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Research on the impact of Digital Transformational Leadership on Digital Innovation Performance

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ABSTRACT
In the rapidly evolving digital economy, digital transformation has emerged as a crucial pathway for enterprises to achieve high-quality growth and maintain a competitive advantage. Enhancing digital innovation performance during the transformation process has become a pressing issue in both theoretical research and managerial practice. Grounded in Resource based View, this study examines the organizational transformation logic of "leader–strategy–performance" and develops a theoretical model that includes digital strategy as a mediating variable and digital transformation openness as a moderating variable. Based on data collected from 348 employees in China's manufacturing sector, the study employed structural equation modeling to test the proposed hypotheses. The results reveal that (1) digital transformational leadership significantly enhances employees' digital innovation performance; (2) digital strategy partially mediates this relationship; (3) digital transformation openness positively moderates the link between digital strategy and digital innovation performance; and (4) it also amplifies the moderated mediation effect of digital transformational leadership on digital innovation performance via digital strategy.

Keywords: Digital transformational leadership, Digital strategy, Digital innovation performance, Digital transformation openness, Institutional theory

1. INTRODUCTION
 Amid rapid advancements in digital technologies, the rise of big data, cloud

41   computing, and the Internet of Things is driving human society into a new
42   digital era[1]. Digital transformation has become a strategic priority for
43   achieving high-quality development, and how to advance it effectively has
44   become a major concern in the business world[2]. It is anticipated that
45   globally 85% of organizations will be digitalized and 42% will be fully
46   automated by 2027[3]. Digital transformation is now a vital pathway for the
47   survival and long-term development of traditional enterprises. Digital
48   innovation performance is increasingly seen as a key indicator for assessing
49   the success of digital transformation[4]. Employees as the direct participants
50   and executors of digital innovation, play a crucial role in shaping a firm's
51   overall digital innovation performance through their behavior and outcomes
52   in digital contexts[5]. Although employee-level digital innovation performance
53   is widely acknowledged as important, the specific mechanisms shaping
54   employees' capacity to produce innovative outcomes in digital contexts
55   remain insufficiently understood. This gap highlights the need to explore how
56   organizational factors can be leveraged to enhance employee digital
57   innovation performance and facilitate successful digital transformation.
58   The Resource Based View (RBV) is a widely applied theoretical perspective
59   in strategic management. It is grounded in an "inside-out" analytical
60   framework, highlighting that a firm's long-term success originates from its
61   distinctive internal resources and capabilities. These resources encompass
62   not only tangible assets but, more critically, intangible ones such as
63   knowledge, organizational culture, and leadership, which are difficult to
64   replicate [6]. According to the RBV, firms gain competitive advantage by
65   possessing resources and capabilities that are unique, valuable, rare, and
66   difficult to imitate[6, 7]. In the context of digital transformation, human
67   resources remain central to managerial decision-making and strategic
68   transformation in all organizations[8]. As individuals with distinct roles and
69   authority, leaders play a pivotal role in guiding organizational transformation
70   and development. In the digital era, transformational leaders must integrate
71   digital technologies and embody digital attributes to meet the evolving
72   demands of leadership roles and effectively lead digital transformation. As a
73   result, the concept of digital transformation leadership has emerged[9].
74   Digital transformation leadership constitutes a unique managerial resource
75   and dynamic capability that is essential for achieving competitive advantage
76   in the digital era[10].
77   The effective deployment of leadership capabilities in digital transformation
78   depends on strategic coordination and resource orchestration. As a core
79   element of complex enterprise management systems, digital strategy serves
80   as a comprehensive blueprint for value creation and has long been a central
81   concern in management research[11, 12]. From the RBV, digital strategy is not
82   only a guiding framework for resource allocation but also a critical
83   mechanism through which enterprises convert diverse digital resources into
84   unique capabilities[13]. Digital strategy acts as a bridge between leadership

85   vision and operational execution, enabling organizations to systematically
86   integrate digital technologies into their business models, processes, and
87   value propositions. The key criterion for evaluating digital innovation
88   performance is whether an enterprise can sustain or even enhance its value
89   creation capacity following transformation[14]. Enterprises undergoing digital
90   transformation must develop new digital strategies aligned with the demands
91   of the digital age to fully harness the benefits of transformation and enhance
92   the tangible outcomes of digital innovation. However, existing research has
93   not adequately examined how digital transformational leadership translates
94   into improved employee digital innovation performance through strategic
95   pathways.
96   During the implementation of digital strategies, organizational members
97   often display diverse attitudes toward change. The success of digital
98   transformation depends not only on technology deployment and leadership
99   behaviors but also on employees psychological readiness and cognitive
100   acceptance[15]. According to the RBV, employee's openness is a vital human
101   resource for the enterprise, and the quality of this resource directly
102   influences   the   effectiveness   of   digital   transformation   strategy
103   implementation. This openness reflects the extent to which organizational
104   members   support   digital   integration,   demonstrated   by   proactive   tool
105   adoption, active participation in technological learning, and adaptation to
106   new work methods[16]. Higher levels of openness reduce employee resistance,
107   thus   improving   the   efficiency   of   digital   strategy   implementation   and
108   strengthening the organization's ability to convert efforts into performance
109   outcomes[17]. Therefore, incorporating digital transformation openness into
110   the analytical framework not only emphasizes the role of human factors in
111   strategy implementation but also uncovers deeper interaction mechanisms
112   within the leadership, strategy, and performance pathway.
113   Building on the foregoing discussion, this study seeks to address two central
114   research questions. First, how does digital transformational leadership
115   influence   employee   digital   innovation   performance   through   strategic
116   mechanisms? Second, under what conditions is this strategic pathway most
117   effective in driving employee digital innovation performance? To address
118   these questions, grounded in the RBV, this study conceptualizes digital
119   transformational leadership as a critical managerial resource that enhances
120   employee digital innovation performance by enabling the formulation and
121   effective implementation of digital strategy. Furthermore, by incorporating
122   digital transformation openness as a key boundary condition, this study
123   emphasizes the importance of employees' proactive engagement with and
124   adaptive capacity for digital transformation. By integrating these elements,
125   this study elucidates the specific strategic pathways and boundary conditions
126   through which digital transformational leadership drives employee digital
127   innovation performance.
128

129 **2. THEORY AND HYPOTHESES**
130 **2.1 Resource Based View (RBV)**
131 The Resource-Based View (RBV) represents a fundamental theoretical
132 framework in strategic management that emphasizes how organizations
133 achieve competitive advantage through the strategic deployment of valuable,
134 rare, inimitable, and non-substitutable (VRIN) resources and capabilities,
135 and goes beyond mere possession to highlight resource orchestration
136 through the structuring, bundling, and leveraging of resources to create
137 value[6, 7]. Within this framework, resources encompass not only tangible
138 assets such as financial capital and physical infrastructure, but also
139 intangible assets including knowledge, capabilities, organizational culture,
140 and leadership competencies[18, 19]. The dynamic interplay between resource
141 accumulation, capability development, and strategic deployment determines
142 an organization's ability to create and sustain competitive advantages in
143 rapidly changing environments[20.]

