Analysis of Disruptive Technology Identification Methods in Foreign Countries

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Abstract: Disruptive technologies, which have groundbreaking effects on existing traditional or mainstream technologies, have great potential applications and are actively recognized and nurtured by all countries. This article summarizes the standard reports on technology identification research released by foreign government agencies, think tanks, intelligence agencies, consulting firms, universities, and patent analysis institutions. It then analyzes and evaluates disruptive technology identification methods in order to provide reference for the corresponding identification methods in China.

Keywords: disruptive technologies; identification; methods

1 Introduction

Disruptive technology (DT) is that for which a different approach is used which will exert a disruptive effect on existing traditional or mainstream technological approaches. From the perspective of technical attributes, DT can be an original innovation based on a new principle, or an integrated innovation based on existing technology, or transfer and innovative application of a mature technology. With significant breakthroughs, disruptive technologies can replace existing technologies, have great application value, and are expected to have a far-reaching influence on technological development in related fields.

Disruptive technologies can improve productivity and drive the upgrading of products and services. If enterprises can identify potential disruptive technologies, they will be able to adjust innovation strategies, mitigate risks, and dominate mainstream markets or create new markets.

Disruptive technologies also greatly change modes of production and industry structure, trigger the emergence of new industry patterns, and promote industry transformation. All countries have actively identified and nurtured disruptive technologies to win competitive advantages in a new round of industry transformation.

Disruptive technologies can greatly improve the working efficiency of the equipment system in terms of firepower, maneuver, and information thereby changing the rules of war games. With deterrent and conquest capabilities, disruptive technologies are given great importance in every country. Military agencies around the world have started to identify and explore disruptive technologies.

This article organizes the reports on technology identification research released by foreign government agencies, think tanks, intelligence agencies, consulting firms, universities, and patent analysis institutions. It analyzes and evaluates the methods for identifying disruptive technologies.

2 DT identification methods in foreign countries

Based on research reports on technological innovation released by nine typical foreign agencies, DT identification methods are classified into five types: literature analysis, technology definition, questionnaire survey, scenario simulation, and technology roadmap.

The agencies and their research reports are ① Thomsen Reuters—*The Future is Open: 2015 State of Innovation* [1]; ② DoD—Technology Watch and Horizon Scanning (TW/HS) project; ③ RAND—*Future Technology Landscapes: Insights, Analysis, and Implications for Defense*; ④ MIT—*MIT Technology Review* [2,3]; ⑤ McKinsey Global Institute—*Disruptive Technologies: Advances that will Transform Life, Business, and the Global Economy* [4]; ⑥ Goldman Sachs—*Summarization of Eight Disruptive Technologies*; ⑦ KPMG—*Technology Innovation Survey 2014* [5]; ⑧ Center for a New American Security—*Game-Changers: DT and U.S. Defense Strategy*; and ⑨ NASA—*Space Technology Roadmap and Priorities*.

2.1 Literature analysis method

Literature analysis is conducted to develop methods to understand facts by collecting, identifying, sorting, and systematically analyzing documents, such as the bibliometric analysis of literature, patent analysis, and knowledge graphs.

2.1.1 Thomsen Reuters: *The Future is Open: 2015 State of Innovation*

Thomsen Reuters mainly provides financial information services for professional enterprises, financial institutions, and consumers and provides intelligence information and solutions for professionals in the law, taxation and accounting, science, healthcare, and media markets. For example, Thomson Reuters is the only organization to use quantitative data to make annual predictions of Nobel Prize winners.

The"The Future is Open: 2015 State of Innovation"report provides an in depth analysis of global scientific literature and patent data across 12 technology areas. The report shows that global patent activities in 2014 hit a record high, the amount of technological literature in the 12 fields declined significantly, and the annual growth of invention and patents slowed sharply. The process of identifying disruptive technologies is as follows:

(1) Analyze the number of patents

The total number of global patents in 2014 reached a record high. More than 2.1 million patents were disclosed in 2014. The fields with the largest increase include food, tobacco and beverage fermentation (21%), pharmaceuticals (11.5%), cosmetics and well-being (8%), and biotechnology (7.3%).

(2) Analyze scientific and technological literature

The total volume of scientific and technological literature declined. In 2014, the total number of new research achievements in 12 technological fields decreased by 34%. The decline may be an early signal of the slowdown. Although the impact of the decline is uncertain, one thing we know with certainty is that innovation is a key driver of economic success and growth. If the trend continues, it will be something to which corporations and governments will want to pay close attention.

(3) Determine and analyze 12 key technological fields

The 12 technological fields are determined based on the analysis of the number of patents (Table 1). Although patent activities had been rising, the total number of global patents grew only by 3% due to factors like changes to patent legislation.

