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Choosing Suitable Project Control Modes to Improve the Knowledge Integration under Different Uncertainties

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Abstract

This paper examines how to design project control modes to improve knowledge integration under different types of uncertainty. Uncertainty can be the precondition of project control choice, and it gives rise to the differing relations between project control (behavior, outcome, clan and self) and knowledge integration. We have conducted a multiple case study from the engineering, software, machinery and infrastructure industries, and examined the project controls design effectively dealing with high uncertainties. On the basis of control theory and knowledge-based theory, this article compares project control modes impact from the three knowledge integration dimensions of efficiency, scope and flexibility. Findings suggest that behavior control improves knowledge integration efficiency under uncertainty related to computational complexity, self-control improves knowledge integration efficiency under uncertainty related to project novelty, clan control enhances knowledge integration flexibility under uncertainty related to ambiguity of user requirements, outcome control enhances knowledge integration scope under uncertainty related to technological complexity. These findings are integrated into a model of the choice of project controls. Implications of these results are drawn, and directions for future research are suggested.

Keywords: Project control, Project uncertainty, Knowledge integration, Case study

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1. Introduction

The project acts as "a temporary organization to which resources are assigned to undertake a unique, novel and transient endeavor managing the inherent uncertainty and need for integration to deliver beneficial objectives of change" (Turner and Müller, 2003). It brings together individuals who are specialized in different functional areas and requires the application of a wide range of differentiated knowledge that must be integrated effectively to create a unique product or service (Pimenta et al., 2016). As such, the ability to achieve effective knowledge integration is increasingly a key issue, and a diverse mix of knowledge within a project team is investigated to produce positive effects on a firm's long term success (Canonico et al., 2012). Thus, the knowledge integration perspective can be a valuable research direction to examine the project phenomenon (Lech, 2014).

One of the relevant roles of managerial control has been considered to coordinate activities by integrating different sources of knowledge expertise instead of simply to supply information to deal with uncertainty (Ditillo, 2004). Both project plans, budgets, and follow-up reports applied to formal control, and common vision, interaction and trust between subjects encompassed in personnel control, reflect the integration of the participants' work and perceptions. Control has been widely studied in manufacturing settings and in new product development (Chenhall, 2003; Abernethy and Brownell, 1997; Davila, 2016). However, its contributions linked to knowledge integration within project contexts of different industries are lacking. Although managerial control functioning as knowledge integration devices has been recognized (Turne and Makhija, 2006), it is not clear how different control modes perform in terms of the multidimensional effects of knowledge integration. Furthermore, managerial control modes have not been explicitly addressed in contexts that are relatively extreme in terms of project uncertainty (Ouchi, 1979). Prior research on control has examined the specific control modes (e.g., behavior, outcome, clan controls or self-control) used during a project, which usually include a "controller" (the person exercising control) and a "controllee" (the target of control) (Kirsch, 1996; 2002). The dynamics of control have been

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explored, and a portfolio of control strategies has been suggested during the lifecycle of a project, considering the factors influencing the choice of control modes (Kirsch, 1997; 2004). However, research on task characteristics and project contexts is still sparse, and the impact of uncertainty has been almost completely neglected. Therefore, it is important to examine the likely influences of the types of uncertainty on the use of different control modes.

As uncertainty is a general feature of projects, scholars have identified the main sources of uncertainty in projects (Sanderson, 2012; Sakka et al., 2016; Saunders et al., 2016). It is defined as the difference between the data required and the data already possessed (Galbraith, 1973). Uncertainty usually appears as an obstacle or even as a threat to successful project management that should be mitigated as much as possible, which leads to the fact that project organizations become less flexible, unable to accumulate knowledge necessary for coping with uncertainty and responding to different situations. Nevertheless, a new theme has recently become increasingly attractive in research (Huemann and Martinsuo, 2016), suggesting the consideration of positive potentials of uncertainty in projects that are "proactive toward their environments rather than reactive to them" (Böhle et al., 2016). It calls for not only a reliance on plan-oriented methods (Sanderson, 2012) but also experienced-based work action in projects can be considered an important strategy to deal with uncertainty (Huemann and Martinsuo, 2016), emphasizing the need for greater flexibility and reflection as a new way of generating knowledge and functioning (Böhle et al., 2016). It places challenges in dealing with uncertainty, from elimination to utilization. Several research approaches have emerged that focus on the ability of humans to accept unplanned changes and to have sufficient freedom to obtain goals and solve problems (Kalkman and Dewaard, 2017).

The aim of this paper is to explore how knowledge integration could be enhanced under different uncertainty circumstances. By adapting controlling mechanisms to different types of uncertainty, how do project controls play a role in knowledge integration? Thus, the specific research question addressed in this paper is as follows:

RQ: How could knowledge integration be improved by choosing suitable control modes under *different kinds of project uncertainty?*

The unit of analysis is the interaction between project uncertainty, project controlling process, and knowledge integration. The study takes the ontological stance of critical realism, thereby aiming for explaining the phenomenon, but not claiming that this explanation is the only possible one (Bhaskar, 2016). To address this question, four case studies from engineering, software, machinery and infrastructure for cross-section comparison with 48 interviews were conducted in China, and the data were analyzed using an abductive approach, following Miles et al. (2014). Since user groups and senior managers are important stakeholders in projects, that is, both have much to lose if the effort fails, this study focuses on ways in which both exercise various modes of control. Thus, the client representative (the sponsor or project owner, the key person responsible for providing the user's perspective), and the executing organization (who form the project steering committee or group) are considered controllers. This study designates the project team as the controllees of interest, including the project manager.

Academics benefit from the study results through the contribution of setting theoretical connections between project uncertainty, project control modes and knowledge integration by articulating the dimensions of project uncertainty. Moreover, it is proposed that the framework of the project controls design considering the industries, which are characterized by typical uncertainty. Practitioners will benefit from this study through the insights provided into senior managers' adoption of suitable control modes for different kinds of project uncertainty. As different control mode shows different advantages in knowledge integration, practitioners can improve the knowledge integration ability of the project team, provide better deliverables embedded with structural knowledge, and sufficiently explore the value of the project for future developments.

In the next section of this paper, background literature is reviewed. Later sections outline the research methodology, case analysis and discussion, and then the conclusions.

2. Literature review

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2.1 Knowledge integration

Kogut and Zande (1992) expound the essence of an organization from the knowledge-based perspective and hold that the existence of an organization is to promote the transfer and sharing of knowledge by individuals or teams to generate new knowledge. Knowledge integration means integrating the specialized knowledge of multiple individuals, including both "explicit" and "tacit" knowledge, and facilitating knowledge creation (Grant, 1996a; 1996b). Recent conceptualizations define knowledge integration widely "as a process of collaborative and purposeful combination of complementary knowledge, underpinned by specific and focused personal, team and organizational capabilities" (Bergek et al., 2011).

Project teams bring together people from two or more discrete areas of organizational function to undertake tasks in a temporary effort (PMBOK, 2017). Therefore, a project team composed of individuals from multiple functional units with the necessary professional knowledge and skills needs to integrate multiple sources of knowledge about technologies and business processes to achieve the project objectives (Lech, 2014). The challenge for a cross-functional project team is to access the breadth and depth of functional knowledge and integrate the knowledge (Clark and Fujimoto, 1992).

