Technology Opportunity Identification: A Review and Outlook (Postprint)

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Abstract

[Purpose/Significance] Technology opportunity identification holds significant importance for technological innovation development and corporate strategic layout. This study systematically reviews existing research findings, identifies current limitations and future development directions, and provides theoretical support for further research and practice in technology opportunity identification.

[Method/Process] First, the connotation and types of technology opportunities are clarified. Then, the current state of domestic and international research on identification of various types of technology opportunities is reviewed, characteristics of different identification approaches are summarized, and finally, existing problems in current research are analyzed and future prospects are proposed.

[Results/Conclusion] Limitations of existing research include: relatively narrow research perspectives and data sources for technology opportunity identification; representation of technology that is either too macroscopic or too microscopic, with insufficient consideration of semantic relationships between terms; inadequate post-evaluation, lacking a comprehensive and systematic evaluation system. Future research prospects: cross-domain and cross-theme technology opportunity identification research to achieve greater convergence among technical elements will become a development trend; data sources, research methods, and content for technology opportunity identification will become more diverse and targeted; analytical frameworks and processes will be more standardized, and post-evaluation systems will be further improved.

Full Text

Technology Opportunity Identification: A Review and Prospects

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Abstract

[**Purpose/Significance**] Identifying technology opportunities is of great significance for technological innovation development and corporate strategic planning. This study systematically reviews existing research findings, identifies current limitations, and explores future development directions to provide theoretical support for further research and practice in technology opportunity identification.

[**Method/Process**] This paper first clarifies the connotation and types of technology opportunities, then reviews the domestic and international research status of different types of technology opportunity identification, summarizes the characteristics of each type, and finally analyzes existing problems in current research and proposes future prospects.

[**Results/Conclusions**] The limitations of existing research include: relatively single research perspectives and data sources; overly macroscopic or microscopic representation of technology with insufficient consideration of semantic relationships between terms; and inadequate post-evaluation lacking a comprehensive, systematic evaluation system. Future research prospects include: cross-domain and cross-topic technology opportunity identification to achieve convergence among more technology elements will become a development trend; data sources, research methods, and content for technology opportunity identification will become more diversified and targeted; analysis frameworks and processes will become more standardized, and post-evaluation systems will be improved.

Keywords: technology opportunity identification; technology opportunity types; research methods; technological innovation; review

1 Introduction

Technology opportunity identification refers to the process of discovering valuable information from scientific and technological intelligence through a series of technical means and methods. Although the terminology varies slightly (also called technology opportunity analysis or technology opportunity discovery), the core concept remains consistent. In the face of increasingly fierce market competition, identifying technology opportunities has become a key focus

for innovation entities to enhance core competitiveness and gain advantages in technological innovation and application. This process represents an emerging research branch in the field of technology forecasting [4,5]. This paper uniformly uses the term "technology opportunity identification" to describe the rapid extraction and mining analysis from objective data.

Previous review studies on technology opportunity identification have primarily focused on summarizing identification methods [3,6] or comparing domestic and international research content [4,7]. When reviewing current progress in technology opportunity identification, this paper emphasizes distinguishing technology opportunity types and corresponding identification methods to better understand the characteristics of various technology opportunities, thereby discovering identification methods based on different opportunity types and grasping development trends in these methods. Technology opportunity identification refers to the possibility or potential direction of technological progress [1,2], and has become a priority for researchers and a think-tank guarantee for innovation entities to formulate development strategies and plan research layouts.

From a theoretical perspective, technology opportunity theory is widely believed to originate from Professor SCHWARTZ' s proposal of technological innovation opportunities in 1974, which can bring new opportunities for innovation in certain industries and cause turning points in industrial R&D directions [8]. From the evolution of the concept, LI Hui et al. [9] believe that technology opportunities refer to emerging technological forms or development points that may appear in a certain field, which can be divided into two forms: new technologies and improvements, innovations of existing technologies. ZHAI Dongsheng et al. [10] believe that technology opportunities exist in the improvement of existing technologies' features and performance, as well as in the fusion of specific technologies with other existing technologies. YOON et al. [11] and ZHOU et al. [12] respectively regard technologies that have not yet been developed or are in emerging stages as technology opportunities.

