ISSN 2409-2665
Journal of Logistics, Informatics and Service Science
Vol. 10 (2023) No. 4, pp. 318-335
DOI:10.33168/JLISS.2023.0422

Examining the Effects of Digital Leadership Strategies on Enhancing Organizational Innovation Performance

Lingyun Fang[1,2]

[1]Innovation College, North-Chiang Mai University, Chiang Mai, 50230, Thailand

[2]School of Medical and Health Management, Guizhou Medical University, GMU, Guiyang 550025, Guizhou, China

18586396666@126.com

Abstract. With the advent of the digital age, organizations and leaders are facing unprecedented opportunities and challenges. This study explores the impact of digital leadership on organizational innovation performance, from the evolution of traditional leadership to the core characteristics of digital leadership, and further to its specific impact on organizational innovation performance. We have found that digital leadership not only focuses on technological capabilities, but also emphasizes strategic thinking, organizational collaboration, and cultural shaping in the digital context. Empirical studies and case studies have shown that digital leadership can significantly improve an organization's innovation capabilities, especially in areas such as product innovation, process optimization, and business model innovation. Finally, this article proposes suggestions and directions for future research, aiming to provide useful insights for organizations and leaders in the digital age.

Keywords: Digital leadership, Organizational innovation performance, Digital transformation, Leadership Evolution

1. Introduction

With the rapid development of technology, we are rapidly entering a digital era. Digitalization has permeated every aspect of our lives, from personal daily life to various organizational and business operations. Digitalization is not only the application of technology, but also a transformation of culture and way of thinking. It redefines the way information is generated, disseminated, and utilized, changing the way people interact with people, people with machines, and even machines with machines.

The advent of the digital age marks the unbounded flow of information and data. With the help of modern communication technology and the internet, people can easily cross the boundaries of time and space, share and obtain information in real-time. The speed and breadth of this information flow are unprecedented, providing people with unprecedented convenience, but at the same time, it also brings a series of new challenges, such as information security, privacy protection, and so on. Digitization has also triggered significant changes in the economic and social structure. Traditional industries and industries are undergoing profound digital transformation, and new business models and service methods have emerged. For example, emerging industries such as e-commerce, cloud computing, and the Internet of Things have emerged in a short period of time, changing people's consumption habits and lifestyles. Digitalization has also achieved innovative applications in various fields such as education, healthcare, and transportation. The emergence of technologies such as online education, remote healthcare, and autonomous driving has made the provision and acceptance of services more convenient and efficient. These changes all indicate that digitization has become an important force driving social progress. Overall, the advent of the digital age is not only a technological revolution, but also a comprehensive social transformation. It is deeply influencing our way of thinking, work, and life, bringing us endless opportunities and also posing new challenges. For any organization or individual, understanding and grasping the significance of digitization is the key to moving towards the future.

With the deep penetration of digitalization into various industries and fields of life, conducting in-depth research on its connotation and impact has become an urgent task. Digitalization is not only a technological phenomenon, but also a comprehensive transformation involving multiple dimensions such as society, culture, and economy. Therefore, in-depth exploration of the logic, principles, and impact behind digitization has important guiding significance for us to grasp the current and future development context (Abraham et al.,2010).

The advent of the digital age means an unprecedented increase in the speed of information transmission and processing, which brings new opportunities and challenges to organizational decision-making, strategic planning, and operational management. Through in-depth research, organizations can better understand how to leverage the advantages of digitalization, optimize business processes, improve efficiency, and stand out in the fierce market competition. Digitization is changing consumer behavior and expectations. Understanding this change is crucial for businesses as it can help them predict future market demand, develop more accurate market strategies, and improve customer satisfaction and loyalty. With the development of digital technology, new tools, platforms, and solutions are constantly emerging, such as big data analysis, artificial intelligence, blockchain, etc. The application of these technologies can not only drive organizational innovation, but also solve some of the long-standing challenges that have plagued society. Therefore, in-depth research on these technologies will help promote the overall progress of society (Argyris & Schon, 1978).

The digital era has brought us enormous opportunities, but it is also accompanied by various challenges. Deeply studying the connotation, mechanism, and impact of digitalization is of indispensable importance and necessity for us to correctly grasp the pulse of this era, formulate reasonable development strategies, and promote sustainable development of society and economy.

2. Related Works

2.1. Traditional Definition and Evolution of Leadership

Leadership, as a long-standing research concept, has always received high attention from the academic and business communities. It covers a wide range of fields, including organizational behavior, psychology, sociology, and has undergone various definitions and interpretations of evolution.

Traditionally, leadership has been defined as a person influencing others through informal channels in a specific context, enabling them to voluntarily pursue common goals. This influence is mainly based on the leader's personality, abilities, and behavior. For example, early leadership research focused on "great people", believing that leaders are innate and possess certain innate traits or traits that distinguish them from ordinary people (Cai & Liu, 2008).

At the beginning of the 20th century, leadership research mainly focused on finding common traits or traits of leaders, such as intelligence, decisiveness, and charisma. Subsequently, the focus of the study shifted to the behavior and style of leaders, attempting to identify the correlation between effective leadership and specific behaviors. By the mid-20th century, scholars began to realize that leadership effectiveness was influenced by various factors, among which situational factors were particularly important. Leadership is no longer seen as fixed and unchanging, but is influenced and constrained by situational factors (Chen, 2005). In recent decades, leadership theories have been further refined, with theories such as transformational leadership and transactional leadership emerging one after another. They emphasize how leaders motivate and guide teams, as well as the interactive relationship between leaders and those being led. With the development of time, especially in the context of globalization and digitization, the definition and understanding of leadership are also continuously evolving. Modern leadership places greater emphasis on cross-cultural communication, technology application, innovative thinking, and other abilities. At the same time, with the transformation of enterprises and organizational structures, such as flattening and remote work, the presentation forms and requirements of leadership have also undergone corresponding changes. Leadership starts from the initial individual traits and gradually evolves into a comprehensive and multi-dimensional concept, involving multiple levels such as individuals, teams, organizations, and culture. In the digital age, the definition and requirements of leadership are still constantly being adjusted and improved.