144 This study develops a theoretical model based on the RBV, emphasizing the
145 pathway from digital transformation leadership to strategy and performance.
146 Within this framework, digital transformation leadership is viewed as a
147 distinctive and valuable managerial resource. As core human capital, it
148 enables firms to integrate and apply other essential resources efficiently.
149 Digital transformational leaders act as resource orchestrators by identifying
150 valuable digital resources and guiding organizational members in strategic
151 initiatives, fulfilling the VRIN criteria through their distinctive combination
152 of digital expertise and transformational competencies. Accordingly, digital
153 strategy serves as the primary mechanism through which leadership
154 transforms its capabilities into tangible outcomes. It represents the bundling
155 process in which diverse digital resources are systematically integrated into
156 coherent organizational capabilities. Digital strategy involves structured
157 planning that enables firms to leverage these resources effectively to
158 redesign business models and drive innovation. Digital transformation
159 openness is also a human resource. This proactive mindset and openness to
160 change not only enhance the efficiency of strategy execution but also
161 constitute a vital aspect of the organizational climate that determines
162 whether resources can be effectively transformed into innovation
163 performance outcomes.
164

165 **2.2 Digital Innovation Performance**
166 Digital innovation performance has emerged as a central topic in recent
167 research on corporate management and innovation, with scholars
168 systematically exploring its definition and evaluation criteria. Drucker[21] was
169 among the first to highlight that innovation performance, in the context of
170 R&D and innovation activities, reflects an enterprise's development status
171 and future growth potential. Coombs[22] further emphasized that innovation
172 performance is a comprehensive, outcome-oriented indicator. It captures not

173 only the inputs and outputs during the technology development phase but
174 also the knowledge, capabilities, and experience accumulated in the process,
175 making it a crucial measure of R&D effectiveness. Tierney and Farmer[23]
176 defined innovation performance, from a product-outcome perspective, as the
177 creation of valuable products, services, or processes within a specific domain.
178 Wang and Zhang[24] broadened the concept of innovation performance by
179 integrating digital technologies, including not only product innovation but
180 also business model innovation and organizational digital transformation.
181 While these perspectives clarify innovation performance at the
182 organizational level, they often overlook individual-level behaviors and
183 contributions. This limitation is especially relevant in the context of digital
184 transformation, where individual employee roles are increasingly vital in
185 driving organizational innovation.

186 To overcome the limitations of previous research, this study redefines
187 digital innovation performance from the viewpoint of individual employees,
188 building on the work of Janssen and Zhou[25, 26]. Digital innovation
189 performance is conceptualized as the extent to which employees, in digital
190 work contexts, intentionally implement creative ideas, actively use digital
191 tools to demonstrate creativity and problem-solving skills, enhance their
192 competitiveness through concrete innovative behaviors, and ultimately
193 generate visible outcomes and value. This definition underscores not only
194 employee's initiative and creativity in the innovation process, but also the
195 pivotal role of digital technologies as enablers, and the strong connection
196 between individual and organizational innovation outcomes. Thus, digital
197 innovation performance extends beyond traditional dimensions such as
198 product or technological outputs. It emphasizes outcomes generated by
199 employees through knowledge integration, problem-solving, and value
200 creation in digital environments. This perspective offers substantial
201 theoretical and practical value for understanding employee behavior amid
202 digital transformation[27].

203

2.3 Digital Transformational Leadership and Digital Innovation Performance

206 As technology evolves and the external business environment continues to
207 change, the digital adaptability of organizational leaders has become an
208 increasingly critical driver of successful transformation[3]. From the
209 perspective of individual leadership traits, digital transformational leaders
210 equipped with digital thinking can accurately anticipate technological trends,
211 define clear strategic directions and investment priorities, and guide their
212 organizations toward enhanced digital performance[28]. These leaders inherit
213 the strengths of traditional transformational leadership, such as motivation,
214 vision-setting, and organizational empowerment while also integrating core
215 elements of digital leadership, including technological sensitivity, data-driven
216 decision-making, and agility in innovation[29].

217   When making strategic decisions, digital transformational leaders typically
218 exhibit insightful and forward-looking judgment. This enables them to
219 identify and seize opportunities arising from digital advances, leading their
220 firms to either transform existing business models or establish entirely new
221 digital ecosystems[30]. Digital transformational leadership influences digital
222 innovation performance through multiple interrelated mechanisms. First,
223 such leaders foster an innovation-friendly organizational climate by
224 encouraging employees to experiment, take risks, and engage in continuous
225 learning. They create a psychologically safe environment that empowers
226 employees to explore novel digital solutions and challenge existing
227 paradigms without fear of failure or punishment. Second, digital
228 transformational leaders excel in mobilizing and allocating resources,
229 ensuring that innovation initiatives have the necessary technological
230 infrastructure, financial support, and human capital required for successful
231 implementation, thereby enhancing employee innovation performance[31].
232 Therefore, we propose the following hypothesis:

233

234   *Hypothesis 1: Digital transformational leadership is positively related to*
235 *digital innovation performance.*

236

237 **2.4 Digital Strategy and Digital Innovation Performance**
238 A digital strategy refers to a strategic initiative through which firms respond
239 to rapidly evolving digital environments by leveraging advanced technologies
240 such as big data, cloud computing, social media, and the Internet of Things
241 to systematically redesign their business models, product architectures, and
242 organizational operations[12]. Digital strategy encompasses not only the
243 adoption of technological tools but, more fundamentally, the enterprise's
244 capability to achieve process automation and organizational restructuring
245 through digital technologies[32]. At its core, digital strategy is a systematic
246 process through which organizations integrate and reconfigure digital
247 resources across key domains such as business models, value creation logic,
248 process design, and organizational management to drive transformation and
249 sustained innovation[13]. As digital technologies become increasingly
250 prevalent, the digital transformation of traditional manufacturing firms has
251 shifted from a purely technical concern to a central issue in strategic
252 management. Digital strategy plays a pivotal role in enhancing firms' digital
253 innovation performance. First, the systematic implementation of digital
254 strategy enhances firms capabilities to leverage technology for product
255 innovation, process optimization, and service redesign, thereby improving
256 overall innovation outcomes[33]. Second, by restructuring organizational
257 frameworks, operational processes, and resource allocations, firms can
258 develop more agile and intelligent operational systems, thereby
259 strengthening their internal R&D capabilities and responsiveness to market
260 dynamics.