2 Connotation and Types of Technology Opportunities

Technology opportunity identification involves discovering technology opportunities through specific methods and techniques. Therefore, to correctly understand its connotation, it is necessary to clarify related concepts of technology opportunities. Technology opportunities reflect the potential or possibility of technological progress. Although scholars have different perspectives on technology opportunity types, they can be comprehensively categorized into three main types: blank technology, emerging technology, and fusion technology [18-20].

This study holds that technology opportunities reflect the possibility of achieving technological innovation, which can be either entirely new technologies or the development of existing technologies. From the perspective of theoretical origins, technology opportunity theory is widely believed to originate from Professor SCHWARTZ' s 1974 proposal of technological innovation opportunities

[8]. From the evolution of the concept, NOH et al. [13] proposed four types of technology opportunities: blank technology, emerging technology, fusion technology, and customer need-based technology. YI Huifang et al. [14] believe that technology opportunities can be divided into emerging technology, incremental technology, and disruptive technology. SONG Hongyan [15] categorized technology opportunities into blank technology, technology fusion, and emerging technology. Although different scholars have different classifications, the essence remains unchanged, representing the potential for technological progress.

The three main types of technology opportunities and their specific interpretations are shown in .

Table 1 Analysis of Technology Opportunity Types

Type	Definition	Characteristics
Blank Technology	Refers to technologies that have not yet emerged in a certain field but have significant development potential [13]. These technology gaps are likely key to future technological innovation and can be considered a type of technology opportunity.	Has domain characteristics and large future development potential; data sources are mainly papers and patents; involves a single research field.
Emerging Technology	Refers to fundamentally innovative technologies that are newly emerging or developing in a field, not yet widely applied, but may have a huge impact on industrial development [21,22]. These emerging technologies may contain technology opportunities that will potentially affect future economic structures or industry development.	Has fundamental innovativeness, impact, relative growth, and uncertainty [23,24]; very high future potential; data sources are mainly papers and patents; involves a single research field.

Type	Definition	Characteristics
Fusion Technology	Refers to new technologies that achieve performance improvement or functional enrichment through the organic combination of two or more technologies [10], representing the main approach and fundamental manifestation of technological evolution and innovation. Exploring future fusion technology opportunities from multiple domains has become a new research focus and challenge.	Has technological breakthrough and cross-domain characteristics; data sources are mainly patents; involves two or more technology fields.

3 Research Progress on Technology Opportunity Identification

This study primarily uses literature review to summarize relevant research status. Since technology opportunities are divided into three types—emerging technology, blank technology, and fusion technology—the search strategy balances recall and precision. Using Chinese and English terms including "technology opportunity," "emerging technology," "blank technology," "patent blank," "fusion technology," and "technology fusion" combined with "identification," "discovery," or "analysis" as titles, we searched in CNKI and Web of Science Core Collection with a time limit up to December 31, 2022. After summarization, manual noise reduction, and selection, we obtained 189 relevant Chinese documents and 428 English documents as samples for content analysis.

Technology opportunity identification research mainly includes four aspects: (1) basic theoretical research, including concept analysis and methodology system design; (2) methodological research, optimizing identification methods; (3) tool research, developing methods and tools for technology opportunity identification; and (4) empirical and applied research, conducting case studies in specific technology fields. Through systematic review, current technology opportunity identification methods can be broadly divided into qualitative and quantitative analysis.

Qualitative research methods are based on expert knowledge, including Delphi method [25], Analytic Hierarchy Process [26], and scenario analysis [27]. Quantitative research methods have made rapid progress with the development of data mining, text mining, natural language processing, and other technologies. Main quantitative methods include morphological analysis, patent mapping, semantic TRIZ, and SAO semantic analysis. Since different types of technology opportunities have specific meanings and corresponding research approaches, this paper reviews relevant domestic and international research progress based on technology opportunity types.

