Situation Revelation and Risk Assessment of Patent Layout from a "Technology-Efficacy" Perspective: Postprint

Authors: Wang Xuezhao, Zhao Ping, Zhao Yajuan, Lyu Lucheng

Date: 2023-04-01T16:02:54+00:00

Abstract

[Purpose/Significance] Mastering the patent layout landscape and assessing current risks is of great significance for conducting strategic patent portfolio development, mitigating R&D risks, and securing competitive advantages in technological innovation and industrial upgrading. [Method/Process] Based on the "technology-effect" matrix, comprehensive indicator representations for identifying patent layout situations are established. Through comprehensive evaluation and case validation, universal risk indicator assessment rules and an analysis process for current patent layout risks are formulated. A composite display format that combines visualization of patent layout situation diagrams and risk levels based on the "technology-effect" matrix intuitively presents patent layout situations and risks. [Results/Conclusions] Focusing on the meso-level of technology, a risk assessment method for patent layout situations based on the "technology-effect" matrix is developed, which effectively reveals patent layout advantage zones, opportunity zones, barrier zones, and blank zones, and explores corresponding strategies. This method can be applied for analysis at multiple levels including national, regional, industry, institutional, project team, R&D team, and individual, supporting patent layout risk monitoring throughout the entire technology life cycle.

Full Text

Revealing Patent Layout Situation and Risk Determination from a "Technology-Effect" Perspective

Wang Xuezhao[1,2], Zhao Ping[1], Zhao Yajuan[1,2], Lü Lucheng[1,2]

[1] National Science Library, Chinese Academy of Sciences, Beijing 100190 [2] Department of Library, Information and Archives Management, School of Eco-

nomics and Management, University of Chinese Academy of Sciences, Beijing 100190

Abstract: [**Purpose/Significance**] Mastering the patent layout situation and assessing current risks is crucial for strategically conducting patent deployment, avoiding R&D risks, and seizing competitive advantages in technological innovation and industrial upgrading. [**Method/Process**] Based on the "technology-effect" matrix, this study establishes a comprehensive indicator system for identifying patent layout situations. Through comprehensive judgment and case verification, universal risk indicator rules and an analysis process for current patent layout risks are formulated. The composite visualization of patent layout situation icons and risk levels based on the "technology-effect" matrix intuitively reveals patent deployment patterns and associated risks. [**Result/Conclusion**] Focusing on the technological meso-level, this study develops a risk determination method for patent layout situations based on the "technology-effect" matrix, effectively identifying patent layout advantage zones, opportunity zones, barrier zones, and blank zones, with corresponding strategies discussed. This method can be applied across multiple levels including national, regional, industrial, institutional, project team, R&D team, and individual, supporting risk monitoring throughout the entire technology life cycle.

Keywords: Patent layout; Patent risk; Technology-effect; Patent analysis
Classification: G253.1 **DOI:** 10.13266/j.issn.0252-3116.2021.16.008

Intellectual property strategy is vital for building an innovative nation. Since the late 20th century, developed countries and newly industrialized nations have successively leveraged intellectual property strategies to secure international competitive advantages. Over the decade since China implemented the National Intellectual Property Strategy Outline, its comprehensive intellectual property strength has rapidly improved, consolidating its position as an intellectual property powerhouse and advancing toward becoming an intellectual property superpower.

Today, as the "Sino-US trade war" intensifies, what lies behind it is essentially a contest of technological strength centered on intellectual property. To seize the initiative in technological innovation and industrial upgrading, patents—as a crucial component of intellectual property—require strategic planning. Conducting patent layout strategically can effectively protect innovation achievements, secure patent competitive advantages, avoid R&D risks, and correctly guide R&D direction.

To achieve effective patent layout, it is essential to grasp the patent layout situation, identify current risks, and monitor them long-term. Patent layout risks exist throughout the entire technology life cycle, with risk subjects spanning multiple levels including national, regional, industrial, institutional, project team, R&D team, and individual. These risks can be identified from macro, meso, and micro technological perspectives [1-2]. Generally, macro-level patent layout risk identification reveals broad competitive patterns to support high-level decisionmaking but cannot truly guide R&D direction or avoid risks; meso-level identification can refine to specific technological sub-directions to plan R&D paths; micro-level identification requires professional technical scheme comparison to propose innovative solutions.

