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The challenges of radical innovation in Iran: Knowledge transfer and absorptive capacity highlights — Evidence from a joint venture in the construction sector

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ABSTRACT

We investigate the collaboration between an Iranian and a French company in a joint venture aimed at developing radical innovation in the construction sector. We identify the challenges involved, the barriers to technological change, and the difficulties of transferring knowledge related to absorptive capacity.
We conduct an in depth case study of a joint venture created by Freyssinet and Azaran to build a new roof to the Mashhad stadium. We conducted 41 interviews over a 19 month period.
Our findings indicate that radical innovation is characterized by safety, quality, and planning challenges which engender delays, non-conformity to specifications, and additional costs. Freyssinet was unsuccessful in transferring explicit and tacit knowledge because Azaran suffered from poor organizational absorptive capacity. Its high absorptive capacity allowed Freyssinet to adapt its operations to Azaran's tacit knowledge routines.
Our research is meaningful to the construction sector, an economically and socially significant sector in Iran that faces serious issues. Our study has practical implications for Iranian firms and for foreign firms operating in Iran.
We contribute to strengthen the understanding of Iranian technology development by focusing on radical innovation standards, joint venture specific learning dyads, and complex knowledge transfer.

1. Introduction

> "I am positively impressed by the design of the roof added to the Imam Reza Stadium in Mashhad. If this technology is now available in Iran, it would be great if we reuse such technology to build the roof to the Azadi stadium in Tehran."
> [Mahmoud Goudarzi, Minister of Youth Affairs and Sports, during a visit to the Imam Reza Stadium, May 2015.]

Emerging economies seek to transform and improve their domestic capabilities by acquiring new technology, by absorbing new knowledge, and by supporting innovation (Ponomariov and Toivanen, 2014). Inspired by the resource-based view of the firm (Barney, 1991), the knowledge-based view of the firm considers knowledge as the firms' most important resource (Nonaka and Takeuchi, 1995; Grant, 1996; Spender, 1996a, 1996b). Thus, organizations seek to acquire knowledge to gain competitive advantage. Transferability of knowledge is critical for businesses engaged in international business exchange (Kogut and Zander, 1993), especially in developing nations endeavoring to develop their economies. Technology transfer between developed and developing countries has drawn interest, not only among scholars, but also among firms, policy makers, and financial institutions.

Several studies have been conducted on knowledge flows in many emerging economies. Some countries have greatly benefited from technology transfer. However, we note that others face more difficulties in their attempt to achieve technological catch up (Ponomariov and Toivanen, 2014). We believe, in line with Argote et al. (2003), that there is a need to further study how and why some factors influence organizational learning, especially in emerging countries facing obstacles to making technological progress.

Over the last two decades, Iran has made significant progress in science and technology development. As a developing country, Iran aims to capture knowledge, imitate best practices, learn from partners, innovate in various sectors, and consequently reduce the technological gaps between it and developed countries (Ghazinoory et al., 2014). Guided by a "national technology strategy" which combines both "national technology policy" and "firm technology strategy" (Ghazinoory et al., 2009), the next step for Iran will be to turn its traditional economy into a knowledge-based economy. There are a limited, but growing, number of empirical studies on Iranian technology development. We identified 39 articles on knowledge and organizational capabilities in various sectors in Iran (see Appendix A), but technological knowledge, R&D, and innovation in Iran require further study (Ghazinoory and Ghazinouri, 2009). More specifically, investigations are needed into the challenges faced by firms operating in Iran and Iranian firms collaborating with external

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partners. Soofi and Ghazinoory (2011) argued that technological knowledge gained in one industry can benefit other industries, and highlighted positive spillovers from the chemicals, chemical products, rubber, and plastics industries to other related sectors.

The construction industry is becoming increasingly global (Ngowi et al., 2005). Technology transfer in this sector contributes to the technological development of emerging nations (Van Egmond, 2012). Construction projects implemented in developing host countries are considered to be of potential benefit to the latter (Bessant and Francis, 2005). Local firms can learn advanced design and new construction technologies from foreign firms (Ling et al., 2005; Ling et al., 2009). Chatterji (1990) believes that emerging nations must implement policies that promote technology transfer between foreign and local firms so as to reinforce the capabilities of the latter and reduce their dependence on foreign businesses.

The construction industry is characterized by complicated projects with unique designs, complex environments and unpredictable working schemes, etc. (Ochieng and Price, 2009). Knowledge management in this sector is also considered to be very challenging: Difficulty to transfer knowledge (Osabutey et al., 2013), poor absorptive capacity (Gann, 2001; Eapen, 2012), a low degree of innovation (Barlow, 2000), and poor project performance (Rwelamila, 2012). Those issues are particularly prevalent in developing countries (Ling and Hoi, 2006; Zhi, 1995). Significant differences with developed countries have been well documented (Lizarralde et al., 2013).

However, we observe that the construction industry, one of the most significant sectors in Iran, did not appear to be benefitting from the diffusion of new technologies. This sector represents a large part of Iran's employment (3.9 million people) and investments (40% of total annual investment) (Tabassi et al., 2012), and studying it is important because Iran is located on a very active seismic region which is part of the Alpine-Himalayan belt where 130 major earthquakes have occurred over recent centuries (Tabassi and Abu Bakar, 2009). Poor construction design, lack of standard materials, disorganized supervision, poor workmanship, and in fine the low quality of Iranian buildings have been identified as the causes of the large number of fatalities in past earthquakes. Jafari and Love (2013) argued that "quality failures remain an endemic problem within the construction industry" (p. 1244). We believe it is important to identify the barriers to technological change in the Iranian construction sector, and that answering such questions could help the construction sector close the existing technological gaps and consequently increase the resistance of future buildings to recurrent earthquakes.

To resist them better, and so avoid future tragedies, radical changes and innovations are needed in the Iranian construction sector. Abernathy and Clark (1985) define radical innovations as those that diverge from conventional technological trajectories and offer a high degree of technological newness to an industry, to its firms, and to their customers (Garcia and Calantone, 2002). While satisfying clients' wants and needs, firms also need to control the costs of radical innovation to remain competitive. Modular innovation (Clark, 1985; Henderson and Clark, 1990; Ethiraj and Levinthal, 2004) can contribute to cost and time saving by assigning the manufacturing of technological modules to external partners. Modular-based innovation requires the development of strategic alliances to obtain missing evidence about new knowledge and capabilities (Emden et al., 2006; Harrison et al., 2001; Chesbrough, 2003). A few studies have focused on transition economies seeking to develop alliances (Hitt et al., 2004; Hitt et al., 2000; Young et al., 2011).

As a specific form of strategic alliance, joint ventures enable mutual and reciprocal learning, but developing a radical innovation within a joint venture may be very risky, since it combines the risks of failure of both the radical innovation and of the joint venture. These two types of risk are usually studied separately in the existing literature, so we need to develop knowledge in this area by studying the development of radical modular innovations within joint venture strategic alliances.

The assimilation of external knowledge is an important but insufficiently studied aspect of absorptive capacity (Cohen and Levinthal, 1990), which requires further study (Lane et al., 2006). Having access to external knowledge does not necessarily mean that an organization will assimilate that knowledge efficiently (Hamel, 1991). To increase the likelihood of efficient knowledge absorption in strategic alliances, the existing literature typically sees a "learning dyad" as involving firms playing the roles of 'teachers' and 'students' (Lane and Lubatkin, 1998). Our intention is to study two-way learning between two organizations playing these roles in joint ventures. We are particularly interested in studying two-way learning between firms that have different degrees of absorptive capacity.

In such two-way learning, we consider flows of both tacit and explicit knowledge to transfer entire bodies of knowledge. Joint ventures appear to be a relevant type of strategic alliance for the transfer and absorption of know-how embedded within organizations (Kandemir and Hult, 2004). The transfer of tacit and explicit knowledge is characterized by different challenges: articulation, transfer, learning, use of performance indicators, communication, 'stickiness', costs, path-dependency etc.

Our aim is to answer the following research question: "*What are the challenges of radical innovation*, *the barriers to technological change*, *and the difficulties involved in the transfer of tacit and explicit knowledge between two organizations with different degrees of absorptive capacity*, *which are involved in a joint venture in the Iranian construction sector*?"

The article proceeds as follows. We first present a theoretical framework related radical modular innovation, absorptive capacity, and consider the nature of knowledge transfer in alliances. We then discuss our case study method, and subsequently present an in-depth case study of the construction of a new roof of the Mashhad stadium in Iran. We conclude by discussing the challenges of radical innovation, the barriers to technological change, and the difficulties of transferring tacit and explicit knowledge.

2. Theoretical background

Our theoretical background considers Iran's current technological development and the need for radical and modular innovation in its construction sector. A joint venture appears to be a relevant form of strategic alliance to develop mutual and reciprocal learning for transferring knowledge about radical innovations. More specifically, a joint venture can enhance the absorption of the tacit knowledge on both sides.

2.1. Alliances in radical modular innovation

Radical changes are needed to support the transition of Iran toward a knowledge-based economy, and to address quality failures in its construction sector, including the development of modular innovation, and of international strategic alliances.

2.1.1. Radical innovation

The improvement of the quality of building works requires a significant effort in innovation to support radical changes in construction. Studying the Iranian construction and housing industry, Akhlagh et al. (2013) argued that innovation strategies could impact its performance. They further argued that a proactive strategy has a positive impact on industry performance because it encourages flexibility, innovativeness, a greater perception of opportunities, and better anticipation of market changes.

Abernathy and Clark (1985) defined the difference between incremental and radical innovation. Radical innovations are characterized by a clear divergence from existing technological trajectories (Abernathy and Utterback, 1978; Anderson and Tushman, 1990). An innovation is considered as radical according to the degree of its technological newness — newness to firms, to the industry and to the customers (Garcia and Calantone, 2002). The degree of such innovations may be evaluated by experts in the field, or by the producer (Dewar and Dutton, 1986; Kleinschmidt and Cooper, 1991; Veryzer, 1998). With the exception of Ghazinoory and Ghazinouri's (2009) study of nanotechnologies, radical innovation has been rarely studied in the Iranian context.

A firm that introduces a new product to the marketplace can be considered as a first mover (Schilling, 2008). Firms have to be market-oriented, and must aim to satisfy clients' wants and needs (Bennett and Cooper, 1981), and Sandberg (2008) argued that innovations are successful when they meet customers' needs, while Bennett and Cooper (1981) discussed the payment of a price premium for superior goods (e.g., usefulness, safety, availability, rarity). However, radical innovations are associated with high R&D costs, uncertainty, and the difficulty of setting standards (Schilling, 2008; O'Connor and DeMartino, 2006).

2.1.2. Modular innovation

Radical innovation can be achieved by recombining existing technological modules (Saviotti, 1996; Saviotti et al., 2005). The design and reconfiguration of modules into a new hierarchy can offer the particular advantage of modular innovation, which consists of putting things together in new ways (Clark, 1985; Henderson and Clark, 1990; Ethiraj and Levinthal, 2004).

Firms have to manage the 'modularity' by which complex products are composed of smaller subsystems. Baldwin and Clark (2000) argued that modularity intends "to make complexity manageable; to enable parallel work; and to accommodate future uncertainty" (p. 175). While modular-in-use and modular-in-production are widely used, modularity-in-design appears to be more challenging for engineers (Baldwin and Clark, 2000). Product design (sometimes termed as industrial, surface or esthetic design) offers the choice between different parameter settings in the design of new products (Baldwin and Clark, 2000).

A large number of studies have observed positive links between modularity and performance (cost, flexibility and cycle time) (Jacobs et al., 2007; Worren et al., 2002; Lau et al., 2007). For instance, Schilling (2000) argued that modularization decreases the costs of coordination, production and time to market; and Langlois and Robertson (1992) find that organizations proceed through trial-and-error learning to pursue modular product innovation more quickly.