2.2. Characteristics and core elements of digital leadership

With the advent of the digital age, the traditional models and definitions of leadership have been challenged and reshaped. Digital leadership, as an emerging concept, emphasizes how leaders can use technology, data, and digital tools to lead teams and organizations to success in a digital environment. Digital leadership emphasizes the understanding, adoption, and application of new technologies, such as artificial intelligence, big data, and cloud computing. In the digital age, data has become increasingly important. Digital leaders need to have the ability to analyze data, extract valuable information from data, and make decisions based on it. Digital leaders need to have the ability to quickly adapt and learn new technologies, and be able to adapt flexibly in constantly changing environments. With the development of technology, the boundaries between teams and organizations have become increasingly blurred. Digital leaders need to have collaborative capabilities across departments, organizations, and even industries.

Understand and grasp the latest trends in digital technology, and how to apply them to organizational strategy, culture, and operations. Being able to develop and execute digital strategies to ensure that organizations remain competitive in the digital age. Identify and cultivate digital talents, ensuring that teams and organizations have sufficient resources and capabilities to address the challenges of digitization. Create a culture that encourages innovation, experimentation, and learning, while providing clear guidance and leadership to ensure the success of digital transformation. While rapidly adopting and applying new technologies, it is possible to identify and manage risks related to them, such as data security and privacy protection.

2.3. Measurement criteria for organizational innovation performance

Innovation performance is an indicator that measures the results and effects achieved by an organization

in innovation activities. It reflects the degree of success of an organization in the development and implementation of new products, services, processes, or business models. Innovation performance is not limited to economic benefits, but also includes a wide range of impacts on organizations, markets, and society.

Product and service innovation is the most common form of innovation performance, involving the development, promotion, and market response of new products or services. For example, the market share, sales growth rate, or customer satisfaction of new products can all be used as measurement indicators (Chen &Ma, 2000). Pay attention to the operational efficiency and effectiveness within the organization. This includes improving production, supply chain, customer service, or other critical business processes to improve efficiency, reduce costs, or add value. Measurement indicators may include increased productivity, reduced costs, or reduced customer response time. Strategic and model innovation involves fundamental changes in an organization's business model, market positioning, or strategic direction. For example, a traditional retailer transitioning to an e-commerce platform, or a product manufacturer transitioning to a service provider (Duan &Tang, 2016). Cultural and organizational innovation focuses on how to create and maintain an organizational culture and structure that supports innovation. This may involve changes in organizational structure, improvement of incentive systems, or employee training and development plans. In addition to economic benefits, innovation may also have a positive impact on society, culture, or the environment. For example, the development of green technology or social enterprise projects for vulnerable groups can serve as examples of social innovation. Innovation performance is a multidimensional concept that encompasses the innovative activities of an organization at all levels. Correctly defining and measuring innovation performance is crucial for organizations as it can help them identify the reasons for success and failure, adjust strategic direction, optimize resource allocation, and ensure a leading position in fierce market competition.

The key to evaluating organizational innovation performance lies in selecting appropriate indicators. These indicators should comprehensively reflect the organization's performance in innovation activities and provide valuable information for future decision-making. The following are some commonly used key indicators of organizational innovation:

Assessing the competitive stance of new products or services in their target market, one might consider the market share in its specific segment within a year post-release. To calculate the economic benefits of innovative projects, use the formula: (Net profit of the innovation project - Cost of the innovation project) / Cost of the innovation project (Fioi & Mlyles, 1985). Gauge the timeframe from ideation to product launch; a swifter development cycle may indicate quicker market responsiveness. The ratio of R&D expenses to total revenue or expenses reveals an organization's financial dedication to innovation. Consider the percentage of revenue from new offerings against total revenue as an indicator of organizational and cultural innovation, spotlighting employee eagerness to engage in innovative endeavors. This mirrors the institution's prowess and milestones in technological innovation. Evaluate market reception and client contentment with new products or services. Determine the ratio of successfully executed innovation projects to the overall number. Understand the level of inter-departmental collaboration within innovation initiatives. Prioritize enduring, sustainable innovation endeavors, such as ventures in green tech or social responsibility.

2.4. The relationship between digital leadership and organizational innovation performance

In the digital age, leadership is no longer just about decision-making and guidance, but also about how to use digital tools and thinking to drive organizational innovation.

Digital leaders value data analysis and insight, ensuring that decisions are based on real-time data and in-depth analysis. This method improves the accuracy of decision-making and encourages innovation based on facts and evidence. Digital leaders can identify and introduce new technological

tools such as AI, machine learning, and automation, integrate them into the core processes of the organization, optimize work efficiency, and create new business opportunities. By encouraging employees to explore and learn new digital skills, digital leaders can cultivate an organizational culture of continuous innovation and adaptation to change (Garvin et al., 2008).

In the rapidly changing digital environment, digital leaders emphasize the agility and flexibility of organizations, enabling them to quickly adapt to market changes and customer needs, thereby quickly launching new products or services. Digital leaders encourage collaboration between teams, departments, and even external partners, breaking traditional information silos and achieving knowledge sharing and innovative collaboration. By utilizing digital tools to collect and analyze customer data, digital leaders can gain a deeper understanding of their needs and preferences, thereby creating a more personalized and efficient customer experience. Digital leaders are usually more willing to take risks, encouraging teams to experiment with innovation, quickly test new ideas, and quickly iterate in the event of failure. While promoting innovation, digital leaders also value digital security and compliance, ensuring that organizational innovation activities are carried out in a secure and compliant environment (Gagnon et al., 2018).

Digital leadership has brought a new innovation paradigm to organizations, combining digital technology and thinking with traditional innovation processes to achieve breakthrough results in a broader field.

