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Leadership improvement and its impact on workplace safety in construction projects: A conceptual model and action research

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Abstract

Leadership is proven as a key factor impacting safety while researchers and practitioners are fostering proactive approaches to preventing workplace injuries. Practitioners' lack of leadership is one of the major causes for the continuous high-level accident frequency within the construction projects. An important yet still unsettled academic issue is how leadership impacts safety performance of construction projects, and how safety leadership can be improved. In order to probe into the mechanism by which leadership improves project safety, this study develops a safety leadership model for construction projects (SLMCP) in both theoretical and pragmatic perspectives. Theoretically, this model incorporates specific characteristics of construction projects and applies a multiple levels-of-management perspective to depict leadership's cascading influences across project stakeholders. Safety culture and safety management are the two major paths by which leadership impacts safety performance. Pragmatically, the action research (AR) method is used to validate the theoretical model empirically and develop feasible measures to implement safety leadership in practice. A five-round longitudinal evaluation confirmed in a case study the validity of SLMCP and the effectiveness of safety leadership improvement measures. This paper contributes to the body of knowledge by clearly depicting safety leadership's cascading top-down influencing mechanism in construction projects and providing concrete and validated measures for leadership improvement. The AR based intervention also establishes a general procedure for leadership promotion in practice. Conclusions of the paper serve as novel ideas and methods for workplace safety improvement in construction projects.

Keywords: Leadership; Safety performance; Construction project; Action research (AR); Longitudinal evaluation

1. Introduction

Despite that an increasing number of occupational health and safety provisions have been introduced in many countries, the accident frequency in construction projects still stays at a high level (Abudayyeh et al., 2006; Fang and Wu, 2013). One of the main reasons is that construction project managers lack safety leadership (Tam et al., 2004; Wu et al., 2016), which has been proven to be able to enforce rules and regulations, and reduce misalignment between management commitment and subordinates' actions in highly hazardous and complex working environments (Martin and Lewis, 2014; Tyssen et al., 2014). Strong safety leadership is gradually regarded as the key to safety performance improvement of construction projects, especially for countries where the construction industry is facing significant safety challenges and requires transformational development (Construction Users Roundtable, 2012; Wu et al., 2016).

Several previous studies have examined the effect of safety leadership on safety performance (O'Dea and Flin, 2001; Barling et al., 2002; Zohar, 2002; Neal and Griffin, 2006; Griffin and Hu, 2013). Safety leadership is a sub-system of leadership (Pater, 2001), and can be defined as "the process of interaction between leaders and followers, through which leaders can exert their influence on followers to achieve organizational safety goals under the circumstances of organizational and individual factors" (Wu et

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al., 2008). A majority of previous safety leadership studies focused on the full range leadership model which is mainly composed of transformational and transactional leadership (Barling et al., 2002; Lu and Yang, 2010; Banks et al., 2016). Transactional leadership is related to monitoring and rewarding whereas transformational leadership is directed towards inspiring and genuinely motivating the workforce (Reid et al., 2008). In particular, the transformational leadership theory has received a tremendous amount of attention in the last three decades and has deservedly emerged as one of the most dominant leadership theories (Braun et al., 2013; Mhatre and Riggio, 2014). Transformational leadership describes how a leader seeks to meet the high-order needs of followers and motivate them to go beyond their self-interests and contribute to the common benefits of the whole organization. As safety is typical organizational higher-order interests than pure pecuniary benefit, transformational leadership is assumed to be especially effective in improving safety performance.

However, safety leadership research pertaining to construction projects and the construction industry is scarce compared with other types of projects and industries (Keegan and Den Hartog, 2004; Chan and Chan, 2005; Ofori and Toor, 2012). In recent years, to further improve safety conditions at the worksite, researchers have shifted their focus from technical approaches to organizational and managerial factors (Zohar, 1980; Reason, 1990; Fang and Wu, 2013), exploring root causes and preventive measures of unsafe behavior on the organizational level. The organizational antecedents of unsafe behavior can be grouped into two categories, i.e. safety management and safety culture (Cooper, 2000; Labodová, 2004). Safety management relates to the actual practices, roles and functions associated with remaining safe (Kirwan, 1998). It can also be understood as mechanisms that are integrated in the organization and designed to control the hazards that can affect workers' health and safety (Labodová, 2004). Safety culture reflects the attitudes, beliefs, perceptions, and values that employees share in relation to safety (Cox and Cox, 1991). The effects of safety management and safety culture on safety performance were explored and analyzed by many previous studies (Fang and Wu, 2013; Morrow et al., 2014; Podgórski, 2015; Karanikas, 2017), among which Mearns et al. (2003) found out the combined effects of safety management and safety culture on safety performance.

However, although safety management and safety culture play crucial roles, they are not the root causes for safety performance improvement (Zohar, 2002). The safety management system and safety culture should be established and also enhanced with the support and promotion of senior leaders (Barling et al., 2002; Zohar, 2002; Construction Users Roundtable, 2012; Hoffmeister et al., 2014; Wu et al., 2016). On one hand, effective safety leadership promotes leader-and-follower exchange, classifies managerial roles and functions, and facilitates managerial measure implementation. On the other hand, by role modeling, idealized influence, inspirational motivation, innovation orientation and individualized consideration, safety leadership can lead to favorable safety culture, distribute good values, perceptions and behavioral norms to all corners of the organization through safety culture, and thus guarantee that all members make right decisions in critical locations and moments (Wu et al., 2015).

However, the academia has not deeply probed into the mechanism by which safety leadership of project stakeholders improves workplace safety in construction projects. Although some studies discussed safety leadership and their impacts on safety performance (Conchie et al., 2013; Hoffmeister et al., 2014), due to insufficient consideration of the specific characteristics of the construction projects such as multiple stakeholders, construction process, management practice, organizational structure and characteristics of worker behavior, results of these studies vary greatly and the validity and reliability of the reported findings are yet to be proven.

To address these limitations in the current academia, this study developed a conceptual model of safety leadership in construction projects, in order to incorporate the features of the construction projects and establish a theoretical framework for safety leadership research within the construction industry. Based on this model, an action research approach was applied to design and implement safety leadership measures in a case construction project. This study thus aims to contribute to the safety leadership and management literature by providing conceptual and empirical evidence of how leadership influences safety performance of construction projects, and what measures can be taken to fulfill safety leadership and thus improve safety performance.

2. Development of safety leadership model for construction projects (SLMCP)

2.1. A multi levels-of-management perspective for safety leadership

The life of construction projects is a phased process (Behm, 2005), which can be divided into several stages and involves different parties at each stage. In the execution stage of construction projects, the project team mainly consists of three stakeholders, i.e. the owner, the contractor and the subcontractors (Fang and Wu, 2013). Safety leadership of different stakeholders interacts with each other in the construction process and exerts combined influence on safety management, safety culture and in turn safety performance of construction projects in a manner which is distinct from safety leadership within the traditional, non-projectized organizations (Chiocchio et al., 2010; Fang and Wu, 2013; Wu et al., 2016). More specifically, strong project safety leadership should go beyond traditional organizational boundaries in order to influence frontline personnel significantly, but this is not necessary for leadership of non-projectized organizations (Wu et al., 2016). However, when interpreting leadership fulfillment and impacting mechanism, the current academic literature tends to only focus on the single-level leader-follower relationship, but has not deeply analyzed leadership fulfillment across multiple hierarchical levels and leadership interaction between different project stakeholders (Chun et al., 2009; DeChurch et al., 2010). As one of the few exceptions, Chun et al. (2009) found that leadership at higher levels of management was positively related to leadership at the next lower level, which was in turn related to follower outcomes at the lowest echelon. Their study also distinguished distant leadership from close leadership and found that leader-follower distance could make a difference in leadership impacting mechanism. In

construction projects, both close leadership and distant leadership are common and have significant influence on safety performance. For instance, although frontline supervisors (with close leadership) have the closest relations and most frequent contacts with workers (and thus play an indispensable role in shaping worker safety behavior), the fulfillment of owners' distant leadership cannot be neglected because the owners' management (as the project senior management) is not only the definer of project safety culture, but also the communicator of the shared values for frontline supervisors and workers. Supervisors and workers can be regarded as followers in a distance with the project owner. However, the impacting mechanism of close leadership and distant leadership can be very distinct from each other depending on different leader-follower distances and the existence of substantial contractual relationship. The extant literature failed to address this issue deeply and clearly, and thus cannot provide clear instructions regarding specific and effective leadership measures for practitioners in different management levels.

Moreover, comparing with other types of projects, construction projects have much more dynamic and inconsistent working environments where workers have to keep changing their work locations as projects proceed (Hinze, 1997). Complicated working conditions on construction sites also produce a result that employees' behaviors are not as standard as those in manufacturing factories (Geller, 2001). In addition, because of decentralization, workers usually operate on separate sites and must make their own decisions when facing specific problems. These features further consolidate that distant leadership in construction projects should fulfill in a specific mechanism in order to influence frontline worker safety behavior.

