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Fostering Ambidextrous Innovation Strategies in Large Infrastructure Projects: A Team Heterogeneity Perspective

Xinyue Zhang, Yun Le, Yan Liu, and Xiaoyan Chen

Abstract—**In emerging economies, infrastructure projects are in full swing. There is a wealth of replicable experience for exploitation. Simultaneously, more technologies and methodologies require further exploration. This makes fostering ambidextrous innovation strategies (i.e., the tradeoff between exploitative and exploratory innovation strategies) a common and vital practical issue. Large infrastructure projects are unique one-off endeavors but have somewhat repetitive and persistent characteristics. It is a particular "intermediate" form between temporary projects and permanent organizations. Previous research on fostering ambidextrous innovation strategies cannot simply be replicated in large infrastructure projects. To address this issue, this article investigates the relationship between team heterogeneity and ambidextrous innovation strategies and also the role of team learning and identification in large infrastructure projects. Data were collected from 269 responses from 31 large infrastructure project delivery teams in China. The findings show that team heterogeneity has a positive linear effect on exploratory and ambidextrous innovation strategies and an inverted U-shaped effect on exploitative innovation strategies; team heterogeneity can better foster ambidextrous innovation strategies through improving team learning; the moderating role of team identification in the overall mechanism differs from the usual assumptions in permanent organizations. Overall, this article extends the existing ambidexterity research in the "intermediate" form between temporary projects and permanent organizations. It provides insights and guidance on fostering ambidextrous innovation strategies in large infrastructure projects.**

Index Terms—**Ambidextrous innovation strategies, large infrastructure project, team heterogeneity, team identification (TI), team learning (TL).**

I. Introduction

THE vast majority of large infrastructure projects deal with universal human needs, including transport, energy, water supply, and waste treatment in economic activities [1]. They are characterized by being bespoke, one-off, and different cultures merging together [2]. Innovation plays a unique role in leading positive technical and managerial change during the management of these projects [3]. However, there is a dilemma of innovation in large infrastructure projects. Merely relying on the incremental improvement of proven technologies and routines may not satisfy the increasing design and construction requirements [4], [5]. Substantial risks in the long term and the one-off characteristic often make most parties reluctant to introduce breakthrough innovations [2], [6], [7]. Especially in emerging economies such as China, a large number of large infrastructure projects are under construction, providing a great deal of replicable experience. At the same time, the development of breakthrough innovations requires facilitation and exploration. This makes balancing exploration and exploitation a common and vital practice issue. A recent notable case was the Hong Kong-Zhuhai-Macao Bridge. It drew lessons from the experience of previous cross-sea bridges, adopted and developed new technical and managerial ideas due to the complex and uncertain environment. It is essential but challenging to balance exploitative and exploratory innovation strategies and maximize their combined effects [8]–[10].

There has been some discussion in permanent organizations and temporary projects about fostering ambidextrous innovation [11], [12]. Nevertheless, large infrastructure projects last for years or even decades [13], making them different from general temporary projects, with some repetitive characteristics and some degree of persistence. Also, different from permanent organizations, they are unique one-off endeavors [14]. Eriksson [13] argued that large infrastructure projects could be conceived as hybrids of temporary projects and permanent organizations. Brookes *et al*. argued that large infrastructure projects, as long-term projects, differ in many issues from temporary projects and permanent organizations [15]. In fostering ambidextrous innovation, temporary projects are often seen as an excellent context for exploratory innovation due to their unique tasks [11]. At the same time, permanent organizations benefit from the accumulated knowledge base and are often considered beneficial to exploitative innovation [15]. How ambidextrous innovation can be fostered in large infrastructure projects that combine the characteristics of both temporary projects and permanent organizations cannot merely replicate the findings of previous studies.

In the context of large infrastructure projects, much of the existing research has focused on the importance of

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ambidextrous innovation strategies [16] and their positive impact on performance [17]. Ex-ante ambidextrous innovation strategies during the project management process remain underexplored. The formation of the project delivery team is critical in how to foster ambidextrous innovation. We take this perspective to bridge the gap in the ambidexterity literature in the large infrastructure project context. Some organization studies have explored the role of team heterogeneity in facilitating ambidextrous innovation [18], [19]. Haans *et al*. [20] offered the outlook that the effect of team heterogeneity on ambidexterity is likely not linear but inverted U-shaped. However, no empirical studies have yet been conducted to prove this. Besides, ambidexterity requires the coexistence of two essentially different strategies, which creates paradoxical challenges. In this sense, team heterogeneity provides the conditions needed to achieve ambidexterity and paradoxically encourages disagreements and conflicts [18], especially in large infrastructure projects with complex tasks. In addition to directly linking team heterogeneity to ambidextrous innovation strategies, integrated team process and climate may also be critical for team heterogeneity to foster effective ambidextrous innovation strategies. Such empirical evidence would be a valuable contribution to the ambidexterity literature. Hence, this article aims to answer the following research questions: (1) what is the impact of team heterogeneity on ambidextrous innovation strategies in large infrastructure projects? (2) Can team heterogeneity better foster ambidextrous innovation strategies through the integrated team process and climate?

