

Review of Disruptive Technology Identification Methods: Postprint

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Abstract

[Purpose/Significance] By conducting a literature review of disruptive technology concepts and disruptive technology identification methods both domestically and internationally, analyzing existing problems, and proposing possible research perspectives for future disruptive technology identification. [Method/Process] Using the literature survey method, six disruptive technology identification methods are summarized, and the current advantages and disadvantages of each identification method are analyzed. [Results/Conclusion] Disruptive technology identification methods still have some drawbacks, such as unclear classification of disruptive technologies, lack of quantitative research on characteristics, and lack of consideration for the correlation between technical knowledge in existing identification methods. Future research should further strengthen the study of disruptive technology characteristics, consider the correlation characteristics of knowledge, strengthen the identification of disruptive technologies from the perspectives of breakthroughs in functional characteristic values and technology fusion, and simultaneously delve deeper into more fine-grained technology topics.

Full Text

A Review of Disruptive Technology Identification Methods

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Abstract: [Purpose/Significance] Through a literature review of the concept of disruptive technology and identification methods both domestically and internationally, this paper analyzes existing problems and proposes potential research perspectives for future disruptive technology identification. [Method/Process]

Using literature research methods, this study summarizes six identification approaches for disruptive technology and analyzes their current advantages and disadvantages. [Result/Conclusion] Disruptive technology identification methods still suffer from several drawbacks, including unclear classification of disruptive technologies, lack of quantitative research on characteristics, and insufficient consideration of correlations between technical knowledge in existing methods. Future research should strengthen studies on disruptive technology characteristics, consider relational features between knowledge pieces, and enhance identification from perspectives of breakthroughs in efficacy feature values and technology convergence, while also mining more fine-grained technical topics.

Keywords: Disruptive Technology; Identification; Method

Disruptive technology was first proposed by Harvard Business School professor C.M. Christensen in *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* [1]. It refers to technologies that alter the original technology performance trajectory, characterized by simple operation, portability, and low cost, producing overall or fundamental substitution effects on existing traditional or mainstream technologies and resulting in market disruption. Such technologies may be entirely new or represent cross-disciplinary, cross-domain applications of existing technologies.

Since the emergence of disruptive technology, countries worldwide have introduced policies to promote its development [2]. For instance, the U.S. White House Office of Science and Technology Policy and the Defense Advanced Research Projects Agency have launched research programs in key technological fields. Japan has implemented the ImPACT program to promote innovations that bring transformative changes to society. The UK released *Technology and Innovation Futures: UK Growth Opportunities to 2030*, selecting key technologies expected to support UK development through 2030. For enterprises, disruptive technologies often invade mainstream markets from low-end or new markets, creating significant shocks to existing enterprises or markets and causing rapid changes in corporate economic benefits. Examples include the impact of digital technology on film companies represented by Kodak, Google's Android system on Nokia's mobile phone market, and wireless telephones' disruptive impact on wired telephones. Disruptive technologies feature uncertainty, difficulty in early prediction, and substantial impact, making their discovery and cultivation crucial for corporate strategic and tactical planning.

Consequently, the selection or identification of disruptive technologies has become a major concern for scholars. Researchers have conducted extensive studies on identification methods, with Su Peng, Shi Hui, Wang Chao, Ma Libin, Wang An, Zhang Jiawei, and others reviewing these methods according to different classification criteria. For example, Su Peng [3] classified identification methods by domain: library and information science, engineering management, economics research, and Christensen school perspectives. Shi Hui and Ma Libin [4-5] categorized methods based on subjective judgment, objective derivation,

and combinations thereof. Wang Chao [6] provided a more detailed classification: supply-and-demand-based identification and prediction, scoring model-based methods, future scenario hypothesis-based methods, quantitative model-based methods, and bibliometric-based methods. Zhang Jiawei [7] reviewed indicators at various levels. Scholars from different classification perspectives have identified common issues: weak theoretical framework research, unclear identification standards, and lack of systematic identification methods integrating technology, industry, economy, and society. After reviewing existing literature, this paper classifies identification methods by data type used, intuitively revealing information resources related to disruptive technology identification from a data perspective. In revealing method deficiencies, this paper not only points out common issues but also proposes classification problems and quantitative characteristic research at the technological level, focusing on different types of disruptive technologies at the technological level—such as radical breakthrough, efficacy breakthrough, and cross-boundary breakthrough technologies—and advocating differentiated identification approaches for these categories. Additionally, this paper proposes considering knowledge correlation and network structure and applying social network analysis methods for in-depth identification.