2.1.3. Alliance

Conducting internal modular innovation may not be sufficient to meet the tight deadlines required in some industries. Time constraints are too tight to allow organizations to innovate alone (Borys and Jemison, 1989; Dunning and Boyd, 1997; Hergert and Morris, 1988; Ireland et al., 2002; Nohria and Garcia-Pont, 1991). Consequently, innovation is pursued with external partners because of limits on resources and time (Lambe and Spekman, 1997; Swan and Allred, 2003). External knowledge is important for fostering firms' innovation and improving performance (Ireland et al., 2002; Zollo et al., 2002; Laursen and Salter, 2006). And developing alliances enable firms to find external sources of knowledge (Hamel et al., 1989; Khanna et al., 1998). Modular-based innovation mobilizes both internal and external stakeholders (Von Hippel, 2005), and the latter may be involved in manufacturing specific modules which are then absorbed into the leading organization's processes (Ethiraj and Levinthal, 2004).

Working with external stakeholders necessitates strategic alliances, which Dussauge and Garrette (2000) define as "an arrangement between two or more independent companies that choose to carry out a project or operate in a specific business area by coordinating the necessary skills and resources jointly rather than operating alone or merging their operations" (p. 99).

Knowledge management in strategic alliances has raised the interest of several scholars (Hamel, 1991; Kale et al., 2000; Mowery et al., 1996). Organizations acquire and create relevant knowledge through engaging in strategic alliances (Dussauge et al., 2004; Grant, 1996; Spender, 1996a, 1996b; Mowery et al., 1996; Reuer et al., 2002).

Strategic alliances are developed to access missing knowledge and capabilities (Emden et al., 2006; Harrison et al., 2001; Chesbrough, 2003), and their main purpose is to enable mutual and reciprocal learning (Grunwald and Kieser, 2007; Lubatkin et al., 2001), so alliance modes must be chosen to facilitate the effective transfer of knowledge (Cantwell and Colombo, 2000; Gulati and Singh, 1998; Mowery et al., 1996; Sampson, 2004; Collins and Hitt, 2006; Kale et al., 2000; Lane and Lubatkin, 1998). Strategic alliances are widely used in the global economy (Grant and Baden-Fuller, 2004; Anand and Khanna, 2000; Dyer et al., 2004).

Additional learning can be obtained via other partnerships, such as R&D consortia, joint ventures, equity partnerships and other arrangements (Vermeulen and Barkema, 2001). As a very specific type of strategic alliance, a joint venture is a co-enterprise created by two or more firms owning variable shares. Joint ventures promote knowledge sharing and acquisition (Kogut, 1988; Diestre and Rajagopalan, 2012; Oxley and Wada, 2009). Ofori (1994) argues that foreign-local joint ventures provide good opportunities for technology transfer in the construction industry. Kaufmann & O'Neill (2007) found that cultural differences could pose a number of difficulties in international joint ventures, although Kogut & Singh (1988) originally argued that joint ventures between culturally distant countries constituted beneficial strategic alliances. Meier (2011) calls for further research into differences in knowledge management practices according to different cultural contexts.

There have been few studies on joint ventures in Iran, where there have been successful and less successful examples. Joint ventures only represent 6.66% of technology transfer methods in the biopharmaceutical industry (Madani et al., 2012). Jafari and Love (2013) studied a successful joint venture between two Iranian companies – MAPNA in charge of procurement and the Kayson Company in charge of engineering and construction – in constructing the Qom monorail in Iran. In an early study, Asheghian (1982) examined the differences between the efficiencies of Iranian firms and Iranian-American joint ventures, finding that the latter are the more efficient.

In contrast, Simiar (1983) studied the reasons why joint ventures in Iran fail, finding that failures were mainly due to human relations problems between Iranian and foreign partners, and to mistrust caused by the lack of congruence of partners' goals. Maroofi and Sadqi (2012) argued that inter-organizational trust was correlated with local firm's performance.

Consequently, there is a need for more empirical studies on joint ventures in Iran, especially into those between Iranian and foreign partners. We are particularly interested in studying the absorptive capacity of organizations involved in such alliances.

2.2. Absorptive capacity

The question of the absorption of knowledge was first introduced by Cohen and Levinthal (1990), who defined absorptive capacity as "the ability to recognize the value of new external information, assimilate it and apply it to commercial ends" (p. 128). Absorptive capacity can be considered at the individual, organizational, and multi-organizational levels (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998).

2.2.1. Individual absorptive capacity

Organizational learning routinely involves both individuals and groups (Nelson and Winter, 1982). Cohen and Levinthal (1990) argued that "due to the intangible nature of absorptive capacity, a firm may be reluctant to sacrifice current output as well as gains from specialization to permit its technical personnel to acquire the requisite breadth of knowledge that would permit absorption of knowledge from new domains" (p. 150). The ability of individuals to learn new knowledge depends on the extent of their existing knowledge (Ellis, 1965; Estes, 1970; Bower and Hilgard, 1981), and the strength of their intentions to learn from others (Kim, 1998).

Studying the construction sector in Mashhad, Tabassi and Abu Bakar (2009) argued that the low degree of construction workers' qualifications (which was is not surprising, since 73.5% of companies do not offer training programs) represented a problem for 53% of the companies, and led to financial problems in 77% of projects and delays in 36.5% of them. In the construction sector, they argued that it was necessary to (1) identify employees' training needs (2) implement on-the-job training (via knowledge transfer from managers and supervisors to employees) and off-the-job training (delivered via external institutions); and (3) monitor the improvements (or their lack) attributable to such training (Tabassi and Abu Bakar, 2009). Also studying construction projects in Iran, Pournader et al. (2015) argued that empowerment and training have a significant impact on projects' performance.

However, there are different barriers to learning and to the increase of individuals' absorptive capacities, such as the associated costs and the required time for training. Employees' low basic education, turnover, and lack of motivation have also been identified as barriers to learning (Tabassi and Abu Bakar, 2009), so it is necessary to increase construction workers' motivation (via worker participation, recognition, and team belonging, etc.). The authors called for further research to study how firms could adapt to such environments, could stimulate workers' motivations and encourage them to follow up on training opportunities, and so how the individual absorptive capacity of firms' construction workers could be increased.

2.2.2. Organizational absorptive capacity

Cohen and Levinthal (1990) find that the absorptive capacity of individuals contributes to the development of organizational absorptive capacity, and that cumulative learning is central to the concept of absorptive capacity at the organizational level. They argue that "two related ideas are implicit in the notion that the ability to assimilate information is a function of the richness of the pre-existing knowledge structure: learning is cumulative, and learning performance is greatest when the object of learning is related to what is already known" (p. 131).

Since prior knowledge shapes the future accumulation of knowledge, we can consider absorptive capacity as being path dependent: consequently, path dependency conditions an organization's ability to perceive the technological potential of new technologies (Cohen and Levinthal, 1990; Zahra and George, 2002). Cohen and Levinthal (1990) argued that firms with high absorptive capacities are more likely to be proactive and to be able to sense and capture external opportunities. Such learning directly affects the general efficiency of firms, cost reductions, process improvements, and product development performance (Dosi, 1988). From their empirical studies of 161 Iranian firms, Tavani et al. (2013) argued that absorptive capacity has positive direct impacts on both financial and non-financial performance.

The acquisition and assimilation of new external knowledge then contributes to further strengthening absorptive capacity and the renewal of knowledge stocks (Jansen et al., 2005). The fact that absorptive capacity is path dependent encourages firms to continuously invest in R&D and to strengthen their absorptive capacity in the pursuit of future developments (Nekoei Moghaddam and Beheshti Far, 2007).

In Iran, for example, organizational learning appears to be efficient in several sectors such as health care (Bahadori et al., 2012), manufacturing (Tohidi et al., 2012), the petroleum industry (Mousaei et al., 2006), services (Sharifirad, 2011), tourism (Ahmadi et al., 2014), etc.

However, the effects of R&D spending on knowledge transfer in alliances are not always supported empirically. Schoenmakers and Duysters (2006) found that R&D spending had a low effect on knowledge transfer. Mowery et al. (1996) found no significant effect of R&D spending on the quality of the knowledge transfer process. In other words, the amount of money spent by organizations on R&D does not guarantee that they will benefit from knowledge transfers.

Given that the acquisition of external knowledge is costly, some organizations may neglect investing in their absorptive capacity (Cohen and Levinthal, 1989): Cohen and Levinthal (1990) argued that "a systematic and enduring neglect of technical opportunities may result from the effect of absorptive capacity on the organization's aspiration level when innovative activity (e.g., R&D) contributes to absorptive capacity, which is often the case in technologically progressive environments" (p. 137). Schilling (2002) argued that firms' lack of investment in learning leads to them being locked out of new technologies (because of their low absorptive capacity), and can lead some organizations to invest less and thus learn less in a path dependent vicious circle.

Ghazinoory and Ghazinoori (2006) argued that the Iranian economy is guided by the government, or affiliated companies, or by public divisions under the supervision of religious leaders. The government and other public institution control 90% of the country's exports and 60% of its Gross National Product (Ghazinoory and Farazkish, 2010). The Iranian government shares part of the responsibility for the low absorptive capacity of its companies by maintaining low levels of R&D investment. While the number of researchers financed by the government has grown from 82 per million inhabitants to 1500 per million between the 1980s and 2011 (Soofi and Ghazinoory, 2011), these numbers remain insufficient to support a change toward a knowledge-based economy in Iran.

The concept of absorptive capacity should not be considered solely from an internal perspective. The literature on firms' absorptive capacity focuses primarily on the effect of their existing capabilities on their ability to acquire external knowledge, but little has been said about the influence of external knowledge on firms' internal capabilities.

2.2.3. Multi-organizational absorptive capacity

The relational approach holds that firm's internal resources alone are insufficient for achieving competitive advantage, and that the latter can only be realized through inter-firm relationships (Dyer and Singh, 1998; Gomes Casseres, 1984; Smith et al., 1995; Lavie, 2006). Dyer and Singh (1998) argued that learning alliances help firms achieve superior performance through knowledge transfer processes. Firms' absorptive capacities have been examined in the context of inter-firm alliances (Dyer and Singh, 1998; Lane and Lubatkin, 1998; Volberda et al., 2010). In keeping with the relational view, we consider that absorptive capacity is not limited to the development of the firm's internal knowledge, and that it involves the acquisition and exploitation of external knowledge, through inter-firm relationships or "learning dyads".

Absorptive capacity enables firms to acquire and exploit external knowledge (Bierly et al., 2009) and to learn from their partners (Steensma and Lyles, 2000). The assimilation of external knowledge, as a dynamic organizational capability (Zahra and George, 2002), is central to the concept of absorptive capacity. Cohen and Levinthal (1990) argued that prior scientific and technical knowledge is necessary to identify and assimilate value from external knowledge. On that point, Hamel (1991) argues that obtaining access to skills and internalizing them are two separate abilities. Absorptive capacity of "host" firms consequently determines the effectiveness of technology transfer (Blalock and Simon, 2009; Girma, 2005; Spencer, 2008; Eapen, 2012). Surprisingly, the assimilation of knowledge as a learning process remains largely unexplored in the current literature (Lane et al., 2006).

The assimilation of valuable new knowledge requires transformative learning (Lane et al., 2006). Learning theory studies the transfer of knowledge across organizations (Doz, 1996), and we consider knowledge transfer to be a process that catalyzes knowledge-sharing routines, which Dyer and Singh (1998) define as "regular pattern[s] of inter-firm interactions that permit the transfer, recombination, or creation of specialized knowledge" (p. 665). Routines are developed between partners to gather, interpret and transfer information (Simonin, 1999).