3.1 Blank Technology Opportunity Identification Research

The core idea of blank technology opportunity identification is to discover blank technologies in a certain field through specific methods and means, and identify technology opportunities by combining them with the future development potential of these blank technologies. Common research methods include patent mapping and morphological analysis.

Patent mapping builds IPC, keyword, or SAO semantic structure-based patent maps through dimensionality reduction techniques, then visualizes them and treats blank areas in the maps as technology opportunities [3]. Common dimensionality reduction methods include Self-Organizing Map (SOM) [28], Principle Component Analysis (PCA) [29,30], and Generative Topographic Mapping (GTM) [31,32]. The first two methods heavily rely on expert knowledge and experience, resulting in strong subjectivity in identification results, while GTM can automatically identify blanks but is sensitive to parameter settings. The technology-effect matrix [34] is also a type of patent map that can identify technology gaps. Patent maps can concisely and intuitively display complex relationships among numerous patents, but whether blank points can become future R&D hotspots or breakthrough points has high uncertainty and requires further evaluation.

Morphological analysis identifies undeveloped technology forms by decomposing a system into several functional parts based on parameter and problem decomposition, finding all technologies that can achieve each function, and then combining them to form candidate solutions [35]. YOON et al. [36,37] proposed a keyword-based morphological analysis method on the traditional foundation and applied it to dye-sensitized solar cells (DSSCs). Although this method reduces dependence on domain experts, it generates many technology combinations without screening and evaluation. YOON et al. [38] later improved it by introducing conjoint analysis to optimize technology form combinations and applied it to Thin Film Transistor-Liquid Crystal Display (TFT-LCD) fields. LENG Fuhai et al. [39] proposed a morphological analysis method based on text mining but did not conduct empirical research. WANG Jinfeng et al. [40] evaluated morphological combinations using indicators such as technical advancement, usage frequency, and technical benefits to identify optimal technology opportunities for 3D printers.

Subsequently, some scholars attempted to introduce quantitative methods such as SAO structure [41-43] into morphological structure construction. SAO semantic structure, typically using Subject-Action-Object groups as basic semantic units to represent specific technical information, clearly describes relationships between phrases containing different semantic information. The problem is usually represented in the Problem & Solution (P&S) model, where Subject and Action represent the problem and Object represents the solution [19,59]. This method can effectively reveal semantic relationships between technical elements but depends on natural language processing technology and has limitations in SAO effectiveness and scale.

3.2 Emerging Technology Opportunity Identification Research

The core idea of emerging technology opportunity identification is to discover newly emerging or developing technologies in a certain field that are not yet widely applied but will have a huge impact on industrial development, and treat them as technology opportunities. Combined with evaluation, further screening is conducted to identify technologies with development potential. Emerging technologies are mainly characterized by fundamental innovativeness, impact, relative growth, and uncertainty [23,24]. Specific characteristics and common discrimination indicators are summarized in .

Table 2 Main Characteristics and Common Discrimination Indicators of Emerging Technologies

Characteristic	Description	Common Indicators
Fundamental Innovativeness	The technology has recently emerged or is developing, forming creative destruction in the industry. Its fundamental innovativeness is specifically manifested in time and content [20].	Grant time, prior knowledge (backward citation count), etc.
Impact	Refers to potential impact on future economic structures or industry development.	Average patent family members, number of claims, forward citation count, number of patent categories, etc.

Characteristic	Description	Common Indicators
Relative Growth	Most studies believe that rapid growth is a necessary condition for emergence, with faster development speed.	Annual growth rate of document count, priority patent applications, technology life cycle, etc.
Uncertainty	The possible output and use of emerging technologies are uncertain [22], mainly manifested in whether R&D can succeed and whether it can successfully enter the market.	Uncertainty performance is complex, and measurement indicators have not been fully explored, lacking operable explanations and direct quantification methods [48,49].