Case analysis is an important tool for understanding and proving how digital leadership actually promotes organizational innovation. The following is an analysis based on real-life scenarios, highlighting the key role of digital leadership in driving organizational innovation:

Amazon's digital strategy: As the world's largest e-commerce platform, Amazon has been searching for ways to combine digital technology with retail business. By creating innovative technologies and services such as Alexa, AWS, and Amazon Go, Amazon not only strengthened its core business but also successfully entered new market areas. Amazon has evolved from an online bookstore to a diversified global empire, largely thanks to its digital leadership strategy.

Netflix's content recommendation algorithm: Netflix hopes to provide its users with a more personalized viewing experience. Netflix has invested in big data and machine learning technology, developing advanced content recommendation algorithms. Through in-depth analysis of user behavior, Netflix can provide customized content recommendations for each user, thereby increasing their viewing time and satisfaction.

BMW's digital manufacturing: BMW hopes to improve its production efficiency and reduce costs. BMW has introduced Industry 4.0 technologies such as the Internet of Things (IoT), robot automation, and 3D printing. Through digital production processes, BMW has successfully improved production efficiency, shortened product launch time, and reduced production costs.

Starbucks' Digital Customer Experience: In order to enhance connectivity with customers and increase sales, Starbucks has decided to strengthen its digital efforts. By developing its mobile app and digital membership program, Starbucks provides customers with a seamless online and offline purchasing experience. This strategy not only increased customer loyalty, but also successfully increased sales per store.

3. Research methods

3.1. Data Collection and Sample Selection

Firstly, the founders of technology enterprises or other senior managers directly involved in the establishment of enterprises are the research objects of this article. Secondly, although technology entrepreneurship has only gained a significant popularity in recent years, the phenomenon of technology entrepreneurship has a long history. As early as after the reform and opening up, there have been

examples of scientific researchers "going overseas" to start businesses. At the same time, as the research object of this study is entrepreneurial enterprises, according to the suggestions of relevant scholars on the selection of entrepreneurial enterprise samples, the establishment period of the research object in this article should be within 8 years, and the specific establishment period is from early 2009 to 2016. Therefore, in summary, the distribution targets of this questionnaire survey are founders of technology enterprises established within 8 years or senior management personnel directly involved in the establishment of the enterprise (He, 2014).

In theory, the most effective way to distribute questionnaires is to randomly select samples from the overall sample, and the most effective way to collect questionnaires is through face-to-face surveys and collection. However, from domestic and foreign research, it can be seen that the basic principle of convenience sampling has been adopted, and most of them have not collected data through random sampling. This is because in actual surveys, random questionnaire distribution and face-to-face collection are difficult to achieve. After the questionnaire design is completed, there are two methods for collecting data. The first method is to distribute the questionnaire through a key intermediary. In this study, the author entrusted some contacts, including personnel from the science and technology bureaus and personnel bureaus of relevant provincial and municipal governments that established work contacts in the early stage, personnel from relevant science and technology parks, industrial parks, and high-tech zones, and personnel from the science and technology departments and industrial departments of relevant universities, to distribute the questionnaire to the respondents. The method of distributing the questionnaire can be through distributing paper versions, it can also be an electronic version of the questionnaire (Holland, 2009). There are two ways to collect questionnaires: one is for the respondents to submit them directly to the author, or for intermediaries to collect them and then hand them over to the author. The second method of questionnaire distribution is direct distribution. On the one hand, the author carefully searches for classmates and friends engaged in technology entrepreneurship and asks them to fill out the questionnaire; On the other hand, utilizing the EMBA and MBA platforms of Suzhou University, invite students to fill out the application or regularly participate in some entrepreneurship related meetings and activities held within Suzhou City, especially in Suzhou Industrial Park and Suzhou High tech Zone, and invite suitable attendees to fill out the application.

In the prediction stage, 300 prediction survey questionnaires were distributed, 254 questionnaires were collected, and 125 questionnaires were found to be invalid. The reasons for the invalidity of the questionnaire include incomplete answers, empty or irregular answers, and the filling out of the questionnaire did not meet the requirements of this study. A total of 129 valid questionnaires were collected, with a valid questionnaire recovery rate of 38.7%. During the formal survey phase, 1000 formal survey questionnaires were distributed and 849 questionnaires were collected. A total of 362 invalid questionnaires were found. The reasons for the invalid questionnaires were incomplete or irregular answers, and the questionnaire respondents did not meet the requirements of this study. Finally, 487 valid questionnaires were collected, with a valid questionnaire recovery rate of 48.7%. Scholars such as Real believe that when using questionnaire surveys for research, the acceptable sampling error rate should be less than 10%, and the number of survey samples should be at least 5 times the number of variables involved in the study, and should reach 100 or more (Hou & Hao, 2012). There are 48 variables involved in the model of this study, with a 5-fold ratio of 240. Therefore, the sample size of this study meets the requirements.

3.2. Research Methods and Techniques

The main content of this chapter is the design of research content and the arrangement of research methods, including: scale design, questionnaire development and determination, small-scale prediction, questionnaire distribution and data collection, data analysis and discussion methods, etc. Research design is the main theme and logical framework of research, which is the principle and foundation of data collection and analysis (Hedberg, 1981). Research design, on the one hand, is the overall

arrangement of the upcoming research, and on the other hand, it is also a strategy for exploring innovative research results. The research design mainly includes two objectives: firstly, to identify problems and clarify the research topic; Secondly, it is necessary to verify and demonstrate the theme, which means that the first step is to answer what problems need to be solved, what conclusions or results may be drawn, and to select and determine the methods and techniques used to solve the problems. The research design process can be represented by Figure 1.