A distant leader influences distant followers indirectly through his/her immediate followers who are also the immediate leaders for the distant followers. Namely, the influence of a distant leader can cascade down to distant followers through intermediate levels of management (Bass et al., 1987; Waldman and Yammarino, 1999; Chun et al., 2009) and thereby manifest a distant leader's behavioral pattern. Thus, safety leadership within construction projects fulfills in a top-down relayed manner.

Thus, it is both crucial and urgent to re-conceptualize the existing safety leadership studies and incorporate a multiple levels-of-management perspective (Chun et al., 2009) to examine safety leadership influences across different management layers and stakeholders. First and foremost, a theoretical model addressing safety leadership's levels-of-management, impacting paths, and mediating variables along the impacting paths (if any) needs to be developed, in order to incorporate characteristics of construction projects for more valid and reliable safety leadership research results.

Several previous studies also laid foundation for the development of safety leadership model for construction projects. Specifically, Fang et al. (2015) established detailed empirical links between supervisors' leadership and worker safety behavior in the construction projects. Wu et al. (2015) explored factor structure and observable indicators of construction safety leadership, and Wu et al. (2016) established clear leadership impacting paths from owners to frontline supervisors. The three studies constitute the fundamental theoretical framework as to how the three main project stakeholders, i.e. owners, contractors and subcontractors, influence safety performance of construction projects.

2.2. SLMCP

Based on the full-range leadership model proposed by Bass (1999), Wu et al. (2015) made an ethnographic study on construction projects and identified four categories of safety leadership practices, which interpreted the types of safety leadership applicable in the construction projects. They are safety influence and role modeling, safety motivation and coaching, safety caring and individual respect, and safety controlling and performance management. The first three dimensions are associated with transformational leadership, and the last one relates to transactional leadership. As mentioned in the Introduction section, safety culture and safety management are the two main points which leaders can focus on in order to improve safety performance. For example, safety controlling and performance management is a typical leadership dimension which depends on safety management as the medium in order to improve safety performance. Approaches by which this leadership dimension improves safety performance include setting up a specific working goal, designing managerial regulations and procedures, allocating obligations and functions for the personnel, and motivating them with incentives and constraints. On this basis, the other three safety leadership dimensions can achieve safety excellence step by step in a relayed manner, by exerting idealized influence, inspirational motivation, innovation awareness and individualized consideration (Wu et al., 2015). These leadership fulfillment effects, as idealized influence, have to rely on safety culture as the organizational medium, in order to penetrate through different stakeholders and distribute to every corner of the project. With safety culture, leaders, especially senior ones, are regarded not as authorities beyond reach, but as approachable mentors. Senior leaders should define project safety culture, and also act as the communicator of the shared values for followers at a distance within the project (Chun et al., 2009).

Thus, it can be safely concluded that there are at least two major ways in which leadership improves safety performance. On one hand, leaders can implement managerial approaches (i.e. reinforcing safety controlling and promoting safety innovation), so as to boost overall safety management levels and in turn improve safety performance (Fernández-Muñiz et al., 2007). On the other hand, leaders can also enhance project safety culture by, for instance, enhancing dynamic interaction among stakeholders, and thus improve safety performance more profoundly (Fang and Wu, 2013; Wu et al., 2016). Thus, safety management and safety culture can be regarded as the two major channels or mediating constructs through which safety leadership influences safety performance. Especially in construction projects, the establishment of project safety management system and maturity of project safety culture are two prerequisites for the cascading influence of senior-level leaders on frontline personnel through boundaries of all project stakeholders. The leader-follower distance (Antonakis and Atwater, 2002) in construction projects is much longer than traditional non-projectized enterprises. On one hand, project senior leaders have longer physical distance with frontline workers/employees than that in traditional non-projectized organizations,

because project senior leaders tend to work in the headquarters which are far from project locations (Fang and Wu, 2013). Moreover, the perceived interaction frequencies in construction projects are also significantly lower than that in non-projectized organizations because, evidently, senior leaders and frontline employees do not even belong to the same enterprises. The enterprise boundaries are significant barriers against the interaction between personnel of different stakeholders (Wu et al., 2016). Given this, distant leadership cannot take sufficient effect without sound safety management systems and mature safety culture.

Based on the above review and interpretation, this paper proposes the safety leadership model for construction projects (SLMCP), which incorporates characteristics of construction projects for more valid and reliable understanding of construction safety leadership and its impact. The SLMCP contains two impacting paths from safety leadership to safety performance (Fig. 1). The first is the safety management path, which means safety leadership enhances safety leadership of the lower-level personnel or worker safety behavior, and boosts overall safety management (i.e. reinforcing safety controlling and promoting safety innovation), so as to improve safety performance of construction projects. The second is the safety culture path, which means safety leadership drives the evolvement and maturity of project safety culture by enhancing dynamic interaction among project stakeholders, and thus improves project safety performance more profoundly and comprehensively with safety culture as a mediator. Safety leadership fulfillment through the safety culture path is accompanied by the development and maturity of project safety culture. By disseminating favorable safety values, perceptions and behavioral norms, safety leadership, especially that of the owner and the contractor, prompts project safety culture development, and eliminates workers unsafe behavior with the durable penetrating power and nurturing effects.

Fig. 1 illustrates the fundamental composition and hierarchical relationships of safety leadership in construction projects. The in-between T shape in the model refers to the three levels of safety leadership associated with major project stakeholders, i.e. the owner, the contractor, and the subcontractor from the top down. Intensive and complex interactions across the hierarchical levels exist in construction projects (Wu et al., 2016). Intermediate levels of management (for example, the contractor) hold dual positions as a leader as well as a follower. Driven by the stakeholder with the strongest leadership (for example, the owner), safety leadership of the three stakeholders can integrate with each other, and play significant top-down roles among all personnel levels, including frontline workers. The short and horizontal arrow lines (in blue color) in Fig. 1 depict that the two impacting paths involve all personnel levels in project phases. This model shows that

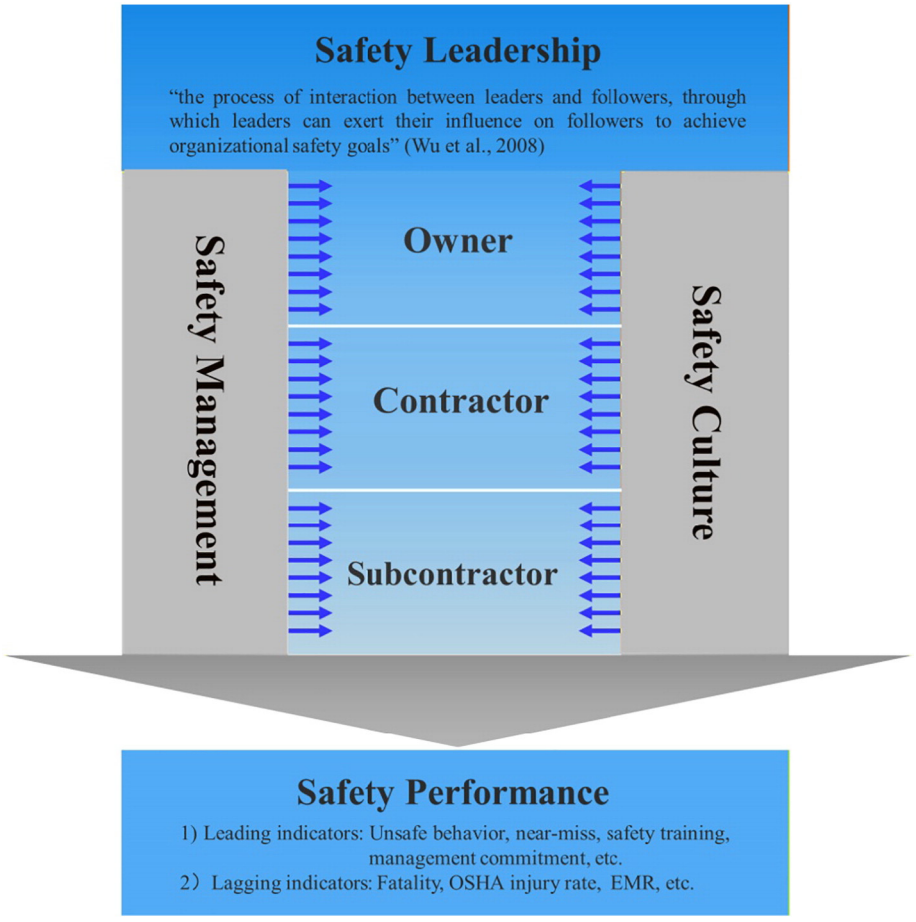

Fig. 1. Safety leadership model for construction projects (SLMCP). (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

improvements in safety leadership and work behaviors of each project personnel level will ultimately result in safety performance enhancement.

It should be noted that in SLMCP, owner leadership is placed at the top and foremost position, which highlights that safety leadership's ultimate impact on safety management, safety culture and safety performance relies on the promotion and initiation of the owner. As significant differences exist among the organizational system, management patterns and leadership attributes of the three stakeholders, safety leadership integration is a long and complicated process. During this process, the stakeholder with the strongest leadership must fill in organizational gaps, eliminate conflicts and expedite the combined effects of leadership behaviors. Therefore, the owner should assume the role of project senior leaders because owners' strong leadership is validated as the key to safety improvement (Dahl and Olsen, 2013; Wu et al., 2016). They have significant advantages over other stakeholders in communicating safety information, carrying out safety policies, and promoting safety culture.