Grant (1996a) conclude that there are three characteristics of knowledge integration associated with the creation and sustenance of competitive advantage under dynamic market conditions. They are, respectively, the efficiency of integration, the scope of integration and the flexibility of integration. The efficiency of integration refers to utilizing the knowledge stored within individual organizational members and is dependent on the capability to access and harness the specialist knowledge of its members. The scope of integration refers to the breadth of specialized knowledge drawn upon by the organizational capability, and different types of specialized knowledge are complements rather than substitutes in production. The flexibility of integration refers to the ease with which a capability can be extended to encompass additional types of knowledge and reconfigure existing knowledge. Generally, the wider the scope of knowledge being integrated, the

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lower is the level of common knowledge, and the more inefficient is the communication and integration of knowledge. Achieving flexible integration, either through continually integrating new tacit knowledge or through constantly reconfiguring existing knowledge, is likely to impose substantial costs in terms of reducing the efficiency of knowledge integration (Grant, 1996a; De Boer, et al., 2010).

Control modes have inherent information processing properties (Egelhoff, 1991; Ouchi, 1979; Tushman and Nadler, 1978). Some researchers have concluded that control modes function as knowledge integration devices for two particular features. First, control modes influence how information is shared and knowledge is disseminated within organizations, whether the mechanisms encompass routines, coordination, organizational norms, or structured relationships between individuals or groups (Turne and Makhija, 2006; Gibson and Earley, 2007); second, controls create incentives and disincentives for team members that are consistent with project goals and objectives. Since meeting goals and objectives requires the use of knowledge by team members, the purposeful structuring control in turn directs the type of knowledge integration behavior exhibited (Turne and Makhija, 2006). Control mode has been considered as a managerial intervention that determines the ways in which knowledge integration is achieved in exploitative project teams (Canonico et al., 2012). Formal organizational process and technical accomplishment specifically planned have been thought to facilitate knowledge integration (Gibson and Earley, 2007), and they are essential in complex environments (Ning, 2017). Structured team communication and personal active participation in team discussions increase coordination by integrating different sources of knowledge expertise in conditions of high uncertainty and high complexity (Canonico et al., 2012； Ditillo, 2004).

2.2 Managerial control modes

From the organizational literature, four modes of managerial control (behavior, outcome, clan and self) are identified (Kirsch et al., 2002; Kirsch, 2004; Kirsch et al., 2010). Due to the fundamental changes in the work environment of organizations, the emergence of team-based organizing and

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cross-functional organizing become a trend. The relationship between the control defined as "a regulatory process by which the elements of a system are made more predictable through the establishment of standards in the pursuit of some desired objective or state" (Leifer and Mills, 1996) and trust as "the confidence in another's will, or faith in a partner's moral integrity" (Schoorman et al., 1995) is established in the temporary project context, and the interplay between control dynamics and trust dynamics has been brought up for debate (Kalkman and Dewaard, 2017). Self-control has been considered highest in system development projects when the project leaders have considerable job experience and are able to further refine existing development procedures (Kirsch and Cummings, 1996). In addition, the controllers of some relatively complex projects with diverse stakeholders enact a control portfolio of formal and informal controls throughout the project lifecycle according to the task characteristics, role expectations and project-related knowledge (Soh, et al., 2011; Choudhury and Sabherwal, 2003; Kirsch, 1997). Therefore, managerial control is defined broadly herein as an attempt to ensure individuals working on organizational projects act in a manner that is consistent with achieving the desired objectives (Jaworski, 1988; Kirsch, 1996; Kirsch, 1997; Merchant, 1988; Tiwana and Keil, 2010), mechanisms including an agreed-upon strategy, socialization through which each group members effectively function as both controller and controllee, as well as self-assessment. We also follow the division of control mode by control theory: formal and informal (Jaworski, 1988; Ouchi, 1979).

Formal control is viewed as a performance evaluation strategy. It comprises behavior control and outcome control (Eisenhardt, 1985). In behavior control, the controller focuses on the process leading to goal achievement. Rules and procedures used to achieve desired goals are prepared in detail, such as contracts and a series of process documents, which define appropriate steps. The controller monitors the controllee's behaviors and exercises the reward based on the degree to which desired procedures are met (Kirsch, 1996; Kirsch, 2004). To implement outcome control, the controller focuses on project outcomes (both interim and final) (Choudhury and Sabherwal, 2003); it is a way to evaluate how targets and goals are achieved. Desired outcomes, including milestones,

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indexes, functional specification and budget, among others, are formally specified, and controllees are allowed to decide how to meet these output targets. Controllees are rewarded or sanctioned for meeting or missing the prespecified outcomes accordingly.

Informal control differs from formal control in that it is based on social or people strategies (Eisenhardt, 1985; Jaworski, 1988). Informal control is a "soft" form of control. It comprises clan control and self-control. A clan is described as any group of individuals who have common goals and who are dependent on one another. Ouchi's conceptualization of clan control indicates that shared norms, values, and vision will guide and influence behaviors. To implement clan control, the organizational group cultivates common values, philosophy, and approaches to problem solving within the clan, and individuals are rewarded for acting in accordance with the group's values. Clan control is viewed in terms of input mechanisms, such as selection and diversity (Kirsch et al., 2010). Careful selection of team members, training and socialization help propagate these common values and beliefs, resulting in individuals with a strong sense of identity with and commitment to the group. Self-control is the study of how and when individuals in organizations control their own actions, a concept that is consistent with the definition of self-management (Erez and Kanfer, 1983; Manz et al., 1987). Behavior that is motivated by self-set goals, self-monitoring, and self-rewarding is an indication that self-control is operating. Individuals with self-control are intrinsically motivated to achieve their objectives (Manz and Angle, 1986), select tasks and ways of working appropriate for the goal, and require feedback to inform them about their performance (Ashford and Cummings, 1983; Von Glinow, 1983). For example, a project leader adds his own goals to existing project objectives and expects his subordinates to use a structured development methodology in an information system project, evaluating their performance accordingly. Rather than accepting the project as it was defined, he expands it to find the optimal business solution.

Ouchi (1979) includes "uncertainty" as a predictor of control strategy from agency theory. Uncertainty supposes flexibility in the way actors response to the demands of their environment (Jaworski, 1988). An important insight by Karl Weick argues that understanding and sensemaking

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of uncertainty affect strategic decisions regarding the choice of alternative actions in response to the situation (Bougon et al., 1977). Limited research has recognized the fundamental role of uncertainty in the management control mode design in projects (Chapman, 1997; Chenhall, 2003; Ditillo, 2004; Hartmann, 2000). Having a portfolio of routines at their disposal, they must accommodate situational expectations (Pentland and Rueter, 1994). In this scenario, researchers have attempted to explain the effectiveness of management control modes by examining designs that best suit the nature of the context in which they operate.

2.3 Project uncertainty

The concepts of uncertainty are originally defined in information system research as "the gap between the information an organization has and the information it needs to perform the task" (Galbraith, 1973). Uncertainty may also indicate that actors have difficulty analyzing the situation (Perrow, 1967) and lack a mode of acting upon expectations (Kogut and Zander, 1992). In all of these cases, uncertainty is defined by the interplay between task characteristics, task environment, and actors involved (Gales and Mansour-Cole, 1995). Although researchers conclude project uncertainty from environmental, individual, complexity, information, temporal and capability multiple perspectives, respectively, there are many similarities in the results of the division of uncertainty (Saunders et al., 2016). As some studies utilized to view uncertainty emerge from research on complexity, which is a major source of uncertainty in projects, in this paper we refer to the "input-process-output" model of complexity (Wood, 1986) to build the dimensions of uncertainty. Additionally, more recent contributions mainly to the project have enlarged the meaning and extension of "uncertainty" by building new dimensions, which are also taken into consideration.

