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Review

Innovation management in the defense sector: A systematic literature review focusing on developing countries

Romullo Girardi

Military Institute of Engineering (IME), Rio de Janeiro 22290-270, Brazil; romullogirardi@ime.eb.br

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Abstract: Innovation management is an organizational iterative process of seeking and selecting new opportunities and ideas, implementing them, and capturing value from the results obtained. In the defense sector, due to the increasing interdependence between military capabilities and technology, countries have adopted innovation management approaches to drive the modernization of their defense industrial bases, promoting the development and integration of advanced technologies. This study presents an original systematic literature review on innovation management approaches applied to defense in developing countries. After the phases of identification and screening, 62 documents both from academic and gray literature were analyzed and categorized into 22 distinct approaches. The advantages, disadvantages, contexts, and potential applications of each approach were discussed. The findings show that the appropriate use of these approaches can strengthen the innovation capacity and technological independence of late-industrializing countries, consolidating their position in the global defense landscape and ensuring their sovereignty and continuous technological progress.

Keywords: innovation; innovation management; defense; developing countries

1. Introduction

Innovation management is an organizational iterative process of seeking and selecting new opportunities and ideas, implementing them, and capturing value from the results (Tidd and Bessant, 2020). This process includes identifying innovation opportunities, assessing their potential, and deciding which strategies to implement (Schilling, 2013). Amid the rapidly evolving technological landscape and rising competitiveness in global markets, cultivating a culture of innovation has become essential for technology-driven organizations (Drucker, 1985).

In the defense sector, given the growing dependency between military capabilities and technology, innovation management models have been sought to optimize processes for acquiring military systems and materials (França Junior and Galdino, 2022). These acquisition processes, whether by purchase or R&D (Research and Development), involve Complex Products and Systems (CoPS), generally characterized by the need for customization of components and subsystems, production in small quantities by a few integrating companies, aggregation of various areas of knowledge, and a lifecycle that lasts for decades (Hobday, 1998).

Given these characteristics, countries have established approaches to support the development of their defense technological capabilities. Some examples of these approaches include innovation management models (Chesbrough, 2003; Etzkowitz and Zhou, 2017), capability-based strategic planning (United Kingdom, 2022; United States, 2018), lifecycle management models (Blanchard and Fabrycky, 2011;

INCOSE, 2023; ISO, 2023), technology readiness assessment procedures based on maturity scales (TRL, IRL, MRL, etc.) (Mankins, 2009; Sauser et al., 2010; United States, 2016, 2020b), multicriteria decision support methods (Girardi et al., 2022; Hwang and Yoon, 1981; Saaty, 1980), technological forecasting and criticality analysis tools (Altuntas et al., 2015; Girardi and França Junior, et al., 2024; Lakemond and Holmberg, 2022; Magistretti et al., 2020), and strategies for protecting/exploiting knowledge through intellectual property assets (Grimaldi et al., 2015; Saksupapchon and Willoughby, 2019).

The current scenario for the implementation of these approaches is prevalent in developed countries, where acquiring defense technological capabilities is predominantly undertaken in partnership with advanced national industrial bases and structured national and sectoral innovation systems (Briones-Peñalver et al., 2020; Granstrand and Sjölander, 1990; Mankins, 2002; Reed and Walsh, 2002).

In developing countries, where high-tech demands often are not met internally (Amann, 2002; Figueiredo, 2009), there is a lack of essential knowledge to develop critical and sensitive technologies, the presence of a modest defense industrial base, and dependency on imported armaments, equipment, and military systems (Galdino and Schons, 2022). This high technological dependency can become a chronic problem (Gu, 1999; Niosi and Zhegu, 2010), especially in the defense sector due to technological restrictions (Longo and Moreira, 2009; Moreira, 2013).

In this sense, within the Armed Forces of late-industrializing countries, there is an urgent need to customize and harmonize established approaches to reconcile short-, medium-, and long-term strategies in developing defense technological capabilities (França Junior and Galdino, 2022).

Aligned with this perception, this manuscript aims to present an original systematic literature review to understand the state of the art related to the application of innovation management approaches in the defense sector, focusing on developing countries. The review brings relevant contributions because it not only addresses a gap in the extant literature but also serves as a guide for improving innovation capability and advancing technological independence in late-industrializing economies. Through a deliberate focus on innovation management, these countries can enhance their stance in the global defense arena, ensuring their sovereignty and ongoing technological advancement.