Current emerging technology opportunity identification methods are mainly divided into three categories:

First, bibliometric methods identify emerging technology opportunities by statistically analyzing bibliometric indicators of literature. These indicators have evolved from early single-dimensional indicators (such as document appearance or citation counts) [45] to multi-dimensional complex indicators. Methods such as citation analysis form metrics for specific issues, enabling more accurate and comprehensive identification of technology opportunities [44]. SHANE [46] identified emerging technology opportunities through technical importance and content-level analysis. However, this approach is only simple statistics of external text attributes and has issues such as coarse indicator weight calculation processes.

Second, outlier detection methods identify emerging technology opportunities by detecting patents that have emerged but deviate from mainstream technologies, considering them as potential new technology opportunities [50]. The process typically includes two steps: first, detecting outlier patents using algorithms such as Local Outlier Factor (LOF), K-means, or DBSCAN [3,51]; second, judging and evaluating whether the detected outlier data represents technology opportunities. Domestic researchers like LI Dengjie [53] and ZHAI Dongsheng et al. [54], and foreign researchers like YOON et al. [51] and LEE et al. [52] have used various anomaly detection algorithms to detect outlier patents and applied qualitative TRIZ theory for evaluation. The advantage of this method is that the identified technology opportunities have relatively specific granularity, enriching the forms of technology opportunities. However, the

limitation is that it focuses on a single dimension and cannot well reveal the scope of technology; the identified opportunities require further evaluation.

Third, semantic TRIZ and SAO semantic analysis methods identify emerging technology opportunities. Since keywords cannot provide semantic association information, recent research has begun using SAO semantic structures for technology opportunity identification [56-58]. The research 思路 typically combines TRIZ theory with other methods to find technological innovation directions. For example, TANG Han et al. [62] identified international technology cooperation opportunities in different fields based on Class A patent citation analysis. GEUM et al. [63] used natural language processing and semantic relationship mining to discover fusion technologies between biotechnology and information technology.

3.3 Fusion Technology Opportunity Identification Research

The core idea of fusion technology opportunity identification is to mine promising technology fusion relationships from the technology fusion process and treat them as technology opportunities. Fusion technology opportunities have attracted widespread scholarly attention, as major technological developments and breakthroughs are often the result of cross-domain research. Cross-domain technologies are characterized by technological foundation diversity, functional novelty, structural complexity, and implementation efficiency [60,61].

The fusion technology opportunity identification process mainly includes two steps: technology fusion relationship construction and fusion degree measurement and important fusion relationship identification. Fusion relationship construction is fundamental and can be divided into three main methods: co-occurrence relationship-based, citation relationship-based [64], and semantic relationship-based [65]. Specific construction methods and their advantages and disadvantages are compared in .

Table 3 Comparison of Main Construction Methods for Fusion Relationships

Method	Advantages	Disadvantages
Co-occurrence Relationship (IPC co-occurrence)	Clear analysis objects, simple operation, high data quality	Limited by classification system, coarse technical granularity
Co-occurrence Relationship (keyword co-occurrence)	Objectively reveals associations between technical themes	Lacks semantic information mining of text content
Citation Relationship-based	Helps dynamically analyze technology fusion process	Affected by citation lag, difficult to represent semantic relationships

Method	Advantages	Disadvantages
Semantic Relationship-based	Improves semantic understanding of text content	Difficult to process, poor adaptability to different domains

Fusion technology opportunity identification methods mainly include two categories:

First, link prediction methods analyze known network structures and potential node information to predict the possibility of links between currently unlinked nodes in fusion networks, thereby revealing hidden relationships [66]. For example, PARK et al. [67] used patent data to construct patent citation networks and technology knowledge flow networks to identify potential technology fusion opportunities between biotechnology and information technology. LEE et al. [68] combined association rules and link prediction to forecast technology fusion patterns in triadic patents. The advantage of this method is using quantitative research to provide more possibilities for potential associations and reduce expert involvement. However, limitations include being mostly confined to single-layer network construction and depending on prediction algorithms. Link prediction indicators can be divided into neighbor-based, path-based, and random walk-based categories [71].