261 Moreover, a digital strategy can enhance information connectivity and
262 promote collaborative innovation among firms and key stakeholders
263 throughout the value chain. Digital strategy promotes collaboration between
264 firms and external partners including suppliers, customers and research
265 institutions[34]. This collaboration facilitates resource integration across
266 organizational boundaries and drives joint innovation, thereby improving
267 digital innovation performance in products and services[35]. This form of
268 digital collaboration helps technology-driven firms achieve high-quality
269 innovation outcomes in product development, service design and process
270 optimization. Therefore, we propose the following hypothesis:

271

272 *Hypothesis 2: Digital strategy is positively related to digital innovation*
273 *performance.*

274

275 2.5 Mediating Effect of Digital Strategy between Digital
276 Transformational Leadership and Digital innovation performance

277 Digital innovation performance is often stimulated by technological change.
278 However, technological advancement alone is not sufficient to ensure
279 sustained improvements in a firm's digital innovation outcomes[36]. During
280 digital transformation, firms need digital transformational leaders who
281 possess strategic vision and the capacity to drive change. These leaders must
282 be able to coordinate comprehensive transformation across internal
283 structures, organizational culture and the external business environment[32].
284 In this context, digital strategy plays a central role in a firm's digital
285 innovation efforts. It functions not only as a structured framework for
286 implementing digital technologies but also as a vital link that transforms
287 innovation achievements into competitive advantage[13].
288 Digital transformational leadership plays a pivotal role in shaping the
289 development and implementation of a firm's digital strategy. It drives
290 cultural change, supports process redesign, and facilitates business model
291 restructuring, thereby improving the effectiveness of digital strategy
292 execution[17]. Acting as a key mediating mechanism between leadership and
293 innovation performance, digital strategic initiatives deepen digital innovation
294 implementation and elevate the firm's overall level of digital
295 transformation[33]. This process facilitates the integration of digital
296 technologies into core business operations and enables the effective
297 conversion of digital innovation outcomes into sustainable innovation
298 returns.
299 In strategic practice, digital transformational leaders adopt a disruptive
300 innovation mindset. They focus on the feasibility of strategy execution and
301 the redesign of business logic to identify and capture new opportunities for
302 organizational transformation[37]. By building an innovative and adaptive
303 digital strategy system, firms can drive fundamental changes in their
304 organizational structures, operational models, and value creation

305 mechanisms. This enables entry into new markets, expansion of customer
306 bases, and diversification of value co-creation channels[38, 39]. Furthermore,
307 by actively building and managing digital platforms and ecosystems, firms
308 can use digital technologies to facilitate more efficient and higher-quality
309 value interactions. This allows them to extensively share and absorb external
310 benefits generated through digital innovation[40, 41]. This ecosystem-oriented
311 strategic mindset fundamentally strengthens a firm's digital innovation
312 performance. Therefore, we propose the following hypothesis:

313

314 *Hypothesis 3: Digital strategy mediates the relationship between digital*
315 *transformational leadership and digital innovation performance.*

316

2.6 Moderating Role of Digital Transformation Openness

318 Digital transformation is not merely a matter of technology adoption but a
319 comprehensive organizational change involving the restructuring of
320 management processes, innovation of business models, adjustment of
321 organizational structures, and reconstruction of corporate culture[42].
322 Therefore, the successful implementation of digital strategies depends not
323 only on the establishment of technological infrastructure but also on
324 organizational members' understanding and acceptance of the impacts of
325 digital technological change[43]. In this context, digital transformation
326 openness is regarded as a key moderating factor influencing the
327 effectiveness of digital strategy implementation. This concept refers to
328 employees' positive attitudes, cognitive understanding, and behavioral
329 intentions toward digital transformation, reflecting their psychological and
330 behavioral acceptance and support for the integration of digital technologies
331 [44]. Specifically, this openness manifests in employees' willingness to adopt
332 new digital tools, actively participate in technological change, and
333 continuously learn and adapt to the evolving digital environment[16].
334 According to the RBV, digital transformation openness is a vital
335 organizational resource. It shapes a firm's capacity to identify, assimilate,
336 and apply digital knowledge. Such openness functions as a complementary
337 asset. It increases the effectiveness of digital strategy implementation by
338 reducing internal resistance and facilitating resource integration.
339 Organizations with high levels of digital transformation openness tend to
340 exhibit stronger dynamic capabilities. These capabilities allow for flexible
341 adjustments to daily operations and processes in response to digital strategic
342 initiatives[45]. The moderating role of digital transformation openness aligns
343 with a central RBV principle: the value of strategic resources is contingent
344 on the existence of complementary assets and a supportive organizational
345 context[7]. When employees demonstrate greater openness to digital
346 transformation, digital strategies are executed more effectively. This
347 openness fosters internal conditions that support resource reconfiguration
348 and capability development[46], enabling employees to better leverage

349 organizational resources to produce innovative outcomes. In other words,
350 digital transformation openness moderates the relationship between digital
351 strategy and digital innovation performance: under conditions of high
352 openness, digital strategies are more likely to generate tangible and valuable
353 innovative outcomes. Therefore, we propose the following hypothesis:

354

355 *Hypothesis 4: Digital transformation openness positively moderates the*
356 *relationship between digital strategy and digital innovation performance,*
357 *such that the relationship becomes stronger when digital transformation*
358 *openness is high rather than low.*

359

360 **2.7 Moderated Mediating Effect**

361 Hypothesis3 and 4 together form a mediation model with moderating, which
362 is based on the moderating mediator inference method[47]. Digital
363 transformation openness moderates the relationship between digital strategy
364 and digital innovation performance. This study further predicted that digital
365 transformation openness positively moderates the mediating effects of digital
366 transformational leadership on digital innovation performance via digital
367 strategy. Therefore, the following hypothesis is proposed.

368

369 *Hypothesis 5: Digital transformation openness positively moderates the*
370 *indirect effect of digital transformational leadership on digital innovation*
371 *performance through digital strategy. In other words, the higher the digital*
372 *transformation openness, the greater the mediating effect of digital strategy.*

373

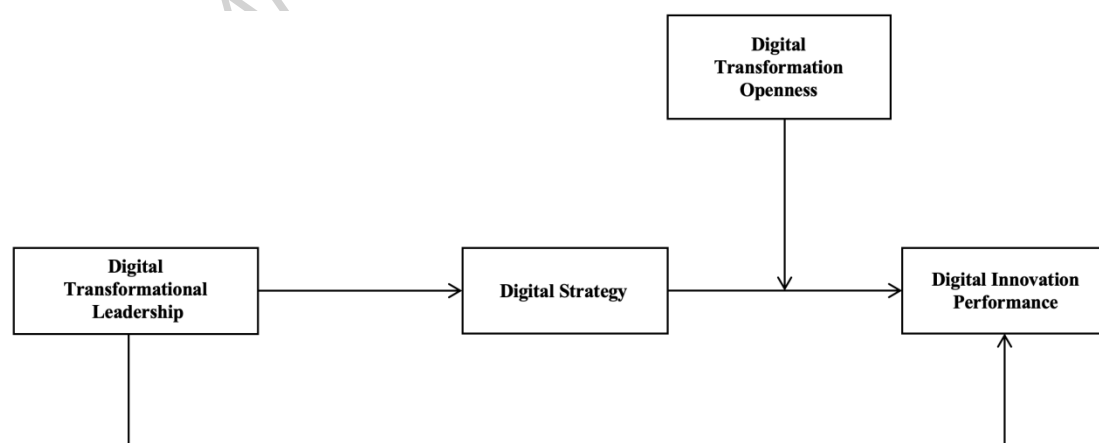374 **Figure 1** shows the theoretical model developed in this study.