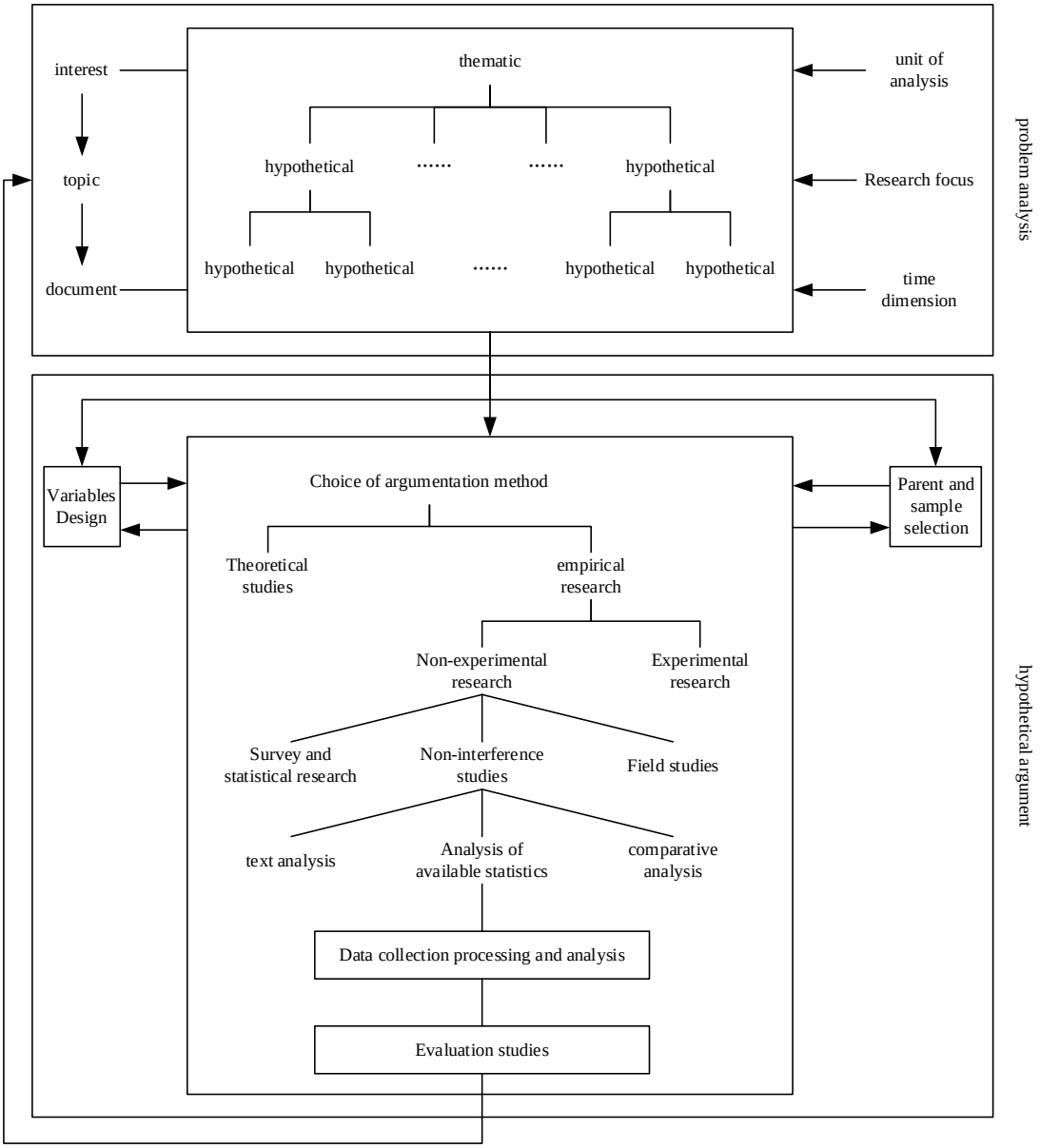

Fig.1: Research Design Process

This study draws inspiration from the scale on entrepreneurial innovation awareness proposed by (Hirak et al.,2012), which is widely used in the research field of entrepreneurial spirit. Therefore, its reliability and validity have been recognized in many authoritative research fields. In combination with the survey results of the Chinese Entrepreneur Survey System on "Chinese Enterprise Managers Questionnaire Tracking Survey on Entrepreneurs' Innovation Consciousness" and the era background of "Internet plus", the (Huang et al., 2016) scale was moderately improved to make it more in line with the current reality, and its dimensions were divided into innovation consciousness, adventure activities and product or service innovation. There are the following items in the table 1 for its measurement:

Table 1. Summary of variables of entrepreneurial innovation awareness under "Internet "+

Variable Type	Variable Name	Star test items
Independent variable	Creative Awareness	1.Enterprises emphasize the awareness of R&D and innovation
		2.Enterprises emphasize Internet technology leadership
		3.Corporate strategy focuses on Internet-based exploration and originality
		4. The enterprise plays a leading role in breakthrough innovation in the industry.
	Risk-taking activities	5. Entering new market areas
		6. The enterprise utilizes the new information technology of the Internet for transformation and upgrading.
		7.Creation of new intelligent enterprises
		8. Found a new foothold in the existing market
		9. Invested in new Internet business opportunities.
		10. Created a new production automation division
	Product or service innovation	11. invested in new intelligent products or services
		12. Launched a large number of smart new products or services
		13. Leading competitors in the development of smart new products or services
		14. Spent much more effort than the industry average on smart product or service enhancements

3.3. Data Analysis and Results

This part of the research mainly follows the following steps: the first step is to distribute survey questionnaires according to the requirements of small-scale prediction and formal survey, collect data, conduct preliminary checks on the data, eliminate waste papers, input and organize the data into software, form data files, and prepare for data analysis; The second step is to use SPSS 22.0 statistical software to conduct descriptive statistics and reliability analysis on the content structure of various variables involved in this study, including family environment, social capital, innovation awareness, and technology entrepreneurship performance; The third step is to use AMOS23.0 statistical software to conduct confirmatory factor analysis and validity analysis on the content structure of organizational entrepreneurial atmosphere; The fourth step is to discuss and summarize the data analysis results, and provide validation results for each validity.