After theoretical development, another important issue for this model is its practical application, i.e. designing and implementing safety leadership measures in order to improve safety performance. The following study applied an action research method. This case study also empirically validated SLMCP and its practical values.

3. Action research methodology

According to the theoretical development, SLMCP features the characteristics of construction projects and emphasizes the multi-stakeholder composition and the two major impacting paths for safety performance of safety leadership in construction. To extend the model from the practical perspective, action research (AR) based model development was undertaken under real-life construction project settings.

3.1. Why AR is chosen

AR represents an interpretivist ontology, which suggests that knowledge is contextual and socially co-created. Therefore, managerial solutions are negotiated in value-laden environments (Ozanne and Saatcioglu, 2008). Epistemologically, both researchers and managers are implicated in the knowledge-creation process, and the resulting accounts are collaborative results of such processes (Reason and Bradbury, 2001). This inevitably means linking conceptual models with managerial theories-in-use (Ozanne and Saatcioglu, 2008). Thus, by AR, SLMCP would be enriched with various practical safety leadership improvement measures, and thus have both theoretical and practical validities. Methodologically, AR researchers review the existing situation (problem domain), identify the problem(s), get involved in introducing some changes to improve the situation, evaluate the effect of those changes, and reflect on the process and the outcome to generate new knowledge (Baskerville, 1999; Naoum, 2001). AR can simultaneously assist in practical problem solving and expand scientific knowledge (Hult and Lennung, 1980). It in essence aims at building and/or testing theory within the context of solving an immediate practical problem in a real setting, linking theory and practice to generate a solution, and providing important knowledge to the scientific community about the theoretical framework which was the basis of the action taken (Azhar et al., 2009).

Thus, by using AR, this study can augment both theoretical and practical implications to the safety leadership model, and link theory and practice to generate effective safety leadership fulfillment measures. In particular, the new knowledge (whether successful or unsuccessful, practical or scientific) gained by AR from the real world can improve the validity and feasibility of the leadership measures.

Generally, several forms of intervention strategies can be adopted in AR. For example, the intervention might be *directive*, in which the research "directs" the change, or *nondirective*, in which the change is sought indirectly (Azhar et al., 2009). This study adopted a directive intervention strategy, which means the leadership changes are based on the theoretical safety leadership model and directed by researchers who are assisted by project personnel.

3.2. Case description

As the two major precedent studies of this paper, Wu et al. (2015) and Wu et al. (2016) both collected empirical data from high-speed railway (HSR) construction projects and provided theoretical basis for the safety leadership model. This study also implemented the case-based model development on HSR because of their typicality as construction projects, especially that they are huge and highly complex construction projects with huge numbers of safety risks. The fulfillment of safety leadership in HSR construction projects is especially crucial for project success (Wu et al., 2015). In addition, as project senior leaders, HSR owners tend to play crucial roles in safety management and have the highest authorities and resource allocation rights, which corresponds to the structure of the SLMCP and the feature of AR mentioned above. The case study in HSR construction projects can also have significant practical implications because construction projects are becoming increasingly huge and complex and those infrastructure projects like HSR contributed much to the improvement of occupational fatalities in construction (Wu et al., 2016).

The HSR construction project (hereinafter called JJQ project) selected as the research case in this study was in China's Zhejiang Province and had a length of 88 km and construction period of 44 months. It was divided into two contract sections (hereinafter called Section A and Section B respectively), which were constructed by two different contractors respectively. Lying in mountainous areas, it had a more than 60% proportion of tunnels. Frequent risks and high injury accident rates characterized this project. The owner strove for safety improvement but could not achieve it because of "safety leadership deficiencies" (quoting the owner's project manager) as well as high pressure of time and funding. Before this AR, long and close research collaboration existed between the owner and the authors' research team. Safety improvement was urgently required by the owner, and the relevant research work was fully supported. Owner's senior managers were informed of the AR design and SLMCP development, and showed great interest, thus promising full participation and promotion of

AR within their project. This constitutes a key success factor of AR, i.e. the full involvement and cooperation of both researchers and practitioners (Azhar et al., 2009).

3.3. AR design: a longitudinal leadership intervention research

As mentioned above, AR design aimed to validate the theoretical leadership model, as well as further develop the model from the practical perspective by incorporating safety leadership improvement measures. Both objectives required robust examination of the relationships among research variables. Thus, this study applied a longitudinal leadership intervention approach. Longitudinal data could robustly validate links between constructs and the effectiveness of practical actions (Wooldridge, 2010).

3.3.1. Overview

The longitudinal study was divided into three stages, i.e. baseline period, intervention period, and follow-up period (Zhang et al., 2017). The baseline period included the first two phases of AR, i.e. diagnosing and action planning; the intervention period corresponded to the third and fourth phase of AR, i.e. action taking and evaluating; the follow-up period corresponds to the fourth and fifth phase of AR, i.e. evaluating and specifying learning (Azhar et al., 2009). In the intervention period, researchers evaluated whether the intervention takes effects, and in the follow-up period, researchers evaluated whether the effects are sustained after the intervention is removed.

Researchers selected Section A of JJQ project as the intervention section and Section B as the control section in order to make the AR results more robust to validate the effectiveness of leadership improvement measures. In other words, leadership improvement actions were taken in Section A but no intervention was implemented in Section B. Comparison between the safety performance of both sections after the AR was undertaken would assess the effectiveness of the leadership improvement measures and validity of the SLMCP.

In order to track the change of related constructs caused by AR and evaluate the intervention effects of leadership improvement actions, five rounds of measurement, R1–R5, were performed with an interval of four months, during the longitudinal AR. The interval was chosen to counteract recall bias while still allowing for the generation of registration of significant fluctuations in the measures (Tholén et al., 2013). Based on the typical longitudinal study designs (Tucker et al., 2010; Tholén et al., 2013), this time interval is suitable for a longitudinal questionnaire survey, especially in the Chinese construction industry. Chinese construction projects are faced with rapidly changing internal and external environments, and a longer time interval would not guarantee that all respondents participate in all the five rounds of measurement. The first two rounds lay in the baseline period and were used to diagnose problems and target for change. The third and fourth rounds lay in the intervention period so as to measure the intervention effects. The last round, in the follow-up period, determined whether the intervention effects are sustainable. In the first round, research members distributed questionnaire copies to specific respondents, and accepted only valid feedbacks, as shown in Table 1. From the second round to the fifth round, the number of distributed copies was kept as equal to the number of valid feedbacks in the first round, and the valid feedback rate of 100% was guaranteed strictly, so as to keep the sample consistency among different measurement rounds (and that is why only the valid feedback rate of the first round is shown in Table 1).

3.3.2. Measures and participants

Safety leadership of the three major stakeholders and worker safety behavior were measured. Safety leadership measurement scales are based on Wu et al. (2016). Four leadership facets of the owner and the contactor were involved, i.e. safety influence and role modeling, safety motivation and coaching, safety caring and individual respect, safety controlling and performance management. The four facets as well as observing indicators within them were initially derived from the Full Range Leadership model (Avolio et al., 1999) and safety leadership scales were developed by other studies (for example, Wu et al., 2008; Lu and Yang, 2010; Griffin and Hu, 2013). The safety leadership measurement scale used by this study has been validated robustly by the ethnographic study of Wu et al. (2015) and confirmatory factor analysis of Wu et al. (2016), and therefore it is suitable for measuring safety leadership in the construction industry. Specifically, safety leadership of subcontractors was represented by supervisors' leadership. Supervisors generally come from the subcontractors in the Chinese construction industry. With the closest relations and most frequent contacts with workers, supervisors have the indispensable duties to influence and motivate them, thus serving as catalysts for good safety performance (Dereamer, 1958). They are responsible for guaranteeing the implementation of almost all safety-related policies, standards, and regulations (Fang et al., 2015). The empowering safety leadership questionnaire of Martínez-Córcoles et al. (2011) was used to assess supervisors' safety leadership. Table 1 shows more detailed information pertaining to the measures and participants.

Safety performance was evaluated by worker safety behavior, which is one of the most widely used leading indicators of safety performance (Griffin and Hu, 2013). It was measured by two constructs, i.e. safety compliance and safety participation (Neal and Griffin, 2006). Safety participation refers to employee's voluntary participation in safety activities, which aims to contribute to the development of a supportive safety environment (Neal and Griffin, 2006). Safety compliance on the other hand refers to the behaviors that are about engaging in core safety tasks, such as compliance with the organization's safety rules and regulations, and following safety procedures (Neal and Griffin, 2006). All the above constructs, including safety leadership of the three major stakeholders and worker safety behavior, were measured by a five-point Likert scale, adopted from one to five. More specifically, the scores one, two, three, four, and five in the measurement scales indicate completely disagree, generally disagree, neutral, generally agree, and completely agree, respectively. It should be noted that in the following figures from Figs. 2 to 5, the scores of the corresponding construct are all based on the above five-point Likert scale.