375

376
377 **Figure 1** Theoretical model.
378

379 **3. MATERIALS AND METHODS**

380 **3.1 Sample and Procedures**

381 Data for this study were collected from March 2025 to April 2025. The
382 research sample mainly included employees from manufacturing firms that

383   are implementing digital transformation in the Shandong province of China.
384   Shandong Province was chosen as the research sample because it is one of
385   China's leading manufacturing hubs and a pilot region for national digital
386   transformation initiatives. The province hosts numerous traditional
387   manufacturing firms that actively adopt digital technologies, making it a
388   highly representative region for examining digital transformation in China's
389   manufacturing sector. To ensure sample authenticity, the following criteria
390   were applied: (1) the firm has formally initiated a digital transformation plan;
391   (2) the firm has invested in digital technologies such as big data, cloud
392   computing, robotics, or the industrial internet; (3) the firm has implemented
393   at least one organizational or process change related to digitalization, such
394   as a digital supply chain or smart manufacturing). The validity of these
395   criteria was verified using official corporate reports, website information,
396   and confirmation from HR managers during preliminary communications.
397   Among the 25 companies approached a total of 7 entities accorded their
398   consent to participate in the study. A formal survey was conducted using a
399   web-based questionnaire. Approval was guaranteed by the relevant human
400   resource heads of the companies, who willingly participated in the surveys.
401   This study separated the independent variables from the dependent variables
402   in survey waves to mitigate common method bias[48]. The questionnaire
403   survey comprised two stages: During Time 1 (T1), employees completed
404   questionnaires regarding a predictor variable (digital transformational
405   leadership), a mediating variable (digital strategy), and demographic
406   variables (age, gender, education, seniority and Years implementing DT).
407   After a month, during Time 2 (T2), the same participants completed
408   questionnaires regarding a moderating variable (digital transformation
409   openness) and a dependent variable (digital innovation performance). To
410   match the responses obtained during T1 and T2, participants were asked to
411   enter the last four digits of their ID numbers in the questionnaires.
412   A total of 560 questionnaires were distributed in this study and 407
413   questionnaires were collected. After filtering out incomplete responses and
414   removing outliers, 348 valid questionnaires remained with a response rate of
415   62.1% In terms of the sample distribution, 175 (50.29%) respondents were
416   males and 173 (49.71%) were females. Most of the respondents were aged
417   between 26 and 30 years (39.08% of the total survey population). The
418   majority possessed a bachelor's degree (49.43% of the total survey
419   population), seniority ranged mostly between 4 to 6 years (28.44% of the
420   total survey population) and years implementing DT ranged mostly between
421   1 to 2 years (27.30% of the total survey population) (**Table 1**). The sample
422   size was adequate to analyze the model. Using the rule of thumb of (no. of
423   items in questionnaire × 5 = 24 × 5) which is 120[49]. Therefore, the sample
424   of 348 is adequate because this is more than the required number of 120
425   responses. To further assess the adequacy of our sample size beyond the
426   item-ratio criterion, we conducted a post hoc power analysis using G*Power

427 3.1. With a significance level of 0.05, a medium effect size ($f^2 = 0.15$), and
428 nine predictors, the analysis yielded a statistical power of 0.99. This
429 substantially exceeds the commonly recommended threshold of 0.80,
430 indicating that our sample of 348 respondents provides sufficient power to
431 detect the hypothesized mediation and moderation effects.
432
433 **3.2 Measures**
434 The scales used in this study were mainly derived from mature scales used in
435 the academic community, with proven reliability and validity in domestic and
436 foreign studies. All scales used the 5-point rating like the Likert scale, where
437 1 means strongly disagree and 5 means strongly agree. The specific
438 measurement of each variable is as follows.
439
440 **3.2.1 Digital Transformational Leadership**
441 Digital transformational leadership was measured with the 6-item scale
442 developed by Alnuaimi et al.[9]. The items are as follows: "Our leaders inspire
443 all members with the digital transformation plans for our organization," "Our
444 leaders provide a clear digital trans formation vision for the organization's
445 members to follow" etc. Cronbach's alpha for this scale was 0.874.
446
447 **3.2.2 Digital Strategy**
448 Digital strategy was measured with the 4-item scale developed by Li et al.[50].
449 The items are as follows: "In my organization, we integrate digital technology
450 and business strategy to attain strategic alignment with the government and
451 other partners," "In my organization, we create a shared vision of the role of
452 digital technology in business strategy" etc. Cronbach's alpha for this scale
453 was 0.867.
454
455 **3.2.3 Digital Innovation Performance**
456 8-item were adapted and modified to fit the digital transformation context
457 from previous employee innovation performance scales (Chang et al.[51]) to
458 measure digital innovation performance. The items are as follows: "I manage
459 to implement my innovative ideas involving digital technologies at work," "I
460 transform innovative ideas into useful digital applications or tools." etc.
461 Cronbach's alpha for this scale was 0.916.
462
463 **3.2.4 Digital Transformation Openness**
464 For the measurement of digital transformation openness, 6-item were
465 adapted from Hinduan et al.[52]. The items are as follows: "I am very
466 interested in using digital technologies and digital tools," "I show strong
467 willingness to learn new knowledge and digital technologies" etc. Cronbach's
468 alpha for this scale was 0.892.
469

TABLE 1 | Demographics of the survey respondents. (N = 348)

Variable		N	Percentage			N	Percentage
Gender	Male	175	50.29	Seniority	≤ 1	65	18.68
	Female	173	49.71		[1, 3]	91	26.15
Age	[20, 25]	49	14.08		[4, 6]	99	28.44
	[26, 30]	136	39.08		[7, 10]	81	23.28
	[31, 35]	94	27.01		≥ 10	12	3.45
	[36, 40]	44	12.64		≤ 1	50	14.37
	≥ 40	25	7.18	Years implementing DT	[1, 2]	95	27.30
Education	High school	10	2.87		[3, 4]	86	24.71
	Associate degree	73	20.98		[5, 6]	68	19.54
	Bachelor degree	172	49.43		≥ 6	49	14.08
	Master degree	68	19.54				
	doctoral degree	25	7.18				

470

4. RESULTS

All statistical analyses were conducted using IBM SPSS Statistics (Version 29.0; https://www.ibm.com/products/spss-statistics), Mplus (Version 8.0; https://www.statmodel.com), and SmartPLS (Version 4.1; https://www.smartpls.com). Specifically, SEM was run with Mplus and SmartPLS to test reliability, validity, and model fit. To examine the hypotheses, this study performed partial least squares structural equation modelling (PLS-SEM) using SmartPLS.