(1) Analytical methods

The specific analysis methods used in this study mainly include descriptive statistics, reliability analysis, and validity analysis (Jiang et al., 2009).

The first is descriptive statistics. Descriptive statistics mainly involves statistical analysis of the basic data of the sample, including the age, gender, educational experience, entrepreneurial experience, industry experience, entrepreneurial years, entrepreneurial enterprise size, industry category, etc. of the entrepreneur, including the average and standard deviation of each variable. At the same time, statistical analysis of variable characteristics and corresponding proportions by category is conducted. In addition, statistical analysis is conducted on the mean, standard deviation, skewness, kurtosis, and other aspects of each variable's items to understand the general situation of the sample data and provide indicators for verifying the normal distribution of the sample data.

The second is reliability analysis. The premise for conducting relevant hypothesis validation is to conduct reliability and validity analysis on the questionnaire data (Jing, 2014). The meaning of reliability is reliability, which tests whether the questionnaire data reaches consistency and stability, and can be measured through internal and external reliability. Internal reliability refers to whether each question item is tested for the same concept, and it is a very important indicator. In research, the CronbachAlpha index is often used to determine the reliability of related items. When the CronbachAlpha value is greater than 0.5, it indicates that the scale has high reliability. On this basis, if it is necessary to purify the measurement items, the indicator used is the overall correlation of the

corrected items, commonly referred to as CITC. The items with CITC values lower than a certain standard are removed to improve the overall reliability of the scale. The relevant judgment standards are not absolutely unified. For example, some scholars believe that a CITC of no less than 0.3 is sufficient (Peng et al., 2017), while others believe that the value of CITC must be greater than 0.5. Otherwise, researchers need to consider whether to delete the measurement clause (Li, 2009). The specific operating process used in this study is that when a certain item fails to meet the following conditions at the same time, the item should be deleted: CITC is less than 0.5, and deleting this clause can increase the CronbachAlpha coefficient.

The third is validity analysis. The definition of validity is that measuring items can accurately measure the authenticity of the research object, and the concept of validity represents the correlation between a specific concept and its measurement indicators. In existing research, there are many validity couples used: content, structure, aggregation, and differentiation. This study also adopted these four validity factors.

Content validity. The definition of content validity is whether a specific measurement tool includes all aspects of the target concept that needs to be measured. It is a qualitative validity that depends more on the researcher's handling of logic than statistical processing (Li et al., 2012). The specific judgment method is to determine whether the measurement items can truly measure the research object, and whether the relevant clauses can include all the objects to be studied. The scale of related research variables in this study underwent multiple steps before being determined, including literature research, interview research, expert testing, and pre research, thus possessing acceptable content validity.

Conceptual validity. Conceptual validity can usually be analyzed through factor analysis, which is defined as the degree to which a scale can measure specific theoretical concepts and features. In existing research, the standard adopted by most scholars is: KMO not less than 0.9, which is very good; Not less than 0.8, not more than 0.9, good; Not less than 0.7, not more than 0.8, moderate; Not less than 0.6, not more than 0.7, average; Not less than 0.5, not more than 0.6, poor; Below 0.5, very poor. Based on the above principles, in actual processing, for KMO values above 0.7, subsequent analysis will be conducted; For values ranging from 0.6 to 0.7, determine whether to conduct factor analysis based on relevant theories and actual situations; For those with KMO values below 0.6, the next step of analysis is not selected (March, 1991). Meanwhile, in existing studies, some researchers also use aggregated validity and discriminant validity for validity testing (Qin, 2016).

Aggregation validity. The definition of this concept is to measure the degree of correlation between different indicators of the same variable. For the measurement of aggregated validity, the commonly used criterion is the average variance extracted (AVE). In specific analysis, there are also some differences in the criteria for determining aggregation validity. Most scholars believe that the variance of error cannot be higher than the explanatory power of the measurement clause (Qian, 2010), because if the explanatory power of the error is greater than the variable itself, then the validity of the variable can be said to be problematic (Qin, 2016). Therefore, the minimum standard for AVE is 0.5. At the same time, for the factor load aspect, the path coefficient of the measured validity factor load should exceed a certain standard and also reach a statistical significance level. Some scholars believe that the minimum level of standardization factor should be 0.4 (Rui & Lv, 2005). This study will refer to the standard range of fitness indicators, standardized factor load factors, and AVE standards to test the aggregation validity involved in this study.

Differentiation validity. The definition of discriminant validity is as follows: multiple measurement indicators of a concept must have correlation, that is, they must aggregate with each other, and at the same time, there must be a certain degree of differentiation between multiple indicators, that is, they must have a certain degree of differentiation. The criterion for discriminative validity is to determine whether the root mean square of AVE of these two factors is greater than the correlation coefficient between the two factors (Xie, 2005). In terms of discriminant validity measurement, this study referred

to previous methods and tested the root mean square of different factors AVE by comparing their correlation coefficients (Xue &Yang, 2014).

Descriptive statistical analysis of samples (Table 2):

Table 2. Characterization of the Formal Survey Sample

Project	Status	assign a value to something	Sample size (number)	Percentage
Age	Less than 25 years old	1	10	2.1
	26 to 30 years old	2	74	15.2
	31 to 40 years old	3	241	49.5
	41 to 50 years old	4	116	23.8
	Over 50 years old	5	46	9.4
Sex	Male	0	384	78.9
	Female	1	103	21.1
Education	Doctoral degree	1	224	46
	Master's degree	2	92	18.9
	Bachelor's degree	3	137	28.1
	College degree	4	26	5.3
	Below College Degree	5	8	1.6
Business field	Others	0	388	79.7
	Biomedical/Device	1	99	20.3
Years in business	Less than 6 months	1	40	8.2
	6 months to 1 year	2	60	123
	1 year to 3 years	3	147	30.2
	3 years to 5 years	4	78	16
	5 years to 8 years	5	78	16
	More than 8 years	6	84	17.2
Enterprise Scale	Less than 50 people	1	405	83.2
	50-100 people	2	50	103
	100-200 people	3	10	21
	200-500 people	4	12	2.5
	Greater than 500 people	5	10	2A
Entrepreneurial experience	No	0	330	67.8
	Yes	1	157	32.2
Management Experience	Less than 1 year	1	100	20.5
	1-3 years	2	112	23
	3-5 years	3	97	19.9
	More than 5 years	4	178	36.6
Industry Experience	Less than 1 year	1	26	5.3
	1-5 years	2	118	24.2
	5-10 years	3	143	29.4
	More than 10 years	4	200	41.1
Overseas Experience Project	No	0	279	57.3
	Yes	1	208	42.7

