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Stage-Oriented Risk Classification in New Product Development: A Systematic Literature Review

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Abstract

Each of the stages of the New Product Development (NPD) process is vulnerable to different forms of risk. The existing categorizations of these risks are partial, ill-defined, or lack depth. Deploying a systematic literature review methodology, we identify 65 empirical studies that identify sources of risk in NPD. Synthesizing this information, we develop a broad, meaningful, and recognizable taxonomy with five main categories of risk, each with a number of sub-categories. It also takes into consideration the increasingly significant role of sustainability-oriented innovation, including how environmental, technological, and operational risks interact in influencing sustainable performance and resilience in NPD systems. This taxonomy is then used to identify the existing risks inherent in each stage of the NPD process, revealing areas for future research and the applicability of the taxonomy for resolving current issues in NPD risk management theory and practice. Linking the issues of NPD risks with sustainability challenges, this study contributes to innovation management theory and the sustainable development of new products.

Keywords: risk; new product development; taxonomy; systematic literature review; sustainability; sustainable innovation; resilience

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1. Introduction

An inherent characteristic of each of the six distinct stages of the New Product Development (NPD) process [1] is uncertainty, and therefore risk. Each of these stages is vulnerable to different forms of risk [2], but currently in unspecified ways. Currently, the risks of NPD are also increasingly linked to sustainability performance: firms must manage not only technological and market risks but also environmental, social, and governance uncertainties that shape long-term innovation outcomes [3].

Despite regular calls for its development [3–6], no classification of NPD risks exists that would permit the comparison of risks between NPD stages or across industries and sectors. This paper develops a more comprehensive taxonomy of NPD risks than is currently available and uses it to investigate the differential occurrence of risk types across NPD stages in existing empirical studies.

In Ref. [7], the authors noted a lack of theorizing on the management of risk in technological innovation, and by extension NPD. This may be attributable both to the absence of a consistent definition of risk and more significantly to the inadequacy of existing classifications of NPD risk, for, without an adequate system of classification, theory development is hampered [8]. Risk is consistently defined nowhere [9–11].

In Ref. [12], the authors defined it as the "likelihood of an uncertain event that would have an adverse effect on project's success" (p. 18). More succinctly, the authors in Ref. [13] define it as the "potential for negative outcomes" (p. 149), and in Ref. [14], the authors note that it is the "subjectively determined expectation of loss" (p. 168). Beyond academia, the US Department of Defense [15] defines risk as "a measure of future uncertainties in achieving program performance goals and objectives with defined cost, schedule and performance constraints" (p. 1), and the authors in Ref. [16] reported it as "an uncertain event or condition that if it occurs has an effect on at least one project objective" (p. 127). Meanwhile, the ISO31000 definition of risk is "the effect of uncertainty on objectives" ([10], p. 1). These definitions indicate that uncertainty may arise both from different sources of risk and from the subsequent impact of these risks on NPD objectives. Here, we focus only on identifying different sources of risk rather than on the nature of their impact, and so we adopt Meyer et al.'s definition of NPD risk: an uncertain factor that can significantly affect achievable [NPD] performance; p. 61 [17].

The existing classifications are inadequate for a detailed empirical analysis and theory development or hypothesis testing for a variety of reasons. Some are sector-specific (e.g., FMCG by [18]), while others are restricted deliberately to specific categories of risk, like technology, market, and operations [19] or supply chains [20], and so lack completeness. Moreover, by not identifying sub-categories of the main risk categories, the existing classifications lack depth, failing to provide adequate granularity to guide "managerial and scholarly analytical purposes"; p. 316 [21]. Furthermore, these earlier classifications may have become outdated as new risks emerge through technological development or environmental change [22]. Moreover, most prior frameworks ignore sustainability-related issues and risk factors, which increasingly affect NPD project risk exposure [23,24].

Finally, these classifications have inconsistent or idiosyncratic definitions or descriptions of categories of NPD risk, and so a common vocabulary to facilitate understanding is missing. According to [25], "consensus is a necessary condition for the systematic advancement of knowledge, p. 600".

Recent developments such as Industry 4.0 have fundamentally altered the way firms conduct NPD processes. As authors in Ref. [26] noted, AI now permeates the innovation process, which accelerates development but amplifies the exposure to data, integration, and cybersecurity risks. These emerging technologies expand the traditional frontiers of technological risk and highlight the requirement for fresh classifications that take into consideration digital, connected, and dynamic NPD contexts. Sustainability objectives also interact with these technological changes; for example, digitalization can make processes more resource-efficient and reduce waste but creates new environmental and ethical hazards due to energy use from data and digital dependencies in supply chains [3,27].

Typologies categorize theoretically derived qualities of observed phenomena into types [26]. Here, we develop a taxonomy of NPD risks and apply it to empirical investigations of risk in different NPD stages. By doing so, the study also contributes to sustainable innovation management by clarifying how different risk types, e.g., technological, marketing, operations, finance, and environmental risks, interact in affecting sustainable NPD performance [3,27]. As the NPD project progresses from one stage to another, the intensity, nature, and types of risks also change. Therefore, this research will also attempt to

explain why certain risk(s) are more influential at a particular stage of NPD. Specifically, this paper will

- Deploy a systematic literature review methodology to identify relevant studies (Section 2);
- Summarize the empirical findings from these studies, noting, in particular, any reported differences in the profile of risks between stages of NPD and between industry sectors, firm size, and project types (Section 3);
- Develop a taxonomy of five main risk types, each with a number of sub-categories following the classificatory process described by [26] (Section 4);
- Apply this new taxonomy to reported empirical data to differentiate risk types according to NPD stages (Section 5);
- Consider the taxonomy's limitations, how it helps to resolve previously identified issues in NPD risk management, and how it suggests alternative avenues for future research (Section 6).

Following this structured approach, the study proposes the following interrelated research questions:

RQ1: *How do the various NPD risks manifest and interact throughout the NPD process*?

RQ2: *How do the sectoral and regional contexts shape the salience and configuration of these risk categories?*

These questions address the fragmentation observed in the previous work and align with recent calls for more integrative and dynamic risk classifications, e.g., [28,29]. Overall, this review deepens our understanding of how sustainable innovation systems can more effectively anticipate, absorb, and adapt to complex risk interactions during the NPD process [3,30].

2. Systematic Literature Review Methodology

Transparent, replicable, and explicit methods were used to plan, search, screen, and extract information according to the systematic literature review methodology described by [31].

2.1. Planning

By addressing the two research questions, the review identifies sources of risk associated with NPD projects from their inception through to product release.

2.2. Searching

Relevant empirical studies from diverse disciplines were located by identifying keywords that represent the main constructs of the review question (Table 1). Search strings were built from these keywords and applied to four major databases (ABI/Inform Global, EBSCO, Scopus, and Web of Science). The following Boolean search strings were applied to these databases:

(risk* OR uncertaint* OR failure* OR vulnerabilit*) AND ("new product" OR "product innovation" OR "project") AND (development OR "introduction" OR "design" OR "innovation process").

The preliminary searches yielded approximately 270 records from Scopus, 245 from Web of Science, 210 from EBSCO, and 185 from ABI/Inform Global, resulting in a combined total of 910 records prior to deduplication. Additionally, references in influential studies (e.g., [19,32]) were reviewed to locate relevant articles not appearing in these databases. Following duplicate removal, this search process identified approximately 910 articles (790 unique after deduplication and database integration).

Table 1. Keywords for each main construct used to develop search strings for the review.

Construct 1: Risk	Construct 2: New Product	Construct 3: Development
Risk*	Product*	Development
Threat*	New Product*	Introduction
Turbulence*	Project*	Design
Barrier*	System*	Innovation
Uncertaint*	Technology	
Failure*		
Hazard*		
Vulnerabilit*		

The asterisk (*) indicates truncation in the search string, representing all possible word endings. For instance, risk* includes "risk", "risks", and "risky".

2.3. Screening

Relevant papers (i.e., representing risks to NPD only) were then selected by applying explicit inclusion and exclusion criteria (Table 2) to first screen the title and abstract, and then full papers. The resulting 90 articles were evaluated against two quality appraisal criteria. First, every article was scored from 0 to 3 depending upon the extent to which they positioned the research within the relevant literature. Some failed to do this, scoring 0, whereas others explicitly related their work to existing theories, scoring 3 (e.g., [33]). Papers scored 1 if they displayed a limited awareness of the existing literature and 2 if there was an understanding of the literature but no connection to theory (e.g., [34]). Second, articles were evaluated for the quality of the research design. The authors in Ref. [35] had previously criticized the empirical robustness of NPD studies. Where methodology and data collection methods were not described, papers scored 0. If they contained a description of methodology but provided an insufficient description of the instruments or inadequately specified the items used for measuring constructs, then the paper scored 1. Articles based on a single case or on a single data source were scored 2 (e.g., [36]), otherwise they scored 3. Scores for these two dimensions were totaled. In total, 65 studies were included. The SLR process, including identification, screening, eligibility assessment, and inclusion of studies, followed the PRISMA 2020 guidelines. The detailed flow of records through each review stage is presented in Figure 1 [37]. The completed PRISMA checklist is available in the Supplementary Materials.