This study, based on the "technology-effect" matrix and focusing on the technological meso-level, establishes indicator expressions for patent layout situations, forms universal risk indicator judgment rules, and builds a model for patent layout situation and risk identification, along with analytical methods and processes. This effectively reveals patent layout advantage zones, opportunity zones, barrier zones, and blank zones. The method enables technology life cycle-wide patent layout risk monitoring, analyzing and revealing patent layout situations and risks for subjects at national, regional, industrial, institutional, project team, R&D team, and individual levels, thereby supporting effective patent strategic deployment for risk-bearing entities.

2 Literature Review

Current domestic and international scholars have conducted relevant research from risk identification, assessment, and prediction perspectives. R. Cerqueti et al. proposed a Bayesian probabilistic method based on similarity for evaluating R&D projects under patent protection, considering project completion time under different cost structures, exogenous shocks, input cost uncertainty, technical uncertainty, and asymmetric information [3]. However, this presents a theoretical method without empirical validation, leaving the risk assessment effect unclear. I. Bergmann et al., based on patent semantic analysis, proposed a patent infringement risk monitoring method using patent similarity assessment, visualizing text similarity on multidimensional scaling patent semantic maps and analyzing real infringement cases between two DNA chip manufacturers to provide strategies for companies facing infringement risks [4]. I. Park et al. proposed a patent risk identification method based on SAO semantic similarity that can automatically generate product patent infringement maps, conducting empirical risk identification research on LED-related patents [5]. C.S. Chang proposed a finite difference method to improve Backer's model regarding patent risk impacts on corporate market value and research incentives [6]. These studies primarily analyze the technical dimension of patents, focusing on infringement risk identification.

Domestic scholar Wang Rong used the analytic hierarchy process and fuzzy comprehensive evaluation to construct an indicator system from four stages—patent creation risk, application risk, utilization risk, and protection risk—achieving quantitative risk analysis and conducting early warning system testing using Chery New Energy Vehicles as a case study [7]. Wang Hongqi et al. [8], Guo Yu [9], and Xie Kai [10] similarly combined analytic hierarchy process and fuzzy comprehensive evaluation for patent risk assessment of strategic emerging enterprises. Dong Li, focusing on pharmaceutical enterprise characteristics, designed an indicator evaluation system from three aspects—patent risks related to enterprises, risks related to patent rights' own characteristics, and risks related to the external patent environment—using qualitative and quantitative methods to construct a pharmaceutical enterprise patent risk assessment system [11]. Information acquisition in these studies presents certain difficulties, and the comprehensive indicators used may have applicability issues due to domain differences.

The "technology-effect" matrix is an effective method for deep-level analysis of patent technical content, with successful applications in multiple domains. For example, in agricultural radiation well horizontal drilling [12], IPC clustering built a "technology-effect" matrix to identify technology-intensive and sparse areas based on patent quantity differences. In banking business methods [13], manual interpretation built a "technology-effect" matrix to distinguish mature and developing technologies based on differences in patent applications and grants. In distance measurement technology [14], IPC group-level "technology-effect" matrices identified patent-intensive and blank areas based on patent quantity differences. Additionally, the "technology-effect" method has been applied in heated non-combustible cigarettes [15], extruder die structure [16], animation industry [17], LED tubes [18], and other domains, helping enterprises and researchers identify technology-intensive, sparse, and blank areas for better patent industrial layout.

Current "patent layout" research mostly focuses on specific domains. For instance, Gao Nan et al. [19] studied the global patent layout and competition situation of artificial intelligence technology, Xiong Xiaoqin et al. [20] conducted composite value-oriented automotive patent layout optimization research, He Yujie [21] compared patent layouts between ZTE and Huawei, and Xue Yaping et al. [22] studied overseas patent layout strategies in the pharmaceutical field. However, these lack universal patent layout guidance for different subjects. Moreover, current "technology-effect" patent analysis mostly uses single-dimensional patent quantity statistics, rarely expanding to other patent information dimensions. Judging technology-intensive and sparse areas solely by patent quantity is one-sided. Considering competitors, R&D personnel numbers, and other factors would provide more reasonable comprehensive revelation of technology zones.