① Reliability evaluation and processing of innovative awareness measurement clauses

The CITC values and CronbachAlpha values of each item in the Innovation Awareness Scale are shown in Tables 3. From the table, it can be seen that the CITC values of innovation awareness, including innovation value awareness and implementation awareness variables, are greater than 0.5. The CITI value of the GR6 item in personal innovation awareness is 0.443, which is less than the

standard of 0.5. Moreover, the coefficient of a of the variable after the item is deleted can be increased to 0.903. Therefore, this question item can be deleted. The CITI value of the QG1 question in the awareness of seeking novelty and education is 0.413, and the coefficient of a of the variable after deleting this question can be increased to 0.835. After deleting the above two items, the overall reliability index coefficients of the three factors in the new scale are higher than 0.7. Therefore, each item of the innovation awareness new scale can be used for subsequent research.

Table 3. CITC and Cronbach Alpha Values of the Innovation Awareness Scale

Variables	subject	CITC	Alpha if Item Deleted	Overall Alpha Coefficient
Awareness of the value of innovation	JH1	.765	.798	.868
	JH2	.781	.785	
	JH3	.700	.858	
A sense of personal innovation	GR1	.766	.838	0.874
	GR2	.746	.841	
	GR3	.763	.838	
	GR4	.745	.841	
	GR5	.689	.851	
	GR6	.443	.903	
Awareness of Seeking Newness and Teaching	QG1	.413	.835	0.816
	QG2	.670	.760	
	QG3	.620	.776	
	QG4	.685	.758	
	QG5	.666	.764	
Consciousness of implementation	ZY1	.635	.621	0.758
	ZY2	.630	.631	
	ZY3	.529	.749	

Before proceeding with the next analysis, first examine the innovation awareness after deleting the unqualified items, including the KMO values and Bartlett spherical significance of various factors such as innovation value awareness, personal innovation awareness, innovation and education awareness, and implementation awareness. The results are shown in Tables 4. From the table, it can be seen that the KMO values of the factors of innovation value awareness, personal innovation awareness, and implementation awareness are greater than 0.7, while the KMO values of implementation awareness are very close to 0.7, and Bartlett's statistical values are not significant. Further analysis can be conducted.

Table 4. KMO and Bartlett's Sphericity Test for Innovation Awareness Scale

	Innovative value consciousness	A sense of personal innovation	Awareness of the need for innovation and education	Consciousness of implementation
0.727	0.846	0.814	0.691	
chi-square (math.)	190.655	395.279	188.965	97.516
df	3	10	6	3
Significance	.000	.000	.000	.000

② Confirmatory Factor Analysis Results of the Innovation Awareness Scale

Because the measurement of innovation awareness basically utilizes mature scales, exploratory factor analysis is not necessary, and confirmatory factor analysis can be conducted directly. Confirmatory factor analysis mainly involves two aspects: first, the reliability and validity test of the scale, and second, the overall suitability analysis of the research model.

3.4. Descriptive statistics

From Tables 5, it can be seen that the normality analysis results of each measurement clause are good, and subsequent analysis is feasible.

Table 5. Descriptive Statistics of Innovation Awareness

	Average	standard deviation	skewness		kurtosis	
	statistic	statistic	statistic	standard error	statistic	standard error
JH1	3.99	.755	-.761	.213	1.453	.423
JH2	3.97	.728	-.692	.213	1.570	.423
JH3	3.88	.767	-.749	.213	1.265	.423
GT1	4.02	.661	-.181	.213	-.146	.423
GT2	4.12	.657	-.461	.213	.626	.423
GT3	4.13	.678	-.473	.213	.371	.423
GT4	4.16	.678	-.505	.213	.399	.423
GT5	4.22	.649	-.419	.213	.112	.423
QG1	3.36	.873	-.265	.213	.100	.423
QG2	3.47	.866	-.184	.213	-.322	.423
QG3	3.43	.768	-.274	.213	.101	.423
QG4	3.36	.758	-.156	.213	.098	.423
ZYI	3.47	.885	-.123	.213	-.391	.423
ZY2	3.64	.918	-.255	.213	-.437	.423
ZY3	4.10	.683	-.428	.213	.252	.423

3.5. Confirmatory factor analysis model

Based on relevant theoretical foundations and mature scales related to innovation awareness, this study divides innovation awareness into four factors: innovation value awareness, personal innovation awareness, innovation and education awareness, and implementation awareness. The four factors include 3, 5, 4, and 3 measurement terms, respectively. Based on this model, a confirmatory factor analysis was conducted on innovation awareness. See Figure 2 for the analysis model.

