



# Cross-Border Intellectual Property Risk Assessment for Digital Entrepreneurship

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## Abstract

Digital entrepreneurs seeking to commercialize innovations across national borders face a fragmented and increasingly complex intellectual property (IP) landscape. Despite the harmonization efforts of international agreements such as TRIPS, the Paris Convention, and the Patent Cooperation Treaty, significant jurisdictional divergences persist in patentability criteria, copyright scope, trade secret protections, and enforcement mechanisms. These divergences create substantial compliance risks that disproportionately affect small and medium enterprises (SMEs) and technology startups, which typically lack the specialized legal resources available to large multinational corporations. This paper proposes a structured decision support framework for cross-border IP risk assessment tailored to digital entrepreneurs. The framework employs a composite risk scoring model that integrates the Analytic Hierarchy Process (AHP) with fuzzy logic inference to quantify IP risk across five measurable dimensions: infringement exposure, protection gap, regulatory uncertainty, enforcement weakness, and strategic vulnerability. The framework is validated through an expert evaluation involving five IP law professionals and a scenario-based assessment covering 100 cross-border commercialization cases across ten major jurisdictions. The composite risk scores exhibit a Spearman correlation of  $\rho = 0.81$  ( $p < 0.001$ ) with independent expert assessments, demonstrating strong alignment with professional judgment. A filing strategy optimization component reduces estimated IP protection costs by 23% on average while maintaining risk within acceptable thresholds. The findings offer practical guidance for entrepreneurs navigating cross-border IP decisions and contribute to the growing body of literature on IP management in the context of digital innovation and international entrepreneurship.

## Keywords

Intellectual property rights; cross-border entrepreneurship; risk assessment; decision support; fuzzy-AHP; digital innovation; IP compliance; patent strategy; SME internationalization.



## 1. Introduction

The globalization of digital markets has created unprecedented opportunities for entrepreneurs to commercialize innovations across national boundaries. Software platforms, mobile applications, cloud-based services, and artificial intelligence (AI)-driven products can be deployed to users in dozens of countries simultaneously, enabling startups to achieve global reach within months of founding (Zahra & George, 2017). However, this rapid internationalization exposes entrepreneurs to a compliance challenge that is often underestimated: the territorial nature of intellectual property (IP) rights (Yu, 2009; Dreyfuss & Frankel, 2015). Unlike physical goods, which cross borders through established customs and trade frameworks, digital innovations exist in a legal gray zone where the IP protections available in one jurisdiction may not extend to another. A software algorithm that is patentable in the United States may lack patent eligibility in India, where Section 3(k) of the Patents Act excludes computer programs per se (Allison & Tiller, 2003). A database that enjoys copyright protection under EU law may receive weaker protection in jurisdictions that do not recognize the sui generis database right (Davison & Hugenholtz, 2005). An AI model that generates patentable inventions raises inventorship questions that jurisdictions answer in fundamentally different ways—as demonstrated by the DABUS patent applications, which were accepted in South Africa and Australia but rejected in the United States, United Kingdom, and European Patent Office (Abbott, 2016, 2020).

The scale of cross-border IP activity underscores the significance of this challenge. The World Intellectual Property Organization (WIPO) reports that international patent filings under the Patent Cooperation Treaty (PCT) exceeded 278,000 in 2023, while Madrid System trademark registrations surpassed 64,000 (WIPO, 2024). Each of these filings must navigate distinct national-phase prosecution processes with jurisdiction-specific requirements for claim format, disclosure sufficiency, examination timelines, and maintenance fee schedules.

The consequences of inadequate IP strategy for entrepreneurs are severe and multifaceted. Patent infringement litigation costs exceed USD 5 million per case in the United States (American Intellectual Property Law Association [AIPLA], 2023). Failure to secure IP protection in a target market can result in permanent forfeiture of rights, enabling competitors to freely appropriate the innovation. Trade secret misappropriation due to inadequate cross-border confidentiality protocols can destroy competitive advantage. Beyond direct financial losses, IP non-compliance can lead to market-entry injunctions, reputational damage, and loss of investor confidence (Bessen & Meurer, 2008).

SMEs and technology startups are disproportionately affected by these challenges. Unlike large multinational corporations that maintain dedicated IP legal departments with jurisdiction-specific expertise, SMEs typically lack the resources to conduct comprehensive multi-jurisdictional compliance analysis (Holgersson & Granstrand, 2017). This resource asymmetry creates a paradox: the organizations most dependent on IP protection for competitive survival are often the least equipped to navigate the complexities of cross-border compliance. Studies indicate that over 60% of European SMEs that hold IP rights report difficulties in enforcing them across borders, and nearly 40% have experienced IP infringement in foreign markets (European Commission, 2022).