Table 1
Summary of measures and participants of leadership questionnaire survey.

Measured construct	Respondents	Number of valid feedbacks	Valid feedback rates in the first round	Average age	Average working experience/years	Percentage of respondents with higher education
Owner safety leadership	Owner managers	27	58.7%	43.33	17.41	96.3%
Contractor safety leadership	Contractor managers of Section A	39	75.0%	38.46	14.10	76.9%
	Contractor managers of Section B	33	70.2%	38.18	13.33	81.8%
Supervisor safety leadership	Supervisors of Section A	38	67.9%	29.21	9.47	39.5%
	Supervisors of Section B	26	66.7%	29.62	9.85	42.3%
Worker safety behavior	Frontline workers of Section A	37	75.5%	27.73	5.14	18.9%
	Frontline workers of Section B	35	77.8%	25.74	5.09	17.1%

Note: valid feedback rates in the first round were calculated by dividing the number of valid feedbacks by the number of distributed copies in the first round. From the second round to the fifth round, the number of distributed copies equaled the number of valid feedbacks in the first round, and the valid feedback rate of 100% was guaranteed strictly, so as to keep the sample consistency among different measurement rounds.

In addition to the questionnaire survey, structured interviews and field observations were also carried out after the intervention began, in order to guarantee that safety leadership improvement measures were actually implemented and perceived by the project staff. This is another approach to guaranteeing the validity of AR and excluding other interference factors that may lead to leadership changes. From the third round, all respondents shown in Table 1 were also requested to accept the structured interviews after the questionnaire survey. The field observations were also implemented meanwhile, in which research members attended project meetings and participated in onsite visits of senior leaders.

For the action of fixed safety session in regular meetings, major questions in the interviews or themes of field observations include: 1) What impresses you most (forms, agendas or topics) in the project meetings you recently participated? 2) Are there any significant differences between your recent meetings and past meetings before AR? Please describe the difference if any; and 3) What is the first discussed topic in these meetings? For the action of regular onsite visits by senior leaders, major questions or themes include: 1) Have you seen, communicated with, or been visited by senior leaders of owners and contractors in your workplace? 2) What is the main topic of your talks and communications? 3) How high is the frequency that you meet project senior leaders, excluding routine meetings? 4) Does the frequency increase or decrease compared with that before AR? What is the main reason? Interviews and observations were conducted in both Section A and Section B spontaneously during the later period of leadership intervention. For Section A or Section B respectively, five owner managers, five contractor managers, five supervisors and ten frontline workers were involved in the interviews and observations.

3.3.3. AR procedures

3.3.3.1. Phase 1: diagnosing. In the baseline period, the initial levels of safety leadership and safety behavior were measured and some typical problems diagnosed. It involves self-interpretation of the complex research problem, not through reduction and simplification, but in a holistic fashion. The first two measurement rounds in the longitudinal study are involved in this phase. Detailed results can be found in Section 4 "Longitudinal evaluation results". In summary, measurement in the baseline period reveals that lack of transformational leadership fulfillment is the most significant problem in JJQ project. Measurement of worker safety behavior also reveals that the safety participation dimension has lower scores. According to Griffin and Hu (2013), safety participation is largely impacted by transformational leadership, which validates the above leadership measurement results.

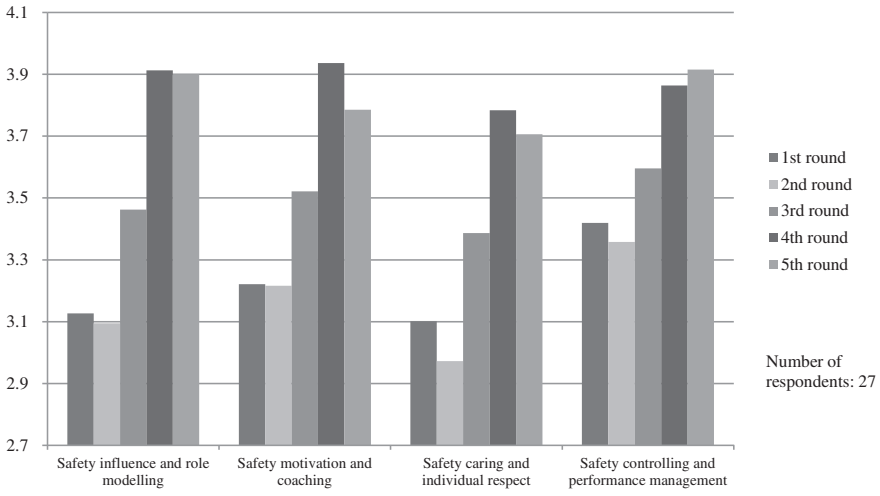

Fig. 2. Longitudinal measurement scores of owner safety leadership by "1–5" Likert scales.

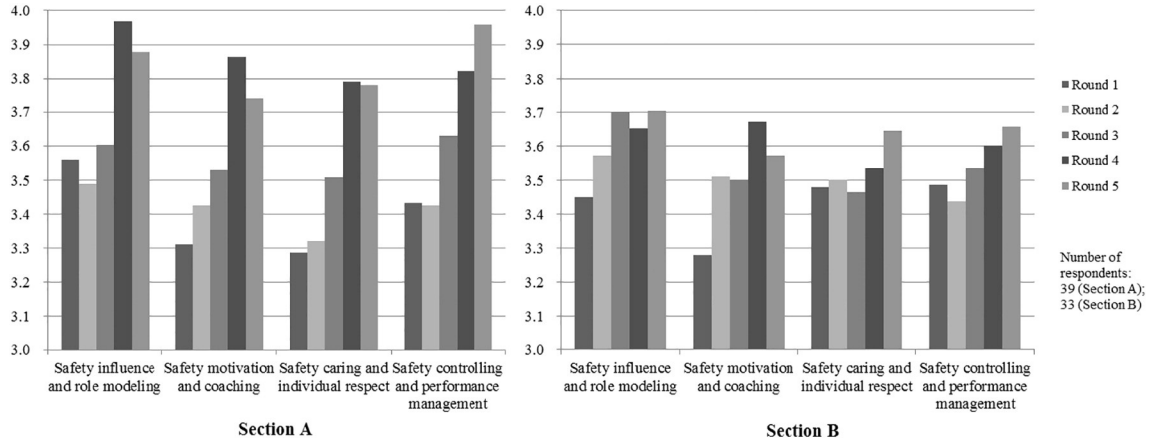

Fig. 3. Longitudinal measurement results of contractor safety leadership by "1–5" Likert scales.

3.3.3.2. Phase 2: action planning. In this phase, actions taken by practitioners (mainly owners and contractors) are specified that should relieve or improve the primary problem(s). In other words, by action planning, the target and approach for change/intervention was established based on SLMCP as well as the diagnosed primary problem in Phase 1.

There are three factors that need to be taken into consideration when designing safety leadership improvement measures/actions. First, all safety leadership behaviors (refer to Wu et al., 2016) can be included in the measures/actions, but in overall they should take on transformational leadership style because the primary problem in JJQ project is the lack of transformational leadership. Second, both safety management and safety culture paths should be applied (see Fig. 1) in order to effectively enhance the leadership and performance improvement effects. Third, measures/actions should be accepted by practitioners, especially the owner and the contractor.

Based on the above criteria, several workshops involving both authors and practitioners in the case project were held for action planning. Worldwide best practices on safety leadership fulfillment were referred to. International prominent engineering enterprises such as Skanska, Fluor, JGC, Hochtief and AMEC were focused on when collecting best practices (including both owners' and contractors' leadership improvement measures). Six preliminary safety leadership improvement measures were developed. As the project manager of JJQ argued that six leadership improvement measures were too big a burden for them, and also they should be validated by some criteria to guarantee their effectiveness and feasibility, expert focus group meetings for selection and optimization were held involving both the authors and practitioners. Evaluative information on both effectiveness and feasibility was solicited from participants. Key evaluative indicators on effectiveness include building up leaders' authorities, establishing close collaboration between different project stakeholders, strengthening sense of responsibility, improving safety philosophy and managerial procedures, and reinforcing onsite safety management, etc. For feasibility, participants were asked to rate "1–5" Likert scales, with five as highly feasible and one as highly infeasible.