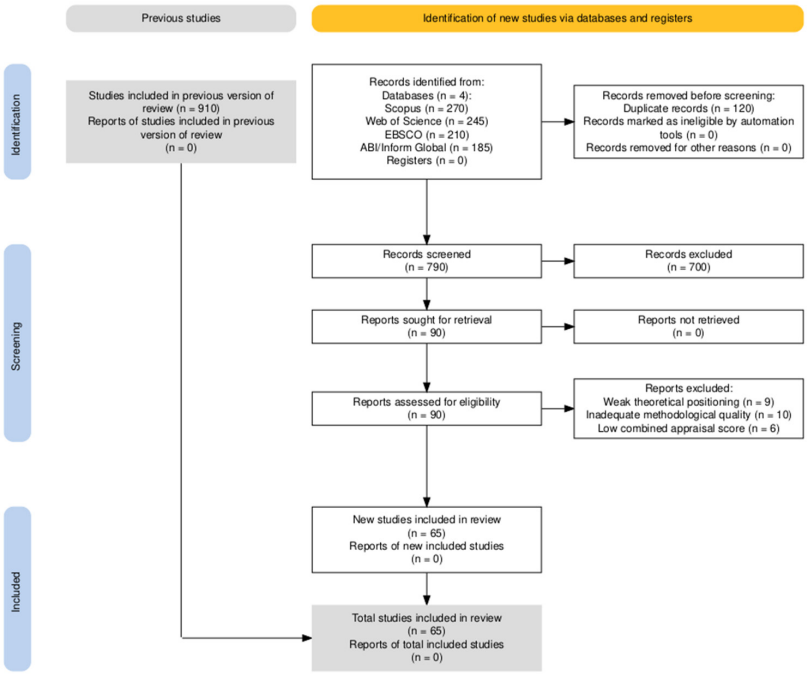

Figure 1. PRISMA flow diagram.

Table 2. Inclusion and exclusion criteria applied to papers.

Inclusion Criteria	Rationale
Publication in peer reviewed journals only	Quality of evidence base
Publications since 1970	Beginning in 1970, though the field produced significant numbers of papers only after 2000
Risks in NPD projects as a main theme	The review focused on risk associated with NPD; exceptionally, three studies on risk management investigated NPD project risk types, and they are included [19,38,39]
Empirical papers only	The review sought reported risks with supporting evidence, not potential risks, as discussed in conceptual papers or literature reviews
Innovative firms only	The study focused on firms using their own facilities for NPD projects
NPD projects as the unit of analysis	This review included only studies where the unit of analysis was an NPD project
Exclusion Criteria	**Rationale**
Risk management but not risk	The focus of the review was risk, so studies focused on risk management in NPD projects were excluded
Unit of analysis other than NPD project	Some studies focused on risks associated with NPD but at the supply chain or portfolio levels
English language only	Language competence of the authors
Domain of literature	Natural Sciences, Computer Sciences, and Engineering Sciences were all excluded
Conference papers	Greater quality assurance through peer review

2.4. Extracting and Synthesizing

A three-step process was followed to create the typology: firstly, mapping NPD project risk classifications; secondly clustering/grouping risk types; and finally proposing the final risk taxonomy (Figure 2).

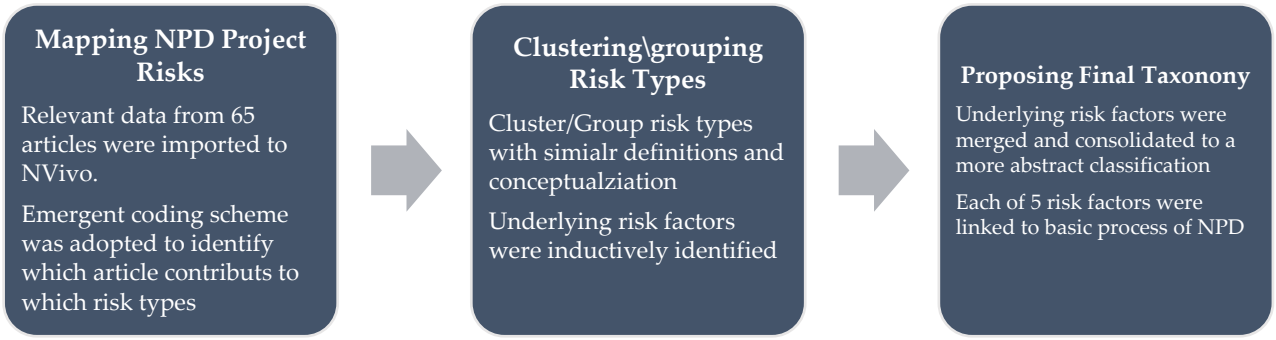

Figure 2. Systematic process for development of risk classification.

2.4.1. Step 1: Mapping NPD Project Risk Classifications

Relevant content (which is, in this case, risk types) from the 65 articles was imported into NVIVO (version 12), and each article was coded using an emergent coding scheme [40,41]. It was then identified which papers would contribute to which risk types. This revealed 305 potential risk factors.

2.4.2. Step 2: Clustering/Grouping Risk Types

In line with [40,42], identical risk factors were grouped together and consolidated to a more parsimonious and unified list of risk factors through a careful analysis of the definitions and conceptualization of extracted risk factors. What is especially noteworthy here is that there was a considerable synergy between the risk factors with different labels.

It was noted that, even though two risk factors were labeled differently, the substances of the two were identical. In other words, the same risk factors have merely been re-labeled under new titles. For example, the label "R&D risk" was used for a firm's lack of necessary technological skills to develop a product. Others, however, used different labels, such as "technological risk" [43] or "technological capability risk" [19]. Commonly cited risk factors were sorted in an iterative and interpretive manner to come up with a list of underlying risk factors. Several iterations were performed to develop these underlying risk factors in which the risk factors were as distinct as possible. This resulted in the 15 underlying risk factors (Figure 3).

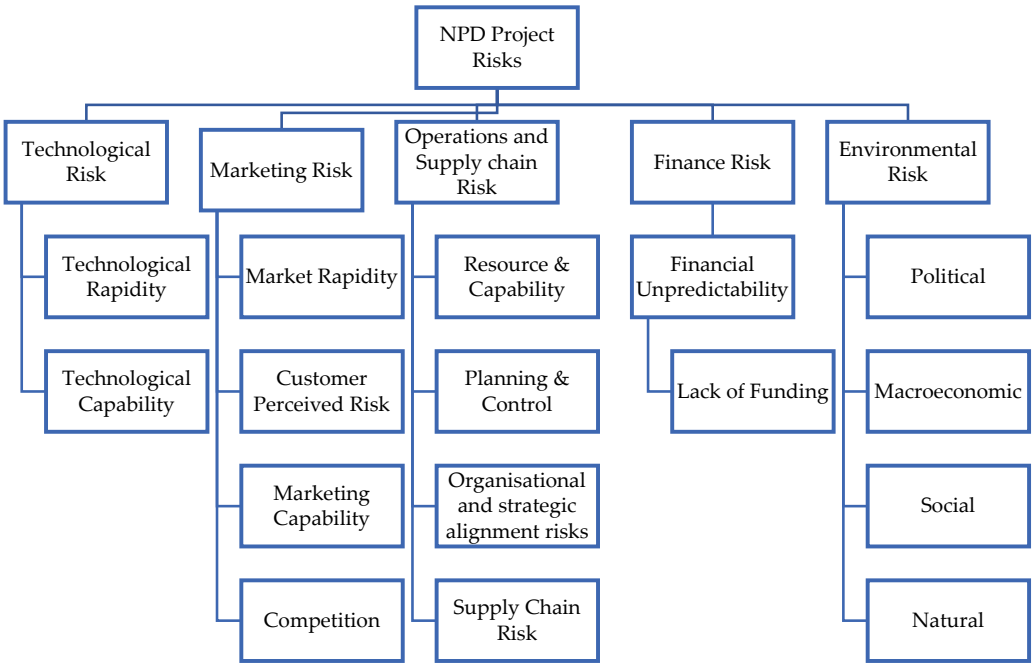

Figure 3. Proposed risk classification.

2.4.3. Step 3: Proposing Final Taxonomy

These underlying 15 risk factors were then consolidated to a more abstract level of risk classification. This was achieved by first analyzing the process nature of NPD project risks. NPD is a process in which ideas or technologies are materialized, managed, and then moved to market. Therefore, technology, operations, and marketing aspects are the three most indispensable NPD process components [19]. An attempt was made to consolidate the 15 risk factors into these 3 indispensable process components of technological risk, market risk, and operations risk. This is also consistent with previous studies, e.g., [32,44], that noticed that, too often, risk analysis in NPD is limited to technology, marketing, and operations factors, and other internal and external factors which might influence the NPD project should have been considered too. Ref. [45], for example, proposed finance-related risks along with technology, marketing, and operations risks. Additionally, a highly complex and uncertain business environment has emerged in the last two decades, witnessing an increase in competition and globalization [46] and enabling firms to re-structure their supply chains on a global basis to take advantage of external expertise, skills, goods, and capital [47]. While the supply chain has become integral to NPD projects, it also contributes significant risks to NPD efforts. Given the increasingly interconnected and interdependent structure of contemporary NPD processes, supply chain tasks are no longer peripheral but are embedded within the core operational framework. Consequently, within this taxonomy, supply chain-related risks are encompassed under the broader category of

operations risk, reflecting the integrated, cross-organizational dynamics characteristic of modern NPD practices [3,24].