Dyer and Singh (1998) argued that absorptive capacity is specific to a given strategic alliance (pre-alliance knowledge, interaction routine between the partners, etc.). Lane and Lubatkin (1998) argued that "the ability of a firm to learn from another firm is jointly determined by the relative characteristics of the two firms" (p. 473). They studied the relative absorptive capacity of 'student-teacher pairings', also known as 'learning dyads' between teacher and student firms in strategic alliances. They argue that "a student firm's absorptive capacity, its ability to value, assimilate, and apply new knowledge from a learning alliance partner, depends upon: (a) the specific type of new knowledge offered by the teacher firm; (b) the similarity between the student and the teacher firm's compensation practices and organizational structures: and (c) the student firm's familiarity with the teacher firm's set of organizational problems" (Lane and Lubatkin, 1998, p. 462). Consequently, learning is dyad-specific, meaning that the connection between two organizations create a unique setting (Revilla et al., 2013).

Effective learning dyads enable learning processes to take place, thanks to the partners' absorptive capacity (Knoppen et al., 2011). Both Lane and Lubatkin (1998) and Dyer and Singh (1998) examine one-way learning perspectives, and consider absorptive capacity as a learning dyad. What appears to be missing in the current literature is the study of the type of two-way learning between two organizations that characterizes strategic alliances.

There is a clear need to build complementarity between the knowledge sender and receiver teams prior to knowledge transfer (Abecassis-moedas and Mahmoud-jouini, 2008). The situation is significantly different when there is or is not overlapping prior knowledge in strategic alliances (Lubatkin et al., 2001). Consequently, a certain element of redundancy and cumulative knowledge is needed to facilitate overall understanding between the different organizations involved in knowledge sharing. Familiarity with being involved in strategic alliances encourages organizations to develop effective knowledge-sharing routines (Dyer and Singh, 1998).

Lane and Lubatkin (1998) argued that in order for the knowledge transfer to be successful, a degree of overlap between the partners' knowledge bases is necessary. The degree of dissimilarity between sets of specialized knowledge has an impact on knowledge creation and knowledge transfer. Overall, similarity between firms' knowledge bases facilitates knowledge transfer and absorption. The need for a degree of similarity should be taken into account in the choice of the technology to be transferred between the members of learning dyads. Ofori (1994) argued that the appropriate choice of technology must be made in order to ensure that the technology transfer is successful: it must be easy to use in the host country, it must be compatible with the technologies already used in the host firm, the development of the technology must contribute to the development of the host country and stimulate the latter's other activities.

D'Aspremont and Jacquemin (1988) and Kamien et al. (1992) have argued that such cooperation between organizations has certain deployment and maintenance costs (Henderson and Cockburn, 1996). Organizations need to consider whether the values of potential learning outcomes are greater than the costs of developing absorption capacity: small ventures may simply not have sufficient resources to invest in building their absorptive capacity (Dadfar et al., 2013).

Further empirical study is needed into the absorptive capacities of Iranian firms – specifically in the case of joint ventures – which has not been undertaken in previous research. Overall, it is the challenges of assimilating external knowledge within joint ventures in Iran that have caught our attention. These can be even greater when organizations do not have the same degree of absorptive capacity (e.g. one organization invests strongly in R&D but the other is locked out of new technologies). In joint ventures, organizations are both teachers and students, and have to exchange both tacit and explicit knowledge routinely.

Kandemir and Hult (2004) argued that a joint venture is a specific form of strategic alliance that allows for the efficient absorption of technology, especially of the tacit knowledge and know-how embedded within organizations. Similarly, Mesquita et al. (2008) argued that among the most important conditions for learning dyads to gain a competitive advantage are their ability to acquire know-how, to develop specific assets and capabilities, and to design an ad hoc relational governance mechanism. Lane et al. (2006) argued that further research is needed to integrate absorptive capacity into a broader process-oriented perspective that can foster the efficient deployment of manufacturing know-how. This further research path appears to be particularly relevant in the Iranian context, where the management of tacit knowledge is crucial.

2.3. The nature of knowledge

There is an ongoing discussion about the distinction between explicit and tacit knowledge (Polanyi, 1967). "Knowledge that can be expressed in word and numbers only represents the tip of the iceberg of the entire body of knowledge" (Nonaka, 1994, p. 439). Nonaka and Takeuchi (1995)) developed the SECI model to illustrate the conversion of knowledge from one type to another to foster the creation of new knowledge.

2.3.1. Tacit and explicit knowledge

Looking at the tip of the iceberg, explicit knowledge (which is codified, documented, and formalized) is transmittable in systematic language modes (Steinmueller, 2000), such as patents, documents, memos, manuals, project reports, process diagrams, etc. But tacit knowledge (knowledge that is not written, is not expressed in words and numbers) represents the larger part of the iceberg, and includes working solutions, job experience, learning, interaction between employees, expertise, intuition, skills, know-how, and memories.

We identified few papers that discussed the distinction between explicit and tacit knowledge in the Iranian context. Both types are needed, for instance, in knowledge transfer (Madani et al., 2012) and in the development of technological capabilities (Mohammadi et al., 2014). Explicit and tacit knowledge are two distinctive and complementary layers that contribute to the development of the Iranian National Innovation System (Chu et al., 2014).

Managing explicit knowledge is much easier than managing tacit knowledge, which is more context dependent and more personal in nature (Polanyi, 1962; Nonaka and Takeuchi, 1995), and likely to be deeply rooted in action, highly experiential, judgmental, difficult to fully document, ephemeral and transitory, making it very difficult to articulate what people know and to disseminate tacit knowledge (action or experience) (Nonaka, 1994). As tacitness, low codification and complexity increase, so do the barriers to knowledge transfer (Foss et al., 1995; Kogut and Zander, 1993; Szulanski, 1996; Zollo and Winter, 2002; Lord and Ranft, 2000). For instance, it is difficult to use procedures to encourage implicit learning (Reber, 1993) or to use objective performance indicators to monitor such learning (Mcevily and Chakravarthy, 2002). Eriksson et al. (1997) find that experiential knowledge is rarely taught, transferred or acquired, and Mowery and Oxley (1995) argue that managing the transfer of tacit knowledge requires a set of skills that include learning and problem solving.

Technology transfer is important for Iran, where technology upgrades, new technology development and productivity improvements are needed (Madani et al., 2012). In studying Iranian SMEs, Nowshahr, Pool et al. (2014) argued that organizational cultures and traits have significant impacts on the employees' attitudes to knowledge sharing. Iranian firms face difficulties in managing tacit knowledge (Mohammadi et al., 2014).

According to Mansfield et al. (1981) and Teece (1986), the tacitness of knowledge hinders it from being communicated easily. Consequently, cognitive 'bridges' must be developed between people or organizational units (Noteboom, 2000). For instance, project management requires procedural routines and governance (Nonaka, 1994; Ahn et al., 2006).

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Cognitive proximity consists of sharing technological capabilities in broad contexts (Noteboom, 2000).Tacitness increases the 'stickiness' of knowledge, which can also increase the costs of transferring it between organizations. Tacit knowledge tends to be idiosyncratic and path-dependent (Nelson and Winter, 1982; Teece, 1986, 2006; Zander and Kogut, 1995). Maintaining knowledge tacitness can create gaps (Mcevily and Chakravarthy, 2002) between the knowledge embedded within people and observed performance outcomes (Polanyi, 1962; Nelson and Winter, 1982).

2.3.2. The SECI model

Transferring knowledge from a sender to a receiver can be seen as an act of knowledge management (Leonard and Sensiper, 1998). Ordanini et al. (2008) present the key outcomes of knowledge management as knowledge creation (new knowledge), retention (embedded knowledge) and transfer (shared knowledge). Within projects, knowledge management is of increasing importance, and requires procedural and governance routines (Nonaka, 1994).

Rarely used in research in the Iranian context (Mehralian et al., 2014), we refer to the SECI model of knowledge management, a Japanese concept developed by Nonaka and Takeuchi (1995) that defines four processes of knowledge transfer: socialization (from tacit to tacit knowledge), externalization (from tacit to explicit knowledge), combination (from explicit to explicit knowledge), and internalization (from explicit to tacit knowledge).Socialization suggests that tacit knowledge sharing often occurs in face-to-face relationships in which experiences can be shared. Socialization addresses the social aspect of knowledge in dialog — it is a privileged learning mode between a trainee and a tutor. Socialization capabilities reflect a shared understanding of rules (Camerer and Vepsalainen, 1988; Volberda, 1998). According to Cohen and Levinthal (1990), socialization influences the ability to mobilize external knowledge. More specifically, it leads to the processes of exploiting new external knowledge (Adler and Kwon, 2002). Various tools can enhance socialization: communication enablers, video conferencing, e-learning, digital whiteboards, etc. (Jashapara, 2010). Related to socialization, Jafari et al. (2013) argue that that individual and group tacit knowledge improve organizational performance.

Externalization captures the shift from tacit to explicit knowledge, via formalizations such as the writing of rules, procedures, instructions and communication (Khandwalla, 1977). Jansen et al. (2005) argued that "in contrast to making established behavior tacit through routinization, codification efforts through formalization enhance a unit's ability to transform and exploit new external knowledge, and to initiate the recombinations necessary for developing new competences and capabilities" (p. 1009). Different tools exist, such as yellow pages, software for collaboration, lessons-learned system, storytelling, etc. (Jashapara, 2010). Shafia et al. (2011) found that tacit knowledge needs to be converted into explicit knowledge to prevent the loss of knowledge due to employee turnover.

Combination is a phenomenon that concerns the transfer of purely explicit knowledge, and is a basic function by which various kinds of documentary knowledge can be combined to create new knowledge. Project managers use this aspect of the SECI model to combine different explicit inputs from various functions (engineering, planning, supply chain, etc.) to produce integrated explicit documents. Combination is what is needed to transmit aggregated explicit knowledge. For instance, a product's nomenclature can be considered as the combination of several explicit descriptions of its sub-parts. Different tools are available to conduct combination of explicit knowledge: Internet, e-mail, on-line network, wiki, knowledge management platforms, groupware, workflow, data mining, the Balanced Scorecard (Jashapara, 2010), etc. The use of the Balanced Scorecard (Kaplan and Norton, 1992) has been very popular in Iranian empirical studies (Ghazinoory and Soofi, 2012; Akhavan et al., 2013; Darvish et al., 2012).

Internalization is the shift from explicit to tacit knowledge. Individuals use explicit knowledge to acquire tacit knowledge through the process of learning by doing, internalizing explicit knowledge which then modifies their existing tacit knowledge. Internalization occurs when a person reads manufacturing procedures or safety rules, which then impacts their behavior as they absorb explicit knowledge. A few internalization techniques exist, such as case-based reasoning (Jashapara, 2010), which aims to use analogy to solve current problems that resemble past problems. By using past explicit knowledge from a data base, it is possible to proceed to a simple match and cut-and-paste job, allowing a solution (tacit knowledge) to be found faster, better, and more easily than if the process was started from scratch: such processes are used by help desks or call centers(Ranjbarfard et al., 2013).Our overall research objectives are to contribute to strengthening the existing body of literature about technology development in Iran by focusing on the challenges of radical innovation and radical technological change. In the context of the construction industry in Iran, we define radical innovation as an innovation: (1) which requires Iranian firms to expend their technological capabilities, (2) which diverges from the existing trajectory of the Iranian construction industry, and (3) which offers something new to the Iranian customers. We define radical technological change as a technological change: (1) which raises the level of Iranian construction workers' qualifications, (2) which closes the existing technological gap between Iran and developed countries, and (3) which significantly improves the design, materials, quality, and resistance of buildings.

Our research aims to study whether local firms develop the ability to learn from foreign partners. We focus on the construction sector because it is economically and socially significant, because it faces difficulties (design, materials, quality, workforce, etc.) and because it requires radical changes. Our goal is to study how modular innovation develops across stakeholders. We specifically choose to study joint ventures, since this type of strategic alliance encourages reciprocal learning and the absorption of the tacit knowledge embedded within partner organizations. We aim to explore the assimilation of external knowledge via two-way learning within a joint venture, and to see how partner firms' specific absorptive capacities and knowledge natures can affect their knowledge sharing routines. Our final objective is to observe if the development of such joint ventures can have an impact on the construction sector – and eventually on related sectors.