2.1.2 DoD: Technology Watch and Horizon Scanning (TW/HS) project

To prevent the technology surprise that may be caused by global disruptive technologies, DoD launched the Technology Watch/Horizon Scanning Project in 2011. The purpose of this object is to monitor emerging technologies and their development trends worldwide closely including improved and disruptive

Table 1. Key technological fields identified by Thomsen Reuters using the patent analysis method.

Technological fields	Number of patents for invention in 2014	Proportion of patents in total (%)	Number of patents for invention in 2013	Increase ratio of the number of patents in 2014 compared to 2013 (%)
Aerospace	62 162	5.0	63 080	−1.5
Automotive	153 872	12.3	152 221	1.1
Biotechnology	42 584	3.4	39 685	7.3
Cosmetics and well being	11 017	0.9	10 197	8.0
Food, tobacco, and beverage fermentation	26 333	2.1	21 758	21.0
Home appliances	71 278	5.7	71 118	0.2
Information technology	380 325	30.4	367 028	3.6
Armarium	93 462	7.5	99 290	−5.9
Oil and gas	24 158	1.9	23 925	1.0
Pharmaceuticals	111 479	8.9	99 950	11.5
Semiconductors	112 625	9.0	119 099	−5.4
Telecommunications	161 739	12.9	153 153	5.6
Total	1 251 034	100	1 220 504	2.5

technologies by analyzing patent application literature, university journals, research magazines, military records, and interview programs.

2.1.3 RAND: *Future Technology Landscapes: Insights, Analysis, and Implications for Defense*

The RAND Corporation is a nonprofit institution that helps improve policy and decision-making through research and analysis. In 2013, RAND released the "Future Technology Landscapes: Insights, Analysis, and Implications for Defense" report. It uses the rapid evidence analysis (REA) based on literature analysis to analyze the development trend of the UK's future defense technologies and enabling factors in the defense technology field in 2035. This analysis is implemented through seven steps, as shown in Fig. 1. The method identifies 16 key future national defense technologies in the UK, including the radar, nanotechnology, cyber warfare, 3D printing, directed-energy weapons, geospatial intelligence (GEOINT), and precision-guided weapons.

2.2 Technology definition method

Research institutes that participate in the identification and selection of disruptive technologies in order to put forward a clear DT definition use the technology definition method. Disruptive technologies are identified according to the definition.

2.2.1 MIT: *MIT Technology Re*view

Every year since 2002, MIT Technology Review has published a list of the 10 technologies that will have the greatest long-term innovative impact. Until now, details of 160 technologies have been published in the journal. The method of identifying disruptive technologies is as follows:

(1) Determine the technology selection criteria

The technologies to be selected each year need to reflect the new characteristics and trends of science and technology development in recent years. When determining whether to select a technology, focus is placed on the potential commercial application of the technology and the significant impact on human life and society.

(2) Release selected technologies on a rolling basis.

The editors and writers of the MIT Technology Review use the criteria to select technologies and recommend candidate technologies each year. In addition, they discuss with the chief editor, senior editor, designer, and R&D personnel to choose 10 technologies.

2.2.2 McKinsey Global Institute: *Disruptive Technologies: Advances that will Transform Life, Business, and the Global Economy*

McKinsey is one of the world's most famous management consulting firms. It provides advisory services to senior management, forecasts new problems and opportunities in the future, and develops timely and practical measures. In 2013, McKinsey released the "Disruptive Technologies: Advances that will Transform Life, Business, and the Global Economy" report. This report disclosed 12 disruptive technologies that will lead to life, business, and global economic transformation. These technologies will promote global economic growth over the next decade, bring business model innovation, product and service innovation, improve life, health, and environmental quality, help developed countries complete product upgrades, and achieve cost savings for developing countries. The method for identifying disruptive technologies is as follows:

(1) Conduct questionnaire surveys and interviews

Contact with more than 100 candidates from academic journals and business and technology publishing houses, analyze the published risk portfolios, and interview hundreds of experts and leading thinkers.