Similarly, the role of the environment also received a lot of attention in business and management research. Ref. [48] argued that business and organizational risks can also emerge from environmental factors. Environmental factors are those that affect the overall business context across industries. Possible examples are government regulations, catastrophic events, and sustainability/green-related factors. While the magnitude of impact across different industry sectors may be different, all businesses are affected to some extent [49]. Risks from environmental factors also pose a significant threat to NPD projects.

To avoid overlapping amongst risks, clear boundary criteria were developed that focus on where a risk originates from, not where it propagates or spreads. For instance, technological risks stem from risks related to technologies, processes, or digital infrastructure. Likewise, marketing risks arise from fluctuations and uncertainties in market conditions or customer interactions. Thus, if a geopolitical or natural event disrupts technological development or causes market unpredictability, it is still classified as per its root, which is an environment-related risk, and the resulting disruptions in technology, market, or finance are considered as interactions across risks, as highlighted in the interaction-based risk modeling framework [3,50,51].

In conclusion, the list of risk factors was refined using a manual clustering technique [52] to identify both main categories of commonly occurring risk types and their sub-categories, which were suggested from a close reading of the 90 papers remaining before quality appraisal criteria were applied. Using this typology, the risks reported for stages of the NPD process were identified from the 65 studies passing quality appraisal. Specific NPD stages were not always explicitly defined in the reviewed studies but could often be inferred by comparing the activities described with those mapped to each stage in [1]'s framework.

3. Descriptive Findings

Empirical studies of NPD risk have become increasingly common and are reported in a wide variety of journals (30 different ones in all) covering a range of subject areas.

Studies were geographically dispersed, but with a majority from North America, the UK, or other EU countries (Table 3). Studies were distributed across a range of industrial sectors; manufacturing and software development dominated (Table 3). This distribution illustrates regional research priorities: European studies primarily emphasize environmental-related risks (e.g., [32]), whereas Asian studies concentrate on technological and resource-related risks within NPD projects [53]. Overall, the proposed taxonomy offers a unifying framework; its relative emphasis may require contextual adaptation across regional innovation systems. While it is commonly argued that radical innovations are riskier than incremental ones [32], most empirical studies failed to identify the nature of the NPD project to test this assertion (Table 3). NPD risks were more often investigated in large firms than small ones, and data were collected from respondents having different roles and therefore perceptions of risk (Table 3). Although only a limited number of studies reported risks for specific NPD stages, inference suggests that risks were investigated more often in the early NPD stages (Table 4). Technological and marketing capabilities and control were risks associated with every stage, while technological rapidity and natural or macroeconomic factors have been investigated only at the planning and concept development stages, respectively. Technological, marketing, operations, and supply chain risks have been examined at every stage, but financial risks have not been investigated at the detailed design stage, and some environmental risks have only been explored at the concept development, detailed design, and testing and refinement stages.

Table 3. Descriptive analysis of 65 empirical studies reporting risks in NPD projects.

Descriptive Category	Sub-Category	Number of Studies
Chronological Order of Studies	2021–2025	7
	2011–2020	18
	2006–2010	20
	2000–2005	12
	1991–1999	8
	1970–1990	0
Countries	USA and Canada	19
	UK	10
	Europe	13
	Asia (China, Japan, Korea, Taiwan)	13
	Multiple	4
	Others (Australia, Brazil)	6
Industries	Manufacturing	26
	Biochemical industry	1
	Software	9
	Agriculture	1
	Aerospace	3
	FMCG	1
	Electronics	2
	Other (mixed, automotive, medical devices, SPV, textiles, defense)	22
NPD types	Not specified	27
	Increment	11
	Radical	7
	Radical and incremental	10
	Others (high tech)	10
Firm Size	Large firm	24
	Small- and medium-sized firms	09
	Both	13
	Not specified	19
Respondent Types	Top management	2
	Middle-level management (R&D, product, marketing, or project manager)	23
	Top and middle management	6
	Staff	5
	Mixed	15
	Secondary data from companies	7
	Not specified	7

It is noteworthy that the reviewed period (2011–2021) coincides with a time when emerging technologies and disruptive global changes began to impact NPD risk analysis. Therefore, recently emerging domains such as AI ethics and data governance, supply chain digitization and automation, and operational disruptions caused by pandemics are not fully reflected in the review. Nevertheless, these phenomena conceptually align with the risk classification framework constructed in this review. For example, AI ethics expand the domains of technological and social risks; digitization exacerbates operational- and resource-related risks; and the impact of the pandemic manifests as a macro-environmental risk that systematically propagates throughout the NPD process. Therefore, while the

timeframe of the review may limit direct empirical research on these new risks, the proposed framework remains sufficiently adaptable to be incorporated into future empirical analyses.

Table 4. Occurrence of risk (sub)-categories by NPD stage.

Risk Types		NPD Stages						References
		Planning	Concept Development	System-Level Design	Detailed Design	Testing and Refinement	Production and Ramp-up	
Technological Risk	Technological Capability	X	X	X	X	X	X	[18–20,22,32,34,39,41–46,53–78]
	Technological Rapidity	X	X	X	X	X	X	[5,6,19,22,33,34,42,45,53,58–60,63,65,66,69,72,73,75,77,79–85]
Marketing Risk	Marketing Rapidity	X	X			X	X	[5,6,19,22,39,45,57–59,63,64,67,71,73,77,79,80,84]
	Customer-Perceived Risk		X	X		X		[6,18,19,32,34,44,46,54,57,64–66,68,69,76,85,86]
	Competition	X	X				X	[6,18,19,22,32,43–46,55,63,64,68,70,72,81,84,87]
	Marketing Capability	X	X	X	X	X	X	[5,6,18,19,21,22,32,41,43–46,55,59,68,69,72,73,79,82,84,85]
Operations and Supply Chain Risk	Resources and Capability Risk	X	X		X			[5,6,21,39,45,46,55,58,60,62,64,67,69,71–73,76–78,82,85,88,89]
	Planning and Control	X	X		X			[5,6,18,20,32,34,39,44,46,54–56,58,60–62,64–66,68,69,71,73,76–78,82,85,86,89]
	Organizational and Strategic Alignment	X		X			X	[6,18,19,32,44,54,58,62–64,68,70–73,77,78,82,85,87,89]
	Supply Chain-Related Risk	X		X	X	X	X	[18,20,32,39,44,46,54,56,62,64,67,68,72,73,76–78,83]
Finance Risk	Financial Unpredictability		X	X		X	X	[6,18,32,34,39,44,46,54–56,61,62,64–68,71,73,78,85,90]
	Lack of Funding	X	X			X		[21,45,53,55,62,64,67,71,73,85]
Environmental Risk	Political Factors		X		X	X	X	[6,18,20,21,32,44,53–55,62,64,67–69,77,78,84,91]
	Social Factors		X		X		X	[6,18,32,44,64,68,78,84]
	Macroeconomic Factors		X					[6,67,70,78,84]
	Natural Factors		X				X	[21,78]

4. Identifying Risk Categories

4.1. Technology Risk

Technological problems in the manufacturing sector are difficult to manage and may escalate into larger issues affecting the whole NPD project portfolio [6,30,92]. Technological risks arise when a firm cannot comprehend and respond to different aspects of the internal and external technological environment [93].

This study adopts a comprehensive view of technology, encompassing both product- and process-related technologies. Product-related technologies include, e.g., material science, product design methods, and embedded systems [43,94,95]. Processes, also known as manufacturing technologies, include production automation, prototyping, digital fabrication, and lab-scale experimentation [46,47]. Additionally, it considers digital- and information-based technologies that increasingly support NPD, including design software, simulation tools, and data-driven testing platforms [24,30]. This inclusive interpretation is consistent with prior NPD research, which distinguishes between product technology and process technology as parallel sources of risk [19,24,43].

A significant internal source of technological risk is a lack of research and development or technological capability [19,30,94]. Technological capability indicates an ability to launch a new product successfully [43,96]. Firms may either not possess the technological capability [93] or possess it only partially, and so are unable to handle new technology challenges [54,86]. Firms may lack the complex knowledge and information required to

understand either technological environments [42] or established procedures [79], or may lack the technological resources required to design and develop products [55]. Moreover, firms may be unable to handle product design changes [56]. Inaccurate definitions of product design and false assumptions about product requirements [57] indicate a poor technological capability, leading to delays and inefficient product development efforts [97]. Additionally, firms may fail to attend to product specification details during the design phase, resulting in poor quality products [58].

Technological environments external to the firm also drive technological risk. Technological rapidity indicates that the extent of technology change over time creates unanticipated obsolescence [30,59,94]. Technological rapidity creates indecision; firms are uncertain which technology to invest in [5] and whether unexpected problems will arise during adoption [79]. The future viability of a particular technology is also a concern [53]. Failing to freeze product specifications to incorporate the latest technological improvements may increase risk [58].