Consequently, our study addresses the following research question: "*What are the challenges of radical innovation, the barriers to technological change, and the difficulties involved in the transfer of tacit and explicit knowledge between two organizations, with different degrees of absorptive capacity, which are involved in a joint venture in the Iranian construction sector*?"

Fig. 1 illustrates our theoretical framework. It shows the two-way learning dyad between companies A and B, both involved in a joint venture. There are knowledge transfers of both tacit and explicit knowledge, as referred to in the SECI model, which are influenced by firms' specific knowledge (tacit vs. explicit) and their specific degrees of absorptive capacity (low vs. high). We want to find out if radical innovation can support radical changes in the construction sector in Iran via the collaboration of two partners.

3. Methods

To answer our research question, our study investigated the challenges involved in radical innovation, the barriers to technological change, and the difficulties of transferring tacit and explicit knowledge, between Freyssinet and Azaran, firms with different degrees of absorptive capacity, which are involved in a joint venture to construct the roof of the new Imam Reza Stadium in Mashhad, Iran's second largest city (with four million inhabitants).

The Imam Reza Stadium was built 15 years ago. A multi-sports infrastructure, the existing uncovered stadium has a capacity of 25 000 seats. In 2010, Astân-e Ghods-e Razavi, a rich religious institution, was willing to add a roof to the existing stadium, to protect supporters from the

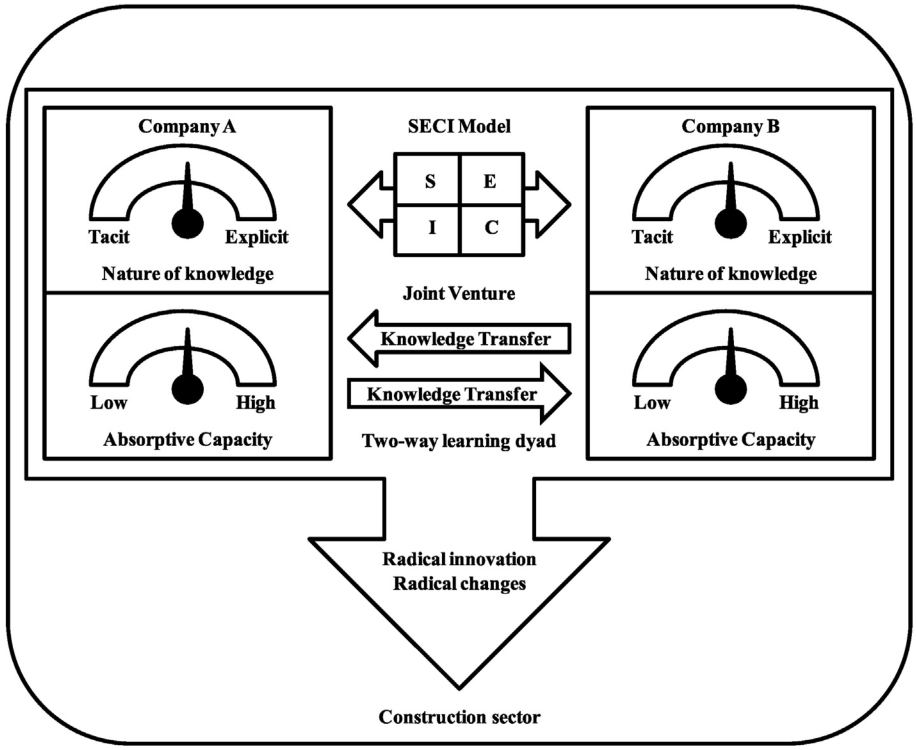

Fig. 1. Conceptual framework.

snow, the rain, and the sun, so allowing it to be used in all seasons. Through the intermediation of the Civil and Development Organization of Khorasan acting as a consultant, the contract for the project was awarded to Freyssinet and Azaran, working as a Franco–Iranian joint venture.

The French company Freyssinet is a worldwide leader in the specialist civil engineering sector, with an organizational culture that relies on core values of safety, excellence, and performance. To operate in Iran, Freyssinet was represented by a local Iranian firm E-Man Serve Co (a company specialized in energy management and engineering services). As the leader of the joint venture, Freyssinet was responsible for project management, the design of the roof, erection methods, supply and installation of cables, rods, membrane, and elastomeric bearings. Freyssinet outsourced the design of the roof (design, calculation, sequencing of the erection, etc.) to RFR, a German engineering company specialized in designing roof structures. Azaran is a large Iranian company specialized in manufacturing steel structures and equipment for various industrial projects. Azaran was in charge of manufacturing the steel elements in Tehran and then assembling the entire steel structure in Mashhad. Design studies for the project started in April 2012. The construction then involved up to 51 people from January 2014 to July 2015 (the latest estimated completion date for the project): 8 managers (2 from Freyssinet and 6 from Azaran), 6 supervisors (3 Freyssinet and 3 Azaran), and 30 workers (18 from Azaran, 6 welders, 6 crane drivers) plus 7 others from various subcontractors.

We collected data from various sources, and conducted 41 interviews over a 19 month period (November 2013–May 2015). We chose this methodology for several reasons. First, conducting research in a real-life environment suited the exploratory nature of our study (Yin, 2003). Second, we wanted to observe both formal and informal processes within a joint venture to investigate technology transfer in Iran. Third, engineers and construction workers were more willing to answer questions during interviews than via online questionnaires. Fourth, the case study methodology allowed us to investigate the effects of decisions taken during the project so as to fully understand the phenomena under study (Golden, 1992; Yin, 2003; Dyer and Wilkins, 1991).

We selected this case study setting because of its richness (Neuman, 1997). We chose the ambitious project of building the Mashhad stadium's roof because it can be considered as a radical innovation of a type that has previously been mostly unexplored in Iran. The joint venture between Freyssinet and Azaran adopted a mixed and complex design using different highly technological materials, which again was something unique in Iran. We wanted to follow how a Franco–Iranian joint venture would handle a great construction project, and how two heterogeneous partners would handle inter-firm knowledge transfer.

The data was collected by the Freyssinet site manager located in Mashhad, who is the second author of this paper. His position gave him unlimited access to any data available, and the opportunity of conducting interviews with all the various stakeholders (members of the joint venture, client, suppliers, subcontractors, and consultants). Our intention was to collect data from all the organizations involved in the project so as to enrich our case study from their various perspectives.

We adopted an inductive approach to explore this project, to gain a deep understanding of the issues, stakes, and influences involved (Strauss and Corbin, 1998). To capture the interactions between individuals and organizations, and to identify key dates when major decisions were made, we studied the knowledge transfer between Freyssinet and Azaran and their abilities to absorb transferred knowledge to solve the problems related to radical innovation. We did not need to use any retrospective approach in collecting our data, since the collection process started from the beginning of the construction phase. Collecting interview data and written reports at the time prevented us from distorting the facts of previous events. We used a semi-structured interview guide to explore events and people's involvement according to the time frame of the project as it developed.

We conducted a total of 41 interviews: fourteen with Freyssinet employees (concerning the installation of cables and membrane); twelve with Azaran staff (about manufacturing and assembling the steel structure); three with RFR (design); two with the Civil and Development Organization of Khorasan (consultants); two with E-Man Serve Co (Freyssinet's intermediary firm); two with Fatzer (the cable supplier); two with Esmery Caron (which manufactured and supplied the membrane), two with ARCHITEXSTEEL (which installed the membrane); and one each with Astân-e Ghods-e Razavi (the client) and Janbaz construction (the local construction company).

We interviewed all the project managers, as well as a few construction workers without managerial functions. This wide selection of respondents from various fields increased the diversity of viewpoints represented and the chance of shedding light on events, networks, dates, places, and policies (Strauss and Corbin, 1998; Wengraf, 2001; Yin, 2003). We selected respondents with different levels of education: 2 with PhDs, 20 with engineering degrees, 7 with bachelor's degrees, 7 with high-school degrees, and 4 without degrees. The data was collected in French, English and Farsi by one researcher (the second author) over a 19 month period (November 2013 – May 2015) in various locations (Mashhad, Tehran, and Paris). The interviews lasted 35 min on average, and were recorded with the respondents' permission. (For further details, please see Appendix B.)

To achieve construct and internal validity, the researcher collected observations, documents on the sequencing of the assembly of elements, quality reports, press articles, meeting minutes, communications, e-mail exchanges, and reports to stakeholders, as well as our interviews with key informants. These were cross-checked via triangulation, which was very useful in comparing the perspectives of various stakeholders (Easton, 1995; Miles and Huberman, 1994).

The content analysis unit of the recorded data was single sentences (Insch et al., 1997). Coding, clustering, and reduction produced a code scheme, with six major categories (technology development, innovation, individual absorptive capacity, organizational absorptive capacity, multi-organizational absorptive capacity, and knowledge) and 43 codes influenced by literature in the field (Strauss and Corbin, 1998; Araujo, 1995; Coffey and Atkinson, 1996). The coding scheme is provided in Appendix C. The use of multiple data sources and data coding ensured internal validity (Rosenthal and Rosnow, 1991; Dane, 1990).

4. The case of Imam Reza Stadium

4.1. Challenges of radical innovation

4.1.1. Radical roof design

The design and build of the Imam Reza Stadium roof can be considered a radical innovation project. If the norms of the Iranian construction industry trajectory had been followed, the roof would have been made of a steel structure covered by polycarbonate panels, as had originally been designed by Masoud Ziaee, the consultant architect. However, such design was not satisfactory: it would have been very heavy, used a lot of steel, and only partly covered the stands. This 'mainstream' design was not selected because it did not match the client's requirements, and because the existing concrete structure could not have supported its weight.

As a consequence, the company RFR developed a second, more radical, design — a 'cable-stayed stadium roof'. The design chosen for the roof of the stadium appeared to be radical – in the sense meant by Abernathy and Clark (1985) – in that it clearly diverged from the existing trajectory of the Iranian construction industry. The new roof design was radical in three ways: the newness of the materials used (a light weight high resistant durable and highly protective membrane, with high resistance steel cables), of the design mix (using different materials — steel profiles, cables and membrane), and of the construction methods (using temporary cables for stability and pre-tensioned cables in the roof plane). All three conditions of technological newness were met (Garcia and Calantone, 2002). Although benefitting from past experiences as a subcontractor on the construction of the Millennium stadium in Cardiff and the BC Place Stadium in Vancouver, this is the first time that Freyssinet had been the leader and main contractor on a stadium roof project. Such a cable-stayed stadium roof design was entirely new to the Iranian joint-venture partner Azaran, to the Iranian industry, and to the client Astân-e Ghods-e Razavi who approved the project.

The specific roof design offered a variety of advantages: it would cover all the stadium's seats, it had a high degree of safety, and involved high-end esthetic design. Esthetic is very important in such large projects, because a stadium can become strongly associated with the city's image (famous examples include Barcelona's well-known Camp Nou stadium, the Millennium stadium in Cardiff, the Sydney Opera House, etc.). Fig. 2 shows the design model, highlighting the two compression rings, one tension ring, and 18,000 square meters of white membrane: such a radical design had never previously been developed in Iran.

4.1.2. Initial design

The design is composed of 48 modules, each with a single axis of symmetry. Since the roof is built on top of an existing concrete stadium, it was necessary to assess the ability of the existing structure to support the additional weight of the roof (1500 t of steel and 200 t of cables). The roof was designed according to European standards to resist earthquakes: both the existing concrete stadium and the cabled stay roof are designed to withstand earthquakes of a magnitude of 10 on the Richter scale.

> "*To assess the ability of the entire structure to resist to wind, we performed several wind tunnel tests on 1:300 scale model. In our calculations of the resistance of the roof, RFR took into account Iranian data on the various meteorological phenomena such as rainfall, wind speed and snow fall duration and intensity. Last but not least, we took into consideration the difference between the highest and the lowest temperature. Temperature has a direct impact on the expansion and the contraction of various materials such as steel.*"
>
> [Respondent 2.]