The rubric of uncertainty is categorized by Ellsberg (1961) using the scheme of "Known uncertainty" and "Unknown uncertainty". "Known uncertainty" refers to "gaps" in information (Dean and Sharfman, 1993) and is consistent with Galbraith's definition, which implies the belief that individuals and organizations can reduce uncertainty and maintain equivalent performance by collecting more information (Galbraith, 1973). The first kind of project uncertainty is related to the

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output, defined as uncertainty related to computational complexity by Ditillo (2004), in terms of the number of people involved in the project, its cost, and its duration. This kind of uncertainty usually arises from the large number of stakeholders and activities, and their interconnections (Galbraith, 1973). It improves the difficulty of task execution by the number of distinct information cues that must be processed and the number of distinct acts that must be executed in performing the task.

The second kind of "Known uncertainty" is related to the innovative features, defined as uncertainty related to project novelty by Ouafa Sakka et al. (2016), and the extent to which the functionalities of the new product and activities are novel to the project team. The processes are either new for the agents and market or entail innovative problem solving and encounter unpredicted events and issues (Sakka et al., 2016). The literature suggests that the higher the project's novelty is for team members, the greater is the amount of information they will need to process the desired functionalities of the new product, as well as the organizational processes and technical accomplishments required to implement the product (Sakka et al., 2016).

In contrast, "Unknown uncertainty" (Ellsberg, 1961), or "mysteries", refers to similar concepts such as task unanalyzability (Perrow, 1967) and equivocality (Daft and Lengel, 1986; Daft and Macintosh, 1981), expressing the lack of clarity about cause-effect relationships, lack of agreement among involved parties and the difficulty of identifying appropriate sources of information to reduce this type of uncertainty. As the user needs are the main sources of input in the project scenario, and the temporary and phased nature of a project may lead to dynamic changes in user requirements as the project progresses, past research has theorized the ambiguity of user requirements as a source of uncertainty (Mehta et al., 2014; Rai and Al-Hindi, 2000). It is usually because the user needs are not clearly described during the requirement specification phase. The literature suggests that users can render the definition of these needs particularly challenging, making their revision necessary in later phases of the project (Ward et al., 2006). For example, user requirements may change during the course of the project, there may be conflicting needs among stakeholders (Hong et al., 2004), and agents may have difficulties in understanding the requirements and in translating them into technical

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specifications (Nidumolu, 1996). It refers to the dynamic complexity related to the need to adapt to changes occurring in the cause-effect relationships or means-ends chain during execution of the task (Ditillo, 2004).

The fourth kind of project uncertainty is related to the process, defined as uncertainty related to technological complexity, similar to the notion of "task unanalyzable" noted by Perrow (1967), largely due to the complexity of the technology involved (Sicotte and Langley, 2000). It is defined as the number of distinctive skills or competencies belonging to many different experienced people (Iansiti and Clark, 1994; Zander and Kogut, 1995), owing to multiple functions involved. It improves the coordinative complexity as a result of the form and strength of the relationships between information cues and acts, including the content, timing, frequency, and location requirements for the performance of demanded acts (Ditillo, 2004).

To deal with a dynamic environment that requires fast and innovative responses, the integration through project teams is particularly suitable (Ditillo, 2004). Uncertainty is seen as being related to the specific characteristics of the knowledge necessary for work activities and influencing the way in which knowledge is transferred, shared and controlled (Floricel and Michela, 2016). When there is a high level of project uncertainty, a flexible way of communication is needed to cope with the constant influx of new knowledge and to interpret a series of information from other members and the external environment. Collective sensemaking and knowledge integration help deal with uncertainty effectively and overcome both asymmetry and observability by reducing knowledge disparities between diverse stakeholders in the project, revealing what the other individuals think and do (Laine et al., 2016; Perminova et al., 2008). Thus, we promote the propositions based on control theory and the conceptualizations of Thompson (1967) and Ouchi (1979) and Kirsch (1996).

2.4 Proposition development

When the uncertainty is related to computational complexity, the task execution is mainly confused by the large number of distinct information cues that must be processed in performing the task. The link between the path and the result is clear, and the uncertainty is derived from the number of information sources and their intercorrelation (Campbell, 1988). In this case, the behaviors that transform inputs into outputs are known, and appropriate behaviors can be specified in advance (Kirsch, 1996). The development procedures can be standardized, and the information can be readily available which enables extension of the codification and formalization of information supports to manage operations (Kirsch, 1996). The control literature recommends controller's capabilities to observe behaviors; their levels of understanding about a large amount of managerial and technical information produced during the process helps the controller address that information to change the person's behavior (Kirsch, 1996). The controllers can observe these types of activities, evaluate whether they are appropriate, and reward or sanction the project team accordingly. In light of the above, we propose the following propositions.

Proposition 1: The project uncertainty related to computational complexity will tend to be regulated through behavior control to achieve the integration of knowledge.

In contrast, the project uncertainty may be subject to novelty involving a great deal of innovative problem solving, creativity, or intellectual activities. The expected results are not specific enough, and the connection between potential path activities and desired outcomes cannot be established with certainty (Campbell, 1988). It is difficult for controllers to identify appropriate behaviors or articulate precise project goals as the predictability of the task is weakened (Kirsch, 1996). New features are scattered among different individuals and everyone undertakes the innovation mission, which introduces observation process difficulties for the controller (Ditillo, 2004). The low level of behavior observability implies the controller is not closely supervising or interacting with the controllee, resulting in less opportunity for clan-type conditions to evolve. Therefore, the controller is likely to rely on the controllee's ability to manage his own work and the controllee has much more discretion or freedom in choosing and managing his work, implying the presence of self-control (Kirsch, 1996). In light of the above, we propose the following proposition:

Proposition 2: The project uncertainty related to project novelty will tend to be regulated through

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self-control to achieve the integration of knowledge.

When the uncertainty stems from the ambiguity of user requirements, task-related behaviors and outcomes cannot be prespecified, and goals are evolving during the task period, although the controllers have a certain knowledge of the conversion process based on their experiences and have invested in the project, e.g., reports, meetings, and personal observations, to follow the progress of the project. This knowledge is clearly insufficient to cope with changing goals. Consequently, the observable behaviors are not very meaningful. However, it provides the controller with an opportunity to implement clan control: he can use his time with the controllee to explain group values, norms, shared experiences and problem-solving approaches. He can sensitize the project leader to the goals of the user community and build a sense of trust between the user and the project team (Chua et al., 2012). It suggests that relying on peer monitoring to reinforce acceptable behaviors and rewards is based on acting in accordance with the clan's values and attitudes (Kirsch, 1996; Kirsch et al., 2010). Chua et al. (2012) has noted that clan controls create the maximum tolerance for ambiguity in social arrangements. Hence,

Proposition 3: The project uncertainty related to the ambiguity of user requirements will tend to be regulated through clan control to achieve the integration of knowledge.

In some other situations, the main project uncertainty is subject to technological complexity, which is the result of using diverse and complex technology. This can be observed abstractly, by thinking of the outcome of each kind of technology as a task dimension that requires attention (Campbell, 1988). Additionally, each dimension entails a separate information processing stream. The knowledge for generating each subfunction or component (process-related knowledge) may be quite diverse, owing to the unique circumstances under which each subfunction is made, although the goal itself is not complex at all (Ditillo, 2004). These observation indicate an absence of complete cause-effect knowledge (Kirsch, 1996). The controller experiences difficulty knowing the whole transformation and can master setting goals for controllees, requiring them to produce the desired output and to evaluate whether outcomes have been met. Control theories argue that when outcomes are measurable, controllers can use outcome-based control, regardless of their knowledge of the transformation process (Kirsch, 1996). As the process-related knowledge is tacit, diverse, and incomplete for the whole project and the outcome requirements are explicit and complete, the use of outcome control is, therefore, most appropriate (Turne and Makhija, 2006).

Proposition 4: The project uncertainty related to technological complexity will tend to be regulated through outcome control to achieve the integration of knowledge.