The rest of the article is organized as follows. Section 2 details the methodological aspects used in the research. Section 3 presents the results obtained in the review. Section 4 discusses the results and drives a comparative analysis between the studied approaches. Finally, Section 5 raises the final considerations.

2. Materials and methods

For the search of documents in this review, both academic and gray literature were consulted, as suggested by Thomé et al. (2016). Initially, the following strategies were outlined for the search in academic literature:

Databases: Scopus and Web of Science (WoS) (Ferreira et al., 2020).

Search String: The search string consisted of combining three blocks of terms related to innovation management, developing countries, and the defense sector.

Firstly, the block of synonyms related to innovation management was composed of the following expressions identified in the literature: “innovation management”, “management of innovation”, “managing innovation”, “management of technological innovation”, “managing technological innovation”, “technology management”, “management of technology”, and “managing technology”. Secondly, the block of synonyms related to developing countries was composed of the following expressions identified in the literature: “late industrialization”, “recent industrialization”, “developing countr”, “developing nation”, “developing econom”, “emerging countr”, “emerging nation”, “emerging econom” or “BRICS”. Finally, the block related to the defense sector required a more complex assembly strategy, considering that this sector is dual (Girardi et al., 2024) and its approaches in the literature are often embedded in studies more related to civilian applications, making their identification difficult. Thus, terms related to the defense sector, aerospace, and CoPS industries were added.

Terms related to the defense sector: “military”, “defense”, “defence”, “navy”, “army”, and “air force”.

Terms related to aerospace: “aerospace”, “aeronautic”, “astronautic”, and “avionics”. It is worth noting that terms related to aerospace were incorporated into the defense scope because some countries treat the two topics as a single strategic theme. The United States, for example, already has the U.S. Space Force subordinate to its Department of Defense (United States, 2020a).

Terms related to CoPS industries (adapted from Hobday (1998, p. 697)): “air-traffic”, “aircraft”, “armoured vehicle”, “avionics”, “airport”, “automation”, “communication”, “battleship”, “bridge”, “network”, “chemical”, “clear room”, “semiconductor”, “turbine”, “cruise”, “dam”, “dock”, “harbour”, “control system”, “electronic”, “manufactur”, “simulator”, “frigate”, “missile”, “rocket”, “helicopter”, “train”, “hovercraft”, “integrated system”, “intelligent building”, “intelligent warehouse”, “jet”, “computer”, “maritime”, “ship”, “nuclear”, “oil and gas”, “oil and gas”, “oands”, “boat”, “radio”, “automobile”, “rail”, “road”, “robotics”, “roller coaster”, “runway”, “satellite”, “sewage”, “space”, “observatorie”, “station”, “bomber”, “submarine”, “supercomputer”, “superserver”, “accelerator”, “tank”, “telecommunication”, “water”, and “yacht”.

Time frame: As the goal of the review is to understand the state of the art of the research area, documents published in the last five years were considered, that is, from the beginning of 2018 until April 25, 2023 (the date on which the publications were obtained from the databases).

Inclusion criteria: Articles written in Portuguese, English, or Spanish were adopted, and the full availability of the article was a requirement. Additionally, the publication should explicitly address the application of innovation management approaches in the defense sector of developing countries.

The search in the academic literature returned 85 documents from the Scopus database and 68 from the WoS database. After analyzing the documents, 46 redundancies were identified. After removing them, 107 documents remained. Subsequently, it was found that 72 articles did not meet the inclusion criteria, leaving 35 documents within the scope of the review.

After this initial search, the snowball technique was used to identify relevant documents that either cite or are cited by the selected publications. Works by the

authors of the selected publications were also sought. This technique yielded 18 additional documents. It is noteworthy that the snowballed documents may have publication dates later than those of the documents initially retrieved from the Scopus and WoS databases.

In addition to the research in academic literature, searches were also conducted in thesis and dissertation databases and websites of defense management government agencies, through which 9 more documents were identified.

Thus, a total of 62 documents were selected for the review. It is worth noting that no works similar to this paper were found during the research. The stages of the systematic literature review are summarized in **Figure 1**, using the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) diagram, a tool for presenting the flow of information through the different phases of a systematic literature review (Page et al., 2021).