The use of different materials (steel, cables and membrane) in a mix material design requires that all elements are manufactured perfectly to match the drawings, and that good transverse communication is maintained between all parties concerned. By choosing this specific design, Freyssinet was setting the bar very high in terms of standards from the beginning, demanding special care in terms of safety, quality and planning.

> "*We* [Freyssinet] *are starting a project at high risk. Quality wise, if we are not able to manufacture the modules within a tolerance of one millimeter, we will not make it. From a planning perspective, if one or several stakeholders do not respect the precise sequencing of our eight-step process, we will not be able to deliver the roof on time. Safety will be extremely important. If a construction worker fell from 50 m, we would be responsible for that. This esthetic design requires a lot of work to be done at height, which is always a challenging issue in this kind of country where this is not in the culture.*"
>
> [Respondent 1.]

This quotation (from the Freyssinet project manager) identifies the challenges related to the radical nature of the design. Later in the project, we observed that Freyssinet and Azaran had different standards, exigencies, references, and habits regarding safety, quality, and planning issues.

4.1.3. Safety issues

Freyssinet faced significant difficulties in making the construction workers respect basic safety rules (wearing helmets, safety shoes, and harnesses when working at heights).

> "*For the first quarter of 2015, the major Projects Department had poor safety performance. Our lagging indicator has been in the red since February with 10 LTI* [Lost Time Injuries] *and it's increasing. The number of minor injury is exploding 39 since the beginning of the year. Linked to*

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Fig. 2. Imam Reza Stadium in May 2015.

this, most of our projects are in the red concerning the leading indicators (Number of Safety inspections, number of unsafe conditions reported, number of safety training hours, BU manager Site Audit)."

[Respondent 20.]

There were some additional issues that related to the Iranian context. Because of the current restrictions on imported goods in Iran, Freyssinet faced difficulties in accessing some specialized equipment and plant commonly used in the construction sector, without which there was an increased risk of accidents. As an example, boom lifts aiming at allowing workers to work safely at any height above the ground were impossible to buy or rent in Iran, or even to import. As a consequence, Freyssinet had to use substitute solutions which were less secure and more time consuming.

"*In my entire career, it's the first time I can't find a boom lift in a country. We have been using a crane as a substitute for a boom lift. Originally, a crane is designed to lift materials only. Now, we use cranes for lifting a man basket with construction workers inside. Although we designed a man basket especially for this application, you never reach the same level of safety as a dedicated boom lift offers many features to increase the safety of the workers, features that are not available on a standard crane. To lift and install a steel beam, the simultaneous coordination of three cranes is required: One for lifting the beam and two for lifting construction workers. What a challenging, unsecured, and time consuming solution!*"

[Respondent 23.]

4.1.4. Quality issues

Radical innovation is associated with difficulty in setting standards. For instance, the geometrical tolerance specified for all steel elements in the design drawings of a steel structure was ± 1 mm – but the tolerances to which the Azaran factory worked were closer to 1 cm. Consequently, as-built and previously manufactured steel elements often had to be repaired or adjusted as needed on site, when possible. Freyssinet clearly identified the quality of the steelwork that Azaran manufactured as a problem. However, when Freyssinet chose to partner with Azaran, it did not detect that the latter performed poor quality work. When Freyssinet discovered this problem, it took the company a long time to implement the corrective measures required to improve Azaran's work quality. The following points were included in the quality process: the geometry and dimensions, mechanical and chemical characteristics of the steel, welds, the assembly, and the anticorrosion protection. For instance, if the anticorrosion protection of the steel structure was provided by a paint system, several dimensions of the paint involved had to be verified: the number of layers, the coverage, the thickness, etc.

"*What was the most problematic was the non-respect of the geometry of the elements. Azaran was manufacturing 10 t steel beams in Tehran, which were then transported by trucks to Mashhad. In case of minor problems, on-site repairing was possible. However, sometimes, the geometry was not reparable. For instance, when the flanges were not welded at the correct angle, the beam could not be assembled to the adjacent one. In such cases, the entire 10 t steel beam had to be returned to the Tehran factory, which implied two week delays and 1800 additional km of transportation.*"

[Respondent 18.]

4.1.5. Planning issues

The sequencing of operations is crucial in construction planning. The modules have to be manufactured in a certain order, as some can only be assembled after the previous modules have been built. The overall sequence was composed of eight steps: (1) Concrete beams and columns, (2) lower compression ring and bearings, (3) columns and upper compression ring, (4) spokes, hangers, tension ring, some arch ties, (5) tension ring closing, (6) plane bracings, (7) arches and remaining arch ties, and (8) membrane. The project suffered because the sequencing was not adhered to in the planning and manufacturing. It seemed to be very difficult to get the right modules manufactured and delivered in the right order. This non-adherence to the planned sequence could have affected the stability of the entire structure, or simply stopped progress on the project until the missing element had been finished and installed.

"*As a method engineer, I encourage people to care more about the sequencing. I observe that the installation of spokes was stopped a few times because the spokes were not supplied in the right order. There is a constant need for negotiating to get the right module at the right time; which is very tiring. And it is useless to send an e-mail clearly explaining what I need and when I need it. They [Azaran] do not care about sequencing.*"

[Respondent 12.]

4.1.6. Propositions

Quality, safety, and planning are the three prerequisites to meet the European standards associated with modular radical design successfully. The standards were certainly set far above what Iran's current technological development, culture, and habits can match. As Freyssinet and Azaran were involved in a joint venture, Freyssinet had no subordination power over Azaran, so there was little it could do to encourage or constrain Azaran to perform better. If Azaran had been a subcontractor, Freyssinet could have obliged it to adhere more strictly to materials' specifications, manufacturing sequencing, and safety rules, or would have simply changed its subcontractor. Arrangements for responsibility sharing between Freyssinet and Azaran were clearly defined in the contract, but not adequate in regards to the partners' interests, priorities, involvements, and differences. Consequently, the type of alliance chosen by the partners (e.g. joint venture) – Freyssinet being the leader – was not the most appropriate. We can therefore argue that:

Proposition 1. *Firms intending to work on projects in Iran should study the nation's technological development, be aware of the commonly* *accepted local standards in terms of quality, safety, and planning, and select the appropriate degree of technology radicalness.*

Proposition 2. *Firms seeking to work on projects in Iran should carefully select the partners they will be working with and the type of strategic alliance that best suits their needs and circumstances. A selection process of this kind requires, among others, a preliminary study on the engineering standards and habits in the host country's industry.*

Proposition 3. *Iranian individuals and organizations were not prepared to handle the newness of the design, the small tolerances, and the precise sequencing, which led to planning, quality and safety issues.*

4.2. Difficulties of transferring tacit and explicit knowledge

Facing issues related to safety, quality, and planning, Freyssinet first intended to use socialization, externalization, combination, and internalization to transfer knowledge to Azaran, which had a different knowledge base.

4.2.1. Different knowledge bases

Freyssinet and Azaran relied on different knowledge bases: Freyssinet utilized both tacit and explicit knowledge, but Azaran's knowledge base was mainly tacit. Freyssinet invested heavily in training its employees to internalize know-how related to post-tensioned concrete structures, project management, etc., and had built its competitive advantage on its specific know-how. Expertise is one of Freyssinet's core competences, and it sends supervisors to transfer tacit knowledge by guiding people in the use of the specialist equipment it has designed and manufactured. Freyssinet developed tacit working solutions to solve daily problems.

Freyssinet makes significant efforts to codify its tacit knowledge. For instance, when finishing a project, the project manager writes a report to share his or her experiences, which is then available on the company's internal data bases. Anyone who is going to work on a similar project, using similar technologies, or operating in a similar country can get access to these reports that outline the problems faced and the solutions found, etc. An excellent report also brings significant recognition to the author, who would then be considered as a key expert on such matters. In Freyssinet's organizational culture, people are encouraged to contact such key experts to benefit from their rich experiences. Freyssinet also pays great attention to formalizing knowledge in a written form: quality check lists, manuals on the use of Freyssinet equipment, procedures, risk assessments, method statement planning, technical notes, drawings, reports on sequencing, minutes of meetings, letters, monthly cost reports, Health Security Environment reports, etc.

In contrast, Azaran mostly relies on tacit knowledge. Knowledge is rarely written down - rather it is embedded in the organization and in people. Construction workers' habits, job experiences, intuitions, and memories are central. For instance, Azaran benefits from solid experience in welding. People use their own judgment to take decisions – but such decisions may not always be fully justified by facts. Azaran does not take much effort to codify its knowledge - the only explicit documents it uses are welding procedure specifications and manufacturing drawings. Based on the general concept drawings developed by RFR, Azaran's engineering office developed manufacturing drawings to be transferred to the production department. Azaran does not write procedures up systematically, and they are generally neglected, as are risk assessments, follow ups of indicators etc. Even under strong encouragement from Freyssinet, Azaran only wrote three procedures in the entire project, and these were of poor quality.

4.2.2. Socialization difficulties: use of face-to-face safety training

Freyssinet aimed to transfer tacit knowledge to Azaran. In the contract, Azaran was responsible for safety on the site, but did not pay much attention to it. As high safety standards were part of its organizational culture, Freyssinet started to get involved in explaining the importance of safety, and instigated the deployment of a life line around the stadium to secure workers working at heights. The original intent was to use socialization to demonstrate the importance of using the life line via face-to-face interactions, and explain risk assessment to all employees verbally. But we observed that Azaran's construction workers did not respect such tacit rules.

> "*Since Azaran workers do not want to learn and do not want to secure themselves, we have to use the reverse method of teaching*: Penalties. *When a worker is seen breaching the safety rules, the equivalent of one day's pay is deducted from his salary. The second time, the equivalent of two days' pay is deducted. The third time, the worker is excluded from the construction site. But my job did not allow me to spend all my time checking people. Consequently the two Health Safety Environment officers employed by Azaran and all supervisors were in charge of the control of safety rules. It did not work*: Those guys never give any tickets to any workers who were at fault, and anyway Azaran would not deduct tickets from their wages… What about giving tickets to the people in charge of giving tickets if they ignore construction workers who do not respect safety rules?"
>
> [Respondent 29.]

4.2.3. Externalization difficulties: use of lifting plans

Freyssinet faced an important safety issue due to its use of cranes. A crane is characterized by specific capabilities, which are normally formalized in an explicit form. The lift capacity varies according to the distance and the angle involved. Normally, a crane's capacity is explicitly written on the frame, and in its official documentation. However, in Iran, this explicit knowledge is lacking.

A first major incident occurred. As they did not rely on explicit knowledge, Azaran's crane drivers never used load charts (indicating the lift capacity at different distances), nor lifting plans (which covered routine and non-routine lifting activities) - such practices clearly put them at risk. One day, a crane driver tried to lift a heavy load located too far from the center of rotation of the crane, and the overload caused the crane's main boom to break. The construction site was lucky on this occasion — the incident only involved material losses. But as this crane was the only one on site with this capacity, the project suffered from an additional two week delay, as well as the additional costs of repairing the crane.

On November 2nd 2014, there was a much closer drama. A rented crane that was supposed to be 120 t started to lift an 8 t beam. Suddenly, the crane started to tip over. Fortunately, the beam felt back on the ground, and after a few oscillations, the crane stabilized itself. Again, the project was lucky, as no injuries occurred. But the incident required further investigations. The crane - which was rented - had been recently repainted, and there was no longer any indication of its lift capacity: nor was technical documentation provided with the crane. The owner of the rented crane only told the driver that the lift capacity was 120 t – if that was really true, the incident would have never occurred. The project supervisor searched for the brand of the crane by comparing it to pictures of cranes available on the internet, and finally came to the conclusion that the crane's lift capacity was 80 rather than 120 t. Thus the crane driver's tacit knowledge was not reliable in this case.

> "*Most of the time, the lift capacity is not written on the machine and the official documentation of the crane is missing. You cannot rely on what the person renting you the crane tells you. You have two options. The first one is to ask an Iranian engineer who is familiar with the use of cranes to estimate its lift capacity, but this option is never actually seriously considered as safety cannot sensibly rely on the opinions of a single person. The second one is to conduct lifting tests and then issue*

an official Freyssinet certificate documenting the cane's real capacity. The failure of a crane always implies wide scale damage to equipment and potential fatalities."