Finally, two leadership improvement measures were agreed on and further improved in the focus group meetings. The first measure is "fixed safety session in regular meetings" and the second is "regular onsite visits by senior leaders". Details of the two measures are provided in Section 3.4. The other four measures

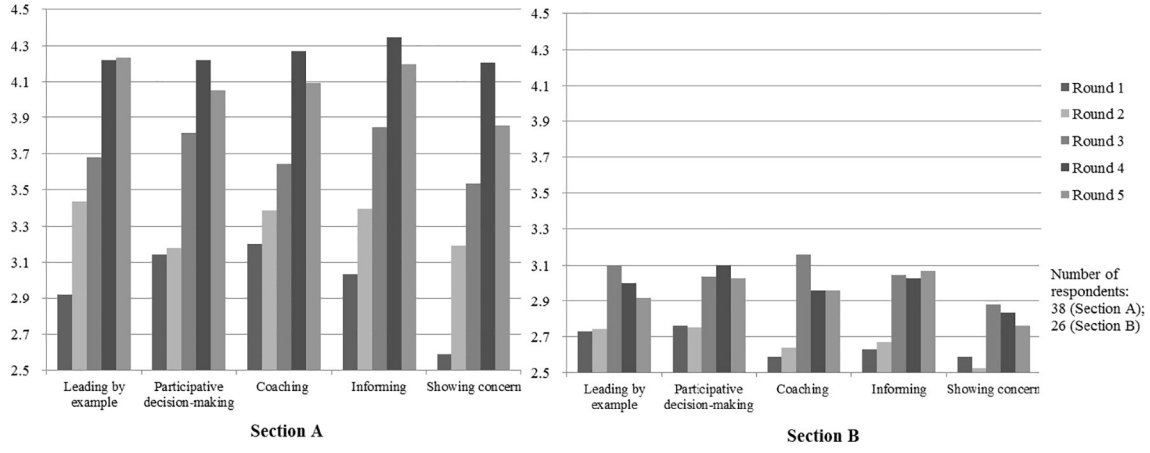

Fig. 4. Longitudinal measurement results of supervisor safety leadership by "1–5" Likert scales.

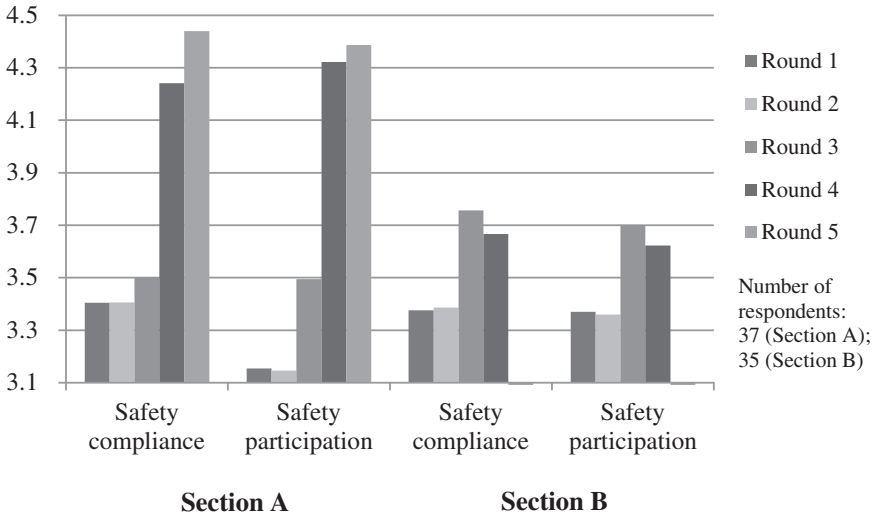

Fig. 5. Longitudinal measurement results of worker safety behavior by "1–5" Likert scales.

include (a) "safety luncheon party", i.e. building equal and open communication platforms between senior leaders and frontline employees; (b) "construction safety photo-taking competition" to encourage the voluntary identification of safety good practices/violations and the subsequent incentives/disincentives; (c) "safety short message distribution for informing, reminding and advising", in order to constantly convey safety management commitment down to the workplace; (d) "safety onsite meetings for the sharing of major violations and good practices", whereby new ideas and creative solutions are solicited from subordinates who address problems and find solutions. These four measures were not selected because they are not preferred by JJQ project managers. However, they were still considered effective and valid.

3.3.3.3. Phase 3: action taking. In the intervention period, the planned actions were implemented by the collaboration of researchers and practitioners to intervene safety leadership of related stakeholders. A written and official document was issued by the owner as the mandatory safety policy for all stakeholders, so as to fulfill its promise of promoting the implementation of AR.

During action taking, strict supervising and supporting measures were taken for leadership improvement actions. First, the three stakeholders, i.e. the owner, the contractor and the subcontractor, were required to incorporate the two actions into their project management system to become their formal safety regulations. Second, researchers visited the project management organization and the construction site constantly to monitor and improve the intervention strategies. Also, specific log table templates were designed for both actions, and practitioners were required to complete and submit the logs periodically. Log tables are the basic meeting minutes or activity records for leadership improvement measures, involves the time, venue, participants, procedures, topics and other important details. For example, for the fixed safety session, the log table include, but is not limited to, the introduction of the presider, the description of the requirements of safety management by the chief director in charge of safety, safety related achievement and major problems of all functional departments, and the conclusion of the presider. A kick-off and orientation meeting was held for the whole involved project staff at the beginning. Regular trainings were also provided for practitioners to guarantee substantial execution of the intervention. Last but not least, online communication network based on WeChat was built involving key AR participants. Following the above logs and spoken reflections, experiences and improvements were extracted for leadership intervention strategies. Real-time communication and interaction also enabled researchers to evaluate and modify action taking processes.

3.3.3.4. Phase 4: evaluating. The last three rounds of the five-round longitudinal evaluation were conducted to measure the possible changes in the JJQ project. As leadership improvement measures were developed based on SLMCP, the model can be validated from a pragmatic perspective. These measures can also be incorporated into the model to enhance its practical implications.

More specifically, the significance testing method was applied to validate the effectiveness of leadership improvement measures. Mean differences between safety leadership and other related constructs before and after AR were gauged with *t*-test analysis. Since the respondents are the same in different measurement rounds, the paired samples *t*-test approach was applied. The significance level was set as 0.05. If the *p*-value was lower than 0.05, a significant divergence existed; otherwise, a significant divergence did not exist. The *t*-tests were undertaken by the software Statistic Package for Social Science (SPSS) 18.0. Details of the testing results are shown in Section 4 "Longitudinal evaluation results".

3.3.3.5. Phase 5: specifying learning. While the phase of specifying learning is formally undertaken last, it is usually an ongoing process. At every AR phase, continuous reflection which leads to understanding takes place, which in turn leads to abstraction of new knowledge or experience. As mentioned earlier, actions were subject to continuous modifications based on researcher-practitioner interaction and constant reflections.

Reflections on one hand lead to better implementation of AR, and on the other hand result in new knowledge. The knowledge can be practical, and mainly contribute to the practitioners (whether AR is successful or not). It can also be scientific, which is gained through reflection on the success or failure of the actions taken. This provides important knowledge to the scientific community about the theoretical framework (Azhar et al., 2009), i.e. SLMCP in this study. Details of knowledge learned can be found in Section 5 "Discussion".

3.4. Safety leadership improvement measures

Two preferable safety leadership improvement measures were undertaken on JJQ project, i.e. fixed safety session in regular meetings and regular onsite visits by senior leaders. Based on SLMCP, the two measures take effects by the safety management path as well as safety culture path. Almost all safety leadership facets (Wu et al., 2016) were incorporated in these measures, but transformational leadership was emphasized, especially the facet of idealized influence and role modeling, or charismatic leadership. Charismatic leadership can be represented by a value-based emotional bond with followers. Charismatic leaders motivate followers to move beyond expectations and transcend their self-interests for the sake of a collective by implicating followers' self-concepts with the leader's values and goals (Bass, 1985; Conger and Kanungo, 1998; Chun et al., 2009).

3.4.1. Fixed safety session in regular meetings

The kernel of this action is that the first session of all project meetings (of all stakeholders) was fixed as occupational safety and health discussion. It is not the purpose of this action to increase the frequencies and types of the current project meetings, but rather to normalize and reinforce safety discussion and communication in existing meetings of various themes. Sharing the common beginning as safety session, meeting participants would be convinced again and again that safety should be firstly considered among all project management issues. The top leader should participate in and preside over the fixed safety session, and setting an example by role modeling and stressing the importance of safety. Therefore, it conveys strong management commitment to safety, and in turn reinforces the first priority of safety among all project objectives.

Participants and procedures were normalized and strictly controlled during AR. First, the presider, i.e. top leader of project management team, opened the session by introducing the detailed procedures and requirements of the session, with special emphasis on safety key points of the current construction activities. Second, the chief director in charge of safety elaborated the policies, ideas and requirements of construction safety management according to the recent schedule and activities. The director should summarize and review the past safety performance and declare incentives and disincentives. He should also set the performance improvement target in the next stage. Third, heads of all functional departments (including safety, schedule, investment, financial affairs, purchase, and contract/law) reported their achievement and major problems related to safety in the past as well as work plans in the next stage. In particular, they should each list at least one effective safety method (whether managerial or technical) and at least one safety problem (including managerial problem, onsite risks, hazards and incidents) in their reports. Content pertaining to working problem/question and method/experience could cultivate organizational learning and innovation. By setting this mandatory procedure in fixed safety session, leaders could motivate subordinates to be innovative and generate new ideas and solutions continuously. This special AR design is based on the leadership facet of safety motivation and coaching (Wu et al., 2016) and develops safety cognition in subordinates' minds both spiritually and intellectually by questioning assumptions, reframing problems and approaching old situations in new ways.