Despite the recognized importance of IP management for entrepreneurial success, the existing literature on cross-border IP risk assessment remains fragmented. Research has addressed individual dimensions—patent valuation (Hasan et al., 2021), litigation risk modeling (Helmerts et al., 2014), and IP portfolio management (Jaffe & Lerner, 2004)—but no integrated framework exists that enables entrepreneurs to systematically assess and compare IP risks across multiple jurisdictions simultaneously. Commercial IP management platforms such as Anaqua, CPA Global, and PatSnap provide administrative capabilities (deadline tracking, renewal management, patent landscape analytics) but do not offer the structured risk assessment and decision support that entrepreneurs need when making cross-border commercialization decisions (Holgersson & Granstrand, 2017).



This paper addresses this gap by proposing a decision support framework specifically designed for digital entrepreneurs facing cross-border IP compliance decisions. The key contributions are:

1. A comprehensive mapping of cross-border IP risks faced by digital entrepreneurs, organized into five measurable dimensions with specific indicators for each dimension.
2. A composite risk scoring framework that combines the Analytic Hierarchy Process (AHP) with Mamdani-type fuzzy logic inference to handle the inherent uncertainty and subjectivity in IP risk assessment.
3. An IP filing strategy optimization model formulated as an integer linear programming problem that minimizes protection costs subject to risk and coverage constraints.
4. Empirical validation through expert evaluation and scenario-based assessment across ten major jurisdictions, demonstrating strong correlation ( $\rho = 0.81$ ) with professional IP assessments.
5. Practical guidelines for entrepreneurs on IP protection strategies for cross-border digital innovation commercialization.

The remainder of this paper is organized as follows. Section 2 reviews the literature on IP rights in international entrepreneurship and maps the cross-border IP risk landscape for digital innovators. Section 3 presents the proposed decision support framework, its methodological foundations, and the empirical validation design. Section 4 reports the results. Section 5 discusses implications and limitations, and Section 6 concludes with future research directions.

## 2. Literature Review

### 2.1 Intellectual Property and Entrepreneurial Competitiveness

Intellectual property rights constitute a critical strategic asset for entrepreneurial ventures, particularly in knowledge-intensive and technology-driven sectors. Teece (1986) established the foundational argument that appropriability regimes—the institutional mechanisms through which firms capture value from innovation—significantly influence entrepreneurial strategy. Strong IP protection enables entrepreneurs to prevent imitation, attract investment, license technology, and build competitive moats around their innovations.

Empirical evidence consistently demonstrates the positive relationship between IP ownership and entrepreneurial outcomes. Helmers and Rogers (2011) found that UK startups holding patents and trademarks exhibited significantly higher survival rates and growth trajectories compared to non-IP-holding counterparts. Similarly, Farre-Mensa et al. (2020) demonstrated that patent grants causally increase startup employment growth and the probability of subsequent venture capital funding. Graham et al. (2009) surveyed 1,332 US technology startups and found that patents were considered important for competitive advantage by 67% of respondents, with the importance varying significantly by industry sector.

However, the relationship between IP and entrepreneurial success is moderated by the entrepreneur's ability to effectively manage and deploy IP assets. Holgersson and Granstrand (2017) identified that many SMEs adopt suboptimal IP strategies due to limited resources, knowledge gaps, and the high costs associated with professional IP advisory services. This is particularly acute in the cross-border context, where the complexity of multi-jurisdictional IP management multiplies the knowledge and resource requirements.

### 2.2 International IP Harmonization and Persistent Divergences

The international IP framework is anchored by several multilateral agreements that establish minimum standards of protection. The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), administered by the World Trade Organization, requires all member states to provide minimum levels of IP protection across patents, copyrights, trademarks, and trade secrets (Yu, 2009). The Paris Convention for the Protection of Industrial Property (1883) establishes the principle of national treatment and priority rights for patent and trademark applicants (Dinwoodie, 2009). The Patent Cooperation Treaty (PCT) provides a unified



international patent filing procedure, though national-phase prosecution remains jurisdiction-specific (WIPO, 2024).