2. Concept of Disruptive Technology and Related Concepts

Since C.M. Christensen proposed the concept of disruptive technology, academia has yet to reach a unified definition. Scholars have primarily defined disruptive technology from three perspectives: technological change, market impact of technology or market demand for technology, and a comprehensive view of technological change and market impact. The technological change perspective includes both technological breakthroughs and new applications of old technologies. Specific research is shown in Table 1 .

In summary, scholars mainly define disruptive technology from “technology push” and “market pull” perspectives. From the technology push perspective, on one hand, it involves entirely new technological transformations—major breakthroughs that fundamentally disrupt existing technologies in significant functions. On the other hand, it involves applying original technologies to emerging fields, producing disruptive effects. Market pull is user demand-driven: first, when product performance excessively satisfies existing market user needs, creating redundancy and enabling low-end disruption; second, when user demand drives the development of new needs, creating new market disruption.

Related concepts include disruptive innovation (technology), breakthrough innovation (technology), destructive technology, emerging technology, and frontier technology. The concept of disruptive innovation appeared in Christensen’s *The Innovator’s Solution* [23]. Compared to disruptive technology, it includes not only technological innovation but also business model innovation. Existing research on destructive innovation [24-29] and breakthrough innovation [30] essentially represents disruptive innovation, all deriving from Christensen’s ideas but with different translations. However, Zhou Lei [31] views breakthrough in-

novation as emphasizing technological innovation intensity more than disruptive innovation, which focuses on the combined dimensions of technological innovation and market competition.

Emerging and frontier technologies differ from disruptive technology. Some scholars [32-34] have not distinguished between emerging and disruptive technologies in their research, but most have separated them. Regarding emerging technology, pioneering research includes the 2000 Wharton School “Emerging Technology Management Research Group” publication *Wharton on Managing Emerging Technologies*, which defined emerging technology as “science-based innovative technology with the ability to create or transform industries.” Subsequent scholars have explored emerging technologies further. Emerging and disruptive technologies share commonalities and differences, as shown in Table 2 .

Frontier technology also differs from disruptive technology. Li Xiaosong et al. [35] note that frontier technology represents the global high-tech development direction and guides the formation and development of emerging industries. Its core characteristic is “frontier-ness,” with prominent features of “forward-looking-ness” and “emerging-ness.” The 2019 Research Frontiers report by the Chinese Academy of Sciences’ Institutes of Science and Development defines research fronts as papers jointly highly cited by other scientists. Frontier technology includes hot fronts and emerging fronts. Thus, frontier technology, emerging technology, and disruptive technology overlap, with progressively narrowing scope: frontier technology > emerging technology > disruptive technology. Their relationship is illustrated in Figure 1 [Figure 1: see original paper].

3. Current Research Status of Disruptive Technology Identification Methods

Domestic and international scholars have conducted extensive research on disruptive technology identification. Through literature review, this paper classifies these methods by data source into objective data-based and subjective data-based identification, as shown in Figure 2 [Figure 2: see original paper].

3.1 Objective Data-Based Disruptive Technology Identification

Most objective data comes from patent literature, with additional sources including scientific papers, web news, and market data. Patent-based research includes TRIZ theory-based technology evolution prediction and patent metric-based identification. Paper and web news-based methods include identification through cited scientific knowledge. Market data-based methods include identification through market demand.

3.1.1 Patent Literature-Based Identification Most innovative technology identification research relies on patent data, with scholars combining TRIZ theory and patent metrics.

(1) TRIZ Theory-Based Technology Evolution Prediction. Guo Jing et al. [40] used TRIZ theory's technology maturity and system function analysis to judge the environment and possible innovation directions for disruptive technology emergence. Xu Zehao et al. [36-37] analyzed sustaining technology evolution using four indicators: patent level, patent quantity, technology performance, and profit. They decomposed technology systems to identify innovation subsystems on different trajectories from sustaining technology at the basic function level, assessing their conflict resolution capabilities to determine growth potential into disruptive technology. J. Sun et al. [38] decomposed technology components and used TRIZ principles to analyze subsystem evolution routes, identifying mainstream and lagging technology evolution. During innovation, they reduced mainstream technology evolution functions while improving lagging technology performance. Sun Jianguang et al. [39] noted that disruptive technology opportunities depend on user demand surplus or product technology evolution imbalance. When user demand evolution reaches over-satisfaction, low-end disruption opportunities emerge; imbalance between mainstream and non-mainstream technology evolution promotes new market disruption opportunities. By analyzing user demand and technology evolution, disruptive technology can be predicted. Guo Jing et al. [40] constructed a new market disruptive technology opportunity identification model by mining IPC classification codes to discover non-mainstream functions and identifying opportunities from non-mainstream functional modules. Using TRIZ for technology system decomposition combined with new and low-end market types enables disruptive innovation, though this approach better suits product innovation than identifying existing disruptive technologies in a field.