This article collected data from large infrastructure projects in China to address the above questions and first examined the effects of team heterogeneity on exploratory, exploitative, and ambidextrous innovation strategies. Given that team learning (TL) is a meaningful construct that involves improving workflow, handling disagreements, obtaining information, collaboration, etc. [21], this article examined whether it mediates between team heterogeneity and ambidextrous innovation strategies as an integrated team process. Since large infrastructure projects are undertaken by temporary inter-organizational teams, we wanted to explore whether different team identification (TI) (an integrated climate) affects the cultivation of ambidextrous innovation strategies in such a particular "intermediate" form.

Considering the above, the article aims to provide insights and empirical guidance on fostering ambidextrous innovation strategies in large infrastructure projects. This article tests the ambiguous relationship between team heterogeneity and ambidextrous innovation strategies by establishing two parallel hypotheses and exploring the influence of TL and identification. We argue that fostering ambidextrous innovation strategies in large infrastructure projects is an essential expansion of the existing ambidexterity theory in a particular "intermediate" form between temporary projects and permanent organizations. This article also provides new insights into fostering ambidextrous innovation strategies in large infrastructure projects in terms of team formation, process, and climate. It provides empirical evidence for the ambiguous relationship between team heterogeneity and ambidextrous innovation strategies.

II. Literature Review and Hypotheses

A. *Team Heterogeneity and Ambidextrous Innovation Strategies*

Team heterogeneity refers to the diversity of team members and the differentiation of members in various aspects including age, work experience, education level, and function diversity [22]. Team heterogeneity is recognized as a critical antecedent in predicting team outcomes, but it is controversial whether the exact relationship is linear or curvilinear. One view holds that team heterogeneity positively affects team outcomes (a relatively linear relationship) [23]. They argue that team heterogeneity provides different types of knowledge and a wider variety of professional perspectives, expands the scope of the information collected, and inspires differences between solutions, leading to more comprehensive decision making. Specific to ambidexterity, Koryak *et al*. [24] suggested that team heterogeneity may positively impact ambidexterity. However, another view claims that higher heterogeneity is not always better, and the relationship between team heterogeneity and team outcomes may be an inverted U-shaped relationship [25]. Teams with high heterogeneity are more challenging to manage, and their focus may become increasingly scattered [26]. When team heterogeneity increases further, it may increase coordination costs and decrease efficiency due to control losses and increasing conflicts [27]. Given these dynamics, it can be considered that the marginal costs of heterogeneity increase rapidly as it hits high levels.

Further focusing on ambidexterity, Haans *et al*. [20] suggested that the relationship between team heterogeneity and ambidexterity is most likely an inverted U-shaped relationship. When teams have to divide their attention and resources more or less between exploration and exploitation, the coordination cost of balancing the two is likely to be highest. In contrast, the coordination cost of focusing on one or the other is much lower [20]. This is because exploitation and exploration require different structures, routines, and processes, and the integration of the two involves tradeoffs across space and time [28]. The coordination cost has been considered as a concave function [20]. Especially in the interorganizational setting of large infrastructure one-off projects [29], the coordination cost of exploration and exploitation may increase faster. The relationship between team heterogeneity and ambidexterity is likely to be an inverted U-shaped relationship. However, there is no substantial empirical evidence to support it, so we established two parallel hypotheses:

> **H1a.** There is a positive relationship between team heterogeneity and ambidextrous innovation strategies in large infrastructure projects.
>
> **H1b.** There is an inverted U-shaped relationship between team heterogeneity and ambidextrous innovation strategies in large infrastructure projects.

B. *Mediating Role of TL*

Ambidexterity is increasingly recognized as a means to manage exploitation and exploration tensions [9]. Likewise, ambidexterity is considered a dynamic capability that evolves through a continuous process of experiential learning, decision-making, and implementation [30], [31]. March linked innovation and internal processes to expound tensions surrounding exploration and exploitation [32]. Therefore, this article adopts a team process perspective and introduces TL to explain how team heterogeneity promotes ambidextrous innovation strategies in large infrastructure projects. TL refers to the process in which team members seek to acquire, share, refine, or combine task-relevant knowledge and experience through interaction within the team [33]. This process may include seeking information, communicating with each other, challenging assumptions, seeking different perspectives, addressing differences of opinion, and reflecting on past actions [34].

The difficulty of cultivating team ambidexterity lies in that exploration and exploitation originate from different learning capabilities. Specifically, exploration refers to learning through planned experimentation, while exploitation means learning through experience refinement and reuse of existing routines [35]. To foster ambidextrous innovation strategies, teams need to focus on excavating existing knowledge to generate exploitative innovation and acquire new knowledge to generate exploratory innovation [36]. Some scholars held that team heterogeneity can lead to the collision and integration of different perspectives, which, in turn, affects the team's exploitative and exploratory learning behaviors [9], [37]. Focusing further on the large infrastructure project, Li *et al*. [38] claimed that team outcomes depend on TL among team members from different parties. We, therefore, infer that TL is needed in large infrastructure projects to bridge team heterogeneity and ambidexterity. Thus, we put forward the following hypothesis:

> **H2.** The relationship between team heterogeneity and ambidextrous innovation strategies in large infrastructure projects is mediated by team learning.