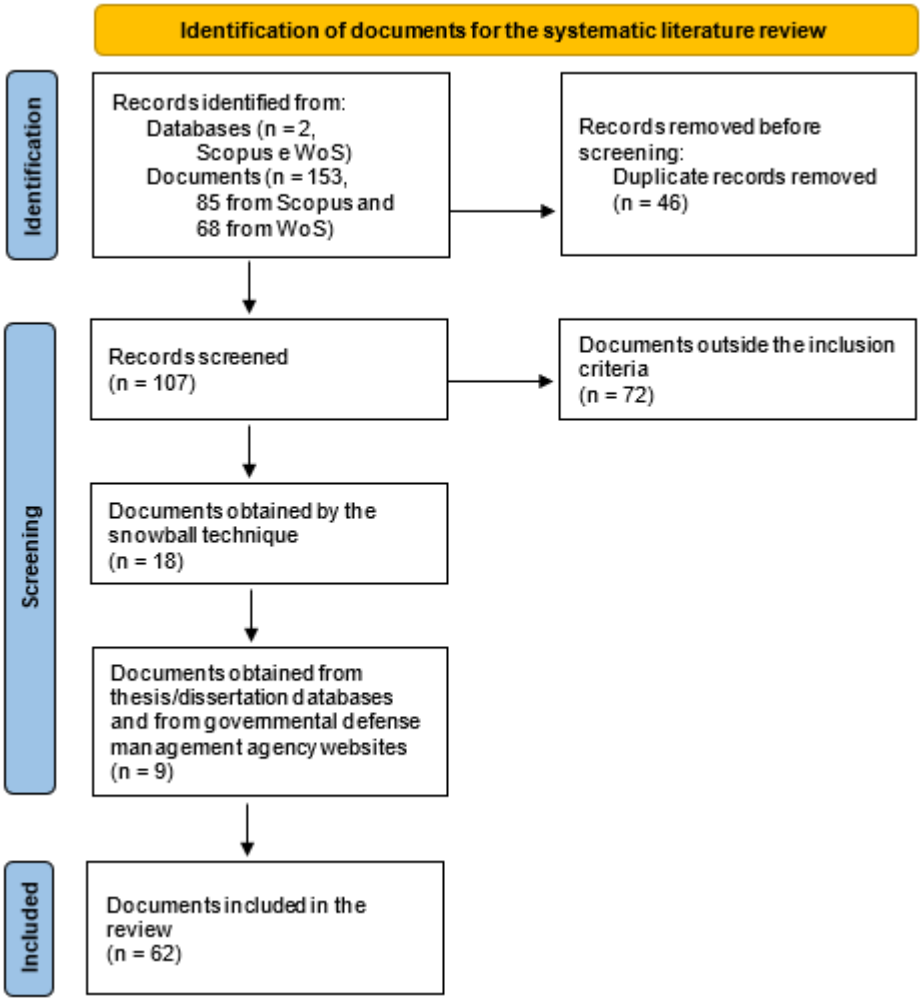

Figure 1. Stages of the systematic literature review.

Source: Adapted from Page et al. (2021).

3. Results

After analyzing the 62 documents selected for the review, they are categorized into the 22 innovation management approaches identified by Girardi (2024). The following sections present how the studies employed the approaches in their specific

contexts. It is noteworthy that the approaches are listed in descending order based on the number of associated documents.

3.1. Dynamic capabilities theory

The dynamic capabilities theory suggests that a firm's long-term success hinges on its adaptability and capacity to evolve new capabilities in response to environmental shifts (Teece et al., 1997). The following reviewed documents employed this approach.

Pandit et al. (2018) studied dynamic capabilities' effect on India's industrial disruptive innovation emergence. Kuo et al. (2018) showcased Acer's rise from an imitator to an innovator using this theory. Fakhreddin et al. (2021, 2022) employed it to assess Iranian firms' innovative product launches. Valdez-Juárez et al. (2023) showed Mexico's digital shift boosting innovation management through dynamic capabilities. Henao-Garcia et al. (2023) suggested that Colombian industries could improve by applying the theory to split managerial and technological innovation. Lastly, Ettlie et al. (2023) contrasted dynamic capabilities' impact on technological innovation in China and the USA.