Last but not least, meetings with fixed safety sessions should also end up with safety issues. "Beginning with safety and ending with safety" is the fundamental requirement, which gradually shapes the whole staff's perception that safety is the most important collective mission and interest.

3.4.2. Regular onsite visits by senior leaders

Constant visibility onsite for safety inspection, instruction and humanistic concern for workers has proven to be very effective leadership behavior (Wu et al., 2015). Regular onsite visits by project senior leaders are theoretically based on the leadership facets of idealized influence, intellectual stimulation and individualized consideration. The on-going high accident frequencies in construction are to a great extent attributed to a misalignment of management commitment and subordinates' actions (Suraji et al., 2001; Arquillos et al., 2012; Sunindijo and Zou, 2012; Martin and Lewis, 2014). Safety remains a concept held by senior managers and is not fully disseminated to their subordinates, and management requirement cannot be fully implemented on construction sites. To address this problem, during AR, senior managers of the owner and the contractor keep their constant visibility on construction sites and communicate safety with supervisors and workers in amicable manners. Close interaction between leaders and subordinates can enhance safety management by shortening communication distance and leading by example.

Regular onsite visits are specified to safety issues and mandatory for all people fulfilling project leadership, including senior leaders, intermediate leaders and frontline leaders. Frequencies and durations are also stipulated for each visiting leader according to their position obligations. There are three main purposes/themes within this action. The first is *influencing and role modeling*, i.e. leaders disseminate safety policies, principles, strategies, attitudes and values to frontline personnel and cultivate their advanced safety behavioral norms and habits. It was assumed that by repeatedly thinking "how could I violate safety provisions and defy safety while my senior leaders are so concerned with our health and safety", frontline personnel would behave safely by themselves. The second is *training and organizational learning*, which means leaders promote onsite safety training by showing examples/cases pertaining to hazards and accidents. Now that the onsite personnel, especially workers, tend to have weak legal consciousness on health and safety, the direct education and enlightenment of senior leaders have significant effects on the formation of their safety compliance. By wide organizational learning, the project can develop new knowledge from those past hazards and accidents

which in turn have the potential to influence behaviors and improve the project managerial capabilities. During onsite visits, leaders are also suggested to hold regular onsite meetings to resolve safety hazards and accidents and share innovative managerial practices, so that safety knowledge can be distributed and communicated through the whole projects. The third theme is *respect and caring*. "Defend the health and safety of the staff" is the core principle set for JJQ project. Senior managers build close and equal relationships with the subordinates, hold their trust, maintain their faith and respect, and convince them that what the senior managers promote is closely bound up with their personal interests. They pay special attention to each individual's need for well-being, self-esteem and achievement by acting as a patriarch and mentor. Keeping constant visibility onsite is not only for inspection, but also to show senior leaders' humanistic concern, which in turn consolidates employees' determination for safety improvement and adherence to leaders' safety beliefs. Table 2 shows the communication approaches with different position targets of leaders during onsite visits.

4. Longitudinal evaluation results

Safety leadership and its relevant construct (especially worker safety behavior, the mostly used leading indicator of safety performance) were evaluated in details. Results of all five measurement rounds were analyzed to examine the effects of AR. Details of longitudinal evaluation results are shown as follows.

4.1. Implementation of safety leadership improvement measures

Before showing longitudinal questionnaire survey results, interviews and field observation results pertaining to whether leadership improvement measures were actually implemented and perceived by the project staff are firstly introduced. The major function of the interviews and field observations is to confirm that safety leadership changes were mainly attributed to the two leadership improvement measures. In other words, if the interviews and observations did not find that the leadership improvement measures were implemented or the project staff did not perceive the implementation, the possible leadership changes (if any) may be due to other factors which are irrelevant to the action research.

Significant differences were observed between the two sections. For example, most informants in Section A responded that safety is given higher priority in their participating meetings, and that health and safety of frontline managers and workers are firstly discussed in most formal and informal communications. Similarly, Section A frontline employees being investigated stated that they see and meet senior leaders of owners and contractors more often in their workplace than before, and if being visited, they feel respect, concern and clear instructive suggestions. In contrast, informants in Section B showed no significant changes pertaining to all of the above questions/themes. It infers that leadership improvement measures have been substantially implemented in Section A, and crucial personnel have perceived them.

4.2. Owner safety leadership

The five-round measurement results and *t*-test results of owner safety leadership are shown in Fig. 2 and Table 3, respectively. The four leadership facets were gauged separately. It shows that owner safety leadership has been improved significantly since AR was implemented on JJQ project. The third-round measurement had already shown a certain degree of score increases although it was undertaken only three months after AR began. In the fourth round, owner safety leadership has been upgraded substantially as AR was

Table 2
Communication approaches in regular onsite visits by senior leaders.

Target positions	Themes of inquiries	Key communication points	Examples of inquiry ways	Solutions to identified problems
Frontline managers from contractors (i.e. onsite safety officer, quality officer, technician, etc.)	Inspect possible delays, attenuations or deviations during safety information dissemination	1. True safety attitudes and understanding levels of frontline managers 2. Difficulties and concerns in meeting top-down safety requirements	1. What is your attitude towards the recent project safety policies and instructions? 2. Is there any difficulty in transmitting safety requirements down to subcontractors?	1. Identify and improve managerial links pertaining to information delays and attenuations 2. Enhance onsite feasibility of top-down safety requirements and instructions
Frontline supervisors from subcontractors	1. Understand safety awareness and details of safety actions 2. Determine whether supporting systems should be augmented for supervisors	1. Supervisors' evaluation for the operability of frontline safety management 2. Subcontractor's resources needs	How do you prevent or solve safety problems in your working groups? Is there any help or support we could provide?	1. Re-analyze feasibility of safety instructions considering subcontractor's concerns 2. Continuously improve project safety management by assimilating onsite experiences
Frontline workers from subcontractors	1. Promote workers' safety awareness and cultivate favorable group safety climate 2. Conduct safety caring and individual respect of project senior leaders	1. Safety priorities of workers 2. Fundamental reasons of workers' safety neglect and violations (if any)	1. Are there any nonconformities, near-misses or incidents in your group? 2. Did you predict possible consequences when you experienced safety accidents?	1. Reinforce humanistic concerns and expanding safety information's transmitting channels to workers 2. Transfer rebuking and scolding to caring and mentoring when managing workers

Table 3
t-Test results for owner safety leadership before and after AR.

Leadership facets	Standard deviation	*t*	*p*-Value	Mean difference
Safety influence and role modeling [a]	0.983	−5.413	0.000	−0.863
Safety motivation and coaching [a]	0.911	−4.514	0.001	−0.667
Safety caring and individual respect [a]	0.959	−4.905	0.000	−0.763
Safety controlling and performance management [a]	0.811	−4.699	0.000	−0.618

Notes: the significance level is 0.05; *p*-values are gauged in a two-tailed manner; mean differences are computed by comparing scores in baseline period and follow-up period, i.e. follow-up-period scores minus baseline-period scores.
[a] Leadership facets that have been significantly improved by AR.

implemented deeply. In the fifth round, in spite of the expiry of AR, safety leadership still showed a significantly higher level than the first two rounds, indicating that AR effects are sustained within the case study; that is, leadership improvement measures take noteworthy effects on the JJQ project, and owner safety leadership is intervened and enhanced in a sustainable manner.

Moreover, the numerical differences between baseline period and follow-up period were computed in the leadership indicator level (refer to Wu et al., 2016 for detailed indicator system of safety leadership in construction). It is found that most significant improvements exist on five indicators, including "make subordinates feel proud of their work and confident about safety improvement", "talk about their safety values to subordinates frequently", "always take major responsibilities when safety problems arise", "actively care about subordinates' everyday life and try to satisfy their need for safety and well-being", and "are confident of subordinates' safety competence and provide sufficient resources for them". The first three indicators belong to the facet of safety influence and role modeling, and the other two belong to safety caring and individual respect. This indicates that driven by AR, owner leaders build up high charisma and morality levels, regard safety as self-ideal causes to which both they and subordinates dedicate themselves, reinforce safety's highest priority within all project stakeholders, and guarantee this priority by providing sufficient individual respect and humanistic concern.

4.3. Contractor safety leadership

The five-round measurement and *t*-test results of contractor safety leadership are shown in Fig. 3 and Table 4, respectively. Both Section A and Section B were assessed to make the comparative analysis on the intervention effect of AR. The results showed that safety leadership of the contractor in charge of Section A has been improved significantly since AR was implemented on JJQ project, and the intervention effect was also sustained till the fifth-round measurement, within the scope of this study. However, in Section B, no significant and continuous improvement was discovered. By contrast, erratic fluctuations occurred between different measurement rounds. *t*-Test results in Table 4 also validate that significant differences exist between contractor safety leadership measurement before and after AR in Section A, because *p*-values for all leadership facets are lower than 0.05 and the average mean difference is −0.45, which is significantly higher than the value of −0.14 in Section B (see Table 4). This comparative study reveals that contractor safety leadership is intervened and enhanced in a sustainable manner. Improvement of contractor safety leadership is on one hand attributed to the direct effect of AR, and on the other hand influenced by the improvement of owner safety leadership (refer to SLMCP illustrated by Fig. 1).