[Respondent 29.]

4.2.4. Combination difficulties: use of e-mails

Freyssinet implemented an online platform to upload and download drawings, which was considered as a document repository. Freyssinet intended to use e-mails to transfer explicit knowledge to Azaran. While all Freyssinet employees had an access to their e-mail accounts, the Azaran managers and engineers only used their e-mail accounts for 5 min per day, while some others did not have accounts. Physical letters sent from one person to another are the most commonly used method for transferring explicit knowledge in the Iranian construction sector. Freyssinet intended to use e-mails to send new drawings, procedures, information, schedules, requests to Azaran managers and engineers. In total, 210 e-mails were sent to Azaran - but we only found 70 low quality replies.

"*I lost hope in using e-mails to communicate with Azaran. They do not read them, or do not take the content into account. I just keep sending e-mails to keep a written proof and traceability.*"

[Respondent 11.]

4.2.5. Internalization difficulties: use of case-based reasoning

Freyssinet used internalization to transform explicit knowledge into tacit knowledge to transfer to Azaran. For instance, Freyssinet provided a written procedure for the use of grout, noting the mix ratio (aggregates, water and grout) that should be adopted: the quantity of aggregate depended on the height above ground. However, Azaran employees always used the same quantities of aggregate whatever the use - they were unwilling to turn explicit knowledge properly into successful practice.

Other internalization attempts at Azaran turned out to be counter-productive. Freyssinet wanted to encourage Azaran to use case-based reasoning and to solve problems by analogy. For instance, Freyssinet explicitly wrote down that epoxy resin was approved when properly used to fill gaps between two beams. The problem was that Azaran workers did not apply the proper methods in using the resin, and did not think it was important to follow the recommendations of the epoxy supplier's Technical Datasheet strictly.

"*I encouraged all supervisors to check if the use of the epoxy resin is relevant or not, and if it was properly used or not. I noticed in a few instances that the use of epoxy resin was relevant but was badly applied. Most of the time, the area of contact between the elements to be linked was insufficient. I also noticed that the use of epoxy resin was incorrect in some cases. Once they have discovered epoxy, Iranian construction workers want to use it to solve any problem. They need to understand that epoxy has a lower compressive strength than steel and its use must be checked and approved on a case-by-case basis depending on the load being transferred in the assembly*"

[Respondent 15.]

4.2.6. Freyssinet adapting to Azaran

Facing difficulties in making progress with Azaran, Freyssinet tried to adapt its procedures to Azaran's through socialization and externalization.

Given the many quality difficulties that arose, on-site reworks were frequently required. Steel work was not part of Freyssinet's core competences, but their engineers were willing to learn how to do it through socialization. They were able to acquire practical techniques about how to modify the geometry of steel structures by heating (location of the area to be heated, duration, temperature, etc.). Thus Freyssinet acquired know-how related to the job of steel manufacturers, and this learning allowed it to better adapt the low quality steel structures that Azaran produced.

Similarly, Freyssinet learnt from commonly faced quality issues. Using the externalization process, such tacit learning enabled Freyssinet to write new quality check lists which took into account the weaknesses identified in the past. In particular, Freyssinet developed some ITP (inspections and test plans) to help Azaran to check the steel elements during the manufacturing process and to reach acceptable quality levels. Based on the experience of working with Azaran, Freyssinet also modified its manufacturing drawings so that the new drawings took Iranian tolerances into account. Additional margins were added to limit the on-site rework - for instance, the size of the holes in the steel structures were sometimes made larger (if structurally acceptable) to make sure it would be easier to assemble them to other elements.

4.2.7. Propositions

Referring to the distinction between explicit and tacit knowledge (Polanyi, 1967; Nonaka & Takeuchi, 1995), Freyssinet maintains a good balance between tacit and explicit knowledge, and benefits from a strong knowledge management culture: in contrast, Azaran mostly relies on tacit knowledge and does not codify its knowledge. These differences acted as a barrier to knowledge transfer, even though Freyssinet and Azaran intended to develop what Noteboom (2000) refers to as a cognitive bridge between the two organizations. Freyssinet attempted to transfer both explicit and tacit knowledge to Azaran. Contrary to the findings of existing literature (Foss, Knudsen, & Montgomery, 1995; Kogut & Zander, 1993; Szulanski, 1996; Zollo & Winter, 2002; Lord & Ranft, 2000), in this case, the transfer of explicit knowledge did not prove any easier than transferring tacit knowledge.

Given its failure in using these four modes of transferring knowledge to Azaran, Freyssinet made significant efforts to adapt to Azaran. Thus we can say:

Proposition 4. *Prior to knowledge transfer, both organizations need to assess that their knowledge bases are similar in term of tacit and explicit knowledge.*

Proposition 5. *When the firm that receives knowledge does not have a good balance between tacit and explicit knowledge, knowledge transfer may not occur and the learning dyad may fail.*

Proposition 6. *The lack of the technological capability to integrate tacit knowledge, the intuitive nature and imprecision of tacit knowledge, the lack of attention to written documents, and resistance to internalizing knowledge will hinder knowledge transfer.*

Proposition 7. *Facing an unsuccessful learning dyad, the teacher should adapt to the student by implementing a reverse learning dyad to best identify the main weaknesses and the common mistakes that need to be addressed.*

4.3. Outcomes of radical innovation

Given the original choice of a radical innovation design, both Freyssinet and Azaran faced difficulties related to differences in their safety, planning, and quality standards. Freyssinet developed a system for transferring knowledge to Azaran to cope with such difficulties - but, unfortunately, such knowledge transfers appeared to be unsuccessful in many instances. Facing difficulties related both to innovation radicalness in Iran and to knowledge transfer, the entire project incurred major delays (300% of the initial planned time), additional costs (which involved financial losses for Azaran), and an as-built structure that was beyond the original design tolerances.

4.3.1. Delays

The construction was planned to last 6 months (January– June 2014) but took an additional 12 months - so that July 2015 is the latest forecast date for completing the project, and September 2015 for opening the stadium. There has been a great degree of uncertainty during the whole project. The need for on-site repair works (quality issues), the non-respect of sequencing (planning issues), the strike by Azaran constructions workers (social issues), and the retention of goods at customs points (political issues) all engendered unexpected delays.

The employees were loyal to the project, although they lacked motivation because of delayed payments from Azaran – at one point, they went on strike when they had not been paid for two months. The economic sanctions against Iran appear to have been a barrier to technological changes: major difficulties in importing goods into Iran hindered the process of radical innovation, as urgently needed materials were blocked at customs.

> "*We* [*Architexsteel*] *are not responsible for the delay of the installation of the membrane. We are dependent on the willingness of the Iranian customs and the final client to allow the importation of the membrane produced by Esmery Caron. When I got to know what happened*, *I went crazy. We had to prove that such a membrane did not exist in Iran and that there was an absolute need for it to be imported. The supply of the membrane was blocked at the customs for a month and a half. Freyssinet even had to send samples of the membrane to be physically tested to demonstrate that it was not comparable to any membrane available on the Iranian market. Only once we proved that this membrane is of a better resistance than any other membranes could we finally get the membrane custom cleared.*"
>
> [Respondent 38.]

4.3.2. Design as-built

As the structure's original design geometry was compromised by the manufacturing and sequencing problems, the design as built differed significantly from the design as planned. So the entire design had to be checked again after the construction to ensure it could resist the various climatic and seismic conditions as originally planned. A few millimeters can represent a considerable added force and significantly modify the stability of the entire structure. Four surveyors were assigned to verify the structure's geometry. RFR provided inputs before, during, and after the project.

> "*When I* [*Project manager at RFR*] *get a call from a phone number starting by* + *98*, *I already know that we* [*RFR*] *will have to work again and again on the design of the Imam Reza Stadium roof. When I get a call*, *it means that they* [*Freyssinet*] *have a problem. We came up with a great design but I am not too sure it was a relevant choice to develop radical innovation in the Iranian context. The quality standards are not met and we constantly have to adapt the design. I am very sorry for Freyssinet*, *but we will have to charge them additional costs for our extra work all along the project.*"
>
> [Respondent 21.]

4.3.3. Additional costs

Freyssinet had to pay extra fees to RFR due to the extra work needed on the project, and also faced extra costs related to renting equipment and paying salaries over the extra 12 months of the construction period. Freyssinet also faced difficulties in assembling the membrane because the design as built did not match the original plans, so additional modules of membrane were needed and were charged as supplementary costs. Freyssinet faced further difficulties in trying to rent some equipment in Iran, such as chain-blocks or pull-lifts, and so were forced to buy those items themselves.

Azaran also faced extra costs related to paying salaries and renting cranes for an extra 8 months, and also suffered financially from not respecting design quality standards. By April 2014 the Azaran quality manager admitted:

> "*We* [*Azaran*] *are facing difficulties in planning our raw materials needs. In the contract*, *we were supposed to use a certain amount of steel* – *but in practice*, *we are using 50% more. I am not in charge of the business*, *so let's say*, *it is not my problem.*"
>
> [Respondent 18.]

In fine, the weight of the entire structure was 50% more than initially planned. This over consumption can be explained by various factors: The client increased the roof's coverage surface, the original structure needed to be strengthened by adding new steel elements, beam sections that were needed were not always available in Iran, which pushed Azaran to use larger diameters, and the weight of connections between the steel beams had been omitted from the original calculations. The extra cost of this 50% over-consumption of steel significantly affected Azaran's profitability so that, by December 2014, it faced financial losses. As a consequence, Azaran stopped fulfilling its initial contract with Freyssinet, and stopped providing equipment and construction workers for project activities.

4.3.4. Propositions

This attempt at conducting radical innovation in the Iranian construction sector suffered from major delays. Quality issues meant that the geometry of the final structure differs from the original design. The development of radical innovation in Iran appeared to be very costly compared to similar projects conducted in developed countries. There is a debate in the literature comparing the costs associated with radical innovation and those associated with modular innovation. The innovation in this case being both radical and modular, the final costs were much higher than those originally estimated. We complement Baldwin & Clark (2000) in arguing that the construction sector in Iran faces the dual challenge of modularity-in-design and modularity-in-production, so that:

Proposition 8. *Planning uncertainty*, *design uncertainty*, *and profitability uncertainty are likely to be greater in developing countries than in developed countries.*

Proposition 9. *Radical and modular innovation are likely to be associated with extensive time delays*, *design modifications*, *and extra costs due to safety*, *quality*, *and planning issues*, *and because of unsuccessful knowledge transfers.*

4.4. Barriers to technological change related to absorptive capacity

To further investigate why Azaran was unable to benefit from tacit and explicit knowledge transfer from Freyssinet, we investigated the inter-organizational absorptive capacity across the two partners, the organizational absorptive capacity of both Freyssinet and Azaran, and the individual absorptive capacities of their employees.

4.4.1. Inter-organizational absorptive capacity

Freyssinet had already worked with Azaran during the construction of the Javadieh stay cable bridge in 2010. In that project, Azaran was the main contractor and Freyssinet was only a subcontractor involved in the stay cable system and supplying bearings, expansion joints and dampers. The project was successful, which offers some evidence of an existing common understanding.

To develop inter-organizational absorptive capacity, effective communication is vital. Although initially frequent, communications between the joint venture partners generally remained weak. Daily meetings were organized at the beginning of the project with the intention of identifying likely problems and developing improvements related to quality, planning, and safety issues. However, Azaran was not committed to attending such meetings, and was unwilling to solve problems by implementing corrective actions, so similar problems were pointed out on a daily basis. Being considered a waste of time, the meetings stopped: when they restarted a month later, they again suffered from similar problems, and finally stopped being organized during the remainder of the project.