3.2. Multicriteria decision support

Multi-Criteria Decision-Making (MCDM) employs mathematical and analytical tools to evaluate, rank, and choose among alternatives based on multiple criteria in complex decision-making scenarios (Hwang and Yoon, 1981). The following reviewed documents employed this approach.

Gupta et al. (2020) employed MCDM to rank innovation management barriers in India's industry. Madeu (2019) presented an MCDM-based technological forecast in the Brazilian defense context. Mathiyazhagan et al. (2021) prioritized Indian agile industrial practices through MCDM support. Girardi et al. (2022) found AHP (Analytic Hierarchy Process) as the prevalent MCDM method in defense lifecycle management. Erbay and Yildirim (2022) crafted an MCDM framework for digital transformation in developing economies, exemplified by a Turkish case study. Abdallah et al. (2022) pinpointed key digital transformation phases in developing nations via MCDM and expert consultation. Lastly, Girardi and dos Santos (2023) assessed Brazilian Army technologies using a hybrid MCDM method and patent analysis.

3.3. Knowledge management

Knowledge management orchestrates the capturing, distributing, and effectively using knowledge to enhance organizational performance and competitiveness through strategic processes and integrated technologies (Nonaka, 1994). The following reviewed documents employed this approach.

Alves et al. (2018) detailed the case of the Brazilian Army's Innovation Management Agency in the development of a framework for implementing knowledge management in large-scale organizations. Blanco et al. (2018) analyzed knowledge absorption's effect on Colombian organizations' innovation. Mamphiswana and Sinha (2019) embedded knowledge management in South Africa's strategies for the

industrial revolution. Wu and Li (2020) linked knowledge management to supply chain advancements in Chinese tech firms. Rico-Bautista et al. (2022) tied cloud computing to knowledge management improvements in Colombia and India. Lastly, Erena et al. (2023) affirmed the role of knowledge management in enhancing Ethiopian companies' innovation.

3.4. Triple helix

The triple helix is a framework for understanding the interactions and relationships among academia, industry, and government in the knowledge-based economy (Etzkowitz and Leydesdorff, 1995). The following reviewed documents employed this approach.

Shuguang et al. (2021) explored Triple Helix-driven collaborative innovation to enhance China's innovation system. Chang et al. (2021) analyzed Taiwan's university-led Triple Helix interactions. Girardi and Passos (2022) suggested Triple Helix-based strategies for the Brazilian Army's corporate university. Kleiner-Schaefer and Schaefer (2022) emphasized the role of university technology transfer offices in fostering Triple Helix collaborations in emerging markets. Goulart (2022) linked Brazilian defense investment with advanced technology sectors and knowledge-intensive services growth. Lastly, Pereira (2022) discussed the Brazilian Army's role in developing innovation ecosystems via institutional projects.

3.5. Digital transformation

Digital transformation redefines business by integrating digital technologies like AI, data analytics, cloud computing, and IoT to revamp operations, models, and customer engagement for enhanced performance (McQuivey, 2013). The following reviewed documents employed this approach.

Bataev (2018) presented a comparative study between organizations in Russia and other countries (especially BRICS) to analyze the dynamics of digital transformation implementation. Kayabay et al. (2022) outlined a Turkish digital transformation roadmap for tech organizations. Huang et al. (2022) investigated the impact of China's digital policy on regional innovation. Erbay and Yildirim (2022) developed a Turkish digital technology selection model. Abdallah et al. (2022) pinpointed key stages of digital transformation in Egyptian firms. Lastly, Valdez-Juárez et al. (2023) showed how digital transformation enhances Mexican firms' innovation management.

3.6. Technology transfer

Technology transfer involves the transmission of knowledge and technology from one organization to another, intending to improve the recipient organization's ability to innovate, produce, and compete in the market (Reddy and Zhao, 1990). The following reviewed documents employed this approach.

Huang et al. (2022) evaluated how China's entrepreneurship policies, including technology transfer, influence regional innovation. Kleiner-Schaefer and Schaefer (2022) emphasized the role of university technology transfer in fostering industry-academia collaborations in emerging economies. Nguyen et al. (2022) affirmed

technology transfer's benefits for Vietnamese firms' competitiveness and efficiency. Brites (2022) illustrated technology transfer's pivotal role in Brazilian defense innovation via the FX-2/GRIPEN NG program. Lastly, Kalko et al. (2023) surveyed Ethiopian firms, confirming technology transfer's positive effect on innovation metrics.