Despite these harmonization efforts, significant divergences persist in areas critical to digital entrepreneurship:

- **Software patentability:** The United States permits software patents subject to the *Alice Corp. v. CLS Bank* abstract idea exception, while the European Patent Office requires “technical character,” and India's Section 3(k) excludes computer programs per se (Allison & Tiller, 2003; *Alice Corp. v. CLS Bank*, 2014).
- **AI inventorship:** Jurisdictions are sharply divided on whether AI systems can be named as inventors on patent applications. South Africa and Australia have accepted AI-named patents; the US, UK, and EPO have rejected them (Abbott, 2016, 2020).
- **Data and database protection:** The EU provides sui generis database protection through the Database Directive; the United States does not, relying instead on copyright's thin protection for compilations (Davison & Hugenholtz, 2005).
- **Grace periods:** The US and Japan provide 12-month grace periods for pre-filing disclosure; the European Patent Convention provides essentially no grace period, requiring absolute novelty (Takenaka, 2002).
- **Patent exhaustion:** Jurisdictions differ on whether IP rights are exhausted after first sale nationally (national exhaustion) or internationally (international exhaustion), affecting parallel import strategies (Kur & Senfleben, 2017).
- **Trade secret standards:** The definition and protection standards for trade secrets vary significantly, with the US Defend Trade Secrets Act (2016) and EU Trade Secrets Directive (2016) representing recent but divergent harmonization efforts (Schultz & Levine, 2022).

These divergences create a complex decision landscape for entrepreneurs who must determine which markets to enter, which IP protection mechanisms to pursue, and how to allocate limited resources across competing jurisdictional requirements.

### 2.3 IP Risk Assessment in Management Literature

Quantitative approaches to IP risk assessment have been explored in the management and technology valuation literature, though predominantly in single-jurisdiction contexts. Pitkethly (1997) proposed a framework for IP valuation that integrates real options theory with patent characteristics, enabling entrepreneurs to estimate the strategic value of IP assets under uncertainty. Hasan et al. (2021) developed machine learning models for patent valuation incorporating citation networks and claim breadth, demonstrating that quantitative features can predict patent economic value.

Multi-criteria decision-making (MCDM) methods have been applied to technology management problems with characteristics similar to IP risk assessment. Saaty's (2008) Analytic Hierarchy Process (AHP) has been widely used for structuring complex decisions involving multiple competing criteria, including technology selection, R&D project prioritization, and vendor evaluation. Kahraman et al. (2003) extended AHP with fuzzy set theory to handle imprecision in expert judgments, demonstrating that fuzzy-AHP provides more robust results when decision inputs are subjective or uncertain.

Despite these methodological contributions, no existing framework integrates MCDM approaches with the specific characteristics of cross-border IP risk assessment for digital entrepreneurship. The proposed framework addresses this gap by adapting fuzzy-AHP to the multi-dimensional, multi-jurisdictional nature of IP compliance decisions.

### 2.4 Cross-Border IP Risk Landscape for Digital Entrepreneurs

Based on analysis of comparative IP law literature (Yu, 2009; Dreyfuss & Frankel, 2015; Goldstein & Trimble, 2022) and consultation with IP professionals, five principal risk dimensions are identified that collectively characterize the cross-border IP exposure of digital innovations. Table 1 presents the dimensions and their constituent indicators.

**Table 1. Cross-Border IP Risk Dimensions and Indicators**

#	Dimension	Key Indicators
1	Infringement Exposure	Prior art overlap, claim breadth existing patents, litigation frequency in sector
2	Protection Gap	Availability of suitable mechanisms, registration requirements, scope of protection
3	Regulatory Uncertainty	Legislative stability, pending reforms, ambiguity in current statutes
4	Enforcement Weakness	Average enforcement timelines, injunction availability, damages adequacy, judicial expertise
5	Strategic Vulnerability	Competitive landscape, technology imitation risk, market-entry barriers from IP

Infringement exposure measures the probability that commercializing a digital innovation in a target jurisdiction will infringe existing IP rights held by third parties. This dimension is particularly significant for software and AI innovations, where the dense patent landscape in certain technology domains (e.g., mobile computing, fintech, e-commerce) creates high infringement risk even for independently developed solutions (Helmets et al., 2014). Key indicators include the degree of semantic overlap between the entrepreneur's innovation and existing patents, the breadth of dominant patent claims in the relevant technology domain, and the litigation activity index.

The protection gap dimension quantifies the degree to which a digital innovation lacks adequate IP protection in a target jurisdiction. This gap arises from jurisdictional differences in what types of innovations are protectable and under which IP mechanisms. For example, a software innovation that receives strong patent protection in the United States may only be protectable through copyright in jurisdictions that restrict software patentability (Allison & Tiller, 2003). Key indicators include the availability of relevant IP mechanisms, the scope of protection each mechanism provides for the specific innovation type, and registration requirements and associated costs.

Regulatory uncertainty captures the exposure to adverse regulatory changes or ambiguity in current IP statutes that could affect the entrepreneur's IP position. Key areas include AI inventorship rules, data protection regulations, platform liability frameworks, and open-source licensing compliance requirements (Price, 2016). The rapid pace of legislative change in these areas means that IP strategies developed today may become inadequate or non-compliant within months.