4.4.2. Organizational absorptive capacity

Freyssinet benefits from a strong innovative culture. Its founder, Eugène Freyssinet was the inventor of pre-stressed concrete, patented in 1928, which is a method for strengthening concrete structures by introducing steel reinforcement bars or cables into them. This technology is now commonly used in most bridges and large concrete constructions.

With its experience in managing challenging tasks, Freyssinet became specialists in complex civil engineering projects. To maintain its position at the edge of building technologies, it invested heavily in R&D. Freyssinet started operating in Iran via the agent E-Man Serve 10 years ago, and has completed multiple projects successfully. These past successes have strengthened its position in Iran, and it has now opened a local agency to enable it to better identify future Iranian business opportunities.

Azaran's core knowledge relates to manufacturing and assembling steel structures. Its activities mainly concern residential building, in which it chiefly uses basic geometries, with horizontal and vertical structure crossing at 90°, and assembled with large tolerances. Besides manufacturing, Azaran does not benefit from existing knowledge in using cables or membranes. Focused on this very narrow knowledge base, Azaran does not perceive the potential of new technologies that are too far from its core activities, and so does not see the importance of learning new technologies. Azaran does not carry out any R&D activities, so is not involved in architectural innovation.

To summarize our findings, the radical innovation design that was chosen raised a number of challenges. The construction project faced safety, quality, and planning issues, which Freyssinet intended to address by transferring both explicit and tacit knowledge to Azaran, using socialization, externalization, combination, and internalization transfer modes. Unfortunately, Azaran did not fully benefit from knowledge transfer because of its poor organizational and individual absorptive capacity. Significant delays, a structure as-built that differs from the initial design, and additional costs can be considered as the consequential outcomes of this radical innovation project. Given the failure of its attempts to transfer knowledge to Azaran, Freyssinet effectively had to adapt to Azaran's practices, habits, and routines, using socialization and externalization, based on its high absorptive capacity (see Fig. 3).

5. Discussion

Kandemir & Hult (2004) argue that joint ventures enable the successful transfer and absorption of tacit knowledge. However, our research studied various knowledge transfers and transfer attempts between Freyssinet and Azaran, and our findings indicate that the transfer of both tacit and explicit knowledge between partners was difficult in this case. Our research contributes to strengthening existing empirical studies in Iranian settings (Madani et al., 2012; Mohammadi et al., 2014; Chu et al., 2014; Pool et al., 2014; Mehralian et al., 2014; Jafari et al., 2013; Ghazinoory & Soofi, 2012; Akhavan et al., 2013; Darvish et al., 2012; Ranjbarfard et al., 2013). To understand Azaran's inability to integrate tacit and explicit knowledge and Freyssinet's ability to integrate tacit knowledge, we investigated the reasons for these differences in the light of absorptive capacity.

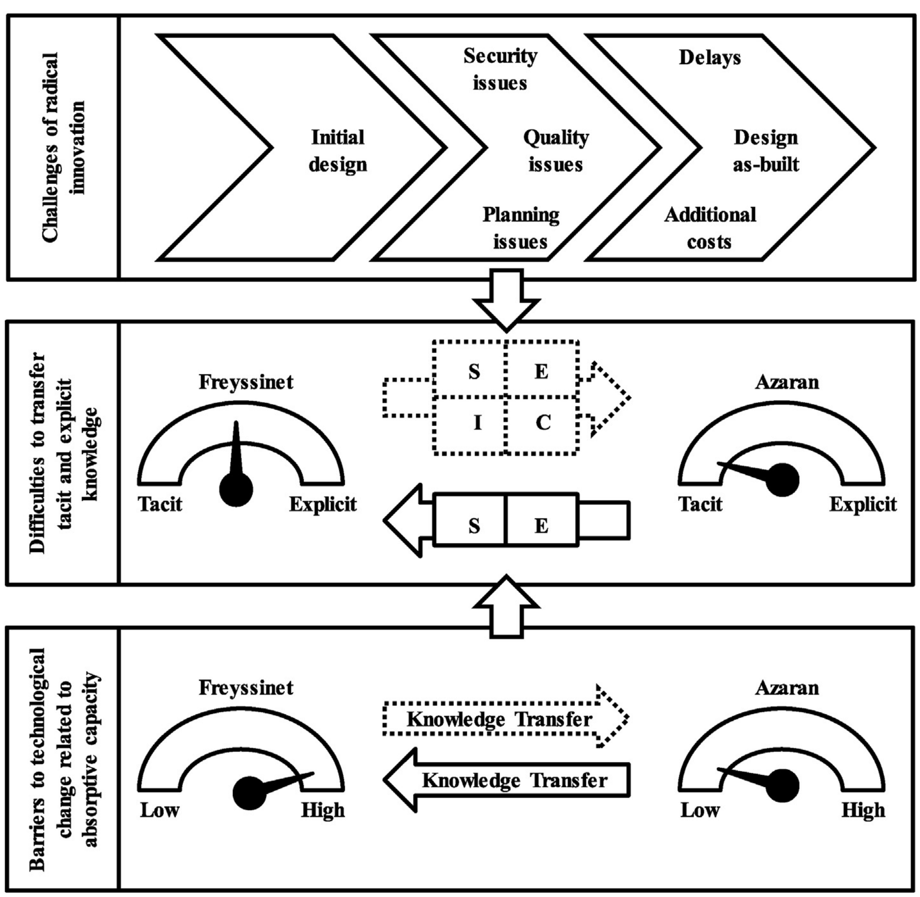

Fig. 3. Challenges of radical innovation, difficulties to transfer knowledge, and barriers to technological change.

The specific involvement of Freyssinet and Azaran in a joint venture contributes to further investigate this specific type of strategic alliance in the Iranian context, again adding to the existing literature (Madani et al., 2012; Jafari & Love, 2013; Asheghian, 1982; Simiar, 1983). Freyssinet and Azaran had previously collaborated together in a strategic alliance - as recommended Lubatkin et al. (2001) - but this partnership did not create much complementarity between the partners as knowledge senders and receivers. Their familiarity in being involved in a past strategic alliance did not encourage Azaran to benefit from knowledge-sharing routines.

We contribute to further investigating the “student-teacher pairing”, as developed by Lane & Lubatkin (1998). We argue that a firm's characteristics have a significant impact on its ability to learn from another firm. Specifically, we studied the impact of the nature of knowledge (tacit vs. explicit), the differences between the partners (high vs. low absorptive capacity), and the familiarity between them (based on a shared past project) on Freyssinet's and Azaran's ability to learn from each other to solve problems. We first studied the ‘unsuccessful learning dyad’ by which Freyssinet attempted to teach Azaran, and then the ‘reverse learning dyad’ in which the teacher tried to adapt to the student.

Referring to Cohen & Levinthal's (1990) definition of absorptive capacity, Azaran was unable to recognize the value of the knowledge Freyssinet tried to transfer, to assimilate it by learning, and to apply it to its commercial ends. Focusing on assimilation capability, we observe that Azaran did not take advantage of the knowledge available from Freyssinet because of the absence of formal learning routines in its structure and nature. Contrary to the empirical findings in various Iranian sectors - such as health care, manufacturing, petroleum, services, and tourism (Bahadori et al., 2012; Tohidi et al., 2012; Mousaei et al., 2006; Sharifirad, 2011; Ahmadi et al., 2014) - our empirical study highlights Azaran's difficulties in developing an organizational learning routine.

Azaran had benefitted from strong experience in manufacturing and assembling basic steel structures with basic geometry and loose tolerances for residential and commercial construction work. But beyond this core activity, Azaran did not perceive the importance of learning new technologies, or investing in R&D activities. Azaran neglected to invest in absorptive capacity and was even unable to pay its workers their wages on time. As Cohen & Levinthal (1990), we observe that the continued neglect of technical learning has a negative effect on innovation, and can be considered as a significant barrier to technological change. Suffering from a low absorptive capacity level, Azaran is locked out of new technologies, a finding that reflects those highlighted by Dadfar et al. (2013) in the Iranian pharmaceutical industry. As a follow up to Tabassi & Abu Bakar's (2009) study of the construction sector in Mashhad, our research supports the fact that one of the barriers to technological change is the low level of construction workers' qualifications due to Azaran's lack of organizational effort in investing in training. In our case, on-site training sessions were only provided rarely, and off-site training was clearly non-existent. The workforce was badly managed, had limited existing knowledge and was not encouraged to learn.

Considering absorptive capacity as a dynamic organizational capability (Zahra & George, 2002), Freyssinet benefitted from prior scientific and technical knowledge, and had knowledge-sharing routines in place via which its employees could learn from others easily. Investing heavily in R&D, Freyssinet had developed a certain degree of organizational cognition, learning and memory. It benefitted from a strong innovative culture, and accumulated and renewed its knowledge over time. It had successfully completed multiple complex civil engineering projects in Iran over the previous 10 years. Benefitting from strong path dependency, Freyssinet was able to sense and capture external opportunities abroad and to expend international efforts to support its long term growth and profitability. Such strong organizational absorptive capacity is based on its engineers benefitting from training throughout their careers, and having opportunities to transfer, recombine and create specialized knowledge in various construction domains. However, Freyssinet was certainly over self-confident due to the experience it had accumulated in Iran and to its previous collaboration with Azaran. As a consequence they neglected to conduct thorough preliminary studies for this unique project and on the partner's specificities and failed to identify the risks inherent to this specific and unusually complex project. Thus:

Proposition 10. *The choice of the joint venture as a specific strategic alliance did not ensure the good absorption of technological knowledge.*

Proposition 11. *The accumulation of experience in Iran and the familiarity between partners should not prevent foreign firms from conducting studies assessing the risks related to the uniqueness and requirements of a project – especially when this project presents technological radicalness - and from carefully examining the partners' knowledge bases and absorptive capacity levels.*

Proposition 12. *A heterogeneous degree of absorptive capacity between knowledge senders and receivers hinders technological change and does not offer locked out firms the possibility of entering new activities outside their existing knowledge bases.*

Proposition 13. *Firms' knowledge bases, their absorptive capacity levels, past experiences, and investment in individual training, condition their organizational capabilities to perceive the importance of learning new technologies, developing knowledge-sharing routines, and assimilating new knowledge.*

6. Conclusion

Our paper contributes to further expand the body of literature on technology development in Iran. We studied the challenges of radical innovation, the difficulties of transferring tacit and explicit knowledge, and the barriers to technological change related to absorptive capacity.

We have examined the challenges related to radical innovation in a project co-developed by a Franco–Iranian joint venture, the most important of which related to planning, quality and safety. We believe that, before defining the degree of technology radicalness of the design, the local standards need to be characterized more realistically. When they are ignored, and when foreign firms try to impose design newness, small tolerances, and precise sequencing, they risk facing major safety, quality, and planning issues. When associated with unsuccessful knowledge transfers, conducting radical innovation may lead to extensive time delays, design modifications, and extra costs which can affect the project's overall profitability. Although this project brought radical technology to a construction sector in need of significant change, we believe that the Iranian partners in this case were unable to capture that technology, so the construction of the stadium roof did not benefit the Iranian construction sector.

We studied the difficulties a local Iranian firm had in learning from foreign partners. The two firms had very different knowledge bases, which created additional difficulties for transferring knowledge. We argue that the local firm's neglect of the explicit knowledge that was available to it from its French partner, associated with its use of intuitive and imprecise tacit knowledge, negatively affected the knowledge transfer and success of the learning dyad.

Integrating knowledge requires the implementation of efficient routines. Knowledge appropriation and the capture of technology appear to be very important functions that should be encouraged and supported. However, we observe that being part of a joint venture with a partner willing to share its technology is insufficient to ensure long term knowledge development. When partner firms have different knowledge bases, different degrees of absorptive capacity, and different resources for individual training, technological growth is hindered and locked out firms cannot progress. In such cases - where the learning dyad is unsuccessful - the teacher may need to develop a reverse learning dyad to identify and address the student's main weaknesses and most common mistakes.