3.7. Systems engineering

Systems engineering is an integrative discipline combining engineering and management to design and oversee complex systems across their lifecycles, addressing technical, organizational, and human factors for optimal functionality (Blanchard and Fabrycky, 1981). The following reviewed documents employed this approach.

The Indian "Defence Acquisition Procedure" established specific life cycles for different forms of systems acquisition (India, 2020). The Brazilian Ministry of Defense also established a best practices manual for the lifecycle management of defense systems (Brasil, 2020). Esquia (2021) assessed lifecycle management to bolster Brazil's defense sector. Girardi et al. (2022) analyzed decision-support tools in defense systems' lifecycle management. Letaba and Pretorius (2022) developed a technology roadmapping framework for R&D in late-industrializing countries, merging technology roadmapping with systems engineering concepts. Lastly, Zhang et al. (2023, 2024) proposed Chinese research approaches to optimize predictive maintenance in the lifecycle management of systems.

3.8. Technology maturity models

Technology maturity models are used to assess the degree of technological maturity or readiness of a particular technology in R&D projects (Mankins, 1995). The following reviewed documents employed this approach.

Lezama-Nicolás et al. (2018) assessed technological maturity using the BIMATEM bibliometric method in innovation management. Xavier et al. (2020) created the IMATEC, a Brazilian Space Agency tool measuring maturity with TRL (Technology Readiness Levels). Ferreira et al. (2021) merged MRL, DFMA, and TRL tools to validate a product innovation model in Brazil. Girardi et al. (2022) described the process of developing a customized TRL scale for the Brazilian Army's technology management. Lermen et al. (2023) gauged agile methods' efficacy in Brazilian startups, incorporating stage-gate and maturity concepts. Lastly, Voltan et al. (2024) reviewed and classified the existing approaches in the literature for the execution of technology readiness assessment based on the TRL scale.

3.9. Open innovation

The concept of open innovation suggests that firms should use both internal and external sources of knowledge to develop new products and services (Chesbrough, 2003). The following reviewed documents employed this approach.

Cepeda and Arias-Pérez (2019) explored how open innovation influences IT resources and organizational agility in a South American multinational. Allahar (2019) found open innovation pivotal for competitive advantage in Caribbean businesses. Baierle et al. (2020) examined the impact of open innovation on Brazilian defense

firms' competitiveness. Lastly, Pereira (2022) linked open innovation with military R&D and innovation ecosystems in Brazil.

3.10. Technology roadmapping

Technology roadmapping is a strategic planning method used to align technology development with business objectives and market needs (Phaal et al., 2004). The following reviewed documents employed this approach.

The Indian "Defence Acquisition Procedure" aligns military procurement with "Make in India" strategic technology roadmaps, promoting indigenous capability (India, 2020). Since 1953, China has strategically employed technology roadmapping. Its 14th Five-Year Plan marks a decisive pivot, with the government's emphasis on evolving from imitation to spearheading global innovation leadership (IEDI, 2021). Kayabay et al. (2022) detailed a Turkish digital transformation roadmapping framework for tech firms. Lastly, Letaba and Pretorius (2022) crafted a roadmapping framework integrating systems engineering for R&D in developing nations.

3.11. Agile approach

The agile approach values communication, collaboration, flexibility, and adaptation to change. The focus is on the rapid and continuous delivery of high-quality functional solutions, with constant customer feedback to guide product evolution (Beck et al., 2001). The following reviewed documents employed this approach.

Abdallah et al. (2021) confirmed agile management's benefits in Jordan's industry, while Mathiyazhagan et al. (2021) ranked agile practices for India's industrial sector. Kayabay et al. (2022) proposed an agile-based roadmapping framework for Turkey's tech transformation. Lastly, Lermen et al. (2023) examined agile methods within Brazilian startups, considering the stage-gate model and technological maturity.

3.12. Absorptive capacity theory

The absorptive capacity theory refers to a firm's ability to acquire, assimilate, transform, and exploit external knowledge (Cohen and Levinthal, 1990). The following reviewed documents employed this approach.

Blanco et al. (2018) examined how Colombia's technological capabilities and innovation correlate through absorptive capacity. Queiroz et al. (2023) assessed Colombian firms using an absorptive capacity model. Lastly, Kalko et al. (2023) linked absorptive capacity with innovation gains in Ethiopian companies.