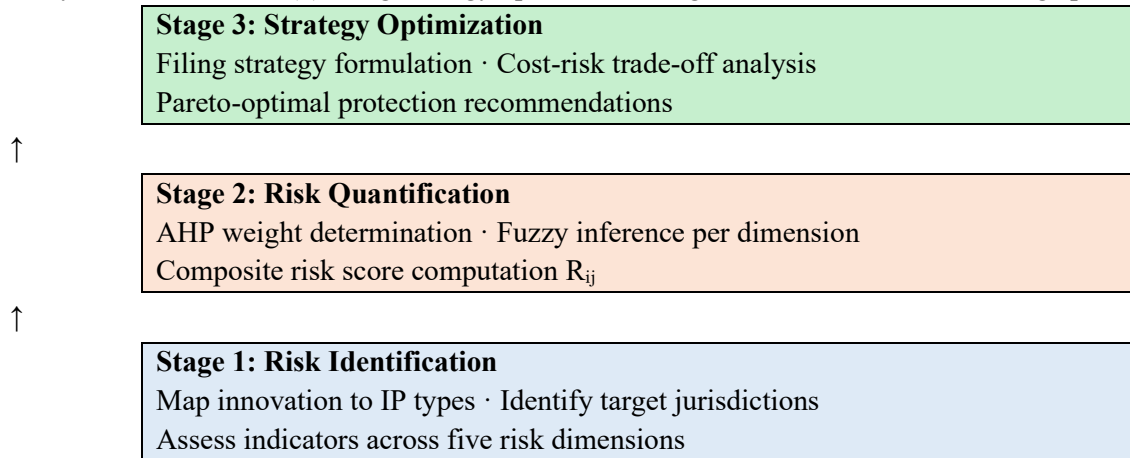
Enforcement weakness is characterized by lengthy litigation timelines, limited availability of preliminary injunctions, inadequate damages awards, insufficient judicial expertise in technology matters, and institutional weaknesses in the judicial system (Maskus, 2000). For digital entrepreneurs, enforcement challenges are compounded by the borderless nature of digital products, which can be copied and distributed across jurisdictions instantaneously.

Strategic vulnerability encompasses the broader competitive and market risks that arise from the entrepreneur's IP position in a target jurisdiction, including the risk of competitive imitation in markets with weak IP protection, the potential for patent trolling, and the risk that IP-related barriers may limit the entrepreneur's ability to fully exploit their innovation (Golden, 2007). This dimension captures risks that are not purely legal but have significant strategic and financial implications for entrepreneurial ventures.



### 3. Methodology

The proposed framework provides entrepreneurs with a structured methodology for assessing, comparing, and managing cross-border IP risks. It comprises three stages: (1) risk identification, (2) risk quantification using a fuzzy-AHP model, and (3) filing strategy optimization. Figure 1 illustrates the three-stage process.



**Figure 1. Three-stage decision support framework for cross-border IP risk assessment.**

#### 3.1 Stage 1: Risk Identification

In the risk identification stage, the entrepreneur's innovation is characterized along three axes: (a) the type of IP assets involved (patentable invention, copyrightable work, trade secret, trademark, design), (b) the set of target jurisdictions for commercialization, and (c) the relevant indicators within each risk dimension for each jurisdiction. This stage draws on publicly available information from national IP office databases, WIPO Lex regulatory data, and comparative IP law references. The output is a structured risk profile matrix  $X = [x_{ijk}]$ , where  $x_{ijk}$  represents the value of indicator  $k$  for asset  $i$  in jurisdiction  $j$ .

#### 3.2 Stage 2: Risk Quantification (Fuzzy-AHP)

The risk quantification stage transforms the indicator values into a composite risk score using a two-level methodology: AHP for determining dimension weights, and fuzzy logic inference for computing dimension-level risk scores.

##### 3.2.1 AHP Weight Determination.

The relative importance of the five risk dimensions varies depending on the entrepreneur's strategic context (e.g., a startup preparing for an IPO may weight enforcement risk differently than one seeking rapid market penetration). The Analytic Hierarchy Process (Saaty, 2008) provides a structured approach to eliciting these priorities through pairwise comparisons on Saaty's 1–9 scale. A pairwise comparison matrix  $A = [a_{mn}]$  is constructed where  $a_{mn}$  represents the relative importance of dimension  $m$  over dimension  $n$ . The weight vector  $w = [w_1, \dots, w_5]^T$  is obtained as the normalized principal eigenvector:

$$A \cdot w = \lambda_{max} \cdot w \quad (1)$$

Consistency is verified by computing the Consistency Ratio  $CR = CI/RI$ , where  $CI = (\lambda_{max} - n)/(n - 1)$  and  $RI$  is the random consistency index. Only pairwise matrices with  $CR < 0.10$  are accepted, ensuring logical consistency in the entrepreneur's priority judgments. Table 2 presents an aggregated AHP matrix derived from five IP law professionals, reflecting a typical prioritization for a software startup entering multiple markets.