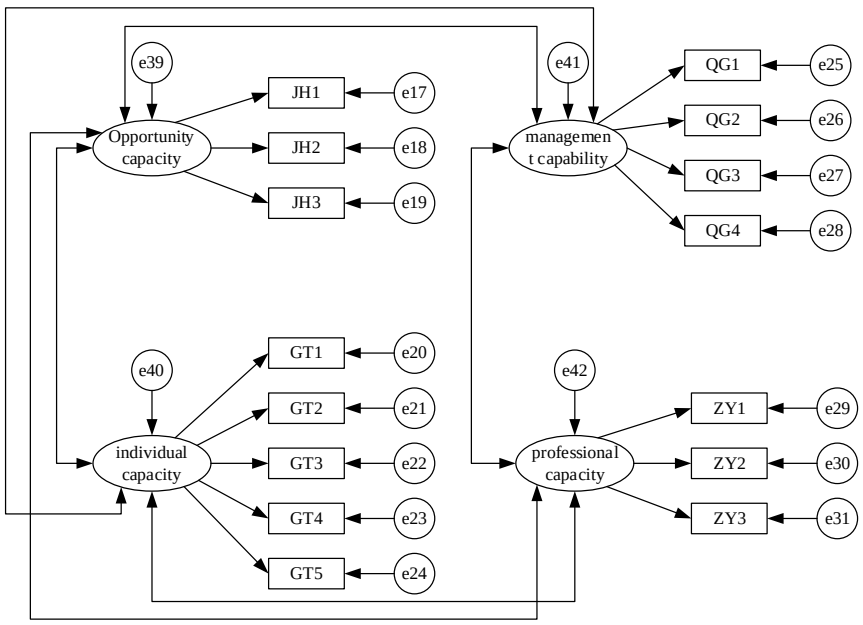

Fig.2: Innovation Awareness Analysis Model

3.6. Construction reliability of each measurement clause

In existing research, the common practice is to use the reliability coefficients of individual variables to represent the overall reliability of each factor. The overall reliability indicator is called construct reliability, and the main function of construct reliability is to test whether the degree of construction between a set of target indicators can reach consistency (Yu, 2008).

$$CR = \frac{(\sum \lambda)^2}{(\sum \lambda)^2 + \sum \varepsilon_j} \tag{1}$$

In the above formula, λ Is the standardized load factor, ε Is the measurement error coefficient corresponding to item j. Regarding the minimum standard for reliability coefficient, in existing research, scholars have adopted inconsistent standards. Some scholars believe that this indicator coefficient cannot be lower than 0.6; Some scholars believe that as long as it is not less than 0.5 (Yang & Wei, 2012); Some scholars also adopt different standards based on different situations, believing that the reliability test for individual variables should be greater than 0.5, while the reliability test for potential variables should be greater than 0.6 (Yin & Cai, 2010).

After calculation, the CR values of the four factors of innovation awareness, namely innovation value awareness, personal innovation awareness, innovation and education awareness, and implementation awareness, are 0.92, 0.96, 0.88, and 0.81, respectively, which are greater than the standard of 0.6.

3.7. Aggregation validity

For aggregated validity, as mentioned earlier, most scholars use AVE, which is the mean variance extraction quantity, to measure, and the corresponding criterion is that the explanatory power of the measurement clause is not less than the error variance. Many scholars unanimously believe that if the error explanation is greater than the measurement clause, there is a serious problem with the validity of the variable (Zhang et al., 2016), so the minimum criterion for AVE is greater than 0.5.

$$AVE = \frac{\sum \lambda^2}{\sum \lambda^2 + \sum \varepsilon_j} \tag{2}$$

Among them, λ It is a standardized load, ε Is the measurement error of item j. After calculation, the AVE values of the two factors of family environment, family support and family conflict, were 0.53 and 0.67, respectively. The results showed that the aggregation validity of the two factors of family environment was good.

After calculation, the AVE values of the four factors of innovation consciousness, namely innovation value consciousness, personal innovation consciousness, innovation and education consciousness, and personal innovation consciousness, are 0.69, 0.66, 0.56, and 0.51, respectively, which are greater than the minimum standard of 0.5 and demonstrate good aggregation validity.

3.8. Differentiation validity

In existing studies, the method of comparing the AVE root mean square of variable factors with the correlation coefficient between variables is commonly used to test the discriminant validity of variables. Therefore, if the correlation coefficient between two variables is less than the square root of the AVE of these two variables, then the discriminant validity of these two variables meets the standard, that is, there is discrimination (Zhu, 2011).

The diagonal of the correlation coefficient between each factor is the square root of the AVE of the four variables. From the data in the table, it can be seen that the square root of the AVE of the four variables is greater than the correlation coefficient between them, indicating that there is a clear degree of differentiation among these four variables.

4. Research results and discussion

4.1. The specific impact of various elements of digital leadership on innovation performance

Organizations tend to make decisions based on real and timely data, thereby improving the accuracy and efficiency of decision-making. Through data-driven decision-making, organizations can quickly identify market opportunities, accelerate the launch of new products, and improve market response speed. Digital leaders can integrate the latest technologies into the operations of organizations and drive digital transformation. This integration enhances the operational efficiency of the organization, creates new business models, and provides customers with a better experience. Digital culture encourages employees to actively learn and apply new skills, promoting knowledge sharing within the organization. This cultural atmosphere enhances the organization's innovation ability and encourages employees to think from multiple perspectives, thus generating more innovative ideas. Digital leadership promotes the flattening of organizational structures and improves decision-making speed. Agile and flexible organizational structures enable organizations to respond more quickly to external changes, enhancing the success rate of innovative projects. Digital collaboration tools and platforms promote collaboration across teams, departments, and even organizations. Through cooperation, organizations can integrate more resources and knowledge to accelerate the implementation of innovative projects. Digital leadership emphasizes a customer-centric mindset and promotes a deeper understanding of customer needs. Providing customers with a more personalized and efficient experience, improving customer satisfaction and loyalty, thereby bringing higher sales and revenue.

4.2. Discussion on Sustainability and Reproducibility

The positive impact of digital leadership on innovation performance has been confirmed, but whether this impact is sustainable and replicable remains a question worth exploring.

With the continuous progress of technology, today's digital innovation may soon become outdated. Therefore, digital leadership requires continuous learning and adaptation to new technological changes. To ensure the success of digital strategies, organizations need to continuously invest in technology, talent, and training. Continuous digital leadership also requires organizations to regularly review and adjust their culture and strategies to ensure consistency with current market and technological trends. The digital market environment is constantly changing, and organizations need to continuously make strategic adjustments based on market changes.