3.13. Technological forecasting

Technological forecasting is a process of predicting the future development of technology and its impacts on various fields, such as business, economics, and society (Coates, 1985). The following reviewed documents employed this approach.

Hafezi et al. (2018) detailed the historical Iran's use of technology forecasting to foster a long-term development culture. Madeu (2019) validated a quantitative technology forecasting method with Brazilian defense sector case studies. Lastly, Girardi and dos Santos (2023) evaluated Brazilian Army technology prospects using

MCDM and patent analysis.

3.14. Technological criticality

Technological criticality is a process of identifying Critical and Emerging Technologies (CETs). CETs are a subset of strategically significant advanced technologies for a country or organization (United States, 2022). The following reviewed documents employed this approach.

Christensen et al. (2018) introduced a risk framework for critical technologies in developing nations. India (2020) showcased efforts to refine technological criticality concepts, aligning defense acquisitions with the "Make in India" slogan to build national tech capacity. Concurrently, China's 14th Five-Year Plan charts a strategic course towards becoming a global innovation hub, focusing on indigenous development of critical technologies (IEDI, 2021). Lastly, Girardi et al. (2024) presented concepts and criteria related to technological criticality in the defense sector based on a case study of the Brazilian Army.

3.15. Intellectual property-based management

Intellectual property (IP)-based management is an approach to managing organizations and businesses that places a strong emphasis on the management and exploitation of IP assets, such as patents, trademarks, and copyrights (Pisano, 2006). The following reviewed documents employed this approach.

Santos et al. (2020) suggested a model merging agile methods and IP utilization to enhance high-tech product development in late-industrializing nations. Lastly, Madeu (2019) and Girardi and dos Santos (2023) presented IP-based management methods focusing on Brazil's defense sector.

3.16. Resource-based theory

The resource-based theory suggests that a firm's resources and capabilities are the key determinants of its ability to innovate and succeed in the market (Barney, 1991). The following reviewed documents employed this approach.

Soewarno and Tjahjadi (2020) showed that Indonesian firms gain a competitive edge by fusing innovation strategies with sustainable improvements, drawing on resource-based theory. Lastly, Fakhreddin et al. (2021, 2022) examined how such resource-based theory underpins Iran's industrial base's capacity for innovation.

3.17. Stage-gate model

The stage-gate model is a structured process for managing new product development, which involves dividing the development process into stages and using gates to evaluate progress and make go/no-go decisions (Cooper, 1993). The following reviewed documents employed this approach.

Robles (2018) confirmed the effectiveness of stage-gate management control systems for tech product development in Mexico. Lermen et al. (2023) surveyed startups incubated at a Brazilian university to assess the use of agile methods in light of the stage-gate model concepts and technological maturity. Lastly, Girardi et al. (2024) presented a comprehensive review of the initial phase of the innovation process

in defense, based on seminal front end of innovation models. The stage-gate model is one of these seminal models, and developing countries are included in the analysis.

3.18. Value chain analysis

Value chain analysis is a business management tool used to analyze and evaluate the various activities and processes involved in delivering a product or service to customers. It involves identifying the different stages of the value chain (Porter, 1985). The following reviewed documents employed this approach.

Allahar (2019) identified the integration of open innovation into Caribbean firms' value chain as key to competitive advantage. Lastly, Erbay and Yildirim (2022) tested a technology selection model using value chain analysis on a Turkish industrial firm.

3.19. Project management

Project management is the practice of initiating, planning, executing, controlling, and closing projects to achieve specific goals and meet specific success criteria (Atkinson, 1999). The following reviewed documents employed this approach.

Midler (2019) explored the boost in innovation performance from evolving project management in multinationals' decentralized branches in developing nations. Lastly, Ul Haq et al. (2019) confirmed the benefits of such practices in Pakistani tech organizations.

3.20. Business incubation

Business incubation is a process of supporting the development and growth of new technology-based firms by providing resources, facilities, and expertise to help them overcome the challenges of early-stage development (Allen, 1988). The following reviewed documents employed this approach.

Chege and Wang (2020) conducted research with organizations in Kenya to demonstrate the positive impact of an innovation environment driven by training programs and business incubation. Lastly, Lermen et al. (2023) surveyed startups incubated at a Brazilian university to assess the use of agile methods in light of the stage-gate model concepts and technological maturity.