(2) Patent Metric-Based Identification. Some scholars use patent data and metrics from three main angles:

First, identifying through patent external features. Buchanan et al. [41] used patent application volume, grant rate, number of applicants, new applicants, patents per capita, application growth per capita, and technology citation trees to identify potentially disruptive innovations, though these indicators don't reflect technology impact or timeliness. Su Jingqin [42] considered timeliness, analyzing patent publication volume, citations, and citation rates over time to reveal evolution trajectories, proposing a "patent impact factor" for identification. Liu Qiuyan and Wu Xinnian [43] built an indicator system from development conditions, technological innovation capability, and technological benefits. Luan Chunjuan [44] measured technological disruption potential through patent applicant activity, citation counts, and innovation indices representing novelty, plus market penetration and implementation. Luo Suping [45] measured disruption potential through five aspects: science linkage (non-patent citation ratio), technology impact potential (forward citation ratio), technology breakthrough potential (backward citation ratio), market attraction potential (patent family ratio), and market competition potential (total claims ratio). While external features enable some identification, results remain broad without deep mining of technical texts [8] to identify sub-technologies causing disruption.

Second, mining technical texts for identification. Dotsika and Watkins [46] constructed keyword co-occurrence networks from academic publications, using social network analysis metrics like closeness and betweenness to identify potentially disruptive keywords—those with high closeness but low degree. Kim, Park & Lee [47] calculated keyword visualization and diffusion growth rates, finding low visualization but high diffusion rates indicate potential disruption. Huang Lucheng et al. [48] used set pair analysis to measure attribute set differences before and after new technology emergence. Later, Huang Lucheng et al. [49] analyzed IPC classification reorganization and citation structure differences to assess disruption potential from a functional perspective. These provide new insights but single-aspect approaches remain limited.

Third, using patent citation networks. Momeni et al. [50] constructed patent citation networks, extracted main paths, used k-core analysis to divide main path technologies into sub-technologies, applied topic modeling to identify latent topics, and validated disruption through scientific paper performance and functional analysis. This risks overlooking off-main-path technologies and missing emerging potential disruptions.

3.1.2 Paper and Web News-Based Identification This approach identifies disruptive technology from the perspective of scientific knowledge mutations causing technological changes. Zhang Jinzhu [51] measured mutations through keyword frequency changes of new and repeated keywords in continuous time windows. Bai Guangzu, Zheng Yurong et al. [52] calculated semantic relatedness of technology topics over time, including new topic emergence, original topic heating, and multi-topic fusion. Shi Hui et al. [53] similarly analyzed topic changes in paper data combined with patent manual code mutations. Zhang Jinzhu and Bai Guangzu both approach from knowledge mutation but differ in element selection and difference calculation—one uses keyword frequency, the other semantic relatedness. Zhao Ge [54] used patent, literature, and web news data, applying hierarchical and cross-layer analysis to identify key technology topics, then used three-year citation rates, average independent claims, and literature growth rates. However, all three studies share a common limitation: they only measure keyword/topic changes or semantic similarity over time, neglecting technology knowledge network structures.

3.1.3 User Demand-Based Identification This approach identifies disruptive technology from user demand. Katz et al. [16] focused prediction on user demand, combining incumbent technology maturity to seek technology substitution. Keller [55] constructed a disruptive potential trajectory map for software industry innovation satisfying two criteria: potential disruptive innovation performance trajectory intersecting with user minimum demand trajectory, and existing technology performance far exceeding minimum demand. Ganguly et al. [56] quantified market demand using four indicators: target market comparison, existing technology maturity, new technology adoption rate (using Bass innovation equation), and expected utility comparison. Diab et al. [57] built a

multiple linear regression model using technology competitive advantage, company business position, marketing, and customer feedback, combined with expert judgment. While comprehensive in covering technology, product, market, industry, and external environment, these methods lack unified standards and rely heavily on survey respondents' or experts' background knowledge, making assessments highly subjective and limited.

3.2 Subjective Data-Based Disruptive Technology Identification

Subjective data sources include industry surveys and expert opinions, covering evaluation criteria-based and technology roadmapping-based identification.