Recent advancements in digitalization and AI have exacerbated this challenge, as technological integration increasingly now spans all phases of NPD, transforming design, analysis, and decision-making processes [98]. The incorporation of AI-driven design optimization, machine learning-facilitated forecasting, and networked Industry 4.0 systems adds additional risks and uncertainties concerning data quality, algorithmic bias, cybersecurity, and interoperability [24,30]. While these digital technologies accelerate innovation, they also increase the exposure to risks such as platform instability, data breaches, and system failures. Consequently, modern NPD efforts must balance technological capabilities with digital vulnerabilities, making digital risk management a critical component of current technological competence [3].

4.2. Marketing Risk

Marketing risks are principally due to external factors, such as changing customer requirements, customer perceptions of the product, or competitors' actions, and therefore are less controllable and predictable [19,92]. However, some marketing risks originate from poor marketing capabilities within the firm [43].

Customer requirements may change according to fad or fashion and may change at any time during the NPD project [30,79,94]. More than three quarters of the respondents from 17 MNCs in the USA indicated that market rapidity was a major risk factor for NPD projects [99]. Recent research emphasizes that digitalization and AI-powered analytics are reshaping how firms sense market trends and engage with customers. However, this transformation brings new risks and uncertainties concerning data accuracy, privacy protection, and the rapid dynamics of online feedback mechanisms [23,98].

Customer skepticism or uncertainty concerning the purpose of a new product increases risk [30,46,94]. Customers showing high levels of satisfaction with existing products [65] may be reluctant to commit to the new product. Furthermore, a new product may require education or changes in customer behaviors [32]. These decrease probable customer satisfaction and increase customer-perceived risk, creating hesitancy amongst customers for the new product [6]. Adverse publicity for the company and its product can affect negatively customer commitment to the product [76], increasing customer-perceived risk.

Competitor risk may reduce firm market share or profitability. An awareness of the competitive strategy, tactics, and product lines of competitors helps to reduce the risk for NPD projects [23,81]. A firm is prone to these risks when it is surrounded by established dominant competitors [63]. Firms may potentially face sudden technology or product obsolescence when customer requirements change due to competitor pressure [73].

Unlike other sources of marketing risk, marketing capability lies within the firm, and yet this is a major source of NPD project failure [23]. Failing to anticipate the exact customer requirements [59], to identify target customers [5], or to understand their demands for different product types [19] and failing to align these demands with appropriate product characteristics are examples of the poor marketing capability of a firm [85]. Poor marketing capability and ineffective advertising [32], together with a lack of marketing expertise [79] and an inability to judge customer requirements [59], perhaps because of differing interpretations of the market by different team members [85], also contribute to marketing risk.

Currently, marketing capabilities are becoming increasingly reliant on a firm's digital proficiency, i.e., on the basis of its capacity to utilize analytics, online platforms, and AI-driven tools for market intelligence. This makes digital competence a critical aspect of marketing risk [27,30].

4.3. Operations and Supply Chain Risk

Operational risk captures uncertainties or disruptions emanating from the internal operations of a firm [47]. An investigation of 12 American firms suggested that all had to contend with internal operational risks on a large scale [72]. Operational risks can be encapsulated by resource and capability risks, planning and control risks, and organizational and strategic alignment risks [47].

Resource and capability risk refers to both the tangible and intangible assets essential to sustaining NPD performance [30,94]. Tangible resources include equipment, facilities, materials, and production infrastructure, all of which, when disrupted or insufficient, can limit innovation capability [47]. A weak infrastructure and a lack of resources (e.g., equipment and facilities [58]) both contribute to resource-related risks for NPD projects. Resource risks can also result from a shortage of material caused by disruptions to supply, defective components [20], or sudden equipment failure. Intangible resources encompass human expertise and organizational knowledge spanning various organizational functions, including manufacturing, engineering, operations, and various support functions [32]. Effectively managing people is the key to project success, and human resources are a significant source of operational risk [100]. A sufficient staff with requisite skills is vital for an NPD project [32]. Inadequate training or a failure to attract and retain the right caliber of people [46] who possess NPD project-related competencies and skills contributes to NPD project risk. Ongoing training and the re-skilling of existing employees are vital for reducing human resource-related risks [46]. The poor management of employee relations also contributes to human resource-related risks. Firms may fail to manage conflict between employees [89] or to manage disputes with employees [76]. Finally, a sudden loss of key NPD project team members adds to uncertainty and increases risk [72]. Therefore, NPD personnel extend beyond R&D or marketing engineers to include cross-functional experts in areas such as HR, supply chains, and quality management, whose coordinated contributions are critical for NPD project success [23,98].

Planning and control risks represent closely related aspects of operations risks in NPD projects [30,94]. The function of planning is to prescribe the scope and objectives of an NPD project, to delimit operations, including development methods, and to determine the roles and responsibilities of NPD project team members [60,73]. Any uncertainty related to these aspects leads to planning risk. For example, [73] observed that ill-defined, immature, and unrealistic project objectives and scope disrupted NPD projects. In other cases, firms created unrealistic timelines and schedules [89] and failed to prioritize key project objectives [6]. In software development projects, [60] reported poorly defined roles and responsibilities of project team members as a major threat. Conversely, control

risk arises from uncertainty related to those activities, procedures, and mechanisms that a firm adopts to control operational processes [23]. The most significant of these are communication between team members [99] and the monitoring of project progress [45]. Aspects of the control structure that support or facilitate NPD projects also contribute to risk. For example, a lack of risk management processes and conflict resolution mechanisms was a common threat for software related NPD projects [60,73].

In NPD projects within Industry 4.0, the role of planning and control risks has changed. NPD projects consisting of agile and digital systems merge planning and control into real-time, iterative processes involving cross-functional teams. In other words, it has become a dynamic, iterative function that relies on real-time data and cross-functional coordination [30,98]. Consequently, planning and control risks primarily arise due to different systems not sharing data properly, unaligned and distributed decision-making, and different digital platforms failing to connect or update in real time [3,23].

Organizational and strategic alignment risks in NPD emerge when internal structures and leadership practices fail to support strategic goals [27]. These risks often stem from a misalignment between project-level decisions and firm-level strategic priorities [6], or from structural rigidities that limit adaptability in dynamic environments [72]. Alignment is an integral part of strategic management. A failure to align firm strategic objectives with environmental changes can result in increasing risks as technological and operational capabilities become unfocused and misdirected [23,58,94]. An inaccurate assessment of the environment results either in an inadequate prioritization of NPD projects [6] or a disinterest in innovation by senior management [70]. NPD projects that do not gain top management commitment, interest, and required resources fail [77]. The centralization of all decisions, authority, and control, a lack of involvement of operational-level management in strategic decisions [36,73], and a failure by managers and employees in NPD projects to understand the role of internal politics [36] all increase NPD risks. A change in top management or ownership of the business [72] creates instability in the organization, and consequently NPD projects may suffer because of changes to project scope [6].

In current NPD settings, operational and supply chain risks are closely linked, as firms must rely on both internal processes and external partners to deliver a product in a timely, cost-efficient, and high-quality manner. The risks, therefore, do not originate only from the firm's internal operational infrastructure but also from across its broader network of suppliers, design collaborators, logistics providers, and technology partners [46,47]. Supply chain failures create risks for the firm. Sources of supply chain risks originate from several sources, including suppliers, buyers, internal operations, and the external environment. Poor supplier management is a major source of supply chain risks for NPD projects [56,94]. Risks arise from poor selection processes [78] or inappropriate selection criteria [32], resulting in unsatisfactory engagements. Risks also result from a lack of attention to legal aspects of contracting [32]. A further set of risks stem from the management of communications between firms and suppliers [20]. Other issues pertinent to supplier management are the poor performance of suppliers, leading to a gap in trust between both parties [77], problems over intellectual property rights, and a lack of conflict resolution mechanisms [62] and contingency planning [64]. Finally, outsourcing may create job insecurity amongst the work force, jeopardizing relations between management and staff [24,76].

4.4. Financial Risk

A study of innovative firms in the US revealed that managing financial risk was critical in determining project continuation or termination [72]. Financial risk comes from financial unpredictability [30,43,101] and the unavailability of adequate finances [53]. The

first stems from a lack of financial analytical skills not only in estimating the costs of labor and materials [71] but also in allocating finances to different project phases [23,73] and the poor financial management of the NPD process. Firms may be unable to predict running development costs or estimate profit margins [32]. The second stems from a lack of funds [85] either because external sources from investors or governments dry up or because cash flow problems develop internally [27,30,53], sometimes caused by escalating development costs [64].

In Industry 4.0, firms face growing financial risks when investing in data platforms, AI design tools, and team-based tech. These costly tools can be unpredictable in the long run, making it harder to plan budgets or allocate funds confidently [3,30].

4.5. Environmental Risk

Environmental risks arise from four sources (political, social, macroeconomic, and natural sources) in the external environment surrounding a firm [21]. These are less controllable or manageable than other risks [32].