Uncertainty changes along with the stages of the project lifecycle and is differentiated in industries (Sanderson, 2012). Although several researchers argue that the different kinds of uncertainty might be correlated, they exhibit varying levels, and some kinds of uncertainty dominate in the project (Sakka et al., 2016). A high level uncertainty should be dealt with by the effective design of project control to achieve the knowledge integration. It is important to note that the depiction of a certain mode of control in each situation is not meant to imply that modes of control occur independently. Rather, the intent is to predict the relative extent to which the various modes of control are present. In other instances, there may be no radical choice between the various forms of control because the projects involve multiple phases and many kinds of uncertainties in a turbulent environment, and more complex interactive controls need to coexist (Liu et al., 2014).

Proposition 5: Different kinds of uncertainty should be regulated by suitable project control modes to achieve the integration of knowledge.

The purpose of the section that follows is to suggest a framework that sets the uncertainty as a moderating factor between project control and knowledge integration, i.e., under different uncertainty factors, knowledge integration could be improved if certain controls are used. On this basis, this article will further compare the differences in the effects of project control modes working on the multidimensional structure of knowledge integration (efficiency, scope, flexibility), expanding existing theories, as shown in Fig. 1.

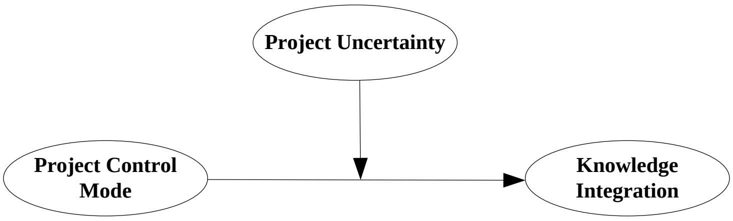

Fig. 1. Research Framework

3. Methodology

3.1 Research design

In the following research design process from Saunders et al. (2009), we chose the philosophical stance of critical realism as the ontological stance for the study. This stance combines the perspective of an objective and measurable reality with the assumption that people's interpretation of this reality is situation-dependent and subjective. Abduction was chosen as the research approach, which combines the credibility of deductive reasoning rooted in existing publications on project uncertainty, with the creativity of inductive reasoning from new empirical insights and the researchers' own experience to derive new knowledge (Alvesson and Sköldberg, 2009).

We focused on how to design project control modes to improve knowledge integration within the uncertainty of different industries. This research used a case study as the methodology to build knowledge about the phenomenon (Yin, 2009). The research design was a multiple-case study that allows replication logic, with each case confirming or not the inferences drawn from the others (Yin, 2009). Multiple cases enable building a more robust, generalizable, and parsimonious theory than single cases (Eisenhardt, 1989; 1991). Our embedded design had several levels of analysis (i.e., round and venture) to improve the likelihood of a rich and accurate theory (Yin, 2009).

3.2 Case selection

Our case selection was in compliance with the principle of typicality (Yin, 2009), and these cases had several characteristics that fit our research. First, the four cases respectively adopted different types of control modes and showed differences in the knowledge integration effect of the project team. Second, these four cases came from different industries. The project uncertainty of these four cases represented specific Chinese industries, which were frequently confronted with relevant problems in a certain phase. These cases were selected due to the dual considerations of project features and Chinese enterprises management practices. Third, we had comprehensive access to project participants and documentation of these cases, which enabled us to obtain a clear understanding of the entire processes of the projects from the early stage.

3.3 Data collection

We were invited by the corporation to observe the projects and developed case reports. Consistent with case study best practices, we obtained data from multiple sources, such as written project documentation including contracts, milestone review presentations, minutes of meetings, and interviews with project participants. We visited the four sites several times during the research and after the project was completed, we also visited to record the project phenomena. The introduction of four projects is shown in Tab. 1.

We developed an interview protocol (Yin, 2009) and adapted it to reflect changes in issues as the project progressed. In the initial interviews, interviewees were asked about the project uncertainty, what difficulties it introduced to the project team, the tasks in which they were involved, and the deliverables for which they were responsible. We asked interviewees to recount their specific experiences in the project, focusing on problems and issues, and which kinds of control modes they chose to resolve uncertainty. We then asked for interviewees' perceptions of knowledge integration. We supplemented the interview protocol based on the information provided by the respondent. Multiple data sources are shown in Tab. 2. The construct validity was performed by deriving the interview questions from existing theoretical constructs for control mode by following the best informants for the questions and continuation of the data collection until clear patterns emerged.

Most interviews lasted at least one hour. During the interviews, at least two, and more commonly three, researchers were present to take notes. Interviewers adopted a specialized role strategy. One interviewer was the primary interviewer, who asked the majority of questions, took fewer notes, and focused on maintaining eye contact with the interviewees. The other two interviewers attempted to take verbatim notes. A tape recorder was used according to the interview needs.

Tab. 1. The Introduction of Projects

	A	B	C	D
Industry	Engineering Construction	Software	Machine Manufacturing	Complex Infrastructure
The name of the firm	Chingchang Engineering Corporation	Lime Software Ltd.	Diego	D&L New Airport Construction Headquarters
Project phase at the time of study	Design-Construction	Development	Processing	Design
Controller	The Client, Project Director & Executive Team	Executive Team	Executive Team	The Client, The airport construction command
Controllee	Planning engineer, Business manager, QA&QC engineer, Construction manager and their teams	Development team, Product Manager, Algorithms engineer, Programmer, Test engineer	The project team, including planner, quality engineer, process engineer, purchasing manager,	Contractor, Design Institute and their subcontractors

Tab. 2. The Introduction of Data Source

Project	Documentation	On-site interviews	Telephone interviews
A	Plans and Reports, 200 pages	10 stakeholders, 14 interviews	2 stakeholders, 2 interviews
B	Burndown chart	6 stakeholders, 7 interviews	1 stakeholder, 2 interviews
C	Drawings, Summary	8 stakeholders, 10 interviews	#
D	Management Program and Plans, 400 pages	7 stakeholders, 10 interviews	3 stakeholders, 3 interviews

3.4 Analysis

The analysis was performed using Miles et al.'s (2014) process of data collection, data display, data reduction and conclusion finding. Initial coding, followed by a second-cycle coding for pattern identification, is carried out by starting with a within-case analysis of each case, in order, to capture all expressions of the phenomenon and interpret them in light of existing concepts, such as uncertainty and managerial control mode. Codes related to the influence of uncertainty on the choice of control mode emerge through constant comparison of newly gathered data with previously

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collected data and their coding, as well as the knowledge integration actions. Coding starts deductively by looking for support of existing theories on uncertainty and control and then gradually expands into inductive interpretation in light of the additional information given the interview data and display of the findings (Miles et al., 2014). Categories are developed and refined after checking the relevance of previously coded text and newly created codes. Emergent codes and connections among categories lead to the identification of variables, such as the three dimensions of knowledge integration, and their interpretation in the context of the interviewee data lead to the identification of reoccurring patterns, which lead to the control mode implementation process.

This process is then expanded to cross-case analysis to validate the findings from before and derive patterns that show the general characteristics of the phenomenon. Through cross-case comparisons, the propositions mentioned above are verified and we find different kinds of control modes differentiate in knowledge integration efficiency, scope and flexibility. We use charts and tables to search for the emergence of similar themes across multiple cases (Eisenhardt, 1989).

An example is the coding for "efficiency of knowledge integration" in the four cases, as shown in Tab. 3. Each of the three researchers gives his own estimate on all the terms for this concept in the four cases, using a five-point scale. Next, they average the results and discuss them together, removing unreasonable coding. As a result, no two researchers differ in their assessment by more than one point on the five-point scale. They should reach a consensus about the final evaluation results through cross-case comparisons and ranking of "high, medium, low" while the fourth team member provides an independent perspective to challenge possible coding bases. The measurement results are fed back to the interviewees for verification.