4.1 Reliability and Validity

We assessed the constructs' reliability using the internal consistency measure analysis, obtaining acceptable values for Cronbach's alpha and composite reliability (CR). However, the factor loadings of items DTL6 and DTO4 in the DTL and DTO constructs were both below 0.5, falling short of the acceptable threshold[53]. Therefore, we dropped item DTL6 and DTO4 to improve the model's internal consistency and reliability and avoid having an issue with the model. A post hoc inspection suggests that the poor performance of these items may have resulted from translation nuances or cultural interpretations, rather than from fundamental flaws in the underlying constructs. **Table 2** summarizes the results of convergent validity and internal consistency reliability. All indicators and constructs meet the required measurement criteria. Specifically, the factor loadings are all above 0.759, demonstrating that indicator reliability is achieved[54]. In addition,

494 Cronbach's alpha value of each construct ranged from 0.867 to 0.916
495 (exceeding 0.7). The AVE values ranged from 0.630 to 0.715 (exceeding 0.5),
496 denoting that convergent validity is also achieved[55]. Furthermore, CR
497 values are 0.908 to 0.932, well above the required minimum level of 0.70,
498 thus demonstrating internal consistency[56]. In other words, the results show
499 that the model has good convergent validity and internal consistency.
500

TABLE 2 | Construct Reliability and Validity

Items	Loading	Cα	CR	AVE
DTL		0.874	0.908	0.664
Item1	0.779			
Item2	0.835			
Item3	0.840			
Item4	0.813			
Item5	0.804			
DS		0.867	0.909	0.715
Item1	0.813			
Item2	0.820			
Item3	0.895			
Item4	0.852			
DIP		0.916	0.932	0.630
Item1	0.779			
Item2	0.806			
Item3	0.780			
Item4	0.812			
Item5	0.759			
Item6	0.782			
Item7	0.828			
Item8	0.803			
DTO		0.892	0.920	0.698
Item1	0.867			
Item2	0.852			
Item3	0.803			
Item5	0.830			
Item6	0.823			

N = 348; Cα, Cronbach's alpha; CR, composite reliability; AVE, average variance; DTL, digital transformational leadership; DS, digital strategy; DIP, digital innovation performance; DTO, digital transformation openness

501
502 For discriminant validity, compared to other competition models, the
503 theoretical four-factor model (digital transformational leadership, digital
504 strategy, digital innovation performance, and digital transformation
505 openness) had a better fit to the data [$\chi 2/df$ = 1.556, (CFI) = 0.974, (TLI) =
506 0.970, (RMSEA) = 0.040, and (SRMR) = 0.043 (see **Table 3**). The CFA

507 results showed that the theoretical four-factor model had satisfactory
508 discriminant validity.
509

TABLE 3 | Results of confirmatory factor analysis.

Models	Factor	χ^2	df	χ^2/df	RMSEA	CFI	TLI	SRMR
Four-factor model	DTL, DS, DIP, DTO	317.802	203	1.566	0.040	0.974	0.970	0.043
Three-factor model	DTL+DS, DIP, DTO	801.334	206	3.890	0.091	0.863	0.847	0.072
Two-factor model	DTL+DS+DIP, DTO	1322.782	208	6.360	0.124	0.744	0.716	0.103
Single-factor model	DTL+DS+DIP+DTO	1963.626	209	9.395	0.155	0.598	0.555	0.122

Note: N = 348; DTL, digital transformational leadership; DS, digital strategy; DIP, digital innovation performance; DTO, digital transformation openness

510

511 Furthermore, the heterotrait–monotrait ratio of correlations (HTMT)
512 criteria were employed to test the discriminant validity. Different
513 recommendations exist for confirming the HTMT criterion, with the
514 conservative criterion suggesting that the HTMT value should be below
515 0.85[57], and the classical criterion indicating that the HTMT value should be
516 below 0.90[58]. The HTMT ratio table demonstrates that all values fall within
517 the range of 0.422 to 0.595, which is lower than the specified criterion, thus
518 confirming discriminant validity **Table 4**.
519

TABLE 4 | Heterotrait–monotrait ratio (N = 348).

	DIP	DTL	DS	DTO
DIP				
DTL	0.461			
DS	0.595	0.503		
DTO	0.422	0.464	0.522	

520
521
4.2 Common Method Variance
523 Common method variance (CMV) may affect the empirical results because
524 our study data were collected through self-report questionnaires. Podsakoff
525 et al.[59] showed that procedural and statistical techniques can be adopted
526 for CMV. In the statistical technique, the possibility of common method bias
527 was tested using Harman's one factor test[60]. A principal component factor
528 analysis with varimax rotation was used on the items of digital
529 transformational leadership, digital strategy, digital innovation performance,
530 and digital transformation openness. This result revealed multiple factors
531 with eigenvalues greater than 1. The first factor accounted for 22.96% (<
532 50%) loading, which proved the absence of CMV[61].

533   Further, we conducted the unmeasured latent method factor[59], to test
534 CMV. A comparison of the latent method factor model ($\chi2/df = 1.276$, CFI =
535 0.977, TLI = 0.971, RMSEA = 0.040, SRMR = 0.043 and the four-factor
536 model ($\chi2/df = 1.566$, CFI = 0.974, TLI = 0.970, RMSEA = 0.040, SRMR =
537 0.043) indicated no significantly changes in CFI[62]. Thus, CMV was not a
538 major problem for the data.
539

540 **4.3 Means and Correlations**
541 The descriptive statistics and correlation analysis results presented in Table
542 5 indicate that digital transformational leadership is positively correlated to
543 digital strategy (r = 0.436, $p < 0.05$), digital innovation performance (r =
544 0.412, $p < 0.05$), and digital transformation openness (r = 0.408, $p < 0.05$).
545 Digital strategy and digital transformation openness are positively correlated
546 to digital innovation performance (r = 0.530, $p < 0.05$ and r = 0.382, $p <$
547 0.05). The correlation between the key variables supports our hypotheses on
548 the direct and indirect effects of digital transformational leadership on
549 digital innovation performance.
550

TABLE 5 | Means, standard deviations (SD), and correlations.