Uncertainties associated with a new government can affect NPD projects [20]. They may interfere with a firm's operations or otherwise fail to cooperate with a firm [78]. Governments may also alter policies, which can negatively impact NPD projects [30]. Examples include changes in environmental regulations, in labor laws, in copyright or intellectual property rights, in import/export restrictions, or in tax policy [20,53,91]. A related and emerging category is digital environmental risk, driven by evolving data governance laws, cybersecurity mandates, and AI ethics frameworks, all of which increasingly shape how firms design, test, and launch digital products [98]. These regulatory uncertainties resemble natural or political disruptions in their unpredictability and broad impact.

Currently, global innovation, due to being part of extended supply chains, is exposed to various geopolitical tensions which have made it harder for firms to obtain key materials and work with international partners, often slowing down NPD and affecting who they choose to team up with [24,30].

The different attitudes, beliefs, and reactions of the public to the outcome of the NPD project may cause uncertainty for the firm. This can be exacerbated by the reaction of key stakeholders such as the scientific community, who may support or oppose the technology, thereby creating confusion for the public [32].

With social media and online activism on the rise, public opinion now plays a bigger role in shaping business decisions. A sudden shift in sentiment can damage a brand's reputation or affect how a product is received, making it crucial to factor social risks into early NPD planning [23].

Macroeconomic factors can adversely impact NPD projects [30]. The recent global economic recession, sudden changes in foreign exchange rates, changes in interest rates or increases in material, labor, and resettlement costs, and sudden changes in foreign exchange rates [6,78,86] are examples from the NPD literature.

Catastrophic events such as floods or earthquakes may affect NPD projects [78]. An earthquake caused several Taiwanese factories to shut down, preventing them from delivering computer components to Apple, who subsequently were unable to meet demand for their iBook and G4 computers [102]. Major global events like the COVID-19 pandemic have shown how quickly things like supply chain breakdowns, travel restrictions, or funding issues can disrupt NPD at any stage. At the same time, extreme weather and changing environmental rules are putting long-term pressure on how resources are used and which sustainability goals take priority [21,53,91].

Today's NPD projects face a wider range of environmental risks, including digital threats, political instability, and global disruptions. Unlike internal risks, these external

factors often hit different domains of NPD projects such as supply chains, finances, and strategies all at once, making NPD projects more vulnerable overall [20,30].

5. Discussion

Each stage of the NPD process is apparently vulnerable to a variety of risks. Previously, Figure 3 illustrates the static classification of NPD risks and their subtypes. Figure 4 combines the findings from the reviewed literature into a single visual model. This model connects various risks with the sequential stages of the NPD process. It expands by illustrating the potential interactions and propagation paths among risk factors. Dashed arrows indicate cross-relationships, highlighting how exogenous, mixed, and endogenous risks dynamically influence each other at different stages of NPD.

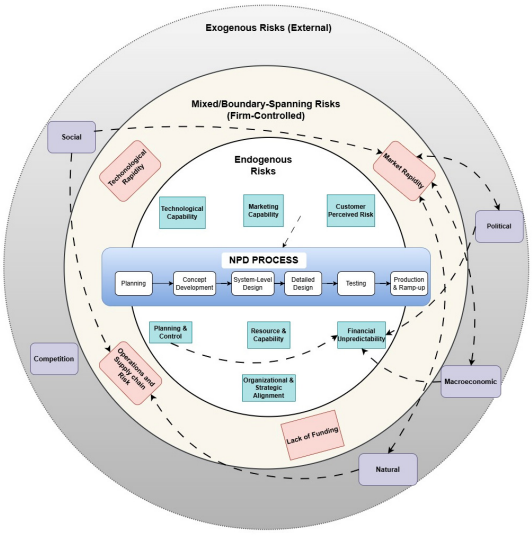

Figure 4. Conceptual framework of NPD risk interdependencies and propagation.

The NPD process is adopted from [43]. Endogenous, mixed, and exogenous risks and their interaction pathways constitute the proposed conceptual framework. This model illustrates how internal and external sources of uncertainty dynamically influence and propagate across the NPD process, providing a systemic view of NPD risk interdependence. The explanation for the observed pattern of association between risk types and NPD stages probably lies in the ease of empirical investigation and the clarity and focus of presenting practical issues surrounding NPD [103].

However, beyond empirical availability, this pattern reflects more than just the availability of studies; it is also shaped by the inherent ways in which risks emerge and develop throughout NPD processes. Exogenous risks such as macroeconomic risks arise from systemic factors such as inflation, fiscal policy shifts, or global market volatility that mainly affect the strategic decision-making and investment phases of NPD [21,86]. During the early stages, firms evaluate feasibility and make resource commitments, so any macroeconomic uncertainty directly influences their perceptions of opportunity and financial confidence [30,72]. On the other hand, as projects move into design, testing, and production, endogenous risks such as technological, operations, and marketing risks become more prominent. This is because outcomes are increasingly determined by the firm's own capabilities, coordination, and control systems [19,23,27]. This pattern aligns with the existing conceptual distinction between exogenous and endogenous risk factors [17,21]. It suggests that the prominence of certain risk types across stages is not merely a function of empirical observation but arises from the causal mechanisms governing risk emergence and propagation within complex NPD systems [30,94].

Investigating a firm's marketing or technological capabilities or control processes has an immediate utility for the firm. It is easier than attempting to explore the reasons for a lack of funding for NPD, which may be personal and political, or how wider environmental factors might adversely affect NPD stages. Nevertheless, this inductively derived classification of empirical studies highlights five main categories of risk to NPD, each with a small number of sub-categories that may arise from both within the firm and beyond the firm boundary (Figure 3). We attempted to relate the 15 risk factors with one or more NPD processes according to their definitions. This helped us determine whether any link exists between NPD phases and specific NPD project risks. This step enabled us to relate the proposed risk classification to the existing theory in NPD and then develop a clear theoretical embeddedness. The list of risk sources extracted from the literature was analyzed carefully to decide if certain risk factors can be associated or classified with NPD process phases. A summary of risk factors and their association with different phases of the NPD process is provided in Table 4. Each X in the table shows that at least one study found the associated risk (sub-) category in that specific stage of NPD. The authors manually coded the data using either direct statements or inferred insights from each study, following [101]'s mapping of NPD stages. When a risk was identified as potentially affecting many stages, it was coded across those stages. This approach aimed to indicate how risks might propagate through the process, rather than implying a clear cause-and-effect relationship.

Almost all risks were repeated during their allocation to the NPD processes. For example, technological capability risk is found almost in every phase of the NPD process, e.g., in the design phase of the NPD process [61] and in the production phase of the NPD process [32]. Similarly, it has been found that a firm is vulnerable to technological rapidity risk at any time during the NPD project, e.g., during the project execution phase or even after launching the product [22]; technological unpredictability in the integration and production phases is discussed by [42]. Recent studies suggest that digitalization and related design systems bring new risks, like relying on accurate data, compatible systems, and trustworthy algorithms. These issues turn technological risks into digital risks and uncertainties that can affect different aspects of the NPD process [30,98].

Marketing risks still play a big role during the NPD process, especially with shifting customer tastes, strong competition, and brand image concerns. As more companies use digital tools to track markets and launch products, they face new challenges like biased forecasts, social media backlash, and unpredictable consumer behavior, all of which make it harder to stay in sync with the market [23,98].

Currently, operations and supply chains are tightly linked, making businesses more reliant on external partners. A slight deviation in planning or coordination can disturb the entire system. With teams now working across borders and using more digital tools, strong communication and easy data sharing are key to keeping NPD projects running smoothly [3].

Financial risks in NPD projects were not addressed to the same extent as others across NPD process stages. While the detailed design phase receives limited attention, risk propagates as NPD projects move to successive stages. During the early stages, the firm's focus lies on deciding and finding investment opportunities. For later stages, firms face issues related to budget overrun, revenue delays, and cash flow problems [3,103]. Understanding this progression highlights the need to align financial planning and risk management with key NPD decision points.

Environmental risks (often beyond firm control) are significantly associated with NPD activities. Shifts in politics, regulation, climate, and social expectations increasingly influence technology access, cost structures, and supply chain stability [20,53]. Events like the COVID-19 pandemic have shown how such disruptions can suddenly affect operations,

finances, and logistics. Additionally, stricter government rules and regulations about the environment and data privacy increase pressure on the firms, slowing down innovation and reducing flexibility. In this way, environmental risks become a significant source of risk at every stage of NPD [98].

These findings directly address RQ1 by demonstrating that risk categories evolve across stages and are deeply interconnected. Technological, marketing, operational, financial, and environmental risks do not exist in silos, but they interact, influence, and propagate across NPD process stages. The typology of NPD risks proposed earlier offers a comprehensive framework to analyze the root causes and interdependencies of risks. The findings also demonstrate the evolving nature of NPD risks across various stages of the NPD process. Previously, during the early stages of a traditional NPD process, technological- and marketing-related risks were prominent. However, it is not the case anymore in the era of Industry 4.0. As NPD projects are now digitalized, operations and supply chain risks are gaining more prominence [24,27,30].