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Tab. 3. A Coding Example

Code	Researcher 1
Project A: The owner would personally actually monitor the progress of the project, controlling the progress on the basis of the review of the weekly plan and comparing the on-site implementation reports with the plan.	●
Project B: Each functional module was the responsibility of one or up to two people. Everyone described their tasks as briefly as possible at the daily meeting, and the purpose was to achieve information sharing between project members.	●
Project C: "There could only be one general plan, which was referred to the previous process cases. " Regarding the internal control plan of each department, the planners usually could only meet the tasks of no more than the next seven days.	◎
Project D: "The estimated time in the milestone was not always accurate." The problem of harmonizing multiple technology interfaces was serious and required took several rounds of negotiations.	○

Note: ○→Low ◎→Medium ●→High

In keeping with replication logic, we then tested emerging theoretical relationships across control modes within and across groups to discuss the processes and mechanisms in detail. Reliability was ensured by cross-validating the interview statements, and the data analysis process was repeated by other researchers in the workshop. We also compared our emergent theoretical framework with extant literature to refine our construct definitions, abstraction levels, and theoretical relationships (Eisenhardt, 1989), resulting in their successful validation and testing. We engaged in repeated iterations until theoretical saturation-that is, the close match between theory and data was reached. However, we also searched for unexpected types of explicit learned content and relationships to validate the consistency of patterns. We then iterated between theory and data to clarify our findings and theoretical arguments. Together, these activities helped us to produce the theoretical framework. Validity and reliability were ensured following Yin's (2009) suggestions, as shown in Tab. 4.

Tab. 4. The Validity and Reliability of the Study

Validity	Reliability
construct validity: multiple sources of evidence, key informants, validation interviews	the use of a case study protocol
internal validity: pattern matching during data analysis	
external validity: replication logic in a multiple case design	

4. Within-case analysis

Project A: The exercise of behavior control

Chingchang Construction Engineering Corporation and the United Arab Emirates Local Projects Corporation (hereafter referred to as “NPC”) had signed a consortium agreement to bid and build the Abu Dhabi Al Reem island development project (hereinafter referred to as “A consortium”). The project signed a design and construction contract. The standard contract conditions adopted the FIDIC 1995 version and turnkey project contract conditions.

The contractual division of labor between the two parties was as follows: Chingchang Company was responsible for a 48-story apartment building and a 34-story office building. NPC was responsible for two 10-story apartment buildings, a supporting parking building and a basement floor. The local Architectural Planning Company was jointly engaged as the design unit. As this was a conventional engineering construction project, there were no doubts about technology or customer needs.

The source of uncertainty was mainly from the computational complexity, reflected as numerous stakeholders, the duration of the project of 28 months, cost consumption of 1 billion RMB, as well as various project requirements including quality, safety and risks, among others, which led to a large number of interconnections. A consortium formulated the REEM Island Project Management Plan in accordance with the contractual requirements, common goals, and respective company regulations, as well as local government regulations. The REEM Island Project Management Plan contained 12 management plans, clarified the ideas and methods of project process and defined the related resources, and possessed sufficient knowledge to decide in advance the way in which activities were to be executed. These plans were authoritative and prescriptive as behavior control means, as shown in Tab. 5.

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Tab. 5. The Plans in Project A

Plans	Content
The management plan for the A consortium	Designed in accordance with the ISO9000 standard, a document that explained how the A consortium designed, implemented, and maintained the project management system.
Organization Plan	Arranged the resources management of the A consortium in the plan.
Internal Communication Plan	Explained various interfaces and lines of communication, document control and reporting methods.
Risk Management	A plan explaining the risk management implementing methods for the A consortium.
Project Quality Plan	Explained the quality management principles, objectives and deployment, explained in detail the process of implementing the quality management of the REEM Island project.
Safety Management	Ensured that local occupational health and safety regulations were implemented.
Environmental Management	Detailed the overall deployment of the project's environmental protection management.
Design Quality Plan	Explained the detailed design quality management process for the REEM Island project design team.
Procurement Plan	Defined the project procurement process of the A Consortium.
Subcontractor Program	Enabled subcontractors to be integrated into the A Consortium project management system.
Machinery and Equipment Plan	Explained the machinery and equipment required for the REEM Island project, as well as maintenance and related inspections.
Completion plan	Provided planning to transfer the project to the owner after completion of the REEM Island project.

Chingchang Corporation executive team controlled the project construction team and the contractor design unit, as well as connecting with its partner NPC by means of these detailed plans. For example, the construction plan should be drafted by the construction team to explain the methods and measurements for fulfilling the design requirements and various application standards. The preparer of the construction plan first checked the documents and then sent them to the relevant functional departments for review. After receiving approval, the construction plan would be reviewed by the executive team by whom the project was governed. Finally, it could be issued to guide the construction implementation on site.

Each subcontractor also formulated his own management procedures, and a consortium embedded these documents into the overall management control systems. (The Project Director)

Then, behavior control was exerted on the project team. In the inspection and test plan, the person responsible for inspection tasks was articulated, and the responsibilities of the departments were

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clearly delineated. The inspection and test standards were also specified in the plan.

Tamouh Company as the owner of the project and the executive team should control the project in terms of technical quality, rate of progress, cost, safety and environment. They controlled the progress based on the overall schedule of the project, monthly plans, and weekly plans. The owner compared the on-site implementation reports with the plan.

The Non-Conformance Project Report (NCR) is a common tool used by consulting engineers to deal with quality deviations that occur on site. It guarantees that the appropriate people respond correctly to problems that arise.

The reinforced concrete floor adopted posttensioning prestressing method and prestressed professional subcontractors had submitted their construction plans. After each layer of prestressed tension was completed, the position of the prestressed steel strand below each layer was marked with a line of red paint. Accompanying the progress of the project, the electromechanical department needed to change the positions of a few hole openings crossing the floor due to design changes. They had prepared an implementation plan for the design change. However, it did not show whether the positions of the new openings were in conflict with the strand position. During the on-site hole opening by the mechatronics team using the concrete cutting equipment, there was no detailed observation of the marked strand position. During the process of opening the electromechanical hole, the steel strand was cut off by mistake. After the problem occurred, the project department convened various professional managers to formulate a special rectification program, reinstall and restretch after extensive consultation. (The Construction Manager)

When the deviation could not be eliminated, the owner issued an engineer instruction, and the related specific project personnel handled it in accordance with the engineering change procedure.

Project B: The exercise of self-control

The product named "GongYing Bao" aimed to build a network platform between hospitals and medical device consumables suppliers. The platform was a completely new product with large amounts of market-oriented new functions and also the first attempt for Lime Software Ltd. It

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covered the hospital consumables category, price, supplier procurement evaluation about the quality and speed of delivery, and their management relationships.

Some individuals were responsible for vendor-side functional development and others for the hospital-side. The objectives of the project were very general at the very beginning, and the product framework and tasks were gradually specified explicitly with the progression of the project, which implied the uncertainty source.

The product owner (PO) within the project team was responsible for early exploitation and collection of the needs of different hospitals and suppliers. Then, PO developed an integrated framework plan about the functional requirements and formed a demand pool based on the plan from the gathered ideas.

The self-control was exerted by the project manager who would first convert demand into the "PRODUCT BACKLOG" (all tasks that could be designed and foreseen, both functional and nonfunctional). Subsequently, the project team collectively held the planning meeting, and the project manager would determine the most basic "POINT" (a small, deliverable useful feature, but not a complete feature, depending on the ability of team members) and prioritize within the "PRODUCT BACKLOG". For example, Lime Software Ltd. defined a point as the workload of "querying the interface". Several iterations were required during the development of a new software project. The required completion points for each iteration were placed in the "SPRINT BACKLOG". During each iteration, the development team needed to complete an incremental, deliverable product. The developers held good professional competence and personal qualities. They would actively learn and apply the latest technologies to complete development tasks if needed.

All tasks would be posted on the whiteboard. Every member of the team chose his own responsible POINTs from the "SPRINT BACKLOG" among of his interests or aptitudes to exert self-control. Each functional module was usually the responsibility of one or up to two people. The project manager would balance the workload and difficulty. The horizontal axis of the whiteboard was time, and the vertical axis was "POINT". The whiteboard was updated every day, and it was called the

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“Burndown chart”, which reflected the gradual completion process of “POINT”s.

According to the trend of “Burndown chart”, once a certain point was stuck, the project manager came forward to find a solution. Sometimes the problem might be an irrational product design, in which case the manager would provide feedback to the PO and adjust the demand pool. (The Project Manager)

“Every morning we held a standup meeting and only talked about three things.” “What did you do yesterday? What problems did you experience? What would you do today?” (The Product Developer)

Everyone expressed their tasks as briefly as possible. Unsolved problems and their possible solutions were not allowed to be elaborated. The daily meeting should be completed within a total of 15 minutes.

Regarding the issues mentioned by the project members, other experienced developers would actively communicate with relevant personnel after the meeting, or the project manager helped to solve the problems. Through daily updates, everyone learned about how much work others performed each day and then adjusted his own schedules, demonstrating that self-control was exerted.

Once an iteration was complete, the product was stored in the “cloud” for customers’ practice. At the end of each Sprint, the development team would demonstrate the work to the PO and other related personnel. The PO communicated with potential users and added the new POINTS for the functions that needed to be enriched in the following iterations, exercising self-control.

The project manager determined the time of the final product launch according to the market demand and the situation of competitors, thereby adjusting the number of POINTs for each iteration.

Project C: The exercise of clan control

Project C consisted of providing product supporting processing business for Intel. The Intel project had been the most important customer to date, who might promise subsequent projects and more market opportunities for Diego. Diego did not undertake design work and received drawing designs

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from Intel.

The drawings were sent in phases, and the time interval for each batch of drawings was different, which implied an uncertainty of dynamic changes in user needs. As Intel was listed as the highest priority and Diego would try hard to meet their requirements, the executive leaders grouped the project team with experienced members who were familiar with the procedures of similar product processing projects to facilitate the establishment of common beliefs to deal with the uncertainties.

The entire production of Intel was carried out under the coordination of a master plan. Each device in Diego usually had its specified drawings of deepening time, cutting time, riveting time, delivery time, spray time, and transport time. However, for the Intel project, there could only be one general plan, which referred to previous process cases. Concerning the internal control plan for each department, the planners usually could only meet tasks for no more than the next seven days.

"Sometimes they hand us 20 drawings in three days, and another only 5 drawings in as long as ten days." "Some of the components were shipped from the United States. They had planned to arrive in half a month, but they didn't arrive on time." "No matter how soon they require us to deliver goods on site, we have to adapt to their rhythm and finish in time." "Intel is in a stronger position than Diego." (The Processing staff)

A large number of project team meetings were held to ensure that project members knew each other's work progress and problems, shared information, and collaborated with each other, to be able to respond to the latest customer needs. Additionally, executives can constantly import values to declare the importance of Intel. Through extensive communication, the executives and project team reached a consensus that they would try to finish the processing within the specified time and ensure the quality, at all costs. As a result of the need for extensive exchanges of decisions and solutions, meetings involving the project team as a whole and regular informal exchanges of people at the peer level ensured the implementation of clan control. They developed a tacit understanding and mutual trust, which made processing, assembly and transportation work closely together. Speaking out freely and sharing information provided the possibility for the whole project organization to make

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timely decisions.

"Any other project would give way to Intel in the case of resource conflicts. When the equipment is insufficient, the production manager shall coordinate and arrange the project team to work overtime in the evening." "There certainly would be some temporary adjustments. Whenever the customer makes a new request, we will adjust the previous plan." "Everyone has gotten used to this, as the Intel project has been positioned as the most important from the early beginning." (The Project member)

"In this project, due to changes in site requirements and drawings, I once adjusted the layout plan three times within one day." "In terms of planning adjustments and overtime work, Intel project employees are psychologically acceptable." (The Planner)

"Due to the tight schedule, many times the plan is adjusted in the head, there is no time to form a written document, and it is too late to communicate with other functional departments." "Sometimes the product has been put into production, but changes are incorporated into the drawings, resulting in losses. We have to sacrifice profits to guarantee product quality." (The Project Manager)

"Because the quality inspection did not follow strict procedures, as well as mistakes caused by the rush, a small problem occurred at the end of the project. As a result, I was fined more than 20,000 RMB this year for the Intel project." (A Quality Manager)

When major changes occurred, the project manager would organize plenary meetings and implement changes to the overall plan to ensure that each department kept up to date with the requirements. The meeting would be held at any time if necessary.

Project D: The exercise of outcome control

D&L New Airport would undertake most of the air transportation business and become a hub airport in the region. It is an offshore artificial island airport that has built new land for aircraft at sea and crossing work interfaces would lead to complex construction procedures.

Technical complexity and diversity were more pronounced than other uncertainties at the design stage. Sea area management procedures involved reclamation, sea area utilization and changes in the navigation channel. The land involved such procedures as the filling source, access and external support. The airspace involved flight procedures, military aviation impacts and bird damage investigations. The contact surface of the sea, land and air intersected each other, which restricted the construction procedure.

On the technical side, multidisciplinary projects involved many new technologies. There was a lack of clear industry regulations and standards, such as the principle documents guiding the design, construction and acceptance, among other, processes.

For example, the applied sea, land and air tripartite coordination system respectively was the WGS84 Coordination System, D&L Urban Construction Coordination System and Beijing 54 Coordination System. The conversion between different coordinate systems was not smooth, and the coordination system was the necessary parameter to guide the construction, which indirectly led to the increase in coordination cost between different specialties.

Simultaneously, there were differences in requirements for the same operation in the three industry norms of sea, land and air. The airport construction command had contracted design companies and related agencies for different technical components. Each professional field had designated the corresponding person in charge. (The Headquarters of The Project)

Milestones that could be identified early in the project determined the logical order between the various professional tasks. The plan established an estimated point of time for deliverables at each stage. However, the estimated time was not always accurate. The project schedule was controlled by the owner based on the milestone plan, which exerted the outcome control.

Each technical group worked independently, and the project generally presented the status of multiple groups working in parallel. Outcome control was achieved through periodic reports and performance measurements to each technical group. Whether the results of each phase met the requirements was judged by the panel discussion. The owner invited the consulting company to hold the expert meeting, convening the domestic first-class experts (from specialist pools, by internationally certified). They raised questions and signed where the technical groups needed to

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adjust. Typically, the draft review would be released throughout the project team, and the design units would refine their work accordingly.

Each technical group also had its own meetings before submitting its engineering report to the client. They had an internal review process and recommended changes to potential problems or pitfalls, and then they submitted the results to the client a day or two in advance. The client would only pay attention to the results. When the technical group was unable to solve internal technical problems, the client would take the initiative to help coordinate. (The Technique Manager)

The problem of harmonizing multiple technology interfaces was more serious. Connections between different technical units needed to be established and communicated in the order specified in the plan. When there were contradictions between different technologies or resource conflicts, the client initiated a meeting to gather experts from all technical groups for coordination. Each group described its requirements and technical standards separately, and finally, the client made the decision. Expert opinions were formed on the spot, and all the amendments were signed. The amendments triggered a response to the combination of multiple technologies and the coping strategy to the latest problems caused by environmental changes. It usually required several rounds of negotiation, and some interests had to be compromised.