Variables	Mean	SD	1	2	3	4	5	6	7	8	9
1.Gender	1.50	0.501	1								
2.Age	2.60	1.100	-0.049	1							
3.Education	3.07	0.897	0.049	-0.093	1						
4.Seniority	2.67	1.128	-0.094	0.475**	0.021	1					
5. Years	2.92	1.266	-0.007	-0.165**	-0.073	0.075	1				
6.DTL	3.77	0.751	0.056	0.042	-0.055	0.034	0.002	1			
7.DS	3.93	0.838	0.073	0.055	-0.029	0.014	0.025	0.436**	1		
8.DIP	3.91	0.758	0.034	0.142**	0.006	0.089	-0.088	0.412**	0.530**	1	
9.DTO	3.77	0.852	0.067	-0.024	-0.080	-0.035	-0.023	0.408**	0.459**	0.382**	1

Note: N = 348; **$p < 0.01$; *$p < 0.05$; DTL, digital transformational leadership; DS, digital strategy; DIP, digital innovation performance; DTO, digital transformation openness

551

552 **4.4 Structural Model**
553 Before testing the structural model, we first tested its collinearity.
554 Collinearity is measured using the variance inflation factor (VIF), and, ideally,
555 the VIF values should be close to and lower than 3[53]. The results show that

556 all VIF values are below this threshold, suggesting no collinearity among the
557 constructs. We also examined the R^2 value, which indicates the model's
558 predictive power by showing the endogenous variable's variance that the
559 exogenous variables can explain. The R^2 value for DIP (0.415) indicates that
560 all the constructs combined explain 41.5% of the variance in DIP. The R^2
561 value for DS is 0.199. Further, we checked the Q^2 values to assess the
562 predictive relevance values generated by the variables. The Q^2 values for DIP
563 (0.260) and DS (0.191) were above 0, which means that the model has
564 predictive relevance.

565   To examine the hypotheses, bootstrapping was carried out using SmartPLS
566 4.1 with 10000 subsamples based upon percentile bootstrapping with a
567 two-tailed test type and a significance level of 0.05. The PLS-SEM
568 bootstrapping approach statistically determined the structural mode
569 coefficients representing the hypothesized relationships. Simultaneously, to
570 ensure the robustness of the results, we included age, gender, education,
571 seniority, and years implementing DT as control variables in the structural
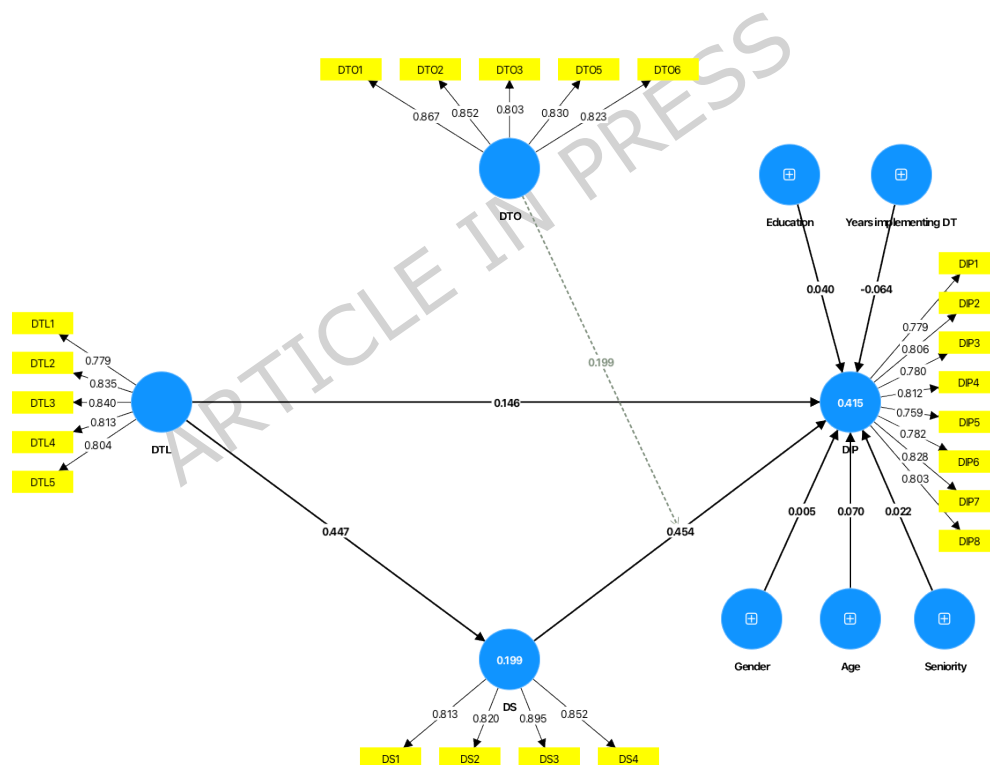572 model assessment.

573

575 **FIGURE 2 |** PLS path model from SmartPLS

576

577 **4.5 Direct Effect and Mediation Effect Testing**

578 **Figure 2** and **Table 6** portray the results of the structural path analysis. The
579 results show that digital transformational leadership has a significant
580 positive impact on digital innovation performance (B = 0.146; $p < 0.05$; 95%
581 CI: 0.039–0.263; T = 2.535), supporting Hypothesis 1. And, digital strategy
582 has a significant positive impact on digital innovation performance (B =

583 0.454, p < 0.001, 95% CI: 0.339–0.554; T = 8.296), supporting Hypothesis 2.
584 Further, the results show that digital strategy significantly mediates the
585 relationship between digital transformational leadership and digital
586 innovation performance (B = 0.203, p < 0.001, 95% CI: 0.136–0.274; T =
587 5.734). Therefore, Hypotheses 3 is supported.
588

TABLE 6 | Hypothesis testing.