While addressing RQ2, it becomes apparent that NPD risks demonstrate significant cross-domain interactions. For example, a shortage of finance can worsen operational delays or hinder new technology implementation [3]. Regional differences also were notable from the findings; for example, while Asian and European studies emphasize managing digital transformation and its related risks, studies from North America emphasize managerial capabilities and resource coordination [23]. This shows that the proposed risk typology is capable enough of capturing interdependencies and contextual nuances in a typical NPD risk system.

Much of the existing literature has focused on endogenous or micro risks (operations and technology) rather than on exogenous or macro risks [104], for example, in the supply chain [76] or global financial markets [53]. Consequently, one might concur with [19] or [32] that technology, marketing, and the management of operations were the most influential factors determining NPD success. However, project managers pay more attention to risk factors that are visible and controllable [73], perhaps ignoring supply chain or environmental risks that are uncontrollable. The literature review reflects this attentional difference. Distinguishing between endogenous and exogenous risks highlights the need for different risk mitigation approaches [105]. Endogenous sources of risk can be minimized with appropriate proactive approaches, whereas exogenous sources generally cannot be reduced, although proper reactive strategies can be developed to increase NPD project resilience [104].

Risk rarely impacts a specific aspect of the NPD process in isolation; rather, it is interactively complex, impacting multiple aspects of the NPD process, with a variety of consequences. For example, environmental risks may influence both technology and marketing aspects of NPD [59,106]. This creates challenges for the classification of risks because a particular risk may be categorized differently depending upon perceptions. It is also apparent that risk categories, and, in particular, risk sub-categories, may overlap. For example, the perceptions of the scientific community (an environmental risk) affect customer perceptions (a marketing risk), and the boundary between these effects is blurred. Likewise, the supply of resources may be a supply chain risk or an operational risk.

In common with other classifications, the categories presented here are dependent on the available empirical evidence and our approach to categorization, which others may dispute. For example, safety may be an environmental, technological, or operational risk depending on perspective. Here, it is classified as an operational risk. To mitigate subjectivity and selectivity, we adopted a review methodology which supports transparency and comprehensiveness. However, hitherto uninvestigated environments may highlight

new risks, which would require a revision to this taxonomy. Changes in the business environment through technical advances [7] may create new types of risk.

Recent descriptions of organizational environments highlight their volatility, uncertainty, complexity, and ambiguity [107]. Each of these characteristics brings a new source of risk. Others have noted variations in the velocity of different environments [108]. The risks in high-velocity industries may be very different to those in slower industries. To obtain sufficient information to support each category, the taxonomy has aggregated data across settings, creating a generic taxonomy that can be applied widely. However, the profiles of risk for NPD may depend on context. For example, the risks associated with radical NPD projects may differ from those associated with incremental projects, although this distinction is rarely observed. Industries with different "clock-speeds" (e.g., fashion and aircraft manufacturing) may each generate specific risks that differ. This also has not been investigated. Other differences in risk profiles might be created by firm size; SMEs may differ from MNCs [70]. Moreover, open and closed innovation may be susceptible to different sources of risk, resulting in different risk profiles. Future research on sources of NPD risks could explore in more detail each of these possibilities.

6. Conclusions

By synthesizing the existing studies of NPD risk, a meaningful taxonomy of NPD risks with a sufficient breadth was created. It differs significantly from other classifications by providing sub-categories that are easily observable and readily understood. Previous studies indicate consistently the need to identify additional sources of risk [5,83]. By surveying the literature from diverse sources, this taxonomy provides a recognizable and logical categorization of risks that has been used in this paper to differentiate risks according to NPD stages and which could now permit industry and sector comparisons. Others [6,20] have called for an explication of appropriate risk management strategies. A comprehensive taxonomy of NPD risks facilitates the assembling of appropriate risk management strategies for different (sub)-categories of risks, leading subsequently to the development of more general risk management strategies for different NPD risk types [109].

The proposed typology contributes to the existing research by examining how NPD project risks emerge, interact, and evolve through NPD processes. It offers a systematic way of analyzing interactions amongst different risk categories during various NPD process stages. It also suggests how various contemporary factors such as Industry 4.0 and sustainability influence the occurrence and propagation of different NPD risks. The proposed typology also contributes to practice by providing a benchmarking tool for specific NPD project risk factors. For example, managers can use this classification to identify NPD-related risks during different NPD process stages and adopt risk mitigation strategies where risks are more pronounced. The proposed classification can be embedded or integrated into an existing NPD process to allow for the early detection of risk factors and to study how they manifest, interact, and propagate across different stages.

While every effort was made to ensure robustness, transparency, and credibility in the SLR review, several limitations must be acknowledged. The quality appraisal criteria used during the paper selection process were applied qualitatively, which may have introduced a degree of researcher bias. The SLR was restricted to peer-reviewed English-language journal articles, which may have limited the findings. The small number of articles available for some years is partly due to how research on NPD risk has developed over time, rather than any limit in the search strategy. For example, between 2011 and 2021, only a few empirical studies focusing on NPD risk were published. In addition, many articles were excluded during quality appraisal because they lacked sufficient methodological or theoretical quality or did not offer a clear empirical contribution to the topic. Thus, the final set of studies

included in this SLR is smaller, but fully meets the quality appraisal criteria established for this review. In addition, this review focused solely on peer-reviewed empirical publications and did not include evidence from industry or consultancy reports or organizational white papers. This may have resulted in the omission of useful practical experiences and recent risk examples observed in professional settings.

The proposed typology can be empirically validated quantitatively or qualitatively to assess its relevance and applicability across different industry sectors. To gain practical insights from professional practices, future research could expand the data scope by systematically integrating industry-based evidence or case study materials. The SLR could enhance methodological rigor and transparency by incorporating quantitative techniques, such as bibliometric or network analysis and meta-analysis.

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References

1. Ulrich, K.; Eppinger, S. *Product Design and Development*; McGraw-hill: New York, NY, USA, 2012.
2. Tidd, J. Innovation management in context: Environment, organization and performance. *Int. J. Manag. Rev.* **2001**, *3*, 169–183. [CrossRef]
3. Bai, L.; Zhang, L.; Zhang, L.; Shao, K.; Luo, X. Unlocking the potential of project portfolio: Value-oriented interactive risk management. *Humanit. Soc. Sci. Commun.* **2025**, *12*, 1–15. Available online: https://www.nature.com/articles/s41599-025-05296-8 (accessed on 6 December 2025). [CrossRef]
4. Persson, J.S.; Mathiassen, L.; Boeg, J.; Madsen, T.S.; Steinson, F. Managing risks in distributed software projects: An integrative framework. *IEEE Trans. Eng. Manag.* **2009**, *56*, 508–532. [CrossRef]
5. Ilevbare, I.M.; Probert, D.; Phaal, R. Towards risk-aware roadmapping: Influencing factors and practical measures. *Technovation* **2014**, *34*, 399–409. [CrossRef]
6. Martinsuo, M.; Korhonen, T.; Laine, T. Identifying, framing and managing uncertainties in project portfolios. *Int. J. Proj. Manag.* **2014**, *32*, 732–746. [CrossRef]
7. Olson, D.L.; Birge, J.R.; Linton, J. Introduction to risk and uncertainty management in technological innovation. *Technovation* **2014**, *34*, 395–398. [CrossRef]
8. Bailey, K.D. *Typologies and Taxonomies: An Introduction to Classification Techniques*; Sage: Thousand Oaks, CA, USA, 1994.
9. PMI—Project Management Institute. *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*; Project Management Institute: Newtown Square, PA, USA, 2008.
10. International Organization for Standardization. *Risk Management—Principles and Guidelines*; International Organization for Standardization: Geneva, Switzerland, 2009.