(2) Determine the technology selection criteria

Provide the selection criteria. The selected technologies must meet the criteria of rapid development, wide potential impact,
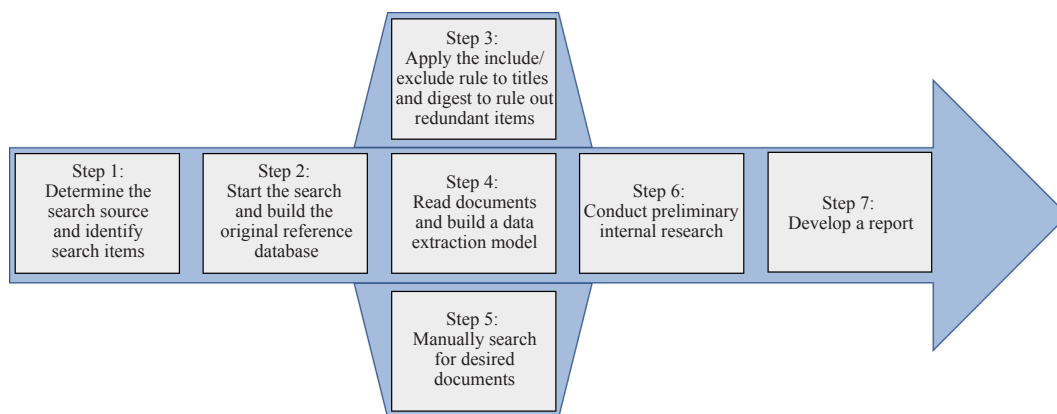

Fig. 1. Working flow of the REA method.

significant economic value, and potential disruptive impact on the economy.

(3) Carefully select the technologies

Evaluate the technologies submitted by each candidate based on the selection criteria and eliminate the disruptive technologies that are unlikely to have significant economic impact over the next decade.

2.2.3 Goldman Sachs: summarization of eight disruptive technologies

Goldman Sachs is a leading international investment bank that provides extensive investment, consulting, and financial services. In 2013, Goldman Sachs summarized eight disruptive technologies in various fields, such as electronic cigarettes, big data, manufacturing, and healthcare. GoldmanSachs uses the following method to identify disruptive technologies:

(1) Define disruptive technologies

Disruptive technologies are those that are likely to be re-shaped and gain more attention from investors over the next few years.

(2) Deeply understand the disruptive process

According to Goldman Sachs, the process of creative destruction is primarily driven by product or business model innovation—often abetted by technology—that results in a superior value offering to consumers, be it higher performance, greater convenience or lower cost. This enhanced value proposition is the source from which economic benefits then flow, first to the innovator and over time to its consumers and competitors. The new product or model often proliferates into a new paradigm until subsequent innovation in turn threatens its dominant position.

(3) Summarize disruptive technologies

Goldman Sachs summarized eight disruptive technologies by constantly improving the definition of disruptive technologies and deeply understanding the disruptive process.

2.3 Questionnaire survey method

The questionnaire survey method is used to obtain information by sending concise questionnaires to respondents and asking them to fill in comments and suggestions on relevant questions. KPMG released the "Technology Innovation Survey 2014" report.

To predict technology trends over the next three years, KPMG surveyed (online questionnaire) 768 technology industry leaders ranging from start-ups and large companies to angel investors and venture capitalists in order to determine emerging and disruptive technologies. In addition, KPMG interviewed some entrepreneurs to explore emerging and disruptive technologies. The records of the interviews with seven entrepreneurs are included in the report. The method of identifying disruptive technologies is as follows:

2.3.1 Conduct online questionnaires and interviews

KPMG is a global professional service provider that provides auditing, taxation, and consulting services. During August and September in 2014, KPMG conduct online questionnaires. In valid response, executives account for more than two-thirds of the participants. The proportions of large companies, mid-market companies, start-up companies, and angel investors/venture capital firms are 34%, 27%, 30%, and 7% respectively. The questionnaires are distributed to around 14 countries. The proportions of the questionnaires distributed to America, Asia Pacific, and Europe are 25%, 28%, and 47% respectively. The proportions of the questionnaires distributed to presidents, vice presidents, director level executives, entrepreneurs, venture capital Angel investors are 19%, 13%, 51%, 10%, and 6% respectively.

2.3.2 Properly set the questionnaires

This report discloses 27 choice questions of six categories, including consumer market-centric disruptive technologies, enterprise market-centric, barriers to commercializing technology innovation, technology innovation trends, technology innovation center, institution and countries, and innovation management.

2.3.3 Organize the questionnaire and interview results

Collect and analyze the questionnaire results, organize interview results, and generate reports.

2.4 Scenario simulation method

The scenario simulation is used to study the relative obstacles, approaches, and application requirements of technology implementation by constructing future scenarios to drive technology development.

In 2014, the Center for a New American Security, a well-known American think-tank that helped the United States develop effective and practical national security and defense strategies, released a research report titled "Game-Changers: DT and U.S. Defense Strategy." This report clarifies five disruptive technologies, focuses on the impact of these technologies on the future operations of the US, and calls on the US defense decision-makers to take measures to ensure the technological advantages of the United States. The method for identifying disruptive technologies is as follows:

2.4.1 Clarify the technology connotation and conduct necessary surveys

A series of surveys is conducted in the early stage of the project, and more than 60 futurists, lab directors, scientists, investors, and venture capitalists are interviewed to determine what the game-changing technology was. At the same time, project team members need to notify the interviewees about technology connotation—technologies that have been developed but have not been noticed by the world in world transformation, similar

to the computer in 1980 and the unmanned aerial vehicles such as Global Hawk in the Quadrennial Defense Review Report. The impact of changes in such technologies is overwhelming.