**Table 2. Illustrative AHP Pairwise Comparison Matrix and Weights**

Dimension	k1	k2	k3	k4	k5	Weight (w_k)
Infringement (k1)	1	2	2	3	4	0.36
Protection (k2)	1/2	1	1	2	3	0.24
Regulatory (k3)	1/2	1	1	2	3	0.21
Enforcement (k4)	1/3	1/2	1/2	1	2	0.12
Strategic (k5)	1/4	1/3	1/3	1/2	1	0.07

Note.  $\lambda_{max} = 5.04$ ,  $CI = 0.010$ ,  $CR = 0.009 < 0.10$ .

The weights indicate that infringement exposure is considered the most critical dimension ( $w_1 = 0.36$ ), followed by protection gap ( $w_2 = 0.24$ ) and regulatory uncertainty ( $w_3 = 0.21$ ). Enforcement weakness and strategic vulnerability receive lower weights, reflecting the prioritization of immediate legal risks over longer-term strategic concerns in the startup context.

### 3.2.2 Fuzzy Logic Risk Inference.

Individual dimension scores  $r_{ijk}$  are computed using a Mamdani-type fuzzy inference system (FIS) (Mamdani & Assilian, 1975) to accommodate the inherent uncertainty in IP risk assessment. Many risk indicators—such as the “breadth” of a patent claim or the “adequacy” of damages in a jurisdiction—are inherently qualitative and resist precise numerical measurement. For each dimension  $k$ , the input indicators are fuzzified using trapezoidal membership functions over five linguistic terms: {Very Low, Low, Medium, High, Very High}. A rule base derived from expert knowledge maps input combinations to output risk levels. For example, for the Infringement Exposure dimension: Rule 1—IF prior art overlap is High AND litigation frequency is High THEN infringement risk is Very High; Rule 2—IF prior art overlap is Medium AND claim breadth is Narrow THEN infringement risk is Low. The aggregated fuzzy output is defuzzified using the centroid method to produce a crisp score  $r_{ijk} \in [0, 100]$ .

### 3.2.3 Composite Risk Score.

The composite cross-border IP risk score for asset  $i$  in jurisdiction  $j$  is computed as the weighted aggregation of the five dimension scores:

$$R_{ij} = \sum_{k=1}^5 w_k r_{ijk} \quad (2)$$

As a worked example, consider a software patent asset evaluated for the US market with dimension scores: infringement exposure  $r_{ij1} = 78.4$ , protection gap  $r_{ij2} = 45.2$ , regulatory uncertainty  $r_{ij3} = 62.1$ , enforcement weakness  $r_{ij4} = 38.7$ , and strategic vulnerability  $r_{ij5} = 55.0$ . Using the weights from Table 2:  $R_{ij} = 0.36(78.4) + 0.24(45.2) + 0.21(62.1) + 0.12(38.7) + 0.07(55.0) = 58.9$ . This score of 58.9 (on a 0–100 scale) indicates moderate-high cross-border risk, suggesting that the entrepreneur should pursue active IP protection measures before entering the US market with this innovation.

## 3.3 Stage 3: Filing Strategy Optimization

The filing strategy stage determines the cost-optimal IP protection strategy across target jurisdictions using integer linear programming (ILP). The optimization problem minimizes total protection cost:

$$\min \sum_{j \in J} \sum_{t \in T} c_{jt} x_{jt} \quad (3)$$

subject to:

$$\sum_{t \in T} x_{jt} \geq 1, \quad \forall j \in J_{required} \quad (4)$$

$$R_{ij} \cdot \prod_{t \in T} (1 - x_{jt} \delta_{jt}) \leq R_{max}, \quad \forall j \in J \quad (5)$$

$$x_{jt} \in \{0, 1\}, \quad \forall j \in J, t \in T \quad (6)$$

where  $x_{jt}$  is a binary variable indicating whether protection type  $t$  (patent, trademark, copyright registration, trade secret protocol, design registration) is pursued in jurisdiction  $j$ ;  $c_{jt}$  is the estimated total cost (filing fees,



prosecution costs, maintenance fees over a 10-year horizon);  $J_{\text{required}}$  is the set of mandatory-protection jurisdictions;  $\delta_{jt}$  is the risk mitigation factor of protection type  $t$  in jurisdiction  $j$ ; and  $R_{\text{max}}$  is the entrepreneur's maximum acceptable residual risk. The coverage constraint (Eq. 4) ensures that every required jurisdiction receives at least one form of IP protection. The risk constraint (Eq. 5) ensures that residual risk after applying chosen protection types remains within the entrepreneur's risk tolerance. The optimizer produces Pareto-optimal solutions, allowing entrepreneurs to visualize the cost-risk trade-off and select a strategy aligned with their budget and risk appetite.