This study proposes a patent layout situation revelation and risk determination method from the "technology-effect" perspective, comprehensively considering multi-dimensional patent information, focusing on key indicator characteristics, adopting multi-dimensional comprehensive expression, forming universal situation and risk indicator judgment rules through correlation judgment and case verification, and using key indicator combinations as visual representations of patent layout risk situations. This effectively reveals patent layout advantage zones, opportunity zones, barrier zones, and blank zones, intuitively presenting patent layout situations and risks. This study applies to multiple subject levels including national, institutional, project team, R&D team, and individual levels, with domain applicability, representing a transferable methodology and process. The method can reveal "technology-effect" patent layout situations, determine current patent layout risks based on the layout situation, and formulate scientific patent layout strategies according to risk warnings.

3 Patent Layout Situation Revelation and Risk Determination Method from a "Technology-Effect" Perspective

3.1 Analysis Process

This study's analysis process can be implemented in seven steps (see Figure 1 [Figure 1: see original paper]): preparation of patent data for specific technical fields, "technology-effect" decomposition, patent data interpretation, indicator calculation and judgment, patent layout risk discrimination, visualization, and result verification.

3.2 "Technology-Effect" Decomposition and Data Interpretation

The "technology-effect" matrix decomposes patent technical means and achieved effects into a matrix-type statistical table or diagram, with effects as the horizontal (or vertical) axis and technical means as the vertical (or horizontal) axis. Based on literature research and expert knowledge, technology is further divided into multiple sub-technologies at multiple levels, and its impacts (i.e., effects) are categorized into multiple or multi-level effects, ultimately determining the "technology-effect" two-dimensional matrix framework for the technology. On this basis, the obtained patent data for the technology is interpreted along both technical and effect dimensions and assigned to the "technology-effect" matrix framework. The interpretation results serve as the foundation for patent data interpretation.

3.3 Indicator Construction and Expression

Numerous indicators exist for patent evaluation and analysis, each with different analytical focuses. Patent layout risk typically considers global patent layout status, technological competition degree, technology monopoly situation, and the subject's own patent layout status. This study presents indicator expressions affecting patent layout risk from these four dimensions: patent layout indicators to grasp global patent application and grant status; technological competition degree indicators to grasp institutional and talent aggregation and technology monopoly; relative important patent indicators to grasp the layout status of relatively important patents; and subject's own patent layout indicators to grasp the subject's patent application and grant status (the subject can be national, regional, industrial, institutional, project, R&D team/individual, etc.). Based on these four dimensions, 13 secondary indicators are designed, primarily representing relative judgments of global patent layout situations. Secondary indicators are expressed through characteristic icons—i.e., icons are assigned when indicators meet 判别 criteria—establishing the indicator expression for patent layout risk analysis, as shown in Table 1 .

In the above indicator system, some secondary indicators in patent layout and technological competition degree require threshold selection for judgment. Based on experience from numerous case analyses, upper limit thresholds are typically defined as 30%-50% above the indicator's average or median value, while lower limit thresholds are defined as 30%-50% below the average or median. Whether to use average or median depends on data dispersion. Typically, X_1, X_2, X_3, X_4, and X_5 can be determined using this universal method combined with actual case situations. For technologies with special backgrounds or data specificity, thresholds can also be determined based on actual conditions.

Talent aggregation degree T is a relative metric. High patent application volume or large numbers of co-inventors can both lead to relatively high inventor counts. Therefore, considering both factors, T is defined as:

T = (A_1's patent applications / A's patent applications) × 0.5 + (A_1's inventor count / A's inventor count) × 0.5 (Formula 1)

Where A_1 is any technology point (any cell in the matrix), and A is the subtechnology to which A_1 belongs (the row where A_1 is located in the matrix).

Technology monopoly degree based on patent quantity is typically represented by the proportion of patents applied by the top 3 patent holders among all patent applications. High technology monopoly degree indicates strong current technology monopoly at that technology point. Using the top 3 threshold is one option provided by this study; in practice, thresholds can also be selected using statistical methods based on data distribution characteristics.