C. Moderating Role of TI

TI refers to the emotional significance that team members attach to their team membership [39]. It is noted that TI differs from constructs such as team cohesion because TI is concerned with the degree to which an individual identifies with the team rather than the individual's relationship with other team members. Large infrastructure projects have a lifespan with multiorganizational interfaces with a specific end date. Project delivery team members in large infrastructure projects come from different parties with diverse functions. In the end, members separate and do not always work together on subsequent projects. However, during the project, they have the shared goal of successfully delivering the project [38]. It is vital to study TI in the large infrastructure project context.

Van Der Vegt and Bunderson [39] held that the effects of team heterogeneity on team processes and team outcomes are considered to be different in teams with high and low TI. In other words, TI can moderate the relationship between team structure, team processes, and team outcomes. According to Social Identity Theory, TI can create a climate of collaboration. Specifically, different perspectives and knowledge originating from the team heterogeneity should be actively shared, constructively debated, and integrated into team goals [40]. Focusing further on ambidexterity, when a team has a high level of TI, the highly heterogeneous team will exchange information, learn across functional boundaries, and better balance exploration and exploitation, thereby promoting ambidextrous innovation strategies. We come up with the following hypotheses:

> **H3a.** Team identification moderates (reinforces) the relationship between team heterogeneity and ambidextrous innovation strategies in large infrastructure projects.
>
> **H3b.** Team identification moderates (reinforces) the relationship between team heterogeneity and team learning in large infrastructure projects.
>
> **H3c.** Team identification moderates (reinforces) the relationship between team learning and ambidextrous innovation strategies in large infrastructure projects.

III. Methods

A. Sample and Data Collection

Our unit of analysis is project delivery teams in large infrastructure projects. On the one hand, project delivery teams consist of engineers and managers from various parties. They are the center of the large infrastructure project network that transcends different functional departments. On the other hand, project delivery teams play a crucial governance role in providing decision-making support for senior executives and convey their strategies to various functional departments [41], [42]. In this study, the respondents are members of project delivery teams, most of whom are the heads of different functional departments.

We adopt the "snowball" and "maximum variation" strategies of the purposeful sampling approach to guide our sample collection. Specifically, we obtained access to senior managers from many large infrastructure projects based on the reliable contact information provided by the two authors of this article. We asked them to distribute electronic questionnaires to their project delivery teams and contact more senior managers involved in other projects. This purposeful sampling makes effective use of limited data sources and guarantees the respondents' appropriateness and willingness to participate in the survey. The "maximum variation" strategy means that we intentionally collect different types of projects to improve the generalizability of current research results. Finally, the investigated infrastructure projects include transportation (airports, bridges, subways, railways, and highways), energy and hydropower, education and health, amenity and utility facilities (parks, scenic spots, environmental governance, and underground pipe gallery). The diversity of infrastructure project types has dramatically improved the representativeness of samples. In addition to the targeted electronic questionnaire, we also collected on-site questionnaires. From November 2019 to April 2020, we collected 312 responses from 42 project delivery teams. If a team had less than three valid respondents, we removed the whole team data. Ultimately, 31 project delivery teams with 269 responses were

TABLE I
PROFILES OF INFRASTRUCTURE PROJECTS AND RESPONDENTS

Item	Number	Percentage
Infrastructure projects (Types)		
Transportation	15	48.4%
Energy and hydropower	3	9.7%
Education and health facilities	4	12.9%
Amenity and utility facilities	9	29.0%
Respondents		
Age (years)		
<30	10	3.7%
30-40	78	29.0%
40-50	129	48.0%
>50	52	19.3%
Work experience (years)		
<5	21	7.8%
5-10	51	19.0%
10-15	119	44.2%
>15	78	29.0%
Education level		
High school or below	36	13.4%
Bachelor	137	50.9%
Master	78	29.0%
Doctor	18	6.7%

considered valid (see Table I for their profiles), with an effective response rate of 86.2%.

B. Measures

1) *Ambidextrous Innovation Strategies:* To generate the scale items, we drew on Mohammadali *et al.*'s [43] research on infrastructure innovation classification, studies on infrastructure innovation [4]–[7], [14], [43]–[47], and the ambidexterity scale developed by He and Wong in the manufacturing context [48]. Through these analyses, we initially developed 24 items that reflect exploratory and exploitative innovation strategies in the context of large infrastructure projects, as detailed in Appendix. We invited eleven functional department managers from the project delivery team in Shanghai Pudong international airport phase IV extension project and five scholars specializing in large infrastructure project management to participate in the pretest. Before starting the pretest, these participants were informed of our research purpose and the background knowledge related to ambidextrous innovation strategies. They were first asked to filter the question items from these 24 items, and by deleting, merging, and modifying them, eight items finally emerged. Besides, they were asked to assess whether the measurements were well worded and interpreted in the large infrastructure project context, ensuring the content validity of the scale items. Based on their feedback, we finalized eight items to measure ambidextrous innovation strategies for the formal investigation, as shown in Table II.