This article makes several theoretical and empirical contributions. Our main theoretical contributions concern the concept of absorptive capacity. First, we have been able to combine individual, organizational, and multi-organizational levels of absorptive capacity, which expands our understanding on the interrelation between those different levels. We argue that existing knowledge plays a significant role in both individual and organizational learning, but not necessarily in learning across organizations when it comes to management of unique projects. We further argue that organizational learning strongly shapes individual learning and plays a key role in learning across organizations.

Second, we have specifically contributed to the relational approach to absorptive capacity (Dyer & Singh, 1998; Lane & Lubatkin, 1998), by considering two-way learning between two organizations involved in a learning dyad. We argue that while complementarity between the sender and receiver teams (e.g. a degree of knowledge overlap between the partners) is needed in a knowledge transfer "from teacher to student", this complementarity is less important in a knowledge transfer "from student to teacher" because the teacher will be able to absorb the student's knowledge more easily.

Third, we further expend the literature bridging absorptive capacity and knowledge management. When the knowledge to be transferred is too complex, the knowledge transfer fails, not because of a lack of trust, nor because of a lack of familiarity between the partners, but because of the student firm's inability to learn from the teacher firm, which is caused (1) by the different degree of absorptive capacity (e.g. one organization invests strongly in R&D while the other is locked out of new technologies), and (2) by the different knowledge bases (e.g. one organization balances explicit and tacit knowledge while the other relies on tacit knowledge only).

Our main empirical contribution concerns the uniqueness of our case. First, we expand our understanding of the development of radical innovation in the specific case of a joint venture characterized by the challenge of defining common standards. Second, by referring to the dichotomy between tacit and explicit knowledge, we highlight the impact of knowledge transfer in trying to solve issues related to radical innovation. Third, we explore the joint impact of radical innovation and knowledge management issues on project management outcomes in the Iranian context.

The challenging project of developing radical innovation in the Iranian construction sector holds several implications for practitioners. For foreign firms operating in Iran, we recommend that they: (1) analyze the commonly accepted local standards in term of quality, safety and planning carefully, (2) select the most appropriate design in term of technology radicalness, (3) select adequate partners which have similar knowledge bases in term of tacit and explicit knowledge, (4) choose the specific type of strategic alliance or contractual relationship carefully, (5) adapt to the local partner when facing difficulties in transferring knowledge, and (6) develop and monitor indicators in respect of planning, design, and profitability dimensions.

For Iranian firms, we recommend that they: (1) increase the codification of their knowledge, (2) reward people engaged in knowledge-sharing routines, (3) balance their tacit and explicit knowledge more carefully, (4) make efforts to benefit from successful learning dyads, (5) pay greater attention to quality, safety, and planning issues (because control of these three dimensions will increase the profitability of the final project, a concept that they have not yet understood) (6) endeavor to meet the standards conjointly developed with foreign partners, (7) carry out new activities beyond their existing ones, and (8) invest in R&D and workforce training.

As a single in-depth case study, our article has limitations in terms of generalization. However, our analysis identifies some important phenomena of the management of knowledge and innovation in the specific case of a Franco–Iranian joint venture and suggests paths for further research. First, we encourage future research to study radical innovation in the specific case of Iran, in different industries, and in different types of strategic alliance. Second, the management of both tacit and explicit knowledge in Iran requires further study to better understand people's resistance to explicit knowledge and the difficulties of knowledge transfer. Third, there is a need for empirical study to measure the impact of radical innovation on the key performance indicators of project management in emerging countries such as Iran. Fourth, the concept of the learning dyad is worth further exploration across different partnerships in specific strategic alliances.

Appendix A. Knowledge and organizational capabilities in various Iranian sectors

Knowledge	Knowledge sharing	Pool et al. (2014)
	Knowledge transfer	Bahrami et al. (2014), Tohidi et al. (2012); Tavani et al. (2013)
	Knowledge management	Darvish et al. (2012), Chu et al. (2014), Jafari et al. (2013), Shafia et al. (2011), Bahrami et al. (2014)
	Tacit knowledge	Pournader et al. (2015), Jafari et al. (2013), Shafia et al. (2011)
	Explicit knowledge	Ranjbarfard et al. (2013)
	Both tacit and explicit knowledge	Madani et al. (2012), Chu et al. (2014), Mohammadi et al. (2014)
	Balanced Scorecard	Akhavan et al. (2013), Darvish et al. (2012), Ghazinoory and Soofi (2012)
	SECI model	Mehralian et al. (2014)
Organizational capabilities	R&D	Ghazinoory & Ghazinouri (2009), Soofi & Ghazinoory (2011)
	Technology transfer	Madani et al. (2012), Bahadori et al. (2012)
	Communication	Pournader et al. (2015), Tavani et al. (2013)
	Learning	Sharifirad (2011), Ghazinoory et al. (2014), Nekoei Moghaddam and Beheshti Far (2007), Ghazinoory and Soofi (2012), Tohidi et al. (2012), Bahadori et al. (2012), Ahmadi et al. (2014)
	Absorptive capacity	Madani et al. (2012), Tavani et al. (2013), Dadfar et al. (2013)
	Innovation	Ghazinoory et al. (2014), Tohidi et al. (2012), Akhlagh et al. (2013), Ghazinoory and Ghazinouri (2009), Soofi and Ghazinoory (2011), Dadfar et al. (2013), Chu et al. (2014)
Sectors	Construction	Tabassi & Abu Bakar (2009); Akhavan, (2006); Berberian & Yeats (1999); Ghafory-Ashtiany & Eslami (1997), Mehrabian & Haldar (2005), Akhlagh et al. (2013), Tabassi et al. (2012), Pournader et al. (2015), Jafari & Love (2013)
	Manufacturing	Sharifirad (2011), Ghazinoory et al. (2011), Azadegan et al. (2011), Soofi and Ghazinoory (2011), Akhavan et al. (2013); Tavani et al. (2013), Tohidi et al. (2012)
	Automotive	Darvish et al. (2012), Mohammadi et al. (2014), Jafari et al. (2013), Shafia et al. (2011)
	Nanotechnologies	Ghazinoory and Ghazinouri (2009); Ghazinoory & Farazkish (2010), Ghazinoory & Soofi (2012)
	Health care	Bahadori et al. (2012), Nekoei & Beheshti (2007)
	Biopharmaceutical	Madani et al. (2012), Dadfar et al. (2013)
	Petroleum	Maroofi & Sadqi (2012), Mousaei et al. (2006)
	Services	Sharifirad (2011)
	Tourism	Ahmadi et al. (2014)
	Public services	Ranjbarfard et al. (2013)

Appendix B. List of interviews

Interview ID	Date	Location	Language	Length	Name	Organization	Job description	Education background
#1	07/11/2013	Paris	French	30′	BG	Freyssinet	Project manager	Engineer
#2	14/11/2013	Paris	English	20′	JC	RFR	Project manager	Engineer
#3	27/11/2013	Paris	French	50′	JFK	Esmery Caron	Design engineer	Engineer
#4	20/12/2013	Mashhad	French	30′	PB	Esmery Caron	Technical manager	Engineer
#5	11/01/2014	Paris	French	20′	AM	Freyssinet	Sales person	Engineer
#6	19/01/2014	Mashhad	English	40′	SK	Azaran	Site manager	Engineer
#7	23/01/2014	Tehran	English	30′	EM	Azaran	Project manager	Engineer
#8	29/01/2014	Mashhad	English	30′	SG	Civil and development organization of Khorasan	Site manager	Bachelor
#9	02/02/2014	Mashhad	English	25′	GB	Civil and development organization of Khorasan	Design Manager	Engineer
#10	06/02/2014	Mashhad	French	30′	MK	RFR	Managing Director	PhD
#11	10/02/2014	Mashhad	English	35′	MN	Freyssinet	Supervisor	High school
#12	18/02/2014	Mashhad	French	45′	AG	Freyssinet	Method Engineer	Engineer
#13	03/03/2014	Mashhad	Farsi	10′	MR	Azaran	Project director	Engineer
#14	03/03/2014	Mashhad	Farsi	15′	AL	Azaran	Surveyor	Bachelor
#15	15/03/2014	Mashhad	French	60′	MG	Freyssinet	Project manager	Bachelor
#16	28/03/2014	Mashhad	Farsi	20′	MN	Freyssinet	Admin. affairs	High school
#17	08/04/2014	Mashhad	Farsi	15′	EM	Azaran	Worker	No degree
#18	10/04/2014	Mashhad	English	50′	MM	Azaran	Quality manager	Bachelor
#19	13/04/2014	Mashhad	English	60′	MD	Azaran	Survey manager	Engineer
#20	15/05/2014	Mashhad	French	120′	AC	Freyssinet	Bus. Unit manager	Engineer
#21	16/06/2014	Mashhad	English	20′	JC	RFR	Project manager	Engineer
#22	07/07/2014	Mashhad	French	30′	BG	Freyssinet	Project manager	Engineer
#23	14/07/2014	Mashhad	English	25′	NH	Freyssinet	Site engineer	Engineer
#24	18/07/2014	Mashhad	English	30′	SB	Fatzer	Sales manager	Engineer
#25	29/07/2014	Mashhad	English	30′	KT	Fatzer	Project manager	Engineer
#26	09/08/2014	Mashhad	Farsi	35′	OM	Azaran	Tea boy	No degree
#27	27/08/2014	Mashhad	English	60′	JL	Freyssinet	Supervisor	High school
#28	07/09/2014	Mashhad	French	40′	RV	Freyssinet	Store man	High school
#29	15/09/2014	Mashhad	English	60′	EM	Freyssinet	Supervisor	High school
#30	23/09/2014	Mashhad	Farsi	20′	RT	Azaran	Supervisor	No degree
#31	24/09/2014	Mashhad	Farsi	15′	SS	Azaran	Supervisor	High school
#32	30/10/2014	Mashhad	French	30′	TC	Freyssinet	Depot manager	Bachelor
#33	12/11/2014	Mashhad	Farsi	15′	AM	Azaran	Worker	No degree
#34	20/11/2014	Paris	English	40′	RP	E-Man Serve	JV manager	Engineer
#35	14/12/2014	Tehran	French	60′	AB	E-Man Serve	Managing director	PhD
#36	14/12/2014	Mashhad	Farsi	45′	AR	Janbaz construction	Site manager	Bachelor
#37	15/12/2014	Mashhad	French	15′	BG	Freyssinet	Project manager	Engineer
#38	16/12/2014	Mashhad	French	30′	SL	Architexsteel	Director	Bachelor
#39	03/03/2015	Mashhad	French	30′	TC	Architexsteel	Technician	High school
#40	03/05/2015	Mashhad	English	20′	RH	Azaran	Drafter	High school
#41	05/05/2015	Mashhad	English	35′	RA	Astân-e Ghods	Managing director	Engineer

Appendix C. Coding scheme

Technology development (7 codes)	Technological gaps
	Technological investment
	Technological diffusion
	Technological spillovers
	Technological design
	Technological materials
	Technological quality
Innovation (9 codes)	Innovation radicalness
	Innovation to firms
	Innovation to industry
	Innovation to customers
	Innovation usefulness
	Innovation safety
	Innovation standardization
	Innovation costs
	Innovation uncertainty
Individual absorptive capacity (6 codes)	Individual existing knowledge
	Individual ability to learn
	Individual needs of training
	Individual on-the-job training
	Individual off-the-job training
	Individual improvement
Organizational absorptive capacity (7 codes)	Organizational pre-existing knowledge
	Organizational path dependency
	Organizational perception
	Organizational acquisition
	Organizational cognition
	Organizational learning
	Organizational memory

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Multi-organizational absorptive capacity (8 codes)	Multi-organizational knowledge transfer
	Multi-organizational routines
	Multi-organizational learning dyad
	Multi-organizational specificity
	Multi-organizational similarity
	Multi-organizational familiarity
	Multi-organizational complementarity
	Multi-organizational overlap
Knowledge (6 codes)	Knowledge in explicit form
	Knowledge in tacit form
	Knowledge socialization
	Knowledge externalization
	Knowledge combination
	Knowledge internalization

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