Hypothe ses	Relationship	B	Std Dev	T Statistic s	P-Value	LLCI	ULCI	Results
	Direct effect							
	DTL -> DS	0.447	0.052	8.649	0.000	0.343	0.544	Supported
H1	DTL -> DIP	0.146	0.057	2.535	0.011	0.039	0.263	Supported
H2	DS -> DIP	0.454	0.055	8.296	0.000	0.339	0.554	Supported
	Mediation effect							
H3	DTL -> DS -> DIP	0.203	0.035	5.734	0.000	0.136	0.274	Supported
	Moderation effect							
H4	DTO x DS -> DIP	0.199	0.055	3.594	0.000	0.079	0.298	Supported

589

4.6 Moderating Effect Testing

591 We examined the moderating effect of digital transformation openness on the
592 relationship between digital strategy and digital innovation performance. As
593 shown in **Figure 2** and **Table 6**, the interaction between digital strategy and
594 digital transformation openness is significantly and positively related to
595 digital innovation performance (B = 0.203; p < 0.001; 95% CI: 0.079–0.298;
596 T = 3.594), indicating that digital transformation openness positively
597 moderates the relationship between digital strategy and digital innovation
598 performance. Hence, Hypothesis 4 is supported. According to the
599 suggestions of (Toothaker, 1994), this study further analyzed the moderating
600 effect by testing the simple slopes at high and low levels of digital
601 transformation openness, and the moderating effect diagram was drawn (see
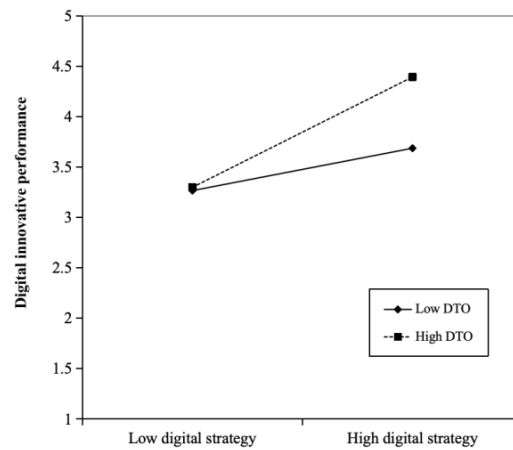602 **Figure 3**).
603

604

FIGURE 3 | Moderating effect of Digital Transformation Openness on the relationship between Digital Strategy and Digital Innovation Performance.

608

4.7 Moderated Mediation Testing

The index of moderated mediation[63] presented in **Table 7** indicates the total moderated mediation effect. The effect was significant (B = 0.105; p < 0.01; 95% CI: 0.053–0.162; T = 3.131), indicating that the indirect effect of digital transformational leadership on DIP through digital strategy was moderated by digital transformation openness.

The conditional indirect effect on the values of the moderator was calculated, namely the mean, one standard deviation above, and one standard deviation below. The results are shown in **Table 7**. The model of digital transformational leadership influencing digital innovation performance via digital strategy shows that at low levels of digital transformation openness, the mediating effect is significant (B = 0.109; p < 0.01; 95% CI: 0.036–0.183; T = 3.001). At higher levels of openness, the mediating effect becomes even stronger (B = 0.288; p < 0.001; 95% CI: 0.182–0.404; T = 5.108). The analysis results show that the higher the digital transformation openness, the stronger the mediating role of digital strategy in the relationship between digital transformational leadership and digital innovation performance, thus supporting Hypothesis 5.

627

TABLE 7 | Results of moderated mediation effect

	DTO	B	Std Dev	T Statistics	P-Value	LLCI	ULCI
DTL -> DS -> DIP	High(+1SD)	0.288	0.056	5.108	0.000	0.182	0.404
	Middle	0.199	0.038	5.242	0.000	0.128	0.275
	Low(-1SD)	0.109	0.036	3.001	0.003	0.041	0.184

18

Index of conditional mediation	0.105	0.033	3.131	0.001	0.053	0.162

628

5. DISCUSSION

5.1 Discussion of findings

Grounded in RBV, this study develops a theoretical model incorporating mediating and moderating pathways to systematically investigate how digital transformational leadership affects firms' digital innovation performance through digital strategy, while also examining the moderating role of digital transformation openness. By conducting in-depth empirical analysis, the study validates the key hypothesized paths in the model, uncovering complex and dynamic mechanisms linking digital leadership, strategy, and performance.

First, the study confirms that digital transformational leadership significantly enhances firms' digital innovation performance. This finding aligns with existing literature highlighting the pivotal role of digital transformational leadership in driving organizational change. Digital transformational leaders demonstrate strong digital awareness and strategic foresight, enabling them to identify emerging technological trends, coordinate resources, and stimulate employees' digital thinking and creativity, thereby accelerating innovation speed and improving outcomes within the digital environment. From the RBV, digital transformational leadership is viewed as a rare and valuable form of human capital that allows organizations to coordinate internal capabilities and produce innovation outcomes, ultimately supporting long-term competitive advantage.

Second, the study reveals that digital strategy partially mediates the relationship between digital transformational leadership and digital innovation performance. This suggests that the impact of leadership on innovation outcomes is indirect and contingent upon the coordinated implementation of strategic systems and the restructuring of organizational processes. This finding aligns with Bharadwaj et al.[13] three-layer digital strategy framework, which posits that digital technology must be embedded within business processes, organizational structure, and the value chain to translate into tangible performance outcomes. Furthermore, the study highlights that through leaders' empowerment mechanisms, digital strategy not only conveys the organization's future vision but also offers guidance and institutional support for employees' innovative activities. This mediation mechanism reflects the RBV that strategic capabilities, such as digital strategy, allow firms to reconfigure and integrate resources, thereby transforming digital potential into actual performance.

Third, digital transformation openness significantly moderates the relationship between digital strategy and digital innovation performance. This implies that employees' open and supportive attitudes toward change enhance the execution efficiency and outcome conversion of digital strategy. This mechanism reveals profound interactions among "leader, strategy, and

671 performance," echoing Subramaniam et al.[64] assertion on the significant
672 influence of "digital cognitive engagement" on innovation outcomes. The
673 study further finds that digital transformation openness amplifies the indirect
674 effect of digital transformational leadership on performance via the strategic
675 pathway. Specifically, employees' attitudes not only influence strategy
676 implementation but also magnify the indirect effectiveness of leadership.
677 This finding underscores the crucial role of employees' proactive agency in
678 organizational change, corroborating Vial[65] claim that cultural elements are
679 indispensable to digital transformation.

680 Fourth, although the moderated mediation effect was statistically
681 significant, the effect size was relatively small. This suggests that although
682 openness to digital transformation can enhance the positive effect of digital
683 strategy on employees' innovative performance, the facilitating role of
684 openness becomes more evident only when it surpasses a certain threshold.

685

686 **5.2 Theoretical Implications**

687 First, drawing on the Resource Based View (RBV) theory[7], this study reveals
688 the internal mechanisms through which firms integrate and utilize digital
689 resource portfolios to gain competitive advantage. Furthermore, the study
690 finds that digital transformation leadership, as a unique managerial resource,
691 is positively associated with digital innovation performance, and that digital
692 strategy functions as a critical channel for resource orchestration within this
693 relationship. Accordingly, this study contributes to the RBV literature by
694 deepening our understanding of how human resources drive value creation
695 in the context of digital transformation.