5. Cross-case analysis

5.1 The impacts of uncertainty on project control modes

Kirsch (1996; 2004) indicated that task characteristics would influence the choice of managerial control. The objective of this research is to develop a conceptual model to explain how to design project control modes to improve knowledge integration within the project uncertainty context. Multiple-case comparison studies have confirmed the above propositions. The variation of uncertainty determines the information process and, thereby, affects the project management control practices in terms of details of goal setting, tightness of process tracking, frequency and range of communication and usage of information.

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Project A was characterized by a clear goal description and procedural coding knowledge, and the active participation of the controller ensured that the activities were monitored. In contrast, the goal of project B was not clear and very broad, and communication between submodules was minimized, and thus, the tasks were completed mainly by the controllees themselves. In contrast, the goal of project C had been changing over time, and the controller had to engage closely in the process and exchange tacit knowledge frequently in both formal and informal forms to control it. Finally, although project D set a clear goal, professional knowledge existed in an embedded form, and there was typically a wide range of knowledge exchanges at milestone nodes.

5.2 Comparison and analysis of different project control modes on knowledge integration

One of the relevant roles of control modes is to coordinate activities by integrating different sources of knowledge expertise (Turne and Makhija, 2006). As the knowledge integration lays the basis for competitive advantage under dynamic market conditions (Grant, 1996b), we compare different control modes from the three dimensions of knowledge integration.

Behavior Control Working on Knowledge Integration

In the situation of project A, adopting behavior control, the task holds a high level of reproducibility, with superior codification. The controllees can perform the task according to the predefined documents and software (De Boer et al., 2010). The efficiency with which organizational routines integrate the specialized knowledge of team members depends upon the sophistication of the system of signaling and responsiveness that develops as a result of repetition and improvement (Grant, 1996a). Thus, the efficiency of knowledge integration is high.

There are many sub plans included in the overall plan. For example, the construction plan would be sent to the relevant departments and reviewed by them, which means that the procedure is not produced by an individual unit but a cluster of stakeholders. The specialized knowledge is complemented by other related types (Grant, 1996a). Thus, the knowledge integration scope is medium.

The case of the electromechanical hole suggests that errors may not be detected until a series of

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procedures are completed, and it is difficult to identify the source of the dysfunction (Kogut and Zander, 1992). The controller has to work on the information on a large scale to change the controllee's behavior, confirming that the completeness of knowledge points to a minimal need to search for new information (Grant, 1996a; 1996b). The existing knowledge would only be reconfigured toward the goals until the end of a series of processes, which implies that the flexibility of knowledge integration is low.

Self-Control Working on Knowledge Integration

As the team of case B performed a self-evaluation (Manz et al., 1987), the innovative work was completed based on the principle of modularity. One or up to two people were responsible for one functional module, which indicated a high degree of specialization. Factoring the total system of decisions that must be made into relatively independent subsystems, each one of which can be designed with only minimal concern for its interactions with the others, optimizes the efficiency of knowledge integration (Grant, 1996a; 1996b).

As described in the case, when an individual stated his problem, the other individuals with related skills would help. Knowledge integration is achieved through mutual adjustment among individuals (Kogut and Zander, 1992), which typically relies on a much more limited set of cues and responses and serves minimally for communication of knowledge (Grant, 1996a; 1996b). Thus, the scope of knowledge integration in self-control shows low performance.

After each iteration, the product was placed "in the cloud", and new environmental knowledge was incorporated, guiding subsequent iterations. This means that a reconfiguration of existing knowledge occurs, which leads to "architectural knowledge" across disciplinary and multiple modules and is associated with the moderate acquisition of new process- and outcome-related knowledge (Turne and Makhija, 2006; Nonaka, 1994). Thus, the flexibility of knowledge integration is medium.

Clan Control Working on Knowledge Integration

Clan control is usually implemented by carefully selecting and socializing members, internalizing

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a set of values, who are committed to the clan (Chua et al., 2012). The socialization process, as well as rituals and ceremonies, serves to identify and reinforce acceptable behaviors (De Boer et al., 2010). Like case C, the team consisted of people with similar project experience. However, “it was difficult to implement detailed internal control plans within each functional department.” Thus, the level of shared behavioral norms and organizational culture cultivated by the clan does not reach a certain extent, resulting in a medium efficiency of knowledge integration.

The exchange of information through socialization and interaction allows the individual decision-maker to gain access to diverse knowledge to the extent necessary (Hoopes and Postrel, 1999). Even though members can exchange their knowledge with others, the scope of knowledge integration is relatively low owing to their similar work experience and medium level of common knowledge. Knowledge that is less diverse would comprise fewer units of knowledge and might be particular to one task, or decision-making situation that involves more similar elements of information (Grant, 1996a; 1996b).

“There are certainly some temporary adjustments.” “Everyone is used to this……” Building relationships and trust are so important if task-level monitoring is possible, as this project is very interrelated (Kohli and Kettinger, 2004). Each analyst could not perform his work independently of the other analysts (Chua et al., 2012). They trust each other, respect each other's work, and communicate well (Kirsch, 1996), which, in turn, facilitates the ability of organizational members to recombine knowledge, allowing for new insights (Galunic and Rodan, 1998). As the new knowledge promoted by customers is explicit or tacit knowledge that can be articulated, difficulty is reducing in integrating new knowledge. Thus, the flexibility of knowledge integration is relatively high.

Outcome Control Working on Knowledge Integration

In case D, various technologies were embedded in different specialists. Experts in their professional fields completed their own tasks, with little need for participation in other areas. However, “Coordination between fields was troublesome.” Each subsystem uses unique search

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capabilities and processes, when aggregated across all subsystems, helping to amass heterogeneous knowledge for organizational purposes (Grant, 1996a; 1996b). Overall, the projects that implement output control have the lowest level of common knowledge, leading to the lowest efficiency of knowledge integration (Kirsch, 1996).

In this case, integration is achieved by joint problem solving, the differentiation of decoupled specialized subsystems and output exchange, and it needs to be further reinforced when the differently specialized subsystems are characterized by a diversity of interests, leading to potential competitive and hostile uses of knowledge (Grandori, 1997; Grant, 1996a; Ditillo, 2004). Different types of specialized knowledge complement each other in production, signifying the widest scope of knowledge integration.

Cohesion and matching between multidomain knowledge usually occur on the milestone node, which ensures acquisition of the individual's creative process-related efforts toward desired goals. The reconfiguration of existing knowledge through new patterns of integration leads to "architectural innovation" across organizational boundaries (Nonaka, 1994). Since outcome controls do not mandate following a detailed process, the requisite flexibility is present for identifying new and unique solutions for problem-solving at the differential knowledge junctions specified in the sequence (Erez and Kanfer, 1983). Thus, the flexibility of knowledge integration is medium.

6. Discussion

This study explores the main source of uncertainty for different types of projects at different stages and takes it as the basis of choice for managerial control, as suggested in Fig. 2. It is a supplement to the existing literature about control dynamics based on task characteristics (Kirsch, 2004), and it does not conflict with research on control portfolios; the result shows high level uncertainties that differ in different phases with potentially significant impacts that should be addressed through the design of effective project control mechanisms (Soh et al., 2011; Choudhury and Sabherwal, 2003).