Second, indicator-based methods define a series of indicators to measure technology fusion degree and identify important fusion relationships as technology opportunities. For example, HAN Yan et al. [72] used network centrality indicators to identify fusion technology opportunities in medical service robots. SHEN Jinhua et al. [73] proposed a technology fusion identification and prediction model based on patent data mining. Indicator methods can identify relatively specific opportunities, but current measurement indicators mainly focus on technical external features, considering factors singly and lacking comprehensive evaluation of technical internal capabilities and economic/social value.

3.4 Review of Existing Research

Through the above review, we find that technology opportunity identification is forming a relatively standardized and systematic research paradigm. By analyzing each technology opportunity type, some common elements can be identified, including representative methods, method principles, data sources, knowledge representation units, technology opportunity definitions, evaluation methods, advantages and disadvantages, and other characteristics. The overall status of technology opportunity identification research is summarized in .

Table 4 Summary of Types and Representative Methods for Technology Opportunity Identification

Type	Representative Method	Method Principle	Data Source	Knowledge Unit	Technology Opportunity Definition	Evaluation Method	Advantages	Disadvantages
Blank Technology	Patent Mapping	Build patent maps through dimensionality reduction, treat blank areas as opportunities	Patent data	IPC, keywords, SAO semantic structure	Sparse blank areas, blank points in maps	Expert experience, TRIZ evolution laws, patent metrics	Concisely displays complex patent relationships	Relies on expert judgment; cannot reveal semantic relationships; dimensionality reduction may cause information loss

Type	Representative Method	Method Principle	Data Source	Knowledge Unit	Technology Opportunity Definition	Evaluation Method	Advantages	Disadvantages
Blank Technology	Morphological Analysis	Decompose system into functions, find all technologies for each function, combine them	Patent and paper data	Technology scheme combinations, SAO combinations, keyword morphologies	New technology morphologies in combinations	Expert experience, technical advancement, usage frequency, technical benefits	Can generate large numbers of candidate solutions	Strong dependence on domain experts; technology combination explosion

Type	Representative Method	Method Principle	Data Source	Knowledge Unit	Technology Opportunity Definition	Evaluation Method	Advantages	Disadvantages
Emerging Technology	Bibliometrics	Build indicator systems characterizing emerging technology features, identify opportunities through word frequency or citation analysis	Patent data	Patents, technical features	Technologies meeting emerging technology features	Expert experience, TRIZ evolution laws	Can effectively identify technologies with emerging features	Lacks in-depth text content analysis; coarse indicator weight calculation

Type	Representative Method	Method Principle	Data Source	Knowledge Unit	Technology Opportunity Definition	Evaluation Method	Advantages	Disadvantages
Emerging Technology	Outlier Detection	Identify outlier patents that may represent new technology opportunities	Patent data	IPC, keywords, SAO semantic structure	Outliers deviating from mainstream	Expert experience, TRIZ evolution laws, patent metrics	Specific granularity of identified opportunities	Focuses on single dimension; cannot reveal technology scope; requires further evaluation

Type	Representative Method	Method Principle	Data Source	Knowledge Unit	Technology Opportunity Definition	Evaluation Method	Advantages	Disadvantages
Emerging Technology	Semantic TRIZ (SAO)	Use TRIZ theory, NLP, and semantic mining to find innovation directions	Patent data	SAO semantic structure	Technical solutions, breakthrough barriers	Expert qualitative judgment	Effectively reveals semantic relationships between technical elements	SAO effectiveness and scale limitations; single dimension, coarse semantic granularity
Fusion Technology	Link Prediction	Predict possible links between unlinked nodes in fusion networks	Patent data	Keywords, SAO, or IPC	New citations, new keywords, or new SAO links; fusion potential	Expert experience, fusion potential	Reveals unappeared network relationships	Fusion networks are single, mostly limited to single-layer construction; depends on algorithms