11. Ward, S.; Chapman, C. Transforming project risk management into project uncertainty management. *Int. J. Proj. Manag.* **2003**, *21*, 97–105. [CrossRef]
12. Simon, P.; Hillson, D.; Newland, K. *Project Risk Analysis and Management Guide (PRAM)*; Association for Project Management: Norwich, UK, 1997.
13. Rowe, W.D. Risk assessment approaches and methods. In *Society, Technology and Risk Assessment*; Academic Press: London, UK, 1980; p. 343.
14. Mitchell, V. Consumer perceived risk: Conceptualisations and models. *Eur. J. Mark.* **1999**, *33*, 163–195. [CrossRef]
15. Simpleman, L.; Mcmahon, P.; Bahnmaier, B.; Evans, K.; Lloyd, J. *Risk Management Guide for DoD Acquisition*, 2nd ed.; Defense Systems Management College: Fort Belvoir, VA, USA, 1999.
16. Project Management Institute. *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)–Seventh Edition and The Standard for Project Management*; Project Management Institute: Newtown Square, PA, USA, 2021.
17. De Meyer, A.; Loch, C.H.; Pich, M.T. Managing project uncertainty: From variation to chaos. *MIT Sloan Manag. Rev.* **2002**, *43*, 60. [CrossRef]
18. Keizer, J.A.; Vos, J.; Halman, J.I.M. Risks in new product development: Devising a reference tool. *RD Manag.* **2005**, *35*, 297–309. [CrossRef]
19. Mu, J.; Peng, G.; MacLachlan, D.L. Effect of risk management strategy on NPD performance. *Technovation* **2009**, *29*, 170–180. [CrossRef]
20. Lin, Y.; Zhou, L. The impacts of product design changes on supply chain risk: A case study. *Int. J. Phys. Distrib. Logist. Manag.* **2011**, *41*, 162–186. [CrossRef]
21. Miller, K.D. A framework for integrated risk management in international business. *J. Int. Bus. Stud.* **1992**, *23*, 311–331. [CrossRef]
22. Bstieler, L.; Gross, C.W. Measuring the effect of environmental uncertainty on process activities, project team characteristics, and new product success. *J. Bus. Ind. Mark.* **2003**, *18*, 146–161. [CrossRef]
23. Peljhan, D.; Marc, M. Risk management and strategy alignment: Influence on new product development performance. *Technol. Anal. Strateg. Manag.* **2023**, *35*, 1547–1559. [CrossRef]
24. Wang, M. Effect of blockchain technology–supply chain risk fit on new product development performance: The moderating role of supply chain upgrading. *J. Gen. Manag.* **2024**, *50*, 26–36. [CrossRef]
25. Pfeffer, J. Barriers to the advance of organizational science: Paradigm development as a dependent variable. *Acad. Manag. Rev.* **1993**, *18*, 599–620. [CrossRef]
26. Rich, P. The organizational taxonomy: Definition and design. *Acad. Manag. Rev.* **1992**, *17*, 758–781. [CrossRef]
27. Mousavi, S.; Hafezalkotob, A.; Ghezavati, V.; Abdi, F. A new fuzzy multi-criteria decision-making approach for risk assessment of competitors' cooperation in new product development projects. *J. Bus. Ind. Mark.* **2022**, *37*, 2278–2297. [CrossRef]
28. Teece, D.; Peteraf, M.; Leih, S. Dynamic capabilities and organizational agility: Risk, uncertainty, and strategy in the innovation economy. *Calif. Manag. Rev.* **2016**, *58*, 13–35. [CrossRef]
29. da Silva Etges, A.P.B.; Cortimiglia, M.N. A systematic review of risk management in innovation-oriented firms. *J. Risk Res.* **2019**, *22*, 364–381. [CrossRef]
30. Liu, S.; Ding, R.; Wang, L. An adaptive simulation based decision support approach to respond risk propagation in new product development projects. *Decis. Support Syst.* **2024**, *183*, 114270. [CrossRef]
31. Tranfield, D.; Denyer, D.; Smart, P. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *Br. J. Manag.* **2003**, *14*, 207–222. [CrossRef]
32. Keizer, J.A.; Halman, J.I.M. Risks in major innovation projects, a multiple case study within a world's leading company in the fast moving consumer goods. *Int. J. Technol. Manag.* **2009**, *48*, 499–517. [CrossRef]
33. Nidumolu, S. The effect of coordination and uncertainty on software project performance: Residual performance risk as an intervening variable. *Inf. Syst. Res.* **1995**, *6*, 191–219. [CrossRef]
34. Jiang, J.J.; Klein, G. Risks to different aspects of system success. *Inf. Manag.* **1999**, *36*, 263–272. [CrossRef]
35. Ernst, H. Success factors of new product development: A review of the empirical literature. *Int. J. Manag. Rev.* **2002**, *4*, 1–40. [CrossRef]
36. Jones, O.; Stevens, G. Evaluating failure in the innovation process: The micropolitics of new product development. *RD Manag.* **1999**, *29*, 167–178. [CrossRef]
37. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* **2021**, *372*, n71. [CrossRef]
38. Charoo, N.A.; Ali, A.A. Quality risk management in pharmaceutical development. *Drug Dev. Ind. Pharm.* **2013**, *39*, 947–960. [CrossRef]
39. Conrow, E.H.; Shishido, P.S. Implementing risk management on software intensive projects. *IEEE Softw.* **1997**, *14*, 83–89. [CrossRef]

40. Ho, W.; Zheng, T.; Yildiz, H.; Talluri, S. Supply chain risk management: A literature review. *Int. J. Prod. Res.* **2015**, *53*, 5031–5069. [CrossRef]
41. Smith, P.G. Managing risk as product development schedules shrink. *Res. Technol. Manag.* **1999**, *42*, 25–32. [CrossRef]
42. Segismundo, A.; Miguel, P.A.C. Failure mode and effects analysis (FMEA) in the context of risk management in new product development. *Int. J. Qual. Reliab. Manag.* **2008**, *25*, 899–912. [CrossRef]
43. Unger, D.W.; Eppinger, S.D. Comparing product development processes and managing risk. *Int. J. Prod. Dev.* **2009**, *8*, 382–402. [CrossRef]
44. Keizer, J.A.; Halman, J.I.M.; Song, M. From experience: Applying the risk diagnosing methodology. *J. Prod. Innov. Manag.* **2002**, *19*, 213–232. [CrossRef]
45. Kim, Y.; Vonortas, N.S. Managing risk in the formative years: Evidence from young enterprises in Europe. *Technovation* **2014**, *34*, 454–465. [CrossRef]
46. Khan, O.; Christopher, M.; Burnes, B. The impact of product design on supply chain risk: A case study. *Int. J. Phys. Distrib. Logist. Manag.* **2008**, *38*, 412–432. [CrossRef]
47. Manuj, I.; Mentzer, J. Global supply chain risk management. *J. Bus. Logist.* **2008**, *29*, 133–155. [CrossRef]
48. Ritchie, B.; Marshall, D. *Business Risk Management*; Chapman & Hall: London, UK, 1993.
49. Kouvelis, P.; Chambers, C.; Wang, H. Supply chain management research and production and operations management: Review, trends, and opportunities. *Prod. Oper. Manag.* **2006**, *15*, 449–469. [CrossRef]
50. Leirvik, T. Interactive effects of economic, geopolitical, and climate risks on commodity volatility. *J. Commod. Mark.* **2025**, *40*, 100518. [CrossRef]
51. Xu, B.; Xiong, Q.; Zhou, P.; Ge, K.; Li, J. Shipping network ripple effect: Interactive propagation and impact of risk-failure. *Ocean Eng.* **2025**, *341*, 122622. [CrossRef]
52. Wiggins, A.; Crowston, K. From Conservation to Crowdsourcing: A Typology of Citizen Science. In Proceedings of the 2011 44th Hawaii International Conference on System Sciences, Kauai, HI, USA, 4–7 January 2011; IEEE: Piscataway, NJ, USA, 2011; pp. 1–10.
53. Wu, J.; Wu, Z. Integrated risk management and product innovation in China: The moderating role of board of directors. *Technovation* **2014**, *34*, 466–476. [CrossRef]
54. Song, Y.; Lee, D.; Lee, Y.; Chung, Y. Managing uncertainty and ambiguity in frontier R&D projects: A Korean case study. *J. Eng. Technol. Manag.* **2007**, *24*, 231–250. [CrossRef]
55. Brun, E.; Steinar Saetre, A.; Gjelsvik, M. Classification of ambiguity in new product development projects. *Eur. J. Innov. Manag.* **2009**, *12*, 62–85. [CrossRef]
56. Zsidisin, G.A.; Smith, M.E. Managing supply risk with early supplier involvement: A case study and research propositions. *J. Supply Chain Manag.* **2005**, *41*, 44–57. [CrossRef]
57. MacCormack, A.; Verganti, R. Managing the sources of uncertainty: Matching process and context in software development. *J. Prod. Innov. Manag.* **2003**, *20*, 217–232. [CrossRef]
58. Owens, J.D. Why do some UK SMEs still find the implementation of a new product development process problematical? An exploratory investigation. *Manag. Decis.* **2007**, *45*, 235–251. [CrossRef]
59. Buganza, T.; Dell'Era, C.; Verganti, R. Exploring the relationships between product development and environmental turbulence: The case of mobile TLC services. *J. Prod. Innov. Manag.* **2009**, *26*, 308–321. [CrossRef]
60. Barki, H.; Rivard, S.; Talbot, J. An integrative contingency model of software project risk management. *J. Manag. Inf. Syst.* **2001**, *17*, 37–69. [CrossRef]
61. Browning, T.R.; Deyst, J.J.; Eppinger, S.D.; Whitney, D.E. Adding value in product development by creating information and reducing risk. *IEEE Trans. Eng. Manag.* **2003**, *49*, 443–458. [CrossRef]
62. Freel, M.S. Barriers to product innovation in small manufacturing firms. *Int. Small Bus. J.* **2000**, *18*, 60–80. [CrossRef]
63. Hottenstein, M.P.; Dean, J.W. Managing risk in advanced manufacturing technology. In *Risk Management*; Routledge: Oxfordshire, UK, 2019; pp. 223–237.
64. Jerrard, R.N.; Barnes, N.; Reid, A. Design, risk and new product development in five small creative companies. *Int. J. Des.* **2008**, *2*, 21–30.
65. Jiang, J.J.; Klein, G.; Discenza, R. Information system success as impacted by risks and development strategies. *IEEE Trans. Eng. Manag.* **2002**, *48*, 46–55. [CrossRef]
66. Jiang, J.; Klein, G. Software development risks to project effectiveness. *J. Syst. Softw.* **2000**, *52*, 3–10. [CrossRef]
67. Kayis, B.; Zhou, M.; Savci, S.; Khoo, Y.B.; Ahmed, A.; Kusumo, R.; Rispler, A. IRMAS–development of a risk management tool for collaborative multi-site, multi-partner new product development projects. *J. Manuf. Technol. Manag.* **2007**, *18*, 387–414. [CrossRef]
68. Halman, J.I.M.; Keizer, J.A. Diagnosing risks in product-innovation projects. *Int. J. Proj. Manag.* **1994**, *12*, 75–80. [CrossRef]
69. Larson, N.; Kusiak, A. Managing design processes: A risk assessment approach. *IEEE Trans. Syst. Man Cybern. Part A Syst. Hum.* **1996**, *26*, 749–759. [CrossRef]