Likewise, variations before and after AR were examined on the contractor leadership indicator level. It is discovered that the most significant improvements occur in five indicators, including "never sacrifice safety to meet other needs and requirements", "talk about safety visions clearly and enthusiastically", "seek different viewpoints and perspectives on safety to avoid arbitrary decisions", "facilitate safety coaching and learning all through the project", and "deal with near-misses and safety unconformities proactively and thoroughly". The first one belongs to the facet of safety influence and role modeling, the last one belongs to safety controlling and performance management, and the other three belong to safety motivation and coaching. Compared with the owner, contractor's safety motivation and coaching was improved to a larger extent. This is probably because the contractor is closer to the frontline construction site in safety management chain. They have more frequent contacts with frontline personnel and exchange safety viewpoints, perspectives and procedures with them more deeply. In particular, they can facilitate safety

Table 4
t-Test results for contractor safety leadership before and after AR.

Sections	Leadership facets	Standard deviation	*t*	*p*-Value	Mean difference
Section A	Safety influence and role modeling [a]	1.108	−2.322	0.026	−0.418
	Safety motivation and coaching [a]	0.999	−2.209	0.033	−0.358
	Safety caring and individual respect [a]	1.030	−2.886	0.007	−0.479
	Safety controlling and performance management [a]	0.954	−3.563	0.001	−0.551
Section B	Safety influence and role modeling	0.716	−1.423	0.162	−0.157
	Safety motivation and coaching	0.683	−0.723	0.474	−0.076
	Safety caring and individual respect	0.741	−1.041	0.304	−0.119
	Safety controlling and performance management	0.614	−2.261	0.069	−0.214

Notes: the significance level is 0.05; *p*-values are gauged in a two-tailed manner; mean differences are computed by comparing scores in baseline period and follow-up period, i.e. follow-up-period scores minus baseline-period scores.
[a] Leadership facets that have been significantly improved by AR.

coaching and learning by encouraging/requiring employees to participate in various safety promotion activities. They can also reinforce safety controlling by adding mandatory managerial measures or strengthening safety inspections. These findings reflect contractors' role and obligation as project intermediate leaders, who are different from owners as project senior leaders.

4.4. Supervisor safety leadership

The five-round measurement and *t*-test results of supervisor safety leadership are shown in Fig. 4 and Table 5, respectively. As the frontline operational-layer project leader, supervisors' leadership change reflects the real quality and depth of leadership intervention actions. Both Section A and Section B were assessed to make the comparative analysis on the intervention effect of AR. It shows that safety leadership of supervisors in Section A has been improved significantly since AR was implemented on JJQ project, and the intervention effect endured till the fifth-round measurement. However, in Section B, no significant and enduring improvement was discovered. In contrast, erratic fluctuations occurred between different measurement rounds. *t*-Test results shown in Table 5 also validated that significant differences exist between supervisor safety leadership measurement before and after AR in Section A. As Table 5 shows, *p*-values for all leadership facets in Section A were lower than 0.05 and the average of their mean differences is −1.03, which is significantly higher than the value of −0.10 in Section B. This comparative study reveals that supervisor safety leadership is intervened and enhanced in a sustainable manner in the case project.

According to the mean differences in Table 5, leadership facets which were improved most significantly are participative decision-making and informing, both of which follow typical transformational leadership style. The analysis in the leadership indicator level also confirms this finding, i.e. the top five indicators which were improved significantly all belong to transformational leadership facets, including showing concern/interacting with the team and the above mentioned two facets. Influenced by AR, especially the consolidation of safety as the first priority and senior leaders' mentoring and caring, JJQ supervisors in Section A go beyond transactional contingent reinforcement and fulfill transformational leadership behavior when interacting with workers. They would proactively think about safety improvement ideas, keep close interactions with workers and informing them of important top-down information concerning their health and safety. This transformation in leadership styles of supervisors would directly impact workers' safety attitudes and awareness, and in turn reinforce their behavioral safety. The next subsection would reveal whether worker safety behavior has also been enhanced by leadership improvement measures.

4.5. Worker safety behavior

The longitudinal evaluation for worker safety behavior focused on two major facets, safety compliance and safety participation. Safety compliance refers to behaviors about engaging in core and fundamental safety tasks, such as compliance with safety rules and regulations, and following safety procedures (Griffin and Neal, 2000). Safety participation means employees' voluntary participation in safety activities, which aims to contribute to the development of a supportive safety environment. Examples include voluntary participation in safety meetings, raising safety concerns and promoting safety programs in the project (Cree and Kelloway, 1997; Mullen, 2005; Griffin and Hu, 2013). It is evident and has been validated (Griffin and Hu, 2013) that safety compliance is influenced by both transformational and transactional leadership, but safety participation tends to be established by transformational leadership fulfillment.

Fig. 5 and Table 6 show the five-round measurement and *t*-test results of worker safety behavior. Both Section A and Section B were assessed to make comparative analysis on the intervention effect. Very significant improvement of the safety behavior scores was found in both two facets of workers in Section A. The intervention effect emerged in the third round, was prominent in the fourth round, and endured till the fifth-round measurement. However, in Section B, no significant and enduring improvement was discovered. *t*-Test results shown in Table 6 also validated that significant differences existed between worker safety behavior measurement before and after AR in Section A. As Table 6 shows, *p*-values for both behavior facets in Section A are lower than 0.05 and the average mean difference is −1.42, which is significantly higher than the value of −0.32 in Section B. This comparative study reveals that worker safety behavior is intervened and

Table 5
t-Test results for supervisor safety leadership before and after AR.

Sections	Leadership facets	Standard deviation	*t*	*p*-Value	Mean difference
Section A	Leading by example[a]	0.764	−5.575	0.000	−0.880
	Participative decision-making*[a]	0.782	−8.102	0.000	−1.267
	Coaching[a]	0.871	−5.625	0.000	−0.980
	Informing[a]	0.781	−6.725	0.000	−1.050
	Showing concern[a]	0.900	−5.406	0.000	−0.973
Section B	Leading by example	0.648	−1.315	0.203	−0.181
	Participative decision-making	0.759	0.094	0.926	0.015
	Coaching	0.620	−1.117	0.277	−0.147
	Informing	0.822	−1.167	0.256	−0.204
	Showing concern	0.953	0.149	0.883	0.030

Notes: the significance level is 0.05; *p*-values are gauged in a two-tailed manner; mean differences are computed by comparing scores in baseline period and follow-up period, i.e. follow-up-period scores minus baseline-period scores.

[a] Leadership facets that have been significantly improved by AR.

Table 6
t-Test results for worker safety behavior before and after AR.

Sections	Behavior facets	Standard deviation	*t*	*p*-Value	Mean difference
Section A	Safety compliance[a]	0.799	−8.570	0.000	−1.318
	Safety participation[a]	1.032	−7.630	0.000	−1.516
Section B	Safety compliance	0.917	1.410	0.172	−0.270
	Safety participation	0.887	1.959	0.063	−0.362

Notes: the significance level is 0.05; *p*-values are gauged in a two-tailed manner; mean differences are computed by comparing scores in baseline period and follow-up period, i.e. follow-up-period scores minus baseline-period scores.
[a] Behavior facets that have been significantly improved by AR.

enhanced in a sustainable manner. As safety behavior is a most widely used leading indicator for safety performance, it can be concluded that safety performance was substantially enhanced by safety leadership improvement measures implemented within AR.

Moreover, it is easily observed that in Section A, safety participation is improved to a larger extent than safety compliance. Based on the interpretation above, it proved again that transformational leadership takes more significant effects. That is another evidence of the deep implementation and influence of AR.

5. Discussion

5.1. Findings and implications

This study developed a conceptual SLMCP model, and applied AR method to validate the theoretical model empirically and developed practical measures to implement safety leadership in construction projects. Longitudinal measurement in a case project showed significant intervention effects of the leadership improvement measures that were developed based on SLMCP. Major findings and implications are summarized and discussed as follows.

Safety management and safety culture are the two major channels (i.e. mediators) through which leadership influences safety performance. The leader-follower distance in construction projects is much longer than that in traditional organizations (Antonakis and Atwater, 2002; Fang and Wu, 2013), so the sufficient effect-taking of distant leadership (for example, the owner's influence on frontline supervisors and workers) should depend on sound safety management systems and mature safety culture. Safety management and safety culture paths are involved in the AR implementation, and have been confirmed to be effective if they are jointly implemented on construction projects. For example, the introduction of fixed safety sessions into regular meetings can be regarded as the modification of safety management, and on the other hand drives the maturity of project safety culture by strengthening the top priority of safety. During fixed safety sessions, dynamic interactions between project stakeholders were enhanced, leading to better safety attitudes, values and supportive environments (which are all safety culture facets). By regular onsite safety visits, senior leaders shorten the power distance and enhance safety leadership of frontline managers directly, which belongs to the safety management path. Constant visibility and leading by example also facilitate disseminating favorable safety values, perceptions and behavioral norms, which prompts project safety culture development. Although a number of prior studies have analyzed safety culture and safety management simultaneously (Mearns et al., 2003), or linked safety leadership and safety performance with the mediation of safety culture or safety management (Zohar, 2002; Karanikas, 2017), they rarely put leadership, culture, management and performance together to depict a more complete impacting mechanism. Thus, one major theoretical implication of this study is that more comprehensive perspectives have been enlightened to interpret the leading factors of safety performance as well as their interacting relationships.

The multiple levels-of-management perspective is another major feature of SLMCP and the action research. Distant leadership is very popular within construction projects because of the special relationship between main stakeholders. Although contractual parties between different stakeholders are equal, there exists a cascading top-down fulfillment manner of leadership in order for the safety management chain to operate efficiently. Within construction projects, owners can influence contractors, and contractors can in turn influence subcontractors whose supervisors impact worker safety behavior directly and thus transform leadership into safety performance. Nevertheless, leader-follower distance is not unchangeable; but rather, a distant and peculiar leader can become a close and amiable leader under special conditions. The AR case study reveals that the hierarchical structure of project management does not necessarily hinder the effectiveness of safety leadership. Leadership can be fulfilled in a distant and relayed manner, and also in a close and direct way, which mostly depends on leaders' intentions and freedom.

Based on Wu et al. (2016) theoretical development, this study continues to interpret how leadership works among project stakeholders and along different management layers. The process and mechanism by which leadership impacts safety performance can also clearly depict how the upper-level leadership influences lower-level ones, and the lower-level leadership influences worker safety behavior. That is also the kernel implication of SLMCP (i.e. what the short and horizontal arrow lines (in blue color) in Fig. 1 depict).

In reality, leadership improvement actions are feasible and reasonable measures for safety accident prevention. Most leadership improvement actions can be implemented from the top down. It should be noted that the effectiveness of these actions is not only determined by the improvement of upper-level leadership, but also the frontline leadership, such as supervisor leadership. With inferior congenital traits and acquired skills, supervisors cannot improve leadership all by themselves. They mostly depend on the continuous influence of owner and contractor leadership. For example, if a leadership improvement measure only contains the

requirement of putting safety as the first priority, but lacks specific ways to disseminate this philosophy down to the working groups (this circumstance is very popular in current practices), this measure cannot have significant intervention effects. Thus, the cascading fulfilling feasibility and penetrating capacity need to be guaranteed when promoting leadership change actions.

That being the case, it is also critical to recognize the importance of building positive images of senior project leaders (DeChurch et al., 2010). Because the information processing of distant organizational members is based on a peripheral route, and hence followers' attitudes towards the distant leader may be susceptible to change, distant followers tend to be vulnerable to symbolic impression management (Chun et al., 2009). The charisma, authority and positive images of owner managers as the senior project leaders are especially pivotal and tend to determine the overall level of safety leadership and safety performance of the project.

Safety influence and role modeling is proven to be the paramount facet of project leaders as they have the most significant impact on other stakeholders. Charisma or idealized influence is the core and fundamental attribute of this facet, and also the overall leadership. Past research and AR reported by this paper prove that followers' identification with leaders, internalization of leaders' safety values and education of leaders' safety skills are readily applicable to charismatic safety leadership fulfillment (Chun et al., 2009). More notably, both identification and internalization depend on leader's initial actions and constant reinforcement. The top-down working manner of SLMCP reminds the owner and contractor that they cannot purely expect the self-directed activities of frontline personnel and spontaneous project safety culture maturity, but activate themselves in safety participation.

Compared with transactional leadership, transformational leadership's influence is more significant and profound. Both transformational and transactional leadership are embodied in AR measures, but the improvement of transformational leadership in all measured levels is larger than transactional leadership, and the improvement of safety participation of workers is more significant than safety compliance. Based on the argument of Wu et al. (2016) that each leadership dimension of lower-level personnel is influenced by its homogenous leadership dimension of upper-level personnel, the role of transformational leadership should be highlighted.

The two implemented leadership improvement measures embodied the prominent leadership facets and behaviors in construction projects, as well as the typical cases of safety culture and safety management impacting paths. The core content of fixed safety sessions in regular meetings includes three aspects. First, the first priority of safety is established and maintained. Second, frequent and deep safety communication covers all project stakeholders. Third, safety innovation and cultural development are promoted continuously. Regular onsite visits by senior leaders, similarly, also represent typical leadership practices and impacting paths. Its three overarching themes include influence and role modeling, training and organizational learning, and respect and caring, i.e. almost all safety leadership facets other than traditional managerial measures. In influence and role modeling, frontline personnel's awareness of senior leaders' constant visibility would in itself serve as a prompt and encouragement of safety excellence. Even without more complicated and concrete activities, safety leadership and behavior of frontline members can be improved. This is also one of the major empirical findings from AR implementation.

However, it should also be noted that project senior leaders cannot realize the all-time controlling of the frontline site only by themselves. Because of this, and that leader-follower distance in construction projects is much longer than that in traditional organizations, another essence of project leadership (especially senior-level one) is to understand the influence processes of cascading leadership and develop close followers' full potential to serve as their surrogates (Waldman and Yammarino, 1999; Chun et al., 2009). As mentioned above, there are several areas a distant charismatic leader can manage simultaneously, i.e. personal identification, value internalization and skill education. Owners' managers have to build personalized relationships with contractors' managers who are both intermediate followers and intermediate leaders. Contractors' managers can on one hand behave on their own, and on the other hand be molded into owners' surrogates when interacting with frontline members.

Last but not least, this paper also contributes to project management practices by providing a general methodology/procedure for leadership improvement practices within the project setting, as shown in Section 3.3. It involves several necessary steps such as problem diagnosing, action planning and prioritization, action taking and supervision, evaluating in both intervention phase and follow-up phase, and specifying learning/action improvement (if necessary). As mentioned above, close researcher-practitioner collaboration is needed throughout the procedure, and it is the major characteristic that distinguishes AR from ordinary intervention studies.

5.2. Limitations and future research directions

Limitations in both model development and AR implementation should be acknowledged. For the theoretical model, several issues need further research. For example, is there any interaction between safety management path and safety culture path? Is the upper-level safety leadership influenced by the lower-level one (i.e. the bottom-up effect)? In particular, considering the real condition in construction projects, this paper tends to consider supervisors as the major leadership fulfilling role. Nevertheless, how do senior managers of the subcontractor influence supervisor safety leadership and worker safety behavior?

For AR, the first limitation is that only two actions were implemented because of the restriction of research resources and practitioners' preference. The other four measures initially designed by this study (see Section 3.3.2) can be implemented in the future to expand the practical implication of SLMCP. Moreover, if conditions permits, leadership improvement measure should be undertaken separately, i.e. each measure is treated as a stand-alone intervention, in order to validate its effectiveness more robustly by excluding the interference of other measures.

The second limitation of AR lies in the time length. In order to validate the intervention effect and its sustainability more

robustly, the current 16 months' length can be further extended depending on the project duration. Thirdly, the AR was in Chinese cultural setting which tend to be with high power distance and low individualism, and the intervention was carried out in a hierarchical top-down manner. One major future direction for this study is to analyze and implement safety leadership improvement in organizations with lower power distance and higher individualism. Last but not least, safety performance was evaluated by worker safety behavior in this study. If conditions permit, it would be more interesting and persuasive to measure safety performance by occupational deaths and injuries, and analyze the effects of AR on deaths and injuries of employees.

6. Conclusion

It is common that safety performance differs greatly among projects, even with the same or similar management systems. One of the crucial reasons is the leadership differences among project management teams, which accounts for the importance of leadership for project workplace safety. In order to probe into the mechanism by which leadership improves project safety performance, this study developed the conceptual model of safety leadership in construction projects (i.e. SLMCP) in both theoretical and pragmatic perspectives. Theoretically, this model incorporates specific characteristics of the construction projects, re-conceptualizes the existing safety leadership studies and applies a multiple levels-of-analysis perspective to depict leadership influences across project stakeholders. Pragmatically, an action research method was used to validate the theoretical model, practical measures were designed out to fulfill safety leadership, and thus safety performance was improved. This case-based model development substantially extends the model by adding effective and valid leadership improvement actions.

This paper contributes to the current research in both theoretical and practical ways. Theoretically, past research did not consider the multiple level attributes and distant leadership fulfillment, and generally focused on the supervisory single-level leadership in construction projects. Thus, the cascading leadership impact as well as its mediators/impacting paths cannot be illustrated. This paper depicted these key issues theoretically and empirically by proposing SLMCP and elaborated the relationship between project stakeholders' safety leadership and safety performance clearly, which serves as a more comprehensive framework for future safety leadership research and practice. Practically, past research did not answer the key question that what the construction practitioners should do to improve safety leadership, and in turn safety performance. This paper offers concrete and validated measures for leadership improvement. The AR based longitudinal intervention also serves as general procedures for leadership improvement practices. As safety leadership contains individualized consideration, inspirational motivation, innovative changes and meeting employees' emotional appeal, which cannot be explained by traditional safety management, conclusions of the paper can provide novel ideas and methods for workplace safety improvement in construction projects.

Conflict of interest

The authors declare that there are no conflicts of interest.

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