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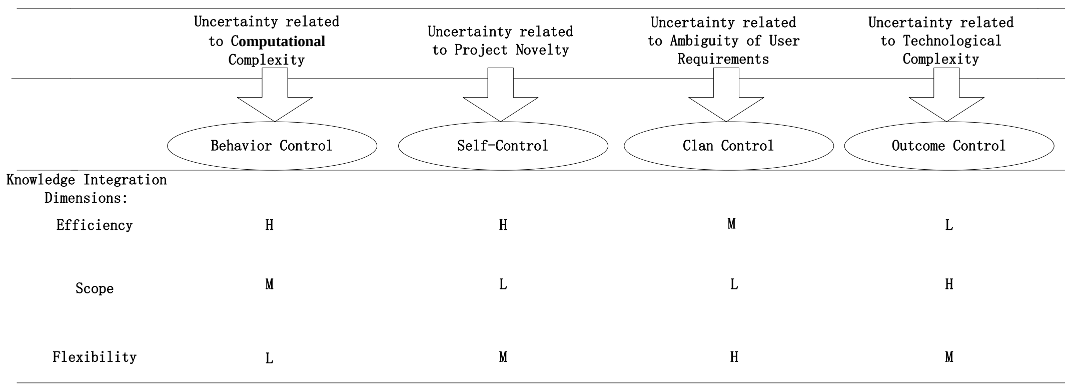
The control dynamics involve changes in the controller-controllee relationship (Kirsch, 1997), which nevertheless usually presents a certain state in a single project phase. It is therefore important to fully consider the phased nature and the industry involved in the project. In addition, the uncertainty as an opportunity for project team knowledge integration is explained in detail (Huemann and Martinsuo, 2016; Böhle et al., 2016). This study further discusses the horizontal comparison of the four project control modes in the three indicators of knowledge integration, reflecting the difference in degree, as shown in Fig. 2. It is suggested that uncertainty moderates the relationship between project control and knowledge integration.



Note: H=High, M=Medium, L=Low

Fig. 2. The Choice of Project Control based on Uncertainty and its Impact on Knowledge Integration

This study reveals the process of knowledge integration within different control modes. It summarizes the main knowledge integration mechanism under different kinds of project uncertainty, as supported by Grant (1996b). In behavior control, the main knowledge integration mechanism is the direction, which provides a means by which tacit knowledge can be converted into readily comprehensible explicit knowledge, and different pieces of knowledge are integrated (Cardinal, 2001; Cohen and Levinthal, 1990; Conner and Prahalad, 1996). In self-control, the main knowledge integration mechanism is routine, the interesting features of which are the ability to support a high level of simultaneity of individuals' performance of their particular tasks in a relatively automatic fashion and permit highly varied sequences of interaction. In clan control, the main knowledge

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integration mechanism is group problem solving and decision making to exchange knowledge of a diverse nature, which allows individuals to view knowledge from multiple perspectives or interpretations (Cohen and Levinthal, 1990; Huber, 1991). In outcome control, the main knowledge integration mechanism is the sequence that defines the logical link relationship between different professions, and continuous coordination serves to organize production activities in a time-patterned sequence such that each professional field's input occurs independently by being assigned a separate time slot. Thus, the knowledge integration mechanism may exist independently but show different degrees in different control modes.

This study compares the knowledge integration of different control modes, which is supported by Grant (1996a), De Boer et al. (2010) and Nonaka (1994). Three factors are important in determining the efficiency of knowledge integration. a) The level of common knowledge, including commonality of vocabulary, conceptual knowledge, shared behavioral norms and experience between individual specialists (Garfinkel, 1967; Zucker, 1987; Chua et al., 2012). Clan control is implemented among members with a certain degree of common knowledge, and outcome control is applied to situations with diverse tasks. b) Frequency and variability of task performance. "The ability to receive and interpret a stream of incoming messages from other members and from the environment." Directions implying the repeatability of work, which contributes to behavior control, determines the high efficiency of knowledge integration (Grant, 1996a; Kogut and Zander, 1992). c) Structure. The principle of modularity is fundamental to the structuring of organizations to achieve communication efficiencies. Modularity, which dominates in self-control, is especially important in organizing highly complex capabilities involving broad-scope knowledge integration. The higher the efficiency of knowledge integration, the lower is the scope and the flexibility (Grant, 1996a).

7. Conclusion and future research

This research aims to explore how to design project control mechanisms to improve knowledge integration under different types of uncertainty. Based on control theory and knowledge-based

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theory, the results reveal that uncertainty alters the project's mechanism for coordinating its business activities and analyzes the role of behavior, outcome, clan and self-control modes during the process of knowledge integration. This research sheds more light on the utilization of project uncertainty and extracts the main control modes for high uncertainties. We propose that when the project uncertainty is related to computational complexity, behavior control should be adopted to achieve improved knowledge integration efficiency. When the project uncertainty is related to project novelty, self-control should be adopted to achieve better knowledge integration efficiency. When the project uncertainty is related to ambiguity of user requirements, clan control should be adopted to achieve better knowledge integration flexibility. When the project uncertainty is related to technological complexity, outcome control should be adopted to achieve a better knowledge integration scope. Thus, both procedures and targets that can be preestablished and human abilities are crucial to projects, and they should be prioritized depending on the uncertainty scenario and incidence.

The theoretical implications of the study include the contribution to the set of theoretical connections between project uncertainty, project control modes and knowledge integration and the theory framework for project uncertainty, by articulating the categories of uncertainty (Galbraith, 1973; Thompson, 1967), and extend the study of predictor variables of managerial control (Ouchi, 1979; Kirsch, 1996). Moreover, our research sharpens the relationship between project control modes and knowledge integration by revealing the knowledge processing when carrying out control modes. Thus, this paper proposes to improve knowledge integration by actively dealing with project uncertainty rather than simply by reducing or reacting negatively, marking a significant expansion of existing theories.

Managerial implications include carrying out effective project control design according to industry features. The need for proactive interventions is becoming increasingly important as businesses initiate larger volumes and more complicated cross-functional projects in different industries, and it is crucial to identify high uncertainties to adopt suitable actions. Practitioners should focus on

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behavior control in engineering projects, self-control in software development, clan control in mechanical processing and outcome control in complex technical facilities. Effective employment and the combination of project control modes facilitate better deliverables embedded with structural knowledge and the subsequent development of the project team, as well as ensuring efficiency and flexibility throughout the project lifecycle. More specifically, this employment requires defining the controller's authority and responsibility, paying attention to the selection of project members, establishing the communication and coordination mechanisms and creating a team atmosphere that is suitable for the implementation of specific control modes. It adds a strategic and interventionist orientation to improve knowledge integration by suggesting specific control modes.

Several limitations of our study should be addressed in future research. Our study focuses on a high level uncertainty, and the effects of multiple coexisting uncertainties are not considered. Additionally, the control dynamics between different project stages are not discussed. The China industry context of this study must also be considered in assessing the generalizability of the findings. We believe that we take full account for the characteristics of different industry projects when distilling project uncertainty; however, the implementation of specific projects may vary from country to country. While these are important considerations, their inclusion in our paper would not only significantly expand its scope and complexity but also dilute our focus of choosing suitable control modes to improve knowledge integration under high uncertainty. We argue that the individual high levels of uncertainty within a project phase in our analysis maintain the simplicity of our conceptual framework without sacrificing its ability to interpret control mode selection.

Future studies could explore the influence of multiple uncertain factors, and the mechanisms and processes by which to implement controls require further in depth discussion. We also acknowledge that complex projects are likely to include multiple control dyads (Soh et al., 2011). Future studies should examine the interactions between multiple control dyads within large, multistakeholder projects throughout the lifecycle.

Altogether, the knowledge contribution of this study is a deepening understanding concerning how project control modes are properly designed to improve knowledge integration dealing with uncertainties. A more complete understanding, better mechanisms and paths, and better project governance capabilities for project uncertainties may potentially promise better project outcomes.

Conflict of interest

The authors of the paper certify that they have no conflicts of interest of any kind.

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