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Article

Impact of Technology Habitual Domain on Ambidextrous Innovation: Case Study of a Chinese High-Tech Enterprise

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Abstract: To obtain a sustainable competitive advantage in the dynamic environment, it is necessary for Chinese high-tech enterprises to focus on their technology habitual domains in formulating ambidextrous innovation strategy. This study integrates technology habitual domain, exploratory innovation and exploitative innovation within a framework and explores the influence mechanism among them. Based on an in-depth case study on KTE, representing a high-tech enterprise in China, we have several findings. Firstly, we depict the evolution mechanism of technology habitual domain; secondly, we find that the high-tech enterprise's technology habitual domain will cultivate and develop the firms' dynamic capabilities; and thirdly, the expansion of technology habitual domain will promote exploitative innovation, while the transformation of technology habitual domain will promote exploratory innovation. These findings can be useful guidance for high-tech enterprises in China who are aiming to achieve ambidextrous innovation to better adapt to the turbulent environment, and thus achieving sustainability.

Keywords: technology habitual domain; dynamic capabilities; ambidextrous innovation; exploitative innovation; exploratory innovation

1. Introduction

Today, enterprises pay more attention to seeking competitive advantages in the turbulent environment by pursuing sustainability [1]. Sustainability refers to the development that meets the current needs without compromising the ability of future generations to meet their own needs [2]. For the interest of sustainability, enterprises should embrace opportunities and control risks from economic, environmental, and social development, which should be reflected in both decision-making and implementation [3]. In addition to considering current economic benefits, enterprises can achieve sustainable development by adding environment concerns during innovation [4]. As discontinuous and imbalanced innovation may cause failure within rapidly changing industries [5], the continuous combination of exploitation and exploration has become a source of sustainable competitive advantages [6]. Therefore, under the hypercompetitive environments, enterprises should pursue both exploratory innovation and exploitative innovation to ensure long-term survival and prosperity [5,7], in order to achieve sustainability.

Researchers classified exploitative innovation and exploratory innovation into the category of technological innovation [8,9]. In the environment of open innovation and the industry 4.0, technological innovation has become particularly critical to high-tech enterprises. Yun et al. [10] suggest that technological innovation is being progressed as one part of a dynamic feedback process amid technology, business model, and market. The firm's technology strategy, along with complex adaptive systems and market reactions stimulated by technological innovation, will promote the evolution of open innovation [11]. Based on the valuable technologies in the economic reality, the business model development cycle has also been proposed from the viewpoint of engineer entrepreneurship [12].

The assessment methodology for sustainability includes technological suitability, economic concerns, environmental considerations (in terms of resources and emissions, risks etc.), and social considerations [13]. The social and environmental consequences caused by new technologies should be fully discussed before the introduction and application of new technologies [14]. Nowadays, the way to predict the future of technology needs the future-oriented technology analysis [15]. Therefore, by exploring the evolution of the technology habitual domain (THD), technology can be revealed from its past to the future in its technology domain. Although researchers have explored the evolution stages of THD [16], the existing research on THD is fragmented and independent. They focus on the state rather than the dynamic, the result rather than the process of the THD's evolution. In a word, still being a black box from an endogenous perspective, the evolution mechanism of THD is under explored to provide this research a dynamic perspective. Besides, to determine the direction of specific technology development in the long run, organizations need to investigate the interaction between technology and the environment, shedding light on the interaction between THD and the environment. The habitual domain (HD) theory is the basis for the formation of knowledge creation and innovation ability [17]. Enhancing innovation ability is the process of the organization constantly expanding THD [16,18,19]. Accordingly, THD is critical for high-tech enterprises to develop technological innovation in the perspective of sustainability. However, researchers have analyzed the selection of ambidextrous innovation strategy during the evolution of THD [19], but how does THD influence the ambidextrous innovation of enterprises still lacks research.

Based on the above research, this study, building on the knowledge management and organizational learning literature, suggests that to obtain a sustainable competitive advantage in the environment of open innovation and the 4th industrial revolution, THD will influence ambidextrous innovation for high-tech enterprises. Specifically, the following questions will be answered: what is the evolution mechanism of THD; how does the high-tech enterprise's THD influence its exploitative innovation and exploratory innovation? This paper is structured as follows. Firstly, the literature review investigates existing research on ambidexterity innovation and THD to identify the theoretical gap. Second, the research method is considered and an in-depth case study of KTE is presented. Based on them, findings of the case study are discussed. Finally, the conclusions and implications of the study are set out, along with the limitation of the research and possible directions for future research.

2. Literature Review

2.1. Ambidextrous Innovation

Since March [20] proposed exploration and exploitation from an organizational learning perspective, these concepts have been adopted in the field of strategic management. Boer [21] suggest that continuous innovation is a continuous interaction between operations, incremental improvement, learning and radical innovation, in order to effectively combine exploitation and exploration. Many researchers tried to figure out a kind of organization that can combine exploitation and exploration until the ambidextrous organization was proposed [22], which stress the firm to adopt multiple structures. The significant features of ambidextrous organization are exploratory innovation and exploitative innovation [6].

The concepts of exploratory innovation and exploitative innovation were proposed by Benner and Tushman [8] according to the differences in innovation degree and knowledge base. *Exploitative innovation* aims at meeting the existing market and customer needs, and enhancing the organization's existing skills, processes, and structure based on existing knowledge. It leads to a slight improvement in quality and performance in products and processes, mainly affecting the organization's short-term gains, and making the organization more competitive [23]. In contrast, *exploratory innovation* is intended to meet the emerging market and customer needs, carry out new designs, develop new markets, or open new distribution channels with new knowledge. It broadens the breadth of knowledge, produces a series of product and process innovations, and improves the flexibility and diversity of the organization. Exploratory innovation may not be effective in the short term, and the results are not easily predictable [20]. As a complementary relationship, exploratory and exploitative innovation will produce better results when they are simultaneously implemented [24].

Researchers have explored the factors that influence ambidextrous innovation from the perspective of organizational resources, organizational capabilities, organizational context, organizational structure, environment, leadership preferences, and the interaction between entrepreneurial orientation and capability-based human resource management [25–37]. However, they overlook the habitual pattern of the organization in its development, which may also affect the implementation of innovation strategy [19]. In the open innovation environment, knowledge is the core asset of organizational innovation, and boundary-spanning is an effective exploration to cross organizational boundaries and acquire heterogeneous knowledge [35]. Knowledge across boundaries has a great effect of pursuing both exploitative innovation and exploratory innovation on firms' performance [35,37]. Innovation within and among organizations stems from the ability to share, combine and create new knowledge to act dynamically and perceive new opportunities in the competitive environment [36,37]. Organizational capabilities are the main factors to influence ambidextrous innovation. By studying absorptive capacity, Jansen [26] found that the potential absorptive capacity positively mediate the realized absorptive capacity and exploratory innovation, which indicates that potential capability of THD will influence exploratory innovation. However, the formation of potential absorptive capacity is not revealed yet. According to Yu [38], this potential capability can be activated with respect to specific events or problems, and is formed in the potential domain of THD. In addition, dynamic capabilities are rooted in both exploratory and exploitative activities [8], and can promote ambidextrous innovation [39–42]. If combined with good strategies, companies can produce the right products for the right market to attract the needs of consumers, and gain promising technology and competitive advantage [43]. We can find the elements of THD in existing research, but researchers often separate them rather than integrating them in a system. Based on this, this study explores the influence mechanism of ambidextrous innovation from THD theory to provide a holistic view.

2.2. Technology Habitual Domain

Researchers have studied the important role of knowledge in promoting innovation [44]. However, companies that are rich in knowledge stock may not be able to successfully innovate. In some cases, the more knowledge accumulated within a company, the more difficult it is to change the direction of technological development, which has been attributed to inertia and path dependence [45]. However, in these two theories, the impact of the organization's potential capability has been overlooked. The habitual pattern of organization in learning and management practice reflects a potential influence on the actual behaviors of an organization [46]. Therefore, Yu [47] proposed HD theory, which explains that the potential influence derives from the collection of all ideas and operators that can be potentially activated with respect to specific events or problems [38]. HD theory was originally applied to the human decision-making area after Yu studied the human decision process and related behaviors. The HD guides people's decision-making and determines certain types of their behavior. Feng [48] believes that the organization is, in abstract, a living entity like a human, and therefore has its own HD, which extended HD theory to the field of organization. Specifically, Ma [49,50] provided a systematic research on the definition, characteristics and evolution of enterprise habitual domain (EHD). With the fierce competition in the process of global economic integration of high-tech products, Yan [18] zoomed in to the technology inside an organization, and proposed THD based on the HD theory. Yan [18] considered that whether high-tech enterprises have the ability to participate in competition and winning competitive advantages lies in how they manage their THD.

THD focuses on the technologies and the collection of technology-related, relatively stabilized knowledge of an enterprise in a period of time [19]. Technologies of an enterprise are a projection of its THD, while the potential *IE* (information element, representing knowledge, experience and information) can provide solutions to change technologies or implement technological innovation when the enterprise deals with environmental changes [18]. The connotation of THD contains two aspects: one is the habituation of the firm in solving technological problems, which is the manifestation of THD; the other is the potential capability formed by technology-related and potential IE, to respond to environmental changes. In this study, we define THD as the technological knowledge and experience of product and process inside an enterprise, gradually stabilizing within a certain domain and forming a habitual way of solving technological problems over a period of time without stimuli.

Originating from the innovation studies in the micro perspective of knowledge and experience, the THD theory will affect the innovation ability of enterprises [16,18,19]. In recent years, researchers have paid more attention to the relationship between THD and innovation. In the study of independent innovation, the innovation is mainly driven by its own THD, the rich and dynamic THD of a company will facilitate continuous innovation [18]. After studying the relationship between the evolution of THD and the dynamic process of continuous innovation, Ma, Liu, Yan, & Chen [16] pointed out that THD's stability and flexibility is the key to continuous innovation. By the interaction of THD's stability and flexibility, THD may either launch new products and services quickly by its high level of flexibility, or become hard to change and even get rigid by its high level of stability, thus hindering the innovation [16]. Accordingly, in order to explore how enterprises select ambidextrous innovation strategy at each stage of THD evolution, Ye, Feng, & Ma [19] discussed strategic selection of ambidextrous innovation based on the evolution of THD. When the firm's THD is at the flexible stage or flexible-to-stable stage, it is suitable for the firm to conduct exploitative innovation. When the firm's THD is at the stable-and-flexible stage, companies can choose the innovation strategy flexibly, enabling the firm to implement both exploitative innovation and exploratory innovation. When the firm's THD enters or is about to enter the rigid stage, new technical solutions are required beyond its potential domain to weaken the rigidity, so the enterprise can be under the guidance of the exploration innovation strategy.

Therefore, the influence mechanism of THD on ambidextrous innovation needs to be specified to further explain why and how THD can influence exploratory innovation and exploitative innovation. Existing research provides basis for this study, and the research gap also provides us with research opportunities.

2.3. Literature Analysis and Research Gap Identification

Even though THD theory emphasizes the habitual way of organizational behaviors, the formation and application of habitual behaviors have not been explained. The habitual pattern of organization in learning and management practice reflects a potential influence on the actual behaviors of an organization [46]. Researchers apply more knowledge base rather than the habituation of organization in their study. Knowledge base is the essential component of THD. Nevertheless, we consider the habitual behavior, as the reflection of THD, provides an insight to study THD, which is combined into this study consequently. To explore the formation and application of THD's habituation, a dynamic and evolutionary perspective is needed, so the evolution mechanism of THD is the primary task to solve.

By matching the characteristics of different stages of THD with appropriate innovation strategies, researchers provides suggestions on exploitative innovation and exploratory innovation with a primary exploration [19]. Nevertheless, they ignored how to allocate the IE of THD in accordance with the appropriate innovation when the firm is faced with turbulent environment, or THD in a rigid condition. Thus, the questions of what the evolution of THD will result in and the inner mechanism of how THD works to influence ambidextrous innovation remain to be studied. In addition, within the organization, IE is stored in the form of organizational memory. THD is not only a collection of the firm's IE, but also the carrier of organizational memory. The enterprise has formed its own THD during its development, constantly changing and evolving by the environmental changes. Hence, a dynamic perspective is needed for us to explore the influence mechanism between THD and ambidextrous innovation. Until now the influence mechanism has remained unclear, leaving an understanding of the effects of THD unsolved. It is quite necessary for high-tech enterprises to combine its THD in formulating ambidextrous innovation strategy. Specifically, the following questions will be answered. By analyzing and explaining these questions with a specific interpretation mechanism, THD theory can be applied into innovation practice.

- What is the evolution mechanism of THD?
- How does the high-tech enterprise's THD influence its exploitative innovation and exploratory innovation?

3. Research Methodology

The research methodology is precipitated by the research questions. By reviewing the literature, we develop a holistic understanding of current studies and determine the research gaps in them. The research questions are put forward with the aim of exploring the influence mechanism between THD and ambidextrous innovation in a high-tech enterprise. This research adopts the theory building approach with qualitative methods. Eisenhardt [51] stated that case study will be of great use in the initial phase of research when we know little about research questions or when we try to do research from a totally new perspective. Since cases allow investigators to have a holistic understanding of the meaningful points of real-life events [52], an in-depth case study will be conducted as the research method. As an exploratory case study, we conduct an in-depth longitudinal analysis of a single case that helps to refine the law. The case study method helps to capture and trace the new phenomena and new problems emerging in the management practice, and better examine the issues raised in the research framework through the in-depth case analysis [53,54]. Therefore, this paper conducted a single in-depth case analysis. A research framework (as shown in Table 1) is derived to explain the main topics and provide operational criteria for each topic.

Table 1. A research framework.

Aspect	Variable	Operational Measure
Basic information about IE	Position of IE	-Based on the elements of HD proposed by Yu [47], we identified the actual domain and potential domain as the position of IE in THD
	Variety of IE	-In terms of the original IE, reconfigured IE, and external IE Original IE—the IE stored in THD without changes Reconfigured IE—the IE formed by reconfiguration of original IE and external IE External IE—the IE outside the THD
	Set of IE	-In terms of the scale, structure of IE, Scale—numbers of IE to meet the needs Structure—IE from customers, suppliers, cooperators, competitors, government policies, etc.
	Interaction of IE	-Base on the interaction ability of THD proposed by Yan [18]. By doing so, the interaction and flexibility of THD can be addressed
Evolution of THD	Improved change	-Based on the definition proposed by Yu [47] and Yan [18], which happens when the technological solution is used by IE from the potential domain of THD
	Heuristic change	-Based on the definition proposed by Yu [47] and Yan [18], which happens when the external knowledge and the original IE reconfigures to the new solution
	Radical change	-Based on the definition proposed by Yu [47] and Yan [18], which happens when THD produces new solutions beyond the potential domain
Ambidextrous innovation	Exploitative innovation	-Based on the definition proposed by Benner and Tushman [8] and He and Wong [9], which is the innovation aimed at meeting the existing market and customer needs, enhances the organization's existing skills, processes, and structure on the basis of existing knowledge, leads to a slight improvement in quality and performance in products and processes, mainly affects the organization's short-term gains
	Exploratory innovation	-Based on the definition proposed by Benner and Tushman [8] and He and Wong [9], which is the innovation aimed at meeting the emerging market and customer needs, carries out new designs, develops new markets, or opens up new distribution channels with new knowledge, broadens the breadth of knowledge, produces a series of product and process innovations, improves the flexibility and diversity of the organization, mainly affects the organization's long-term gains, and has unpredictable results

3.1. Case Selection

The selection of proper cases is an important step in the case study [51]. Firstly, we selected several high-tech enterprises in the Yangtze River Delta region and chose out companies that implemented the ambidextrous innovation strategy for a period of time. Then, according to the typicality and feasibility, we selected Jiangsu Kaiteer Co., Ltd. (KTE for short), Jingjiang, China, as the research case.

Research questions determine the criteria for the selection of case company. The sample enterprise has typical representation in their industries and has obvious competitive advantages over competitors. First, located in Jingjiang, Jiangsu Province, KTE is a high-tech enterprise awarded by both the nation and the province. Secondly, originally of a small size company specialized in industrial furnace production, KTE spent a dozen years growing into the leading firm in the industry of industrial furnaces. Moreover, during the development of KTE, energy saving, and environmental sustainability are its themes. KTE aims to provide support and services in the energy-saving transformation and emission reduction of industrial furnaces. With the increasing development of stone and wood, KTE is also trying to maintain the ecological balance and achieve the purpose of resource recycling by developing the technology of printed metal plates. This technology allows alloy materials to be coated on the surface by high-tech means, which was the first innovation in China. KTE also leads the drafting of the industry standards. In addition, after 2008, KTE gained a rapid development which is inconsistent with the global financial crisis. We can find the strong adaptability in facing with environmental change in this case. Thus, KTE is a typical case for this research.

Besides, KTE is in the same province as our research group, with convenient traffic condition. Since KTE has cooperation with the university authors affiliated, they have strong willingness to participate in the research, which is also helpful for the implementation of the research.

3.2. Data Collection

The longitudinal case study is a very important single case study method that can be used to study the same subjects at two or more different time points [52]. To increase research reliability and validity, different methods are used to collect data and conform to the principle of triangulation [52]. Therefore, we collected multiple forms of data through different methods, including interviews, internal company data, and public information. The data collection lasted from October 2013 to August 2014. We conducted three semi-structured face-to-face interviews with senior managers and R&D personnel of the company. The average time for each interview and discussion was 1 to 2 h. At each interview, interviewees were asked to introduce the basic information about their development of THD, and implementation of ambidextrous innovation (as shown in Table 1). Then the interviewers asked open questions based on the information above. The interviews were recorded and then transcribed for feedback and checking data. Besides, we consulted KTE's website, searched for KTE's news using Baidu and other search engines, and retrieved KTE's patent applications on the Chinese and foreign patent database service platforms. Moreover, we reviewed KTE's corporate yearbook, product introduction, internal publications, speech materials of top management team, and other relevant information. On the one hand, we can get longitudinal information which helps to understand the dynamic development process of this case. On the other hand, when analyzing the same change in a certain period, the coverage of this research involves multi-level. These two aspects of work have greatly improved the external validity of the theory and its adaptability in different situations. Lastly, we combined data from interviews and documents to generate a case report. Simultaneously, we carried out data analysis along with the data collection, which is beneficial to flexibly collect data and make adjustments during this process [51]. The data analysis follows Ritchie & Spencer's framework [55], which includes five steps: transcription, identifying a thematic framework, indexing, charting, and mapping and interpretation.

The entire case study process is independent of the case company. By repeatedly visiting the relevant departments of KTE, we have found relevant issues and findings and have communicated with the managers of KTE. As a result, relevant information was continuously obtained and supplemented to demonstrate relevant judgments and conclusions. By continuously summarizing and analyzing the information obtained from various sources, we are clearer about the evolution of KTE's THD and its impact on ambidextrous innovation. Upon that, we can verify the validity of the research model and try to develop the theory.

4. Case Analysis and Results

4.1. Case Description

Established in 2001, KTE is a leading enterprise in industrial furnaces and printed metal plates. Since its establishment, KTE has been actively absorbing talents and continuously developing new products and cooperating with foreign industrial furnace companies in various forms. KTE's industrial furnace products are always at the forefront in terms of manufacturing and control technology. Compared with other domestic electric heating furnaces, the full hydrogen hood type industrial furnace (B-type industrial furnace for short) uses hydrogen as its energy source initiatively, which fills the gap in the Chinese market. This product was named the national key new product and obtained two patents. KTE's products are mainly supplied to domestic well-known steel companies, such as Wuhan Iron and Steel and Hebei Iron and Steel, and other internationally renowned steel groups such as Goktas Metal in Turkey. In 2006, industrial furnaces were exported to Vietnam and Indonesia, then exported to Russia in 2012. Sales in overseas markets grow at an annual rate of 10%.

Before 2006, many domestic manufacturers still used smart meters and small PLCs to control the hood furnaces. This single independent control system could not meet the requirements of users, especially in large furnace group control, which severely restricted the production efficiency of the hood furnace, accompanied with many hidden troubles in terms of safe use and daily maintenance. With the continuous advancement of automation technology, KTE began to develop the microcomputer-controlled system of industrial furnace in 2006 and obtained the software copyright of the system in 2008. This project was listed as a national resource conservation and environmental protection alternative in 2009 and was supported by special funds.

At the same time, as energy became increasingly scarce, users became more aware of energy conservation. KTE proposed new research topics due to the large loss of heat storage and high heat-dissipating found in the actual application of scientific research personnel. Thus, a new combination of furnace lining has been researched and developed. After inspection, KTE has reduced the heat loss per furnace by 5%, increased production capacity by 3%, and saved gas by 3%. In 2009 alone, KTE completed six R&D projects on the products and processes of microcomputer-controlled full hydrogen convection hood furnace (RB-type industrial furnace for short) and applied for five patents.

Since KTE's independent R&D of B-type industrial furnace, technological and process innovations around RB-type industrial furnace have not been interrupted. The company has R&D institutions such as *Jiangsu Industrial Annealing Furnace Engineering Technology Research Center*, *Taizhou Enterprises' Technology Center* and *KTE Industrial Furnace Research Institute*. KTE has established cooperation with Shanghai Electromechanical Design and Research Institute, Beijing Iron and Steel Design and Research Institute, and Wuhan Iron and Steel Design Institute. In 2008, KTE cooperated with Nanjing University of Science and Technology and established *Research Center of Nanjing University of Science and Technology -KTE Industrial Furnace Engineering Technology*. In March 2010, KTE established *Academician Workstation of Huazhong University of Science and Technology* together with Huazhong University of Science and Technology.

In addition, a complete set of management systems was built by KTE, involving scientific research project management, R&D investment accounting system, internal management of engineering technology research center, performance appraisal reward system of R&D personnel. KTE has established a lean and efficient management model, and continuously strengthened technological innovation by improving technical skills of industrial furnace design, new material development, and modular production.

In 2008, under the influence of the global financial crisis, the sales volume of KTE's products decreased by 20–30% compared with previous years. Therefore, KTE implemented a diversification strategy, extensively researched domestic and overseas markets, and introduced steel materials printing technology from Korea and Japan. In 2009, KTE began to develop color-coated printing metal plates, which is a new type of building decoration material and green products of energy-saving and environmental protection. Relying on KTE's rich experience in the integration of mechatronics continuous production lines, KTE persistently digested and absorbed advanced international technologies. After three years of construction and adjustment, KTE has built the first high-grade automated production line of printing metal decorative plates in China. KTE applied for ten patents on printing design technology. KTE's performance has increased substantially. With the optimization of the product structure of the color-coated printing plate industry, the color-coated printing technology has set off a new revolution in the decoration materials industry and saved a lot of resources such as wood and stone. KTE is the first domestic company to independently research and develop printing metal plates, and use them as a building decoration board, which fills the gap in China.

4.2. Case Analysis

4.2.1. From THD_0 of B-Type Industrial Furnace to THD_1 of RB-Type Industrial Furnace

According to the development of KTE since 2001, the firm's products have developed from the initial full hydrogen hood industrial furnace to diversified products. From the development of the B-type industrial furnace to RB-type industrial furnace, KTE's THD constantly absorbed external knowledge and reconstructed the original knowledge, extending from THD_0 to THD_1 through a heuristic change (as shown in Figure 1). In this process, the company increased IE of THD through various ways to maintain the flexibility of THD, cultivated and improved the dynamic capabilities in the meantime, which promoted exploitative innovation (as shown in Table 2).

- By establishing sales offices throughout the country and maintaining business cooperation with well-known companies since the establishment of the company, the IE_1 of the market can enter THD in time. As a result, the company gained and improved its sensing capability to catch market opportunities during this process. With the consequent realization of increased market demand by the development of the automotive and home appliance industries, the improved performance requirements for plates and strips, and the new government requirements for enterprises on waste gas treatment and energy saving, KTE could consciously develop new industrial furnaces and promote exploitative innovation.
- During the development of the RB-type industrial furnace, KTE established several R&D groups and set up research centers in cooperation with Nanjing University of Science and Technology and Huazhong University of Science and Technology. IE_2 represents the research finding, entering THD_0 and enabling KTE to track the latest achievements in science and technology, which gradually nurture the sensing capability of KTE. Therefore, in the process of R&D, KTE can find solutions to overcome technological difficulties, promoting the exploitative innovation.
- KTE emphasized R&D management, established performance appraisal contracts, new product R&D project contracting systems, etc. These actions stored as IE_3 to improve KTE's quality assurance system and the efficiency of R&D, which gradually enabled the reconfiguring capability. By reconstructing management methods and adjusting working relationships, the relationship between existing knowledge and resources was further established, which accordingly supported exploitative innovation.
- According to different customer requirements, the thin slab needed to be smelted into different levels of thickness, demanding higher requirements for the welding process. In 2006, when visiting peer companies in Germany and the United States, KTE's executives found that robot welding process had already been used in manufacturing. This was a new IE_4 entering the THD_0, which inspired the company's integrating capability, prompting KTE to introduce this

robot welding process. Due to the integration of the new process, the products satisfied different customer's requests, and the production efficiency of industrial furnaces increased, releasing more resources to support the exploitative innovation.

- Considering the existing hood furnace control technology can no longer meet market and safety requirements, KTE was inspired by the new computer communication control technology, which is a new IE_5 entered and stabilized in the THD_0, enabling KTE to achieve the integrating capability. Therefore, KTE developed and established a microcomputer-controlled system, providing support for the efficiently producing the industrial furnaces, and promoted the exploitative innovation.

4.2.2. From THD_1 of RB-Type Industrial Furnace to THD_2 of Color Printing Metal Plate

After being built and improved, the THD_1 of RB-type industrial furnace underwent a radical change by the stimulation of external IE and transformed to THD_2 of color printing metal plate (as shown in Figure 1). During this process, dynamic capabilities were cultivated, and exploratory innovation was made as follows (as shown in Table 2).

- During an academic conference in Japan, KTE's executives found that environmental protection and energy conservation had become a hot topic. This IE_6 entered the KTE's THD, deeply touching the executives and bringing more attention to energy conservation and environmental protection, which cultivated the company's sensing ability. At that time, the domestic construction industry and the decorating industry are developing, while the decorative materials industry has a huge space for the replacement of wood and stone with steel. Perceiving this huge market opportunity, KTE, carried out exploratory innovation then.
- KTE introduced high-end technology and equipment (IE_7) from Germany, South Korea, and Italy, such as PLC automation control system, high-precision automatic digital printing unit, and roller coating continuous production equipment, to develop steel printing technology, which improved its capability to integrate resources. Based on this, KTE pioneered the production process of "6 printing and 6 baking of metal printing plates" and metal fluorocarbon ink printing technology in China, which promoted exploration innovation.
- KTE took full advantage of the company's supporting network relationships with upstream and downstream industries in the non-ferrous metals industry over the years, as well as the company's existing production experience and technical strength (IE_8), which constructed the capability to reconfigure resources, and supported the exploration innovation.

Table 2. Ambidextrous innovation along with the evolution of THD.

	IE/Events	Changes of THD	Outcome	Dynamic Capabilities	Ambidextrous Innovation
THD_0~THD_1	-(IE_1) Establishing sales offices throughout the country and maintaining business cooperation with well-known companies	-Reinforcement	-Information about requirements in existing market	-Sensing capability	-Exploitative innovation
	-(IE_2) Establishing several R&D groups and setting up research centers	-Improved change	-Research trends, latest technology, transformation of science and technology	-Sensing capability	
	-(IE_3) Improving R&D management	-Improved change	-Improvement of efficiency	-Reconfiguring capability	
	-(IE_4) Using robot welding process in manufacturing	-Heuristic change	-Small adaptations to existing products and services	-Integrating capability	
	-(IE_5) Using new computer communication control technology	-Heuristic change	-Improved, but existing products and services for local market	-Integrating capability	
THD_1~THD_2	-(IE_6) Participating in an academic conference in Japan to find the importance of environmental protection and energy conservation	-Radical change	-New demands beyond existing products and services	-Sensing capability	-Exploratory Innovation
	-(IE_7) Introducing high-end technology and equipment from Germany, South Korea, and Italy to develop steel printing technology	-Radical change	-New products in local market	-Integrating capability	
	-(IE_8) Exploiting existing network relationships, production experience and technical strength	-Reinforcement	-Commercialization of new products in new markets	-Reconfiguring capability	

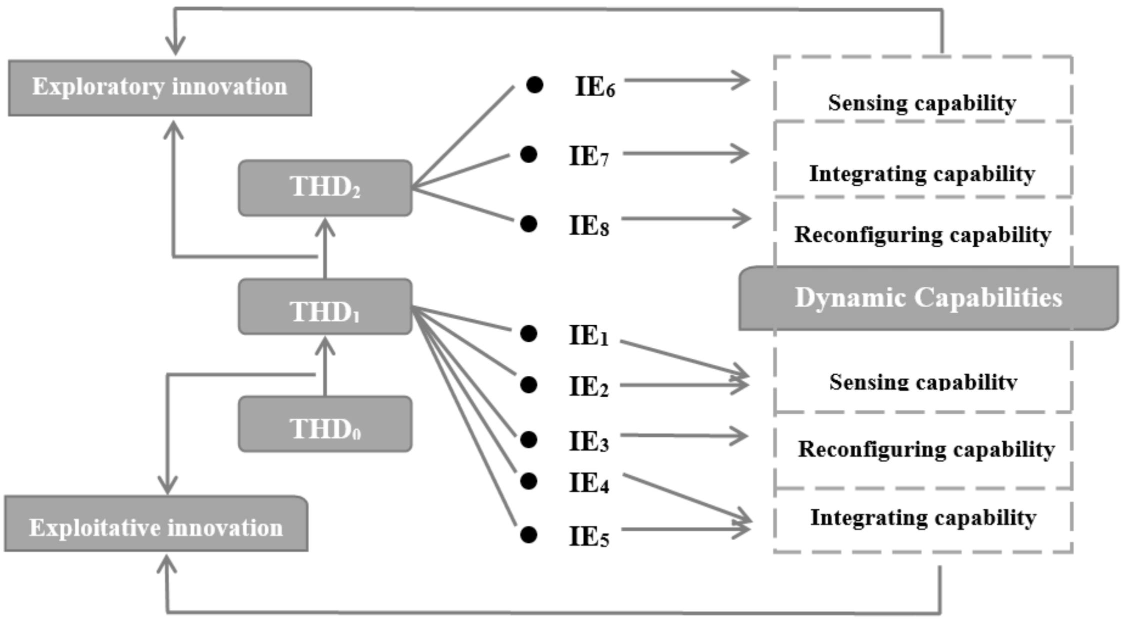

Figure 1. The process of ambidextrous innovation in KTE.

5. Discussion

5.1. The Evolution Mechanism of THD

Organizations' technological activities can employ existing IE, reconfigure existing IE, or absorb new IE from outside. These IE are stable in the organizations, some stored in the actual domain (AD), and some stored in the potential domain (PD) of the organization's THD [18]. When stimulated by the environmental changes, sensing internal or external charges, the organization will generally assign THD's IE from AD, based on previous experience, to solve the old and new problems. Neither the organizational nor the technological boundary is spanned during this local search [35]. If this solution works, then it will bring a positive feedback to the THD, and result in a reinforcement of this IE (shown as IE-AD with dotted circles in Figure 2), which will lead the firm to reuse it next time, thus, forming a unique habitual behavior of the firm. However, the reinforcement of IE from AD will not result in any changes in THD. For example, KTE increases sales offices to repeat the IE_1, which enables the company to have advantages in product sales by collecting local demand information and improve product service quality. This becomes its habitual behavior in solving sales expansion problems.

Proposition 1. *IE will be reinforced by a positive feedback, which will be repeated to form a habitual behavior of a firm.*

If the IE from AD is unable to solve the problem, the organization will seek solutions from its PD [56], which activates this IE and deploy it into AD (or expand its AD), accompanying with the improved change of THD (See IE-PD in Figure 2). In the case of KTE, we can find that IE_2 and IE_3 are a continuously improved IE based on the existing experience. Take IE_2 as an example, by cooperation with several universities (external IE), KTE can grasp knowledge and information from its PD to solve different technological problems. Therefore, KTE masters more difficult and novel technologies than before, which is also the process of achieving potential technical capabilities by relocating IE from PD to AD. As for IE_3, by learning from various management methods (external IE), KTE improves the performance and is sufficient for R&D. When the existing production and process are no longer suitable for the environment, the company will use IE_3 again to match the requirement through R&D management, which also shows the reinforcement of IE_3.

When no IE is available in its own THD to solve the problem, the organization will seek solutions from the outside world. If the external IE can be combined with its own IE to form a new solution, heuristic changes will occur (See Figure 2). From KTE we can see that the IE_4 and IE_5 are combined with information outside the edge of KTE's THD and the original IE of production process. If relying entirely on external IE to solve the problem, the THD will undergo a radical change. In KTE, the IE_6 and IE_7 are both absorbed from outside, and treated as the solution to overcome the problem of steel printing technology.

5.2. Formation and Improvement of the Organization's Dynamic Capabilities from the Perspective of THD

During the case analysis, we find the dynamic capabilities (DC) are cultivated and improved by the evolution of THD, and help the firm align resources, knowledge, and capabilities from THD to match the ambidextrous innovation strategy when facing the turbulent environment. DC were considered to be the abilities to sense and seize opportunities, integrate, build, and reconfigure internal and external competencies to adapt to a rapidly changing environment [57,58]. DC consist of dynamics and capabilities, explaining why some enterprises perform better than others in a dynamic environment, which solves the problem that core competencies theory cannot explain. Teece divides DC into sensing, seizing, and reconfiguring capabilities [36]. Eisenhardt and Martin also pointed out that DC should include integrating, reconfiguration, gain and release resources capabilities [59]. Wang and Ahmed point out that DC consist of three components: adaptive capability, absorptive capability, and innovative capability [60]. In this study, we have discovered sensing capability, integrating capability, and reconfiguring capability as DC. We will discuss the influence of THD on these three capabilities separately.

On the one hand, during the evolution of THD, if being used more than once, the old solutions will be strengthened, which will become more stable by repeated reinforcement (shown as IE-AD with dotted circles in Figure 2), then become organizational routines as memory carriers for organizational knowledge [61]. For example, IE_3 shows a repeated reinforcement of a set of specific and identifiable processes in R&D management, which set up a habituation to improve the R&D efficiency. This process has led to the generation of dynamic capabilities, as Wang & Ahmed [60] argue that DC are embedded in processes as a firm's constant behavioral orientation. The company can correct its operational routines and improves efficiency through DC [42]. On the other hand, the new solution will be stored as a new IE in the firm's THD for use when necessary. The behaviors of repeated absorbing and storing IE exist in the organization's management and learning process of knowledge, skills, and expertise, continuously improving and updating organization abilities, thereby nurturing DC to adapt to environmental changes. In turbulent circumstances, if IE that can respond are stored in the THD, the organization will be able to perceive opportunities and challenges. When there are more such IE, or the IE have been stabilized by gradually being repeated and reinforced, the organization will have stronger sensing capability.

Proposition 2. *IE that are stored in the THD can cultivate the organization's sensing capability, and IE that are reinforced in the THD will improve the organization's sensing capability.*

However, routines will result in the formation of inertia, which hinders firms to adapt to the changing environment [62]. They may lead to information overload, and ultimately force enterprises to shrink their attention to a limited external knowledge source [63]. If the IE is being repeatedly used, the inertia of the IE will get stronger by continuous reinforcement. As a result, the THD will become unwilling to absorb external IE, which will weaken the organization's sensing capability. Therefore, on the contrary, it can be explained that when a firm discards its accumulated knowledge, innovation can be the result [64].

Proposition 3. *The level of organization's sensing capabilities will increase first but decrease then by more IE being stored in the THD, or more often the IE being repeatedly used.*

According to the proximity dimensions, firms cooperate with partners that share the same technological knowledge are less possible to recombine knowledge of diverse technological domains [65]. When the organization often conducts internal and external learning and communication activities, its THD will continue to absorb and store IE from different areas, and then each new area of IE has the possibility of bringing more relevant IE into the organization. Once the environment changes, the organizations can use more IE, involving wider areas, and improve the capability to organize and integrate resources. In the case of KTE, managers are used to visiting and learning from peer companies, and absorbing the various IE into THD, such as IE_4, IE_5, and IE_7. When KTE searching new solutions to respond to environmental change, the IE_7 was activated and applied to develop steel printing technology. As shown in the research of Dubickis and Gaile-Sarkane [66], technology transfer based on learning outcomes can be used successfully. DC as a collective learning pattern from the perspective of organizational knowledge evolution [42], is cultivated by THD.

Proposition 4. *The wide distribution of THD's IE can cultivate organization's integrating capability.*

When companies face new things and new problems, they first establish a connection between the IE they already have. Once the correct relationship is established, the knowledge and experience of the past will be automatically applied to the understanding of new things and new problems. Reconfiguring capability requires the company to continuously monitor changes in the environment and reconfigure resources [57]. When the environment changes, IE within THD will try to connect with the outside information to develop new solutions, integrating knowledge by external boundary-spanning that is close to the technology of interest [35]. By building more connections, firms can absorb IE from external sources to reconstruct existing IE in THD. Knowledge reconfiguration, by developing new routines and reconfiguring existing routines, will result in novel and formalized know-how, and stimulate changes in firm boundaries [67]. Meanwhile, THD has more IE to work as solutions to changes, thereby enables companies to acclimate to dynamic and complex circumstances. In the case of KTE, to fully support the development of color printed metal plate technology, KTE uses IE_8 to reconfigure its existing resources. The IE_8 consists of the upstream and downstream companies of non-ferrous metal industry, with a strong connection to the color printed metal plate technology, which facilitates the reconfiguration of IE_8 and improves the reconfiguring capability.

Proposition 5. *The connection between IE inside* the *THD and IE outside the THD can cultivate organization's reconfiguring capability.*

Overall, researchers have involved THD theory in studying the construction of DC, but not explicitly from a THD point of view. DC come from the co-evolution of experience accumulation and knowledge articulation and codification [42], and are reliant on the organization's values, culture, and collective ability, which are mainly resulted from past management efforts [68]. These experience and knowledge are considered to be stored and stabilized in the THD, work as IE to provide solutions for daily operation and addressing stimulus. Improving and expanding THD can enhance the flexibility of the enterprise to adapt to a changing environment [49], while DC are essentially the adaptation mechanism to the dynamic circumstances [69], thus, THD can improve DC. Meanwhile, THD's potential capability enables an organization to generate all the capabilities that may arise for a period of time. It may meet the needs or not to cope with environmental changes. However, although the organization does not possess this capability, it has the operator or program to achieve it [70]. In a turbulent environment, the ability of enterprises to create, accumulate, and use resources and knowledge is the source of long-lasting competitive advantage, which is also the essence of DC [71].

Moreover, future-oriented technology assessment is considered to predict unintended negative results of technological innovation, or reveals the future outcomes of new technologies that are not currently recognized [13]. DC, working as the adaptation mechanism between THD and environment, enables the sustainability of technological innovation by identifying the level of maturity and obsolescence of a given technology, or even identifying emerging technologies [15]. Accordingly, high-tech enterprises need to manage their THD to improve the DC in using and changing technologies and competencies to cope with environmental changes and achieving sustainability.

5.3. The Influence of the Organization's THD on Its Exploitative Innovation and Exploratory Innovation

It has been shown that the internal reaction of firms and organizations in their innovation can differ dramatically, the difference rests on how the knowledge flows related to an innovation are strategically shaped [72]. By focusing on the knowledge flow and second order competence, researchers distinguish the internal and external boundary-spanning exploration that spans technological and organizational boundaries [35]. Innovation in production and IT processes favors ambidexterity performance [73]. Though THD has the mechanism to self-renew and self-reconstruct by storing, reconfiguring, and releasing IE [50], the absorbed resources and capabilities are not always capable of responding to the environmental changes, which may turn into the capability trap. The rigidness or the inertia is not often caused by a lack of capabilities, but the failure of managers to connect them to the opportunities in the environment [74]. Therefore, firms need a capability to adapt to the environmental changes quickly and actively. O'Reilly and Tushman [75,76] point out that the key problem to be both excel at exploration and exploitation is the ability to sense and seize new opportunities, which lies in the DC. The basic assumption of DC theory is that the DC enable the organization to adapt to changes in the environment, thereby enabling the organization to achieve lasting competitive advantage. In the case analyses, we find that DC are built and improved by the evolution of THD and help the firm align resources, knowledge, and capabilities from THD to keep THD suitable to the ambidextrous innovation strategy when facing the turbulent environment.

From B-type industrial furnace to RB-type industrial furnace, KTE improved its industrial furnace technology from THD_0 to THD_1, exploited the existing market, and achieved the leading position. As industrial furnaces are the existing products and technology of the firm, KTE continuously improved the quality and performance of its products, aimed at meeting the market and customer needs and the environmental protection requirement. Besides, the IE that KTE applied are within the THD_0, means that KTE uses the existing knowledge to solve technology problems. During this period, KTE adopted exploitative innovation strategy. Through learning and accumulation, firms gradually construct and improve DC along with the evolution of THD, to improve the adaptability of the firm. THD's improved change and heuristic change are happened by using IE from AD [19], which causes the expansion of THD. Therefore, KTE developed its technology along the original path and bring about the exploitation innovation, not only helping to ensure the implementation and performance of technology, but also helping to improve existing technologies and optimize product plan.

From RB-type industrial furnace to color printing metal plate, KTE expanded its technology from THD_1 to THD_2, explored a new market in China, and achieved the leading edge. In the case of KTE, the company adopted exploratory innovation during this period. The color printing metal plate was a product and technology outside its original THD_1, the solution to solve this technological problem was from the IE_6 and IE_7 outside THD_1. When the static equilibrium of THD_1 formed in the stable environment is broken, the competitive advantage of enterprises often cannot persist. If THD_1 becomes too stable to change, it will get rigid that the inertia will hinder the innovation. However, KTE has strong DC which can overcome the inertia by taking the initiative to integrate existing and outside IE. Thus, KTE used the external knowledge and experience as solutions to make the radical change, which causes the transformation of THD. As a result, KTE breaks through the old technology and develop a path of new technology [19], allowing companies to launch new products and develop new markets, consequently facilitating the exploratory innovation (as shown in Figure 2).

Meanwhile, we also proved that the DC of a Chinese high-tech enterprise can promote ambidextrous innovation and achieve the competitive advantage, which supports the existing research findings [39–42]. It is necessary for the organization to maintain competitive advantage in a highly competitive environment [57,59,77,78]. It is also necessary to adjust the firm's strategy flexibly and avoid rigidness.

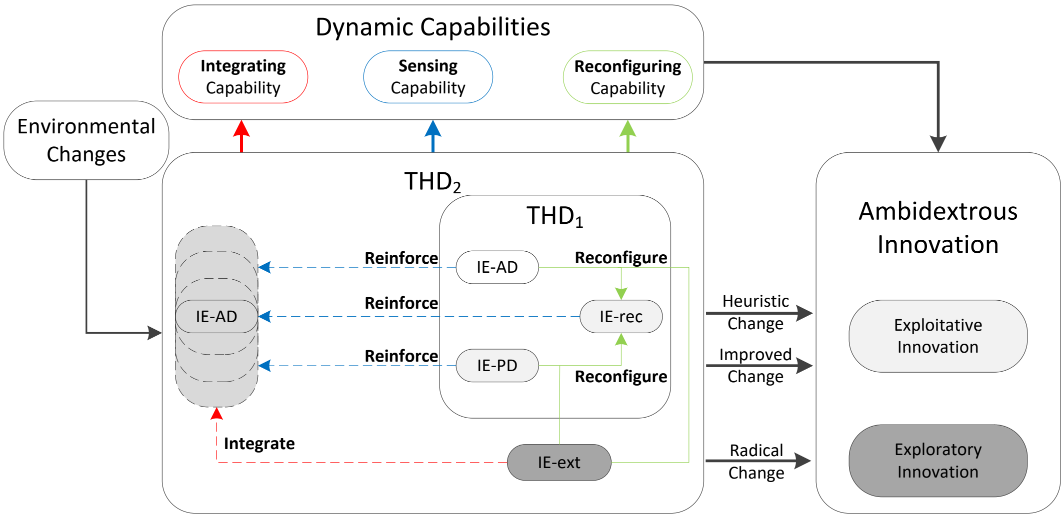

Figure 2. The influence mechanism of THD-DC-Ambidextrous innovation. Note: IE-rec refers to the reconfigured IE; IE-ext refers to the external IE compared to THD_1.

6. Conclusions

6.1. Theoretical Implications

Based on literature review, this paper adopts theory building approach with in-depth case study on KTE, a representing high-tech enterprise in China, to reveal the influence mechanism among THD, DC, and ambidextrous innovation of Chinese high-tech enterprises, to obtain a sustainable competitive advantage in the environment of open innovation and the 4th industrial revolution. This longitudinal case study makes several contributions to reveal the influence mechanism between THD and ambidextrous innovation. Firstly, this study contributes to the evolution mechanism of THD. Researchers have shown the evolution process of THD from a longitudinal point of view [16,19], dividing its evolution into four stages. We consider the evolution of THD from a horizontal point of view, separate the actual domain and potential domain of THD, and focus on the knowledge flow of a firm. We believe this evolution mechanism helps to reveal the black box of THD and provide a specific and dynamic perspective to study THD. As a result, retrieving IE from PD to solve technological problems will activate the corresponding IE and expand the AD, along with an improved change of THD; reconfiguring existing IE with external IE to solve technological problems will produce a reconfigured IE in the AD, along with a heuristic change of THD; absorbing external IE to solve technological problems will introduce a new IE in the AD, along with a radical change of THD. Meanwhile, we reveal the formation of habitual behavior in the THD perspective. We consider that IE will be reinforced by a positive feedback, which will be repeated to form a habitual behavior of a firm.

Secondly, from the case study, we extend the formation and improvement of DC in the perspective of THD. Research on the formation and developing of DC [42,78] ignored the influence of a firm's habitual pattern in learning and cognition, and did not combine DC with the evolution of a firm's THD to study high-tech enterprises. We suggest that IE stored in the THD can cultivate organization's sensing capability, and reinforced IE will improve the organization's sensing capability. However, the level of organization's sensing capability will increase first but decrease then by more IE being stored in the THD, or more often the IE being repeatedly used. The wide distribution of THD's IE can cultivate organization's integrating capability. The connection between IE inside the THD and IE outside the THD can cultivate organization's reconfiguring capability.

Thirdly, we contribute to the influence mechanism between THD and ambidextrous innovation, combining with the DC. It is necessary to adjust the firm's strategy flexibly and avoid rigidness. Researchers have studied the ambidextrous innovation from various perspectives [25–33], but overlooked the habitual pattern of the organization in developing technology [18], which may also affect the implementation of innovation strategy [19]. Based on this, we further explore the influence mechanism among THD, DC and ambidextrous innovation. Results show that the expansion of THD will promote exploitative innovation, while the transformation of THD will promote exploratory innovation. We also prove that the DC of a Chinese high-tech enterprise can promote ambidextrous innovation and achieve the competitive advantage, which supports the existing research findings [39–42].

6.2. Practical Implications

Under the concern of sustainable development among the society and governments, high-tech enterprises should not only focus on their own economic interests, but also attach importance to the environmental issues and social development [79]. Continuous combination of exploratory innovation and exploitative innovation enables companies to achieve sustainable development. These can be useful guidance for other high-tech enterprises in China who are aiming to conduct ambidextrous innovation strategy to better adapt to the turbulent environment and seeking for sustainability.

This study provides Chinese high-tech enterprises with the evolution mechanism of THD. Understanding and mastering the evolution mechanism of THD provides an exercisable method for high-tech enterprises to change the situation of THD. High-tech enterprises need to store more IE, expand the distribution and connection of IE by boundary-spanning, to improve the DC in using and changing technologies and competencies, to adapt to environmental changes. Thus, high-tech enterprises can either flexibly adjust the ambidextrous innovation strategy according to the environment changes or enable the sustainability of technological innovation by future-oriented technology assessment. Besides, to avoid rigidness, enterprises should pay attention to the frequently used IE. It means they have been reinforced that may be difficult for enterprises to cope with environmental changes by them. It is necessary for the organization to maintain competitive advantage in a highly competitive environment [57,59,77,78]. Furthermore, as knowledge intermediaries, gatekeepers, providers, and evaluators, universities need to be valued in the open innovation environment [80]. In conclusion, to become flexible and adaptable in the environment of Industry 4.0, Chinese high-tech enterprises should continuously focus on their THD, to improve their DC and maintain sustainable competitive advantages.

6.3. Limitations and Research Directions

Due to the limitations of the single case study itself and other factors in the enterprise, the conclusions do not necessarily have universal applicability. Therefore, in the future, the results of this study can be tested or expanded by multiple case studies or simulation method. Besides, we only analyze the role DC plays between THD and ambidextrous innovation. Whether there are other factors that affect the relationship at the same time is also worthy of further research. Furthermore, whether the routine behavior dependent on specific leader traits, or organization ramifications [81] is still uncovered. Leaders and managers should be able to weigh the conflicts between short-term efficiency and long-term adaptability in the process of ambidextrous innovation, and constantly adjust their leadership style to match the management activities [6,75]. As top management support may impact information in daily activities [82], leaders and managers' personal habitual domain may also play an important role in decision-making of innovation strategy.

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