70. Millward, H.; Lewis, A. Barriers to successful new product development within small manufacturing companies. *J. Small Bus. Enterp. Dev.* **2005**, *12*, 379–394. [CrossRef]
71. Miorando, R.F.; Ribeiro, J.L.D.; Cortimiglia, M.N. An economic–probabilistic model for risk analysis in technological innovation projects. *Technovation* **2014**, *34*, 485–498. [CrossRef]
72. O'Connor, G.C.; Rice, M.P. A comprehensive model of uncertainty associated with radical innovation. *J. Prod. Innov. Manag.* **2013**, *30*, 2–18. [CrossRef]
73. Schmidt, R.; Lyytinen, K.; Keil, M.; Cule, P. Identifying software project risks: An international Delphi study. *J. Manag. Inf. Syst.* **2001**, *17*, 5–36. [CrossRef]
74. Song, M.; Montoya-Weiss, M. The effect of perceived technological uncertainty on Japanese new product development. *Acad. Manag. J.* **2001**, *44*, 61–80. [CrossRef]
75. Stockstrom, C.; Herstatt, C. Planning and uncertainty in new product development. *RD Manag.* **2008**, *38*, 480–490. [CrossRef]
76. Tang, C.S.; Zimmerman, J.D.; Nelson, J.I. Managing new product development and supply chain risks: The Boeing 787 case. *Supply Chain Forum Int. J.* **2009**, *10*, 74–86. [CrossRef]
77. Thamhain, H.J.; Skelton, T.M. Success factors for effective R&D risk management. *Int. J. Technol. Intell. Plan.* **2007**, *3*, 376–386. [CrossRef]
78. Van Thuyet, N.; Ogunlana, S.O.; Dey, P.K. Risk Management in Oil and Gas Construction Projects in Vietnam. In *Risk Management in Engineering and Construction*; Routledge: Oxfordshire, UK, 2019; pp. 225–247.
79. Nidumolu, S.R. Standardization, requirements uncertainty and software project performance. *Inf. Manag.* **1996**, *31*, 135–150. [CrossRef]
80. Bstieler, L. The moderating effect of environmental uncertainty on new product development and time efficiency. *J. Prod. Innov. Manag.* **2005**, *22*, 267–284. [CrossRef]
81. Floricel, S.; Ibanescu, M. Using R&D portfolio management to deal with dynamic risk. *RD Manag.* **2008**, *38*, 452–467.
82. Huang, S.; Han, W. Exploring the relationship between software project duration and risk exposure: A cluster analysis. *Inf. Manag.* **2008**, *45*, 175–182. [CrossRef]
83. Lee, R.P.; Johnson, J.L. Managing multiple facets of risk in new product alliances. *Decis. Sci.* **2010**, *41*, 271–300. [CrossRef]
84. Souder, W.E.; Bethay, D. The risk pyramid for new product development: An application to complex aerospace hardware. *J. Prod. Innov. Manag. Int. Publ. Prod. Dev. Manag. Assoc.* **1993**, *10*, 181–194. [CrossRef]
85. Stevens, E. Fuzzy front-end learning strategies: Exploration of a high-tech company. *Technovation* **2014**, *34*, 431–440. [CrossRef]
86. Yao, T.; Jiang, B.; Liu, H. Impact of economic and technical uncertainties on dynamic new product development. *IEEE Trans. Eng. Manag.* **2012**, *60*, 157–168. [CrossRef]
87. Wu, D.D.; Kefan, X.; Gang, C.; Ping, G. A risk analysis model in concurrent engineering product development. *Risk Anal. Int. J.* **2010**, *30*, 1440–1453. [CrossRef]
88. Ropponen, J.; Lyytinen, K. Components of software development risk: How to address them? A project manager survey. *IEEE Trans. Softw. Eng.* **2000**, *26*, 98–112. [CrossRef]
89. Wallace, L.; Keil, M.; Rai, A. Understanding software project risk: A cluster analysis. *Inf. Manag.* **2004**, *42*, 115–125. [CrossRef]
90. Adler, T.R.; Pittz, T.G.; Meredith, J. An analysis of risk sharing in strategic R&D and new product development projects. *Int. J. Proj. Manag.* **2016**, *34*, 914–922. [CrossRef]
91. Köhler, A.R.; Som, C. Risk preventative innovation strategies for emerging technologies the cases of nano-textiles and smart textiles. *Technovation* **2014**, *34*, 420–430. [CrossRef]
92. Santiago, L.P.; Bifano, T.G. Management of R&D projects under uncertainty: A multidimensional approach to managerial flexibility. *IEEE Trans. Eng. Manag.* **2005**, *52*, 269–280.
93. Moreira, A.C.; Ferreira, L.M.D.F.; Silva, P. A case study on FMEA-based improvement for managing new product development risk. *Int. J. Qual. Reliab. Manag.* **2021**, *38*, 1130–1148. [CrossRef]
94. Chauhan, A.S.; Nepal, B.; Soni, G.; Rathore, A.P.S. Taxonomy of new product development process risks: An empirical study of Indian automotive industry. *IEEE Trans. Eng. Manag.* **2020**, *69*, 1987–1998. [CrossRef]
95. Munck, J.C.; Tkotz, A.; Heidenreich, S.; Wald, A. The performance effects of management control instruments in different stages of new product development. *J. Account. Organ. Chang.* **2020**, *16*, 259–284. [CrossRef]
96. Tao, Y.; Yu, X.; Hughes, M. Learning from New Product Development Project Failure in High-Tech Firms: The Role of Risk Anticipation and the Underlying Mechanisms. *Entrep. Res. J.* **2025**, *15*, 699–723. [CrossRef]
97. Munthe, C.I.; Uppvall, L.; Engwall, M.; Dahlén, L. Dealing with the devil of deviation: Managing uncertainty during product development execution. *RD Manag.* **2014**, *44*, 203–216. [CrossRef]
98. Cooper, R.G. The AI transformation of product innovation. *Ind. Mark. Manag.* **2024**, *119*, 62–74. [CrossRef]
99. Thamhain, H. Managing risks in complex projects. *Proj. Manag. J.* **2013**, *44*, 20–35. [CrossRef]
100. Epstein, M.J.; Rejc, A. *The Reporting of Organizational Risks for Internal and External Decision Making*; CMA Canada: Toronto, ON, Canada, 2006.

101. Unger, D.; Eppinger, S. Improving product development process design: A method for managing information flows, risks, and iterations. *J. Eng. Des.* **2011**, *22*, 689–699. [CrossRef]
102. Tang, C.; Tomlin, B. The power of flexibility for mitigating supply chain risks. *Int. J. Prod. Econ.* **2008**, *116*, 12–27. [CrossRef]
103. Marzi, G.; Ciampi, F.; Dalli, D.; Dabic, M. New product development during the last ten years: The ongoing debate and future avenues. *IEEE Trans. Eng. Manag.* **2020**, *68*, 330–344. [CrossRef]
104. Trkman, P.; McCormack, K. Supply chain risk in turbulent environments—A conceptual model for managing supply chain network risk. *Int. J. Prod. Econ.* **2009**, *119*, 247–258. [CrossRef]
105. Ritchie, B.; Brindley, C. Supply chain risk management and performance: A guiding framework for future development. *Int. J. Oper. Prod. Manag.* **2007**, *27*, 303–322. [CrossRef]
106. Candi, M.; Van Den Ende, J.; Gemser, G. Organizing innovation projects under technological turbulence. *Technovation* **2013**, *33*, 133–141. [CrossRef]
107. Bennett, N.; Lemoine, G.J. What a difference a word makes: Understanding threats to performance in a VUCA world. *Bus. Horiz.* **2014**, *57*, 311–317. [CrossRef]
108. McCarthy, I.P.; Lawrence, T.B.; Wixted, B.; Gordon, B.R. A multidimensional conceptualization of environmental velocity. *Acad. Manag. Rev.* **2010**, *35*, 604–626.
109. Tamburri, D.A.; Palomba, F.; Kazman, R. Success and failure in software engineering: A followup systematic literature review. *IEEE Trans. Eng. Manag.* **2020**, *68*, 599–611. [CrossRef]

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