3.4 Risk Determination Rules

Based on calculations and judgments of the 13 indicators across four dimensions, the patent layout risk situation for each technology point is formed. To avoid scientific and rationality issues from indicator weighting, this study uses a combination of indicator parsing and case practice analysis to interpret patent layout risk, summarizing universal risk judgment rules. Table 2 shows some typical rules. Considering multiple indicators including patent quantity, R&D institution density, subject layout situation, and relative important patent aggregation, patent layout risk situations are categorized into four risk levels: patent layout barrier zone, opportunity zone, advantage zone, and blank zone. The judgment rules are independent without hierarchical relationships—i.e., after calculating and representing all indicators for each technology point, the technology point's patent layout risk situation can be determined. It should be noted that this study provides risk discrimination at the time node when patent data was obtained; in practice, technology life cycle-wide patent layout risk monitoring can be conducted.

Patent Layout Barrier Zone: Typically, technology points have numerous domestic and international patents with intense R&D institution competition. These technology points have Chinese patent layout, but relatively important patents are aggregated and not owned by the subject. When patenting in barrier zones, focus on peripheral patents—R&D should primarily layout peripheral improvement patents around core patents to prevent forming tighter patent portfolio barriers; or conduct follow-up research to find technical defects or innovate, raising the R&D starting point based on existing patented technology to seek secondary innovation; or comprehensively combine advantages in other technology directions to seek breakthroughs in technology intersection areas.

Patent Layout Opportunity Zone: Typically, technology points have international patent layout but not large quantities, with fewer patent holders and generally no or few relatively important patents, and the subject already has patent layout. From the layout perspective, these technology points have international patent layout but not large quantities, or have Chinese patent layout; from the competition perspective, there are fewer patent holders; from the relative core patent layout perspective, there are no core patents or triadic patents. **Layout suggestion**: Focus on core patents, strengthen patent layout on the existing basis to form portfolio protection, build a "patent Great Wall," and prevent being surpassed by competitors, while considering patent layout in peripheral industrial chains or other indispensable technical branches.

Patent Layout Advantage Zone: Typically, technology points are key layout areas for the subject, with no relatively important patents or relatively important patents owned by the subject. From the layout perspective, these are subject patent aggregation areas with high Chinese patent quantity and many patent holders, and no core patent layout. **Layout suggestion**: Closely align with the subject's own technical advantages, excavate technology solutions with differentiated competitive advantages, consolidate and strengthen control at these advantage points, strive to occupy industry-leading positions at advantage points, and make the subject's patents more defensive and offensive.

Patent Layout Blank Zone: Currently no patent layout exists. **Layout suggestion**: Patent layout in blank zones requires cautious treatment—first determine whether technical bottlenecks exist. If none exist or bottlenecks can be broken, immediately adopt a first-to-file strategy to form patent barriers against others; also consider cooperating with partners on patent methods to jointly stabilize and expand the patent scope.

3.5 Visualization

The "technology-effect" diagram uses a two-dimensional matrix for visualization. Using indicator-represented icon combinations as composite displays of patent layout risk situations, secondary indicators are displayed in different colors by dimension. Four color blocks indicate different risk warnings. This study ultimately forms a composite visualization of "technology-effect" perspective patent layout situation icons and risk levels, which is highly informative and clear.

4 Case Study: Organic Polymer Materials for 3D Printing

4.1 Data Preparation

This study selected patents related to organic polymer materials for 3D printing as the research object. Printing materials are crucial material foundations for 3D printing technology development, and to some extent, material development determines whether 3D printing can have broader applications [23]. Currently, 3D printing materials mainly include engineering plastics, photosensitive resins, rubber materials, metal materials, and ceramic materials; additionally, colored gypsum materials, artificial bone powder, cell biological materials, and food materials like sugar have also been applied in 3D printing [24]. Among these, organic polymer materials have become the primary choice for 3D printing due to their excellent properties such as strong plasticity, high hardness, heat resistance, wear resistance, and corrosion resistance [25].

Based on the Derwent Innovation Index (DII) and Derwent World Patents Index (DWPI), a search strategy combining broad and branch technologies with keywords and IPC classification numbers was constructed for global patent retrieval, with a search date of July 2017. The retrieved dataset was interpreted by technical domain experts. Experts determined whether patents were related to organic polymer materials for 3D printing by reviewing titles, abstracts, and first claims. For relevant patents, experts identified which technologies were used and which beneficial effects were achieved through full-text review, marking patent numbers in the "technology-effect" framework table. If a patent improved multiple technology points or had multiple beneficial effects, it was marked in multiple cells; if irrelevant, it was excluded from the final analysis dataset. After interpreting all retrieved patents, a "technology-effect" interpretation table for organic polymer materials for 3D printing was formed. Expert interpretation yielded 651 patent families (953 members) closely related to organic polymer materials for 3D printing. Data from the most recent three years is less than actual due to publication lag and is for reference only. To avoid ambiguity, "patent items" refers to patent family counts, while "patent members" refers to family member counts. The same patent may belong to different technology points.

4.2 "Technology-Effect" Decomposition and Data Interpretation

Based on investigation and expert consultation, organic polymer materials for 3D printing were technically subdivided into sub-technologies: heat/photosensitive resins, thermoplastic materials, thermosetting materials, rubber, biological materials, fibers/cellulose and starch. Effect dimensions were subdivided into: cost reduction, curing time reduction, precision improvement, molding efficiency improvement, molding speed improvement, stability improvement, strength improvement, plasticity improvement, insulation and corrosion resistance, environmental protection, particle size control, color addition, and operation temperature reduction, as shown in Figure 2 [Figure 2: see original paper].

Based on the decomposition framework and 13 important effect indicators, a "technology-effect" matrix for organic polymer materials for 3D printing was constructed. Experts interpreted patents within this matrix. The interpreted data is shown in Table 3 , where thermoplastic materials are a relatively concerned material.

4.3 Indicator Calculation and Expression

Considering domain characteristics and actual data features, upper and lower limit thresholds in this case were determined by floating 50% above and below median values. Therefore: $X_1 = 18$; $X_2 = 6$; $X_3 = 30\%$; $X_4 = 17$; $X_5 = 50\%$. This study used the Innography database to select patents with value $ $8 as core patents, totaling 27 items. Innography patent value considers patent litigation, patent and application family status, application duration, patent age, citation counts, family size, claim counts, originality, and generality, establishing a mathematical model to represent patent strength, enabling rapid core patent identification from massive data. Related indicator calculations and expressions are shown in Table 4 .

4.4 China's Patent Strategic Layout Situation and Risk Analysis

Based on comprehensive "technology-effect" multi-angle analysis, this section discusses the international patent protection status and recommendations for organic polymer materials for 3D printing R&D in China (see Table 5):

4.4.1 Patent Barrier Zone for 3D Printing Organic Polymer Materials (blue cells in Table 5) - Situation: Heat/photosensitive resins, thermoplastic materials, thermosetting materials, biological materials, and fibers/cellulose and starch all have technology points in the patent barrier zone. Specifically, using heat/photosensitive resins for cost reduction, curing time reduction, molding efficiency improvement, stability and plasticity improvement, strength improvement, and color addition; using thermoplastic materials for precision, molding efficiency, molding speed, plasticity improvement and insulation/corrosion resistance, environmental protection, particle size control, and color addition; using thermosetting materials for cost reduction, stability and strength improvement, and color addition; using biological materials for environmental protection; and using fibers/cellulose and starch for molding efficiency, strength, plasticity improvement and environmental protection are China's patent barrier zones. These technology points have numerous domestic and international patents, intense R&D competition, and Chinese patent layout, but with many core and triadic patents. - **Recommendation**: Focus on peripheral patents—R&D should primarily layout peripheral improvement patents around core patents to prevent tighter patent portfolio barriers. Alternatively, conduct follow-up research to find technical defects or innovate, raising the R&D starting point based on existing patents to seek secondary innovation.