2.4.2 Carry out the "war game" simulation and "moral game" debate

In the project, a series of war games are simulated to explore the relative obstacles to technology implementation and methods for using technologies. A unique moral war is carried out in this project. Defense strategy experts, military and civil lawyers, representatives of human rights organizations, different philosophers, and ethicists are organized to explore disruptive technologies and their impact on laws, ethics, and policies during application.

2.4.3 Determine disruptive technologies

The results of technology surveys and "war games" ultimately determine disruptive technologies related to the US defense strategy.

2.5 Technology roadmap method

Based on the systematic research on the future social, economic, and technological development, the technology roadmap method puts forward the key technology groups, leading products, or industries that need to be preferentially developed and their relationships, and describes the development priorities, implementation time, and development paths of technologies through a time sequence diagram. This method lays the foundation for effectively organizing technology R&D, developing products, and properly configuring innovation resources. For example, National Aeronautics and Space Administration (NASA)

developed a technology roadmap for future space development.

In 2010, NASA's Office of the Chief Technologist (OCT) took the lead in implementing the research on technology roadmaps. A comprehensive technology roadmap consisting of 15 technology fields and more than 300 technologies was formed. The NASA technology roadmap is developed through seven steps: ① Collect input information from the tasks committees and centers as the basis for technology selection. ② Build a technology research team. ③ Determine the research method used by the team. ④ Propose a 10-year plan to increase the technology maturity level to level 6. ⑤ Develop the draft roadmap for each technology field. ⑥ Carry out internal and external review of the draft. ⑦ Update the technology roadmaps and prioritize them.

3 Analysis and evaluation of the methods for identifying disruptive technologies in foreign countries

Five types of DT identification methods are analyzed and evaluated in terms of qualitativeness, quantitativeness, input, output, applicability, technology tools (Table 2).

The literature analysis method is the only quantitative analysis method in the five methods. It is used to quantitatively and visually reflect the hotspot fields and trend of technology development. The technology definition method combines the qualitative and quantitative analysis methods and is used to identify technologies with definite standards. The questionnaire survey method is carried out through online questionnaires and expert interviews to identify disruptive technologies. The scenario simulation method is used to find the obstacles and approaches of technology implementation by simulating future scenarios. This

Table 2. Analysis and evaluation of typical methods for identifying disruptive technologies in foreign countries.

Method	Qualitative/ quantitative	Input	Output	Applicability	Technical tool
Literature analysis (bibliometric analysis of literatures and patent analysis)	Quantitative	Technology search items, references, and patent database	Key technology fields identified through data extraction, data analysis, and selection by experts	Used to quantitatively and visually reflect the hotspot fields and trends of technology development	Knowledge graph and cluster analysis
Technology definition	Qualitative/ quantitative combination	Technology selection criteria	Selected key technology fields	Used to identify technologies with standard criteria	Consulting and evaluation
Questionnaire survey	Qualitative	Questionnaire and experts' comments	Collective judgement results of experts	Used to identify dedicated technologies	Online questionnaire and interviews with experts
Scenario simulation	Qualitative	Future scenarios	Obstacles and methods of technology implementation	Used to identify demand-driven technologies	Consulting and evaluation
Technology roadmap	Qualitative	Systematic research on the future society, economy, and technology development	Development priorities, implementation time, and development approaches of technologies in a specific field	Used to identify technologies in a specific field	Consulting and evaluation

method is applicable to identify demand-driven technologies. The technology roadmap method is used to identify the development priority, implementation time, and development approach of technologies in a specific field.

4 Conclusions

By analyzing, summarizing, and evaluating the methods of identifying disruptive technologies, we can make the following suggestions.

(1) Flexibly combine the methods to make full use of their advantages. For example, we can combine the scenario simulation and questionnaire survey methods so that we can exert the expertise and experience of experts to conduct scenario simulation as well as use big data to conduct online questionnaire surveys.

(2) Use the methods of identifying disruptive technologies in this article for reference. For example, the report entitled "Disruptive technologies: Advances that will Transform Life, Business, and the Global Economy" released by McKinsey identified and predicted the disruptive technologies that will lead to industrial transformation before 2025. We can use the method described in the report for reference to study disruptive technologies in the economy and business field over the next decade.

(3) Recognize the limitations of the methods for identifying disruptive technologies and reconstruct the methods adaptively. For example, the technology roadmap method is suitable for identifying predicable technologies constantly used in a specific field. If the technology roadmap method is used to identify disruptive technologies in each field, the technology transformation path model should be used and subjective prediction implemented.

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