696 Second, despite extensive research on traditional transformational
697 leadership, systematic investigations of Digital Transformational Leadership
698 in the context of digital transformation remain limited. This study integrates
699 theories of traditional and digital leadership to define and empirically
700 examine the pathways through which Digital Transformational Leadership
701 influences digital innovation performance. It emphasizes DTL's vital role in
702 helping organizations navigate environmental uncertainty, foster technology
703 adoption, and reshape organizational culture[9]. The study broadens the
704 scope of leadership theory by responding to Benitez et al. (2022)'s call for a
705 redefinition of leadership in the digital era, while clarifying the leader's role
706 in legitimizing organizational change[66].

707 Third, although previous research has confirmed the positive effects of
708 leadership behaviors on organizational performance, the underlying
709 mechanisms driving this transformation remain insufficiently explored. This
710 study employs digital strategy as a mediating variable, focusing on how
711 leadership enhances performance via strategic deployment and restructuring
712 of business processes. The study confirms Bharadwaj et al.[13] assertion that
713 the strategic layer constitutes a critical channel for technology-enabled
714 performance, aligning with Alnuaimi et al.[9] claim that strategic alignment is

715   essential for effective digital leadership.
716   Fourth, although recent years have seen growing recognition of employees'
717   subjective role in organizational change, empirical evidence on how
718   "openness" moderates the strategy–performance relationship remains
719   limited. This study introduces "digital transformation openness" as a
720   moderating variable and empirically confirms its significant impact on the
721   effectiveness of digital strategy, representing a critical manifestation of
722   employees' digital cognition and behavioral engagement[64]. In high-openness
723   environments, digital strategies are implemented more effectively, and
724   employee collaboration is strengthened, thereby improving organizational
725   performance. This finding also addresses the theoretical gap identified by
726   Vial[65] regarding the mechanism through which digital culture shapes
727   transformation outcomes.
728
729   **5.3 Practical Implications**
730   First, the findings indicate that managers, acting as organizational agents,
731   can influence key factors that improve digital innovation performance,
732   thereby benefiting both the organization and its employees. Management has
733   significant authority over the development and implementation of digital
734   transformational leadership capabilities. Leadership development programs
735   that emphasize digital transformation skills such as data-driven decision
736   making, digital ecosystem thinking, and technology-based empowerment can
737   better prepare managers to foster innovative digital environments. These
738   leaders can effectively navigate their teams through the complexities of
739   digital transformation and convert technological potential into tangible
740   innovation outcomes.
741   Second, the design of digital strategy systems falls within the domain of
742   management influence. Our findings highlight that digital strategy acts as a
743   key mediating mechanism through which leadership affects innovation
744   performance. Managers should develop comprehensive digital strategies that
745   extend beyond technology adoption to include systematic business model
746   transformation, process digitization, and value chain restructuring. An
747   effective approach to implementing digital strategy is to initially focus on
748   organizational processes that best align with existing digital capabilities. The
749   resulting sense of competence, clarity, and technological mastery facilitates
750   the transformation. For example, organizations with strong data analytics
751   capabilities might prioritize digital strategy elements that utilize data-driven
752   insights to drive product innovation.
753   Third, organizations should place greater emphasis on fostering an
754   innovative culture. The organizational culture for digital transformation
755   openness may take longer than structural elements (such as digital
756   infrastructure or formal digital policies) to change. In environments with
757   limited digital openness, employees are more likely to preserve existing
758   routines, as innovation often entails elevated perceived risks and

759 psychological stress. Even under strong leadership, strategic initiatives may
760 fail to produce tangible innovation outcomes. In contrast, cultural
761 transformation efforts are more likely to deliver meaningful outcomes only
762 when digital openness exceeds a moderate level, such as when digital
763 engagement and adaptive practices are deeply embedded in everyday
764 workflows. Practitioners should evaluate the baseline level of organizational
765 openness and tailor interventions accordingly, emphasizing capability
766 development, psychological safety, and digital communication channels to
767 cultivate a culture of adaptability and openness.
768

5.4 Limitations and Future Research
770 First, this study used a time lag data collection approach to reduce common
771 method variance (CMV) and better examine causal relationships between
772 variables across time. However, since all variables were reported by
773 employees themselves, concerns regarding CMV may still remain. Future
774 studies may consider using data collected from multiple time points and
775 multiple sources. In particular, when assessing digital innovation
776 performance, using objective indicators from company records would be
777 helpful in mitigating CMV more effectively.
778 Second, the sample for this study was exclusively drawn from
779 manufacturing firms located in Shandong Province, China. Although these
780 firms vary in size and digital development maturity, the sample is still limited
781 in terms of industrial scope and cultural context. Future research should
782 further examine the generalizability of the findings across countries, regions,
783 and different industry sectors. A cross-national and cross-industry
784 comparative perspective may help explore how digital leadership influences
785 strategic implementation and innovation performance under varying
786 conditions, thereby enhancing the external validity and universality of the
787 conclusions. Moreover, future studies should examine whether the
788 effectiveness of digital transformational leadership differs across specific
789 digital technologies, as technologies such as artificial intelligence, IoT, and
790 blockchain may require distinct leadership responses and strategic
791 configurations.
792 Third, although this study introduced digital transformation openness as a
793 moderating variable and obtained initial findings, several influential
794 contextual factors remain unaccounted for in the model. These include
795 organizational learning capacity, corporate culture, and the maturity of
796 technological infrastructure, all of which could significantly shape the
797 functioning of leadership in digital contexts. Future research may expand the
798 scope of moderating or mediating variables and construct more complex
799 interaction models to deepen insights into the collaborative dynamics among
800 individuals, strategy, and technology during digital transformation.
801 Fourth, although this study included several individual-level control
802 variables, such as age, gender, education, seniority, and years of digital

803 transformation implementation, it did not incorporate potentially relevant
804 organizational-level controls. Organizational characteristics such as firm size,
805 R&D intensity, and market competition may also affect the adoption of digital
806 strategies and innovation performance. However, constraints related to data
807 availability and concerns about model over-control prevented their inclusion
808 in this study. Future research should integrate multilevel control variables
809 and employ hierarchical or cross-level modeling techniques to better rule out
810 alternative explanations and enhance the robustness of findings within
811 organizationally nested data structures.
812

813 **Data availability statement**
814 Data are available upon reasonable request from the corresponding author.
815

816 **Ethics Statement (Methods)**
817 As protection of all participants, all subjects provided informed consent
818 before participating in this study and voluntarily made their decision to
819 complete surveys. The protocol was approved by an institutional review
820 board in Kangnam University of Korea. All methods were carried out in
821 accordance with relevant guidelines and regulations.
822

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824 CZ and YW: Writing – original draft, Writing – review & editing. JP: Writing –
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832 The authors declare that the research was conducted in the absence of any
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835

836 **Electronic supplementary material**
837 Below is the link to the electronic supplementary material.
838 Supplementary Material S1
839

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