4.4.2 Patent Opportunity Zone for 3D Printing Organic Polymer Materials (yellow cells in Table 5) - Situation: All material types have technology points in the patent opportunity zone. Specifically, using heat/photosensitive resins for precision, molding speed improvement and insulation/corrosion resistance and environmental protection; using thermoplastic materials for cost reduction, curing time reduction, stability and strength improvement, and operation temperature reduction; using thermosetting materials for curing time reduction, stability and strength improvement, plasticity improvement, particle size control, and operation temperature reduction; using rubber materials for cost reduction, precision, molding efficiency, stability, strength, plasticity improvement and insulation/corrosion resistance, environmental protection, particle size control, and color addition; using biological materials for cost reduction, curing time reduction, precision, molding efficiency, molding speed, stability, plasticity improvement and particle size control, color addition, and operation temperature reduction; and using fibers/cellulose and starch for cost reduction, molding speed improvement, stability improvement, and insulation/corrosion resistance are China's patent opportunity zones. These technology points have international patent layout but not large quantities, fewer patent holders, and no core or triadic patents. - **Recommendation**: Focus on core patents, strengthen layout on the existing basis to form portfolio protection, build a "patent Great Wall," and prevent being surpassed by latecomers, while considering patent layout in peripheral industrial chains or other indispensable technical branches.

4.4.3 Patent Advantage Zone for 3D Printing Organic Polymer Materials (pink cells in Table 5) - Situation: Using biological materials for strength improvement is China's patent advantage zone. This technology point is a key Chinese patent layout area with high Chinese patent quantity, many patent holders, and no core patent layout. - **Recommendation**: Closely align with China's own technical characteristics, excavate technology solutions with differentiated competitive advantages, consolidate and strengthen control at this advantage point, strive to occupy an industry-leading position, and make Chinese patents more threatening and offensive.

4.4.4 Patent Blank Zone for 3D Printing Organic Polymer Materials (white cells in Table 5) - Situation: All material types have patent blank points. Using heat/photosensitive resins for particle size control and operation temperature reduction; using rubber materials for curing time reduction, molding speed improvement, and operation temperature reduction; using biological materials for insulation/corrosion resistance; and using fibers/cellulose and starch for curing time reduction, precision improvement, particle size control, color addition, and operation temperature reduction are China's patent blank zones. - **Recommendation**: Patent layout in blank zones requires cautious treatment—first determine whether technical bottlenecks exist. If none exist or bottlenecks can be broken, immediately adopt a first-to-file strategy to form patent barriers. Also consider cooperating with partners on patent methods to jointly stabilize and expand the patent scope.

This case study also applies to other countries/regions, industries, institutions, project teams, R&D teams, and individuals. Replacing China's patent data in Table 5 with other subjects' patent data yields their patent strategic layout situations and current layout risks.

5 Conclusion and Outlook

Based on "technology-effect" decomposition and focusing on the technological meso-level, this study develops a risk determination method for patent layout situations based on the "technology-effect" matrix, comprehensively considering multi-dimensional patent information, focusing on key indicator characteristics, adopting comprehensive expression, forming universal risk indicator judgment rules through comprehensive judgment and case verification, and using key indicator combinations as visual representations to intuitively reveal patent layout situations and risks. Using organic polymer materials for 3D printing as a case study, this research analyzes China's patent layout situation and determines current patent layout risks in this field, discussing coping strategies. The "technology-effect" perspective-based patent layout situation revelation and risk determination method can be applied at multiple levels including national, regional, industrial, institutional, project team, R&D team, and individual, helping risk subjects conduct technology life cycle-wide patent layout risk monitoring, strategically implement patent layout, and seize technological innovation and industrial upgrading opportunities.

This study forms a complete analysis process and universal risk determination rules, though a few rules may have discriminative differences in different domain applications, requiring refinement through more practical cases. Future research can expand in multiple directions: refining and improving risk determination rules according to industry/domain characteristics; combining deep learning and related technologies for automatic identification and judgment of patent "technology-effect" to enhance automated patent layout risk monitoring; combining micro-level technical scheme comparisons to conduct practical innovative scheme design research; extending the research method and process to other intellectual property forms; and optimizing multi-layer correlation relationships in visualization icon expression.

Acknowledgments: During this research, experts from multiple institutes of the Chinese Academy of Sciences provided suggestions and guidance on technical issues in different domains. In-depth understanding and discussion of domain technical issues enhanced the effectiveness of this study in solving practical patent layout problems.

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Author Contributions: Zhao Yajuan: Research guidance Wang Xuezhao: Research design, methodology, and paper writing/revision Zhao Ping: Research investigation, data analysis, and paper writing Lü Lucheng: Research investigation and data analysis

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