We assessed these items using a scale ranging from 1 "not important" to 5 "very important." Factor analysis was performed to test the validity of the scale [48]. As shown in Table II, the eight items were reduced to two variables through factor

TABLE II
FACTOR ANALYSIS FOR AMBIDEXTROUS INNOVATION STRATEGIES SCALE

Goals or resource allocations for undertaking infrastructure projects (1=not important to 5=very important)	Exploratory i.s.	Exploitative i.s.
Cronbach alpha	0.776	0.718
Apply new facilities or materials	**0.745**	-0.161
Adopt new services	**0.828**	0.149
Develop new technologies	**0.783**	-0.003
Adopt innovative processes	**0.744**	0.130
Improve existing facilities, technologies, and processes	0.158	**0.809**
Improve engineering quality	0.079	**0.713**
Reduce engineering cost	-0.127	**0.693**
Accelerate engineering schedule	0.014	**0.744**

Note. i.s.: innovation strategies. Extraction method: Principal component analysis. Rotation method: Varimax with Kaiser normalization. Explained variance: 58.91%.

analysis, which can be interpreted as exploratory and exploitative innovation strategies (Cronbach alphas are acceptable, 0.776, and 0.718).

Following the research of He and Wong [48] and Cao *et al.* [49], we consider that ambidextrous innovation strategies are composed of the "balance dimension of ambidexterity" (BD) and "combined dimension of ambidexterity" (CD). BD is related to the balance or relative magnitudes of exploratory and exploitative innovation strategies, and it can be calculated by the formula $\mathrm{BD} = 5 - |\mathrm{exploratory\ innovation\ strategies} - \mathrm{exploitative\ innovation\ strategies}|$. While CD concerns the combined magnitude of exploratory and exploitative innovation strategies, and it can be calculated by the formula $\mathrm{CD} = \mathrm{exploratory\ innovation\ strategies} \times \mathrm{exploitative\ innovation\ strategies}$ [48].

1) *Team heterogeneity*: The heterogeneity of team members' age [18], work experience [50], education level [51], and functional department [18] were taken into account to calculate team heterogeneity. Age, work experience, and education level were provided with several ranges or category options in the questionnaire. The respondents could choose the corresponding choices according to their actual situation. The functional department needed to be filled in manually. The team heterogeneity was calculated using Blau's heterogeneity index, which uses the formula $H = 1 - \sum p_i^2$, where p is the proportion of a team in the respective diversity categories, and i is the number of different categories represented on the team [52]. Manual calculations are complex and error-prone, so we developed a program to simplify team heterogeneity calculations through Python. The Blau's heterogeneity index ranges from 0 to a theoretical maximum of 1. The higher the index, the more significant the heterogeneity among team members. It is noted that team heterogeneity is a team-level variable. The calculated value is based on all team members' demographic characteristics, so the team heterogeneity index of all members in the same team is consistent.

2) *TL:* Seven items were adapted from Edmondson [34] to measure the direction and intensity of the efforts made in TL. All the items were measured on a Likert scale ranging from 1 "very inaccurate" to 7 "very accurate."

TABLE III
MEASUREMENT MODEL: LOADINGS, CONSTRUCT RELIABILITY, AND CONVERGENT VALIDITY

Construct/item	Loading	CR	AVE
Team heterogeneity (TH)		.818	.533
TH1: Age heterogeneity	.799		
TH2: Functional heterogeneity	.676		
TH3: Work experience heterogeneity	.830		
TH4: Education level heterogeneity	.590		
Team learning (TL) [34]		.886	.529
TL1: We regularly take time to figure out ways to improve our team's work processes.	.734		
TL2: We tend to handle differences of opinion privately or off-line.	.697		
TL3: We often go out and get the information we can from others.	.879		
TL4: We frequently seek new information that leads us to make essential changes.	.648		
TL5: In our team, someone always makes sure that we stop to reflect on the team's work process.	.746		
TL6: We often speak up to test assumptions about issues under discussion.	.679		
TL7: We often invite people from outside the team to present information or have discussions with us.	.684		
Team identification (TI) [39]		.811	.520
TI1: I feel emotionally attached to our team.	.838		
TI2: I feel a strong sense of belonging to our team.	.641		
TI3: I feel as if the team's problems are my own.	.668		
TI4: I feel like part of the family in our team.	.724		
Ambidextrous innovation strategies [48]		.923	.857
Balance dimension of ambidexterity (BD)	.898		
Combined dimension of ambidexterity (CD)	.953		

TABLE IV
IMPACT OF TEAM HETEROGENEITY ON EXPLORATORY, EXPLOITATIVE, AND AMBIDEXTROUS INNOVATION STRATEGIES

Predictors	Exploratory i.s.	Exploitative i.s.	Ambidextrous i.s.
Team heterogeneity	$.775^{***}$	$.008^{ns}$	$.736^{***}$
Team heterogeneity²	$.074^{*}$	$-.218^{***}$	$.067^{*}$
U-shaped relationship robustness check	Non-U-shaped relationship (Turning point is outside the data range)	Inverted U-shaped relationship	Non-U-shaped relationship (Turning point is outside the data range)

Note. i.s.: innovation strategies. $^{*}<.05$, $^{**}<.01$, $^{***}<.001$.