3.2.1 Evaluation Criteria-Based Identification This approach builds evaluation criteria or propositional frameworks from disruptive technology concepts and mechanisms, typically covering technology, product, market, and external environment, using surveys or expert interviews. Adams et al. [58] evaluated energy technology disruption potential from cost and quality dimensions. Sainio [59] defined disruptive innovation as business model change, measuring from new attributes, uncertainty, market impact, and corporate disruption capability. Hang, Chen & Yu [60] assessed disruption potential from market position, technology itself, and other factors through information sources, official documents, and industry reports. Collins et al. [61] used surveys to evaluate software function extraction technology from usefulness, output quality, utility, compatibility, and usage intention. Sun Yongfu, Wang Liheng et al. [21] built an evaluation system with four primary indicators—technology breakthrough, product substitution, market universality, and industry transformation—selecting 26 industry-transforming technologies through expert questionnaires. Guo et al. [62] constructed a comprehensive measurement framework with metrics including technical features (integration, leadership, maturity, diffusion, simplification), market dynamics (emerging markets, value networks, cost reduction), and external environment (policy and macroeconomics). While comprehensive, these methods lack objective standards and depend heavily on subjective expert knowledge.

3.2.2 Technology Roadmapping-Based Identification Domestic scholars Lu Guangsong and Lu Ping [63] described how technology roadmapping promotes disruptive and systematic thinking, technology integration, and path creation, though participant subjectivity and stakeholder interests may hinder prediction. They [64] also outlined enterprise disruptive technology roadmapping processes. Kostoff et al. [65] started from research problems, retrieved literature to find technology alternatives and experts, and conducted roadmapping. Vojak et al. [66] proposed considering five elements in roadmapping: industry standard changes, architecture changes, super-system element relationships, element integration/decomposition, and subsystem substitution. Uchihira [67] started from basic technology functions to find applicable markets, then predicted extended functional needs to identify R&D directions, addressing un-

clear target market issues for some potential disruptive technologies. While roadmapping facilitates information exchange and identification, it relies excessively on developers' subjective consciousness and social background, requiring substantial time, financial, and human resources, making it more suitable for national-level implementation.

4. Existing Problems and Future Research Perspectives

Through comprehensive review, this paper identifies several problems in current research:

First, quantitative research on disruptive technology identification remains insufficient. Most studies focus on qualitative evaluation using criteria, with limited systematic quantitative research. Much of the quantitative research applies emerging technology identification methods without fully considering disruptive characteristics.

Second, quantitative studies lack consideration of correlations between technical knowledge. Current research identifies disruptive technology from five aspects: technology, technology products, investor/attitude perspectives, market impact, and external environment. Technology-focused studies include IPC reorganization, attribute set differences, and scientific knowledge topic semantic similarity. These approach from knowledge innovation outcomes rather than mechanisms, neglecting knowledge correlations and failing to dynamically demonstrate knowledge recombination and evolution.

Third, disruptive technology types are diverse but current research lacks clear classification. Patent citation of scientific papers identifies from fundamental breakthroughs; TRIZ system decomposition and attribute set difference analysis indicate performance breakthrough directions; IPC reorganization and citation structure differences identify from technology convergence. Existing research doesn't clearly classify these types.

Fourth, identification granularity remains coarse. Most results stay at broad secondary technology topics without drilling down to tertiary or quaternary topics. The specific sub-technologies causing disruptive impact remain unknown, yet such fine-grained topics are the ultimate targets and basis for national technology follow-up and innovation.

Therefore, future research should strengthen:

First, disruptive technology innovation theory research, including sources and evaluation standards/characteristics, to conduct quantitative identification research based on these standards.

Second, identification from a knowledge network perspective. Disruptive technology represents knowledge innovation emerging from knowledge mutation and recombination during evolution. Knowledge network attributes and evolution

can explain domain knowledge development trends to some extent. Future research should consider network structural features—node positions, relationships, and attributes—to identify disruptive technology.

Third, focus on efficacy features, numerical breakthroughs, and technology convergence. Besides fundamental scientific breakthroughs, disruptive technology may emerge from new features attracting attention or from existing technologies applied to new fields. Future research should strengthen studies on functional breakthroughs and technology fusion identification.

Fourth, achieve finer-grained identification. Future research should delve into technology knowledge ontology rather than remaining at the knowledge carrier level, combining patent text mining with intelligence analysis methods for deeper mining at keyword and topic levels.

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