Type	Representative Method	Method Principle	Data Source	Knowledge Unit	Technology Opportunity Definition	Evaluation Method	Advantages	Disadvantages
Fusion Technology	Indicator Method	Define indicators to measure fusion degree, identify important fusion relationships	Patent, keyword, IPC data	Patents, keywords, IPC	Technologies meeting fusion features	Multi-dimensional measurement	Identified opportunities are relatively specific	Indicator system reflects fusion features incompletely; mainly focuses on external features

The main limitations of existing research are:

1. **Research Perspective**: Most studies are conducted from a single perspective, and there is still a lack of empirical research on technology opportunity identification from a cross-domain perspective. A complete system for cross-domain technology identification and reference has not yet been formed.

2. **Data Sources and Methods**: The data sources for technology opportunity identification are mostly single papers or patent data, lacking multi-source data integration. Current research mainly relies on text keywords or patent classification numbers to represent technology, which is either too macro or too micro, and seldom considers semantic relationships between words. Although some studies have introduced SAO-based semantic TRIZ to overcome these limitations, most are based on single-dimensional SAO with coarse semantic representation.

3. **Post-Evaluation**: Current post-evaluation of identified technology opportunities is insufficient. Although some scholars have explored this area and applied some quantitative indicators, they mainly rely on qualitative evaluation methods such as expert experience. There is still a lack of a

comprehensive and systematic evaluation system that considers technical value, economic and social factors.

4 Future Research Prospects

Based on clarifying the connotation and classification of technology opportunities and reviewing current research status and limitations, this paper proposes that future technology opportunity identification research may focus on the following three aspects:

First, cross-domain and cross-topic technology opportunity identification will become a development trend, enabling cross-convergence among more technology elements. Major technological developments and breakthroughs are often the result of cross-domain research. Cross-domain technologies have characteristics such as technological foundation diversity, functional novelty, structural complexity, and implementation efficiency. Currently, research on technology opportunity discovery from a cross-domain technology fusion perspective is still limited. Future research should expand from focusing on specific domains and technology directions to analyzing related cross-technology fields and directions to discover technology opportunities with development prospects.

Second, data sources, research methods, and content for technology opportunity identification will become more diversified and targeted. With the emergence of massive online information, data sources should fully utilize multi-source data, such as combining basic research information (patents and papers) with product information for comprehensive analysis, thereby returning to the original intention of technology opportunity discovery and more accurately identifying technology opportunities from a market economy perspective. In terms of research methods, although current identification methods have produced a series of results, there are still few operational methods. Future improvements may include applying cloud computing and text mining to improve existing technology-effect matrices, identifying new ways to achieve technical functions, and developing combined research methods that complement the advantages and disadvantages of various analysis methods. For example, combining semantic TRIZ with technology-effect methods for patents, and integrating multi-granularity text representation and enhanced semantic representation for papers. In terms of dynamic aspects, time factors can be added.

Third, the analysis framework and process will become more standardized, and the post-evaluation system will be improved. The full chain of technology opportunity identification is a process combining formation, identification, and evaluation of technology opportunities. Post-evaluation of technology opportunities will be an important research topic. Building a multi-dimensional, multi-indicator evaluation system will be a development direction. How to comprehensively consider technical value, economic and social factors to make identified technology opportunities align with industrial technology development directions, enterprise development needs, and national S&T devel-

opment directions and policy guidance will be a noteworthy issue. The optimal technology opportunities can be discovered by combining optimization algorithms, and empirical analysis of various technology opportunity values should be strengthened to make technology opportunity identification and verification more practical.

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Note: Figure translations are in progress. See original paper for figures.