3) TI*:* Following the study of Van Der Vegt and Bunderson, four items were used to measure TI [39]. We assessed these items using a scale ranging from 1 "completely disagree" to 7 "completely agree."

C. Data Analysis Method

Hierarchical regression analysis was used to test our hypotheses. This technique allows examining nonlinear evidence of statistical associations and has been widely used in organization and management research to assess curvilinear relationships [53]. First, we assessed the reliability and validity of the measures (outer model) [54]. Second, we applied STATA to analyze our moderated mediation model (inner model) through hierarchical regression analysis. In detail, we constructed the baseline model, mediation model, and moderated mediation model, respectively. Besides, we measured the curvilinear relationship by constructing a quadratic term [20] and measured the moderating effect by constructing interaction terms.

IV. RESULTS

A. Measurement Model

As shown in Table III, the measurement model's validity and reliability are satisfactory for individual items and constructs. Standardized indicator loadings evaluated the reliability of individual items. Among the seventeen items, nine items' standardized loadings were significantly higher than 0.7 [54]. Eight items were around 0.6, higher than the threshold of 0.5 [54]. Composite reliability (CR) can be used to evaluate construct reliability. Each construct's CR scores exceeded the threshold of 0.7 [54], which indicate acceptable reliability. The average variance extracted (AVE) values exceeded the threshold of 0.5 [54], which indicated good convergent validity.

B. Structural Model

In the baseline model [see Fig. 1(a), the baseline model], before measuring the impact of team heterogeneity on ambidextrous innovation strategies, we measured the impact of team heterogeneity on exploitative and exploratory innovation strategies. Second, we tested whether TL mediates the effect of team heterogeneity on ambidextrous innovation strategies and whether this mediation effect is partial or full (see Fig. 1(b), the mediation model). Third, we tested whether the indirect effect of team heterogeneity on ambidextrous innovation strategies through TL is moderated by TI (see Fig. 1(c), the moderated mediation model).

As shown in Table IV, team heterogeneity has a significant positive effect on exploratory innovation strategies ($\beta = .775$, $p < .001$), but the quadratic effect is also significant ($\beta = .074$, $p < .05$). To check robustness, drawing on Lind and Mehlum's U-shaped relationship validation procedure [55], we found that the curve turning point is outside the data range, not a U-shaped relationship. The relationship between team heterogeneity and exploratory innovation strategies is positive and linear. Team heterogeneity has no significant linear effect on exploitative innovation strategies ($\beta = .008$, n.s.), and the quadratic effect is significant ($\beta = -.218$, $p < .001$). Robustness checks were also carried out, and we found that the relationship between team heterogeneity and exploitative innovation strategies was indeed an inverted U-shaped relationship. Team heterogeneity has a significant positive effect on ambidextrous innovation strategies ($\beta = .736$, $p < .001$). However, just like exploratory innovation strategies, the quadratic effect, although significant ($\beta = .067$, $p < .05$), has not passed the U-shaped relationship validation procedure recommended by Lind and Mehlum [55]. This means that the relationship between team heterogeneity and ambidextrous innovation strategies is not U-shaped but positive and linear. H1a is supported, and H1b is rejected. To further validate and compare the effects of team heterogeneity on exploratory, exploitative, and ambidextrous innovation strategies, as shown in Fig. 2, we performed quadratic curve regressions, again verifying that only the relationship between team heterogeneity and exploitative innovation strategies is inverted U-shaped.

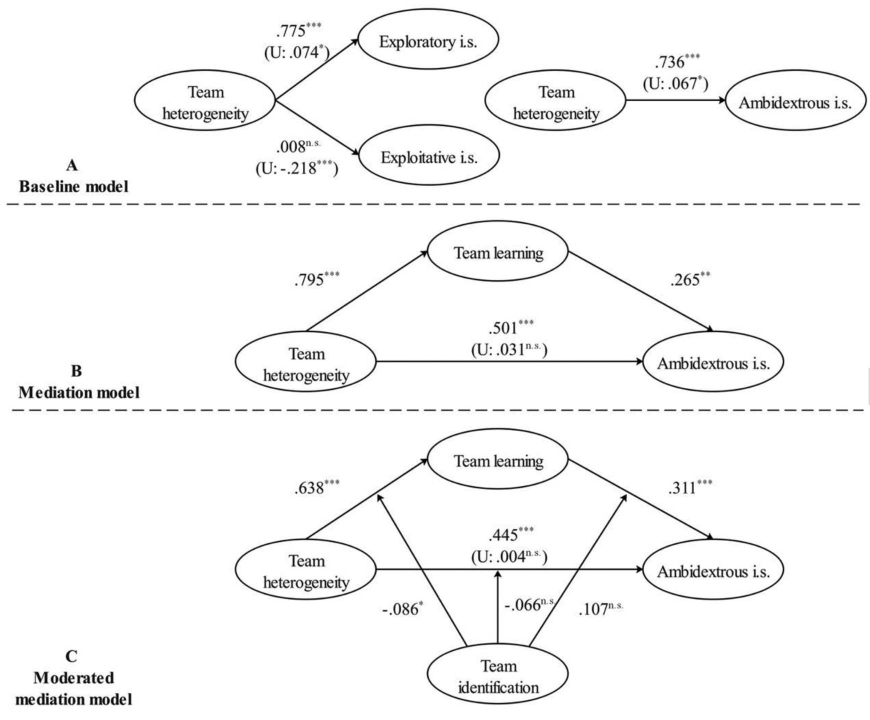

Fig. 1. Models used to test mediation and moderation. (Note. i.s.: innovation strategies.)