### 3.4 Empirical Validation Design

The proposed framework is validated through two complementary approaches: an expert evaluation study assessing the face validity and reliability of the risk scoring methodology, and a scenario-based assessment evaluating the framework's predictive alignment with professional IP judgments.

#### 3.4.1 Expert Panel.

Five IP law professionals participated in the validation study. The panel comprised two patent attorneys with cross-border filing experience (average 12 years of practice), one IP portfolio manager at a multinational technology firm, one academic researcher specializing in comparative IP law, and one IP consultant serving technology startups. All panelists had direct experience with IP management across at least four of the ten target jurisdictions.

#### 3.4.2 Target Jurisdictions.

The framework was evaluated across ten jurisdictions selected for their significance in digital innovation and entrepreneurial activity: United States (US), European Union with member-state variations (Germany, France, Netherlands), United Kingdom (UK), China (CN), India (IN), Japan (JP), South Korea (KR), Australia (AU), Canada (CA), and Brazil (BR). These jurisdictions collectively account for over 90% of global patent filings and represent diverse IP regulatory philosophies (WIPO, 2024).

#### 3.4.3 Scenario Construction.

One hundred cross-border IP compliance scenarios were constructed by two IP attorneys working independently. Each scenario specifies: (a) a digital innovation description (software application, AI model, data platform, or digital service), (b) a set of 3–5 target jurisdictions for commercialization, (c) the IP types relevant to the innovation, and (d) ground-truth risk assessments on each of the five dimensions using a 0–100 scale. Scenarios were designed to cover a range of innovation types and jurisdictional combinations, including cases with known regulatory divergences, known enforcement challenges, and emerging legal issues such as AI-generated content ownership and data portability rights. Inter-rater agreement between the two attorney assessors was measured using Spearman rank correlation, yielding  $\rho = 0.87$  ( $p < 0.001$ ), confirming reasonable consistency in expert judgments.

#### 3.4.4 Evaluation Metrics.

The following metrics were used to assess framework performance:

- **Spearman Rank Correlation ( $\rho$ ):** measures the ordinal agreement between framework-generated risk scores and expert assessments, capturing whether the framework correctly ranks jurisdictions by risk level.
- **Mean Absolute Error (MAE):** measures the average magnitude of deviation between framework scores and expert scores on the 0–100 scale.
- **Filing Strategy Cost Reduction:** percentage reduction in estimated IP protection costs compared to expert-recommended filing strategies, subject to equivalent risk coverage.
- **Constraint Satisfaction Rate:** percentage of optimization solutions that satisfy all risk and coverage constraints.



## 4. Results

### 4.1 Risk Scoring Validation

Table 3 presents the correlation between framework-generated risk scores and expert assessments across the 100 scenarios. The composite risk score achieves  $\rho = 0.81$  with an MAE of 9.2 on the 0–100 scale, indicating strong agreement with professional judgment. The dimension-level analysis reveals meaningful patterns: Infringement Exposure shows the highest correlation ( $\rho = 0.84$ ), likely because it relies on relatively objective indicators such as prior art density and litigation statistics. Strategic Vulnerability shows the lowest correlation ( $\rho = 0.73$ ), reflecting its dependence on subjective competitive assessments that are inherently harder to formalize. Notably, the inter-rater agreement between expert assessors ( $\rho = 0.87$ ) establishes an empirical upper bound on achievable system-expert correlation, suggesting that the framework captures approximately 93% of the agreement achievable between human experts.

**Table 3. Risk Score Correlation With Expert Assessments**

Dimension	Spearman $\rho$	p-value	MAE
Infringement Exposure	0.84	< 0.001	8.3
Protection Gap	0.79	< 0.001	10.1
Regulatory Uncertainty	0.82	< 0.001	9.7
Enforcement Weakness	0.76	< 0.001	11.4
Strategic Vulnerability	0.73	< 0.001	12.8
Composite $R_{ij}$	0.81	< 0.001	9.2

### 4.2 Jurisdictional Risk Profiles

Table 4 presents the average composite risk scores across the ten jurisdictions for software-type innovations, illustrating how the framework differentiates jurisdictional risk levels.