The culture, values, and strategies of different organizations may affect the effectiveness of implementing digital leadership strategies. Therefore, a successful strategy for one organization may not necessarily apply to other organizations. The differences in resources and abilities of organizations in terms of technology, funding, and talent may affect their ability to replicate successful experiences in digital leadership. Different markets and customer groups may have different demands for digital products and services, which can also affect the replication effect of the strategy. In different regions and cultural backgrounds, digital strategies may need to be adjusted accordingly. Although digital leadership has a significant positive impact on innovation performance, its sustainability and replicability require sustained efforts and adaptation by organizations. Organizations need to recognize that successful digital leadership strategies not only involve adopting new technologies, but also require continuous investment, learning, and adjustment. At the same time, when replicating the successful experiences of other organizations, it is necessary to consider various internal and external differences.

4.3. Application of digital leadership in different organizational cultures and structures

The impact of digital leadership is not isolated, it is closely related to the culture and structure of the organization.

Innovation oriented culture, in which digital leadership can provide organizations with new tools and methods to further drive their innovation activities, such as open innovation and rapid experimentation. A stable oriented culture, for more traditional and conservative organizations, digital leadership may require more effort to integrate and focus on how to introduce innovation without

compromising stability. A culture centered around people, in which digital leadership should focus on improving employees' digital skills and knowledge, while ensuring that technological change does not alienate employees.

Hierarchical structure, in highly centralized organizations, digital leadership strategies may require top-down promotion. Leaders need to become the main driving force for digital transformation and ensure that information flows between different levels of the organization. Matrix structure, in which digital leadership needs to span multiple teams and departments, emphasizing cross departmental collaboration and communication. Network structure, for organizations that emphasize external cooperation, digital leadership can help connect all parties and promote the sharing of resources and knowledge. For hybrid organizations with multiple cultural and structural characteristics, digital leadership strategies need to be more flexible and diverse. It may be necessary to combine different methods and tools to ensure that digital strategies meet both internal organizational needs and respond to external environments. Digital leadership is not a 'one size fits all' strategy. When organizations consider how to cultivate and apply digital leadership, they need to have a deep understanding of their own cultural and structural characteristics to ensure that digital strategies match the actual situation of the organization. At the same time, organizations need to continuously learn and adjust to ensure competitiveness in the digital age.

4.4. Practical suggestions for organizational management and leaders

Digital leadership is becoming increasingly critical in today's organizational environment. For the management and leaders of an organization, how to effectively cultivate and apply this leadership is an important task.

Leaders themselves should maintain an understanding of digital technology and actively participate in training and learning to lead digital transformation. Encourage team members to participate in training on digital technology and trends to enhance overall digital literacy. Leaders should establish a clear digital strategy that is aligned with the organization's long-term goals and core values. Promote the formation of digital cultural values such as open communication, failed rapid learning, and continuous innovation. Encourage collaboration and communication between different departments to utilize digital technology for more efficient resource sharing and knowledge transfer. Promote collaboration tools such as Slack and Microsoft Teams to enhance communication and collaboration between teams. Use digital tools to collect and analyze customer data, ensuring that products and services meet the true needs of customers. Utilize digital technology to provide personalized services, simplify customer journeys, and improve customer satisfaction. While pursuing digital innovation, it is important to ensure a clear understanding of potential risks and develop response strategies. Encourage teams to explore new innovative directions and control risks through small-scale experiments and rapid iterations. Leaders should pay attention to digital trends within and outside the industry to ensure that the organization remains at the forefront of the industry. To cope with future uncertainty, leaders should promote the establishment of agile decision-making and execution mechanisms in the organization.

5. Conclusion

5.1. Main findings of the study

This study delves into the definition, core elements, and impact of digital leadership on organizational innovation performance, and concludes with the following key findings:

Digital leadership is not just a supplement or extension to traditional leadership, but a new interpretation of the concept of leadership in the digital age. Digital leadership not only focuses on technological capabilities, but also on strategic thinking, organizational collaboration, and cultural shaping in the digital context. Understanding digital strategies, cross departmental collaboration, digital decision-making ability, and technical acumen are the core elements of digital leadership. These core elements are closely positively correlated with the innovation performance of the organization.

Strengthening digital leadership within an organization can significantly improve its innovation capabilities, especially in areas such as product innovation, process optimization, and business model innovation. Digital leadership indirectly drives organizational innovation performance by promoting better data-driven decision-making, cross departmental collaboration, and rapid adaptation to market changes. There are significant differences in the application and impact of digital leadership under different organizational culture and structural backgrounds. Innovation oriented and open organizational culture make it easier to accept and apply digital leadership, making it easier to achieve high innovation performance.

5.2. Suggestions and directions for future research

With the continuous progress of digital technology and the increasingly complex organizational environment, research on digital leadership will continue to deepen and expand. Here are some suggestions and directions for future research:

Provide a clearer and more specific definition of digital leadership, and explore its differences and connections with other leadership concepts. Analyze the multidimensional nature of digital leadership, such as emotional intelligence, cultural adaptability, and their significance in the digital context. Combining interdisciplinary methods such as psychology, sociology, and management, this study delves into the formation and functional mechanisms of digital leadership. Consider multiple dimensions such as technology, human resources, and organizational behavior to provide a richer theoretical foundation for digital leadership. Analyzing the characteristics and challenges of digital leadership in different cultural, regional, and market environments. Explore how to shape and enhance digital leadership in a multinational context, promoting the global competitiveness of organizations. Study the impact and challenges of emerging technologies such as artificial intelligence and blockchain on digital leadership. Explore how to utilize these technologies to train and enhance digital leadership. Collect and analyze successful and unsuccessful cases of digital leadership in actual organizations, providing empirical support for theoretical research. Explore the best practices for digital leadership training and development, providing practical guidance for organizations.

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