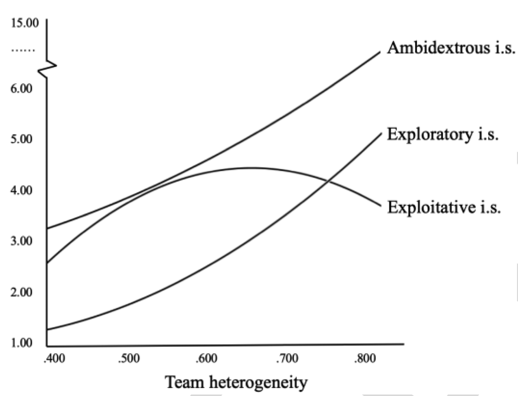

Fig. 2. Impact of team heterogeneity on exploratory, exploitative, and ambidextrous innovation strategies. (Note. i.s.: innovation strategies.).

TABLE V
TESTING THE MODERATED MEDIATION MODEL WITH BOOTSTRAPPING

	Model TL					Model AIS				
Predictors	β	SE	t	Bias-correlated 95%CI Lower	Upper	β	SE	t	Bias-correlated 95%CI Lower	Upper
TH	.638***	.055	11.594	.530	.747	.445***	.081	5.514	.286	.604
TL						.311***	.074	4.225	.166	.457
TI	-.258***	.052	-4.922	-.361	-.155	-.032ns	.066	-.493	-.161	.097
TH^2						.004 ns	.052	.074	-.084	.082
TH×TI	-.086*	.038	-2.236	-.161	-.010	-.066ns	.074	-.890	-.212	.080
TL×TI						.107ns	.068	1.568	-.027	.241
R^2	.681					.5494				
F	188.795***					64.1426***				

Note. 5000 bootstrap samples. TH: Team heterogeneity; TL: Team learning; TI: Team identification; AIS: Ambidextrous innovation strategies. $* < .05$, $^{**} < .01$, $^{***} < .001$.

As depicted in Fig. 1(b), the relationships between team heterogeneity and TL ($\beta = .795$, $p < .001$), TL and ambidextrous innovation strategies ($\beta = .265$, $p < .01$) are significant, and the effect of team heterogeneity is significantly reduced ($\beta = .501$, $p < .001$, non-U-shaped relationship), providing evidence for partial mediation, supporting H2.

As noted, H3a, 3b, 3c predicted that TI would moderate the associations between team heterogeneity and ambidextrous innovation strategies through TL in large infrastructure projects. As shown in Table V, in model TL, we estimated the moderating effect of the TI on the relationship between team heterogeneity and TL ($\beta = -.086$, $p < .05$), H3b was rejected. When the level of TI is high, the positive impact of team heterogeneity on TL is weakened, and the moderating effect of TI is negative. In model ambidextrous innovation strategies, we estimated the moderating effect of the TI on the relationship between team heterogeneity and ambidextrous innovation strategies ($\beta = -.066$, n.s.). Simultaneously, we estimated the moderating effect of TI on the relationship between TL and ambidextrous innovation strategies ($\beta = .107$, n.s.). H3a and H3c were not significant.

V. DISCUSSION

A. *Impact of Team Heterogeneity on Exploratory, Exploitative, and Ambidextrous Innovation Strategies*

The effects of team heterogeneity on exploratory and exploitative innovation strategies are positively linear and inverted

U-shaped, respectively. With increased team heterogeneity, exploratory and exploitative innovation strategies both increase in the first stage. However, in the second stage, as team heterogeneity further increases, exploratory innovation strategies continue to increase, while exploitative innovation strategies tend to decrease. This can be explained as the team heterogeneity grows further, more innovation is inspired by more diversified knowledge, but more coordination costs are associated with more conflicts and distractions. In the pursuit of exploratory innovation strategies, more innovation inspired by diversification may be more prominent than the increase in coordination costs. However, in the pursuit of exploitative innovation strategies, the coordination cost increase brought by high team heterogeneity overweighs more innovations stimulated. Thus, an inverted U-shaped relationship is formed. We consider that this may stem from the fundamental difference between the pursuits of exploitation and exploration, with exploration pursuing significant change while exploitation pursuing greater efficiency.

The effect of team heterogeneity on ambidextrous innovation strategies is also positively linear. In this article, ambidextrous innovation strategies are measured by the balance dimension and the combined dimension of the two innovation strategies. In the first stage, the effects of team heterogeneity on both innovation strategies are positive. However, in the second stage, these two strategies' effects are the opposite: the two innovation strategies become increasingly unbalanced. It shows that high team heterogeneity promotes exploratory innovation strategies for more than it inhibits exploitative innovation strategies.

This article is contrary to the inverted U-shaped effect of team heterogeneity on ambidexterity speculated by Haans *et al.* [20]. One possible reason for this is that Haans *et al.* did not conduct an empirical study but only proposed such speculation [20]. This difference may stem from the peculiarities of the large infrastructure project context. The large infrastructure project is a vital innovation ecosystem [56] and has to strike the right balance of open and closed innovation [47]. Researchers have investigated how innovation improves the performance and frame the future of large infrastructure projects and the industry [7], [57]. As a result, in large infrastructure projects, compared with the cost increase brought by high heterogeneity, the breakthrough brought by knowledge diversification may be more significant.

B. *Mediating Role of TL*

As a dynamic integration process, TL partially mediates the relationship between team heterogeneity and ambidextrous innovation strategies (H2). Team heterogeneity can better foster ambidextrous innovation strategies by improving TL. Temporary projects are often seen as an excellent context for knowledge creation due to their unique tasks, but their relative impermanence negatively impacts TL [58]. TL is often considered to occur in permanent organizations because various factors of TL, including trust, interaction frequency, knowledge base construction, etc., are all related to the organization's long-term existence [59]. Thus, as Sydow *et al.* [60] argued that, despite a definite end date, large infrastructure projects may endure for far more time than many organizations, and their learning process maybe not very different from those of permanent organizations.

We observed four project delivery team meetings in the Shanghai Pudong Airport Phase IV extension project from December 30, 2019, until January 13, 2020. A notable example is that in one meeting, the head of the baggage working group proposed to continue to invite the external consulting company of Phase III to provide baggage consulting services, which is a typical kind of exploitation. While other functional department heads claimed a big difference between Phase IV and Phase III, and more consulting companies could be invited to obtain different proposals. Then the best proposal could be selected. After the discussions, the exploitative "keeping the previous consulting company" and the exploratory "comparing the proposals of various consulting companies" were integrated. Similarly, in many cases, we observed that exploratory and exploitative innovation were better integrated during the TL process.

C. *Moderating Role of TI*

Interestingly, TI's moderating effect is significant only between team heterogeneity and TL (H3b), while it was not significant in other paths (H3a and H3c). A possible reason that H3a and H3c are not significant may be that TI can create an integrated ambidextrous organizational culture [61]. It can moderate the impact of team heterogeneity on team processes (TL) but cannot directly moderate team outcomes (ambidextrous innovation strategies). They are consistent with the finding from Mesmer-Magnus *et al.* [62] that strong TI does not guarantee a positive team effect. Another possible reason is that the one-off and somewhat persistent nature of large infrastructure projects affects TI's moderating effect. Project organizing has a different goal setting with permanent organizations [63]. Mesmer-Magnus *et al.* [62] believed that whether the team is temporary or long-term will affect TI's moderating role.

H3b was rejected, possibly due to the highly complex nature of large infrastructure projects. Porck *et al.* [64] believed that TI was negatively correlated with team outcomes when team tasks were highly complex. Teams with high task complexity will lead to more depletion when performing TI, whereas depletion is negatively correlated with team innovation. Porck et al.'s [64] view contradicted many studies on TI but is consistent with our results.

This interesting finding could be a starting point for future research about project climate. It is generally recognized that organizational climate could be maintained and stable as time goes. This may not be true in large infrastructure projects where different parties with diverse cultures work together toward a particular task [65]. On the one hand, it is challenging to quickly establish the project climate to influence the team outcome quickly. On the other hand, there are possibilities of conflicts between different organizational climates from project parties.

VI. Conclusion

Since large infrastructure projects are a particular "intermediate" form between temporary projects and permanent organizations, the results of previous research on fostering ambidexterity cannot merely be replicated. This article addresses the research gap of the ambiguous relationship between team heterogeneity and ambidextrous innovation strategies in large infrastructure projects. The findings showed that team heterogeneity has a positive linear effect on exploratory and ambidextrous innovation strategies and an inverted U-shaped effect on exploitative innovation strategies; team heterogeneity can better foster ambidextrous innovation strategies by improving TL; high TI weakens the positive relationship between team heterogeneity and TL.

A. Theoretical Contributions

This article contributes to the ambidexterity and large infrastructure project management literature fourfold. First, unlike permanent organizations, large infrastructure projects are unique one-off endeavors [14], while unlike general temporary projects, they have specific repetitive characteristics and are somewhat persistent. Thus, they are considered to be the hybrid of temporary projects and permanent organizations. In fostering ambidextrous innovation, temporary projects are often seen as an excellent context for exploratory innovation due to their unique tasks [11], while permanent organizations benefit from the accumulated knowledge base and are often considered beneficial to exploitative innovation [15]. In this respect, we believe that exploring how to foster ambidextrous innovation strategies in large infrastructure projects is not a simple expansion of a new context but an essential expansion of the existing ambidexterity theory in the particular "intermediate" form between temporary projects and permanent organizations. Second, there was some literature on the balance of efficiency and innovation in large infrastructure projects, which can be regarded as ambidexterity. However, they have focused on the critical role of ambidexterity [16] and its positive impact on performance [17]. Our study focuses on fostering ambidextrous innovation strategies in large infrastructure projects, making a complementary contribution to the large infrastructure project management literature [15]. Furthermore, we provide new insights into fostering ambidextrous innovation strategies in large infrastructure projects in terms of team formation, process, and climate. Third, by establishing two parallel hypotheses and exploring the influence of integrated process and climate, this article provides implications and empirical evidence on the ambiguous relationship between team heterogeneity and ambidextrous innovation strategies. Fourth, we also explore the impact of team heterogeneity on exploration and exploitation, respectively, and analyze the reasons for the two different results, which simultaneously provide inspirations for the discussion related to exploration and exploitation.

B. Managerial Implications

Our findings have practical implications for large infrastructure project managers. First, the different impact of team heterogeneity on exploratory, exploitative, and ambidextrous innovation strategies provides meaningful guidance for project management. On the one hand, when forming a project delivery team, it is important to focus not only on the individual characteristics and traits of team members but also on the team heterogeneity as a whole. On the other hand, large infrastructure projects have different requirements and needs for exploratory and exploitative innovation. The formation of the project delivery team should be different accordingly. For infrastructure projects with high exploratory requirements (such as technically challenging benchmark infrastructure projects) or high ambidexterity requirements (there is a tradeoff between exploration and exploitation), it is best to form highly heterogeneous project delivery teams. It is better to form project delivery teams that are not very heterogeneous for ones with high exploitative requirements (much successful experience for replicating and learning). Second, TL also plays a key role in large infrastructure projects that are both persistent and one-off, through improving TL, team heterogeneity can better foster ambidextrous innovation strategies. Thus, in large infrastructure projects, to leverage the interplay between exploratory and exploitative innovation strategies and to effectively allocate and integrate resources, project delivery teams should hold both regular and ad hoc activities to promote TL. Third, due to the task complexity and one-off characteristics of large infrastructure projects, too much emphasis on TI may bring more organizational losses, which may obliterate ambidextrous innovation strategies in large infrastructure projects.

C. Limitations and Future Research

This article suggests new directions for project management studies. First, the measurement of team heterogeneity in this article is based on demographic characteristics and is relatively simplistic. It would be interesting to study team networks through the social network approach or measure the deeper psychological and cognitive team heterogeneity. Second, since we focus on large infrastructure projects under construction in this research, objective measurement in such a context is quite challenging, so the more subjective data were adopted. More objective measurements could be adopted to evaluate exploratory and exploitative strategies [66]. Third, the results of the moderating effect of TI are different from most organizational management literature. We guess that it may attribute to the temporary and complex characteristics of large infrastructure projects, so it is recommended to conduct more case studies or in-depth interviews to extend our future findings. Fourth, ambidextrous innovation strategies can be explored in other specific project contexts in the future, for example, smart city projects [67].

APPENDIX
DEVELOPMENT OF AMBIDEXTROUS INNOVATION STRATEGIES SCALE IN THE INFRASTRUCTURE PROJECT CONTEXTS

Item design	**Item source**	**Item processing**
Exploratory innovation strategies		
1 Adopt new machinery, equipment or tool	Extracted from the	Integrate with 9
2 Apply new construction materials and products	classification of infrastructure	Integrate with 9
3 Develop or introduce new tasks	innovation by Noktehdan et al.	Integrate with 10
4 Combine the tool and function innovation	[43]	Integrate with 10
5 Combine the material or product innovation	Extracted from the research on	Integrate with 9
6 Adopt innovative plan, design, sketches or concepts	infrastructure project	Integrate with 12
7 Adopt a significant level of novelty in one area of the system	innovation by [4]–[7], [14],	Delete, as it cannot be juxtaposed with other items
8 Adopt small changes while leading to major changes on other components	[43]–[47]	Delete, as the grasp of the conceptual domain is suboptimal
9 Apply new materials	Adapted from the scale	Modify: Apply new facilities or materials
10 Adopt new services	developed by He and Wong in	Retain
11 Develop new technologies	the manufacturing context [48]	Retain
12 Adopt innovative processes		Retain
Exploitative innovation strategies		
13 Take small changes based upon current knowledge and experience	Extracted from the	Delete, as it cannot be juxtaposed with other items
14 Integrate multiple independent innovations	classification of infrastructure	Delete, as the grasp of the conceptual domain is suboptimal
15 Direct cost savings or better utilization of current resources	innovation by Noktehdan et al.	Integrate with 23
16 Reduce the adverse impact of the construction processes	[43]	Delete, not considered in many cases
17 Improve the safety and wellbeing of the employees and public	Extracted from the research on	Delete, not considered in many cases
18 Improve the degree of conformance with specifications	infrastructure project	Integrate with 22
19 Reduce the lead-times or increase the speed for the project	innovation by [4]–[7], [14],	Integrate with 24
20 Reduce adverse impact on communities	[43]–[47]	Delete, not considered in many cases
21 Improve existing technologies and processes	Adapted from the scale	Modify: Improve existing facilities, technologies, and processes
22 Improve engineering quality	developed by He and Wong in	Retain
23 Reduce engineering cost	the manufacturing context [48]	Retain
24 Accelerate engineering schedule		Retain

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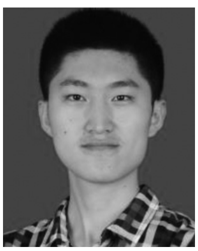

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