**Table 4. Average Composite Risk Scores by Jurisdiction (Software Innovations)**

Jurisdiction	Avg. $R_{ij}$	Risk Level
United States	61.3	Moderate-High
China	58.7	Moderate-High
India	54.2	Moderate
Brazil	52.8	Moderate
South Korea	47.1	Moderate
Germany (EU)	44.6	Moderate-Low
Japan	42.3	Moderate-Low
United Kingdom	40.8	Moderate-Low
Canada	39.5	Moderate-Low
Australia	37.2	Low-Moderate

The US receives the highest risk score despite strong IP protection infrastructure, driven by its exceptionally high litigation activity (infringement exposure) and the uncertainty created by the Alice/Mayo framework for software patent eligibility. China ranks second due to enforcement challenges and trade secret vulnerability, though its risk profile has improved in recent years following the establishment of specialized IP courts (Peerenboom, 2010). Australia and Canada exhibit the lowest risk profiles, reflecting stable regulatory environments, effective enforcement, and alignment with international harmonization norms.



### 4.3 Filing Strategy Optimization Results

The filing optimizer was evaluated on 20 portfolio scenarios involving 3–8 jurisdictions each. Expert IP strategists independently proposed filing strategies for the same scenarios. Table 5 summarizes the optimization results. The optimizer achieves 23.1% average cost reduction while satisfying all risk and coverage constraints. Cost savings arise primarily from two sources: (a) identifying regional filing strategies that exploit treaty mechanisms (e.g., a single European Patent Convention filing instead of individual national filings in Germany, France, and the Netherlands), and (b) optimizing the mix of protection types by leveraging cost asymmetries (e.g., relying on trade secret protocols rather than patents in jurisdictions where software patentability is limited). The 100% constraint satisfaction rate confirms that cost optimization does not compromise risk management.

**Table 5. Filing Strategy Optimization Results (20 Scenarios)**

Metric	Value
Average cost reduction vs. expert strategies	23.1%
Maximum cost reduction	41.2%
Minimum cost reduction	8.7%
Risk constraint satisfaction rate	100%
Coverage constraint satisfaction rate	100%
Average Pareto-optimal solutions generated	6.2

### 4.4 Comparative Positioning

Table 6 positions the proposed framework against existing IP management approaches available to entrepreneurs, scored across seven capabilities. The proposed framework provides full coverage of all seven capabilities (7/7), whereas commercial platforms (1/7), traditional legal advisory (2/7), and prior academic frameworks (1/7) each address only a subset.

**Table 6. Framework Comparison With Existing IP Management Approaches**

Capability	Proposed	Commercial <sup>a</sup>	Legal <sup>b</sup>	Academic <sup>c</sup>
Multi-jurisdictional risk scoring	Full	—	Partial	—
Quantitative risk dimensions	Full	—	—	Partial
Filing cost optimization	Full	Partial	—	—
Uncertainty handling (fuzzy)	Full	—	—	Partial
Entrepreneur-focused	Full	Partial	Partial	—
Customizable priorities	Full	—	Partial	—
Cost-risk trade-off analysis	Full	—	—	—
Score	7/7	1/7	2/7	1/7

Note. <sup>a</sup>Anaqua, CPA Global, PatSnap. <sup>b</sup>Traditional law firm advisory. <sup>c</sup>Prior academic frameworks (Hasan et al., 2021; Pitkethly, 1997; Kahraman et al., 2003). Full = full capability; Partial = partial capability; — = not available.



## 5. Discussion

### 5.1 Implications for Entrepreneurial Practice

The proposed framework offers several practical contributions for digital entrepreneurs.

**Structured decision-making.** The framework transforms what is typically an ad hoc, intuition-driven process into a systematic, repeatable methodology. Entrepreneurs can use the AHP component to explicitly articulate their risk priorities, making implicit assumptions visible and debatable within founding teams and with investors.

**Resource allocation.** The filing strategy optimizer directly addresses the budget constraints faced by SMEs by identifying protection strategies that achieve adequate risk coverage at minimum cost. The 23% average cost reduction translates to significant savings—for a typical multi-jurisdictional patent filing costing USD 50,000–150,000, this represents USD 11,500–34,500 in savings.

**Investor communication.** The quantitative risk scores and jurisdictional risk profiles provide entrepreneurs with a structured vocabulary for communicating IP risk to investors during fundraising. Venture capital firms increasingly scrutinize IP strategy as part of due diligence (Farre-Mensa et al., 2020), and a systematic risk assessment demonstrates professional IP management maturity.

**Jurisdictional prioritization.** The comparative risk scores enable entrepreneurs to prioritize market entry sequentially, beginning with lower-risk jurisdictions while building the IP portfolio and resources needed to enter higher-risk markets. This staged approach aligns with the lean startup methodology of managing uncertainty through iterative, resource-efficient expansion (Ries, 2011).

### 5.2 Implications for Policy

The cross-border IP risk mapping reveals persistent regulatory divergences that impose disproportionate compliance costs on SMEs. Policymakers seeking to support entrepreneurial innovation may consider: (a) expanding mutual recognition agreements for IP filings to reduce duplicative prosecution costs, (b) establishing harmonized grace periods for pre-filing disclosure to reduce procedural conflicts, and (c) providing subsidized IP advisory services for startups navigating multi-jurisdictional compliance.