3.21. Diffusion of innovation theory

The diffusion of innovation theory explains how new products and ideas spread through society and how they are adopted by individuals and organizations (Rogers, 1962). Within the universe of documents reviewed, this approach was employed by Teh et al. (2021). The authors conducted research with organizations from the Malaysian industrial base to assess these companies' energy transition based on the diffusion of innovation theory.

3.22. Disruptive innovation theory

The disruptive innovation theory describes how new entrants disrupt established industries by introducing simpler, more affordable products that meet the needs of underserved customers (Christensen, 1997). In the universe of documents reviewed, the disruptive innovation theory was employed by Pandit et al. (2018). The authors

investigated how dynamic capabilities act in the manifestation of disruptive innovations in the context of the Indian industrial base.

4. Discussion

Following the presentation of the review results, a deeper exploration of the key findings and considerations identified throughout the study is necessary.

4.1. Synthetic diagnosis of the results

After reviewing innovation management approaches applied to defense in developing countries, **Table 1** summarizes a comparative analysis of the advantages, disadvantages, context, and potential application of each approach.

Table 1. Comparative analysis of innovation management approaches in the defense sector of developing countries.

Innovation management approach	Advantages	Disadvantages	Context of application	Potential of application in the defense sector of developing countries
Dynamic capabilities theory	Emphasizes the need for internal capabilities to adapt and reconfigure resources in response to technological changes and threats, enhancing competitive advantage	Demands a culture of continuous learning and rapid adaptation, which may be challenging to establish	Applied in dynamic and technologically advanced industries to maintain operational readiness and innovation	Can strengthen internal innovation processes and reduce dependency on external technologies, crucial for the defense sector of developing countries
Multicriteria decision support	Considers multiple criteria for evaluating and selecting suitable options	Can be complex and require extensive data collection	Decision-making in science, technology, and innovation projects	Use specific criteria to prioritize and select projects with high national defense impact potential
Knowledge management	Facilitates the efficient creation, sharing, and use of organizational knowledge	May encounter cultural resistance and lack of teamwork	Organizations with vast knowledge bases and high reliance on innovation	Establish processes to capture, store, and transfer specialized technical knowledge within the defense industry
Triple helix	Encourages collaboration among government, industry, and academia	Requires coordination and interest alignment among stakeholders	Contexts where interaction between different sectors is crucial for technological progress	Establish strategic partnerships between government, defense firms, and academic institutions
Digital transformation	Increases operational efficiency, agility, and market adaptability	May require significant investments in infrastructure and training	Organizations aiming to adapt to the digital age and explore new tech opportunities	Implement advanced digital technologies in defense processes, like automation, real-time data analytics, and AI, for operational efficiency and decision-making
Technology transfer	Allows quick acquisition of external technology and knowledge	Can lead to over-reliance on foreign technology	Industries seeking rapid adoption of new technologies	Acquire ready-to-use foreign technology and adapt it to national defense needs
Systems engineering	Systematic approach to complex systems design, implementation, and management	Requires specialized engineering knowledge and system integration	Development of complex and integrated systems	Apply systems engineering principles to the design and development of military systems and defense infrastructure
Technology maturity models	Provides a framework to assess technological maturity and identify development gaps	May require significant resources to implement and maintain	Organizations wanting to assess tech status and identify improvement areas	Use technology maturity models to assess the readiness of existing defense capabilities and identify areas for improvement
Open innovation	Access to external knowledge, resources, and ideas through partnerships and collaboration	Requires an open organizational culture and external partnership management	Sectors where external collaboration is valued and promoted	Form strategic partnerships with high-tech firms, research institutions, and startups for developing innovative defense solutions
Technology roadmapping	Plans and directs technological development in a structured, goal-oriented manner	Can be affected by uncertainties and shifts in the tech environment	Organizations aiming to align innovation strategy with technological development	Develop a strategic technology roadmap for defense, identifying key technologies and setting milestones to monitor progress

Table 1. (*Continued*).

Innovation management approach	Advantages	Disadvantages	Context of application	Potential of application in the defense sector of developing countries
Agile approach	Promotes flexibility, adaptability, and rapid iteration in product and project development	May require cultural and organizational change to adapt to agile principles	Innovation projects with volatile requirements and demands	Adopt agile project management and product development methods to accelