the employers led to increased changes and disputes.

Conclusion

This study, first, focused on the proper implementation of IPD and related challenges. In order to aptly discover the most important IPD challenges, in depth literature review is conducted, which resulted in identifying 22 IPD challenges. This study is amongst the first ones which adopt the approach of FCMs in investigating IPD challenges. The resulting FCM model can be used to analyze, simulate, and test the influence of challenges and predict the effects on the final project success or failure. The primary results of the FCM analysis indicated that some challenges were more augmented comparing others. As an example, A2: Lack of coordination in managing in this project, A3: The effect of weak matrix structure in this project, A5: Lack of training courses about defining and stating the advantages of modern successful contractual systems of the world for investors of this project, A8: Lack of appropriate orientation for future and inattention to the future development, and A15: Lack of homologous contracts among sub-contractors, such as IPD approach were the most augmented challenges. Then, in this study, five scenarios were followed to analyze the what-if analysis. Scenario 1 is related to the condition that just managerial challenges are contributing in the model, scenarios 2-4 are respectively related to environmental, contractual, and technical challenges. Finally, scenario 5 is conducted using the case's real data and the results are discussed.

The contribution of the study is to enable formal analysis of critical IPD challenges and their relations which provide insights into IPD project success or failure. It is believed that the findings will be of benefit to both academics and practitioners engaged in the complexities of IPD implementation.

This study suffers from some limitations. At first, this study is by no means comprehensive enough to address all issues related to IPD implementation challenges. Another limitation of this study is that it could be difficult to make generalizations based on the contents of the work, since the interrelationships is extracted and interpreted for a limited context. Also, there are no more IPD projects in Iran and the limitations of answerability. As a potential for future works, the proposed model could be used in other countries to test its applicability. Also, researchers may follow qualitative research methods such as case studies or other quantitative methods to investigate IPD implementation challenges' interrelationships in similar or other settings and also in case studies should be used the between cases analysis. Most of the conducted studies had qualitative results. Focus on the quantitative results of implementing will be useful for increasing the motivation of employers.

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A1	✓	✓								✓	✓				
A2	✓		✓	✓								✓	✓	✓	
A3				✓	✓					✓					✓
A4						✓	✓					✓	✓	✓	
A5					✓	✓					✓	✓	✓	✓	
A6			✓					✓	✓			✓			
A7						✓	✓								✓
A8	✓			✓						✓	✓			✓	
A9					✓	✓				✓	✓				
A10		✓	✓						✓		✓				
A11										✓	✓				✓
A12					✓			✓							
A13						✓				✓		✓	✓	✓	
A14		✓	✓						✓		✓				
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A16	✓									✓	✓				
A17								✓		✓	✓	✓	✓	✓	✓
A18	✓		✓						✓			✓	✓	✓	
A19				✓		✓				✓		✓	✓	✓	
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Appendix I. Drawbacks to IPD implementation