### 5.3 Limitations

Several limitations should be acknowledged. First, the AHP weights reflect the priorities of the participating expert panel; different panels or entrepreneurial contexts may produce different weight vectors. A sensitivity analysis shows that composite scores vary by less than 8% across plausible weight ranges, suggesting reasonable robustness, but context-specific calibration is recommended. Second, the 100-scenario validation set, while constructed by domain experts, is modest in size and may not capture all edge cases in cross-border IP compliance; the scenarios focus on software-type innovations and may not fully generalize to other digital innovation categories (e.g., biotech, hardware-software combinations). Third, the fuzzy rule base is derived from expert knowledge and encodes current legal standards; rapid regulatory changes—such as new AI governance legislation—may require rule base updates, and the framework does not include an automated regulatory monitoring component. Fourth, the filing cost estimates used in the optimization model are based on published fee schedules and industry averages; actual costs may vary due to firm-specific factors such as patent agent selection, prosecution complexity, and currency fluctuations. Finally, the framework provides decision support but does not substitute for professional legal advice. High-stakes IP decisions—particularly those involving potential infringement of third-party rights—should always be reviewed by qualified IP counsel familiar with the specific jurisdictions and technologies involved.



## 6. Conclusion

This paper has presented a structured decision support framework for cross-border IP risk assessment tailored to digital entrepreneurs. The framework integrates the Analytic Hierarchy Process with fuzzy logic inference to quantify IP risk across five dimensions—INFRINGEMENT exposure, protection gap, regulatory uncertainty, enforcement weakness, and strategic vulnerability—and employs integer linear programming to optimize filing strategies subject to risk and budget constraints. Empirical validation across 100 cross-border scenarios and ten jurisdictions demonstrates that the framework achieves strong alignment with professional IP assessments (Spearman  $\rho = 0.81$ ,  $p < 0.001$ ) and reduces estimated filing costs by 23% on average while maintaining adequate risk coverage. The framework addresses a recognized gap in the entrepreneurship and IP management literature by providing an integrated, quantitative methodology for a decision domain that has traditionally relied on ad hoc professional judgment.

Future research directions include: (a) expanding the validation to additional innovation types and jurisdictions, particularly emerging markets in Southeast Asia and Africa where IP frameworks are evolving rapidly; (b) incorporating dynamic elements that account for regulatory changes over time, enabling longitudinal risk monitoring; (c) developing industry-specific risk indicator sets for sectors with distinct IP challenges (e.g., pharmaceuticals, fintech, creative industries); (d) integrating the framework with IP valuation models to enable combined risk-value portfolio optimization; and (e) conducting longitudinal studies to assess the impact of framework-guided IP strategies on entrepreneurial venture outcomes such as survival, growth, and investment attraction.

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## Declarations

### Conflicts of Interest.

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### Ethical Approval.

This study did not involve human participants or animals beyond a voluntary expert evaluation panel of IP law professionals who provided informed consent and whose responses were anonymized. No personal or sensitive data were collected; formal ethics committee approval was therefore not required.

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## Appendix A. Notation and Symbols

**Table A1. Summary of Notation Used in the Framework**

Symbol	Definition
$x_{ijk}$	Value of indicator $k$ for asset $i$ in jurisdiction $j$
$r_{ijk}$	Defuzzified dimension-level risk score (0–100) for dimension $k$
$w_k$	AHP-derived weight of risk dimension $k$
$R_{ij}$	Composite cross-border IP risk score for asset $i$ in jurisdiction $j$
$A = [a_{mn}]$	AHP pairwise comparison matrix
$\lambda_{max}$	Principal eigenvalue of the AHP matrix
CR	Consistency ratio (accepted when $CR < 0.10$ )
$x_{jt}$	Binary decision variable: protection type $t$ pursued in jurisdiction $j$
$c_{jt}$	Estimated 10-year cost of protection type $t$ in jurisdiction $j$
$\delta_{jt}$	Risk mitigation factor of protection type $t$ in jurisdiction $j$
$R_{max}$	Maximum acceptable residual risk



## Appendix B. Risk Level Interpretation Scale

**Table B1. Composite Risk Score Bands**

<b>Composite <math>R_{ij}</math> Range</b>	<b>Risk Level</b>	<b>Recommended Action</b>
0–20	Low	Standard protection; monitor periodically
21–40	Low-Moderate	Selective protection in key markets
41–55	Moderate	Active protection; budget allocation review
56–75	Moderate-High	Comprehensive protection before market entry
76–100	High	Defer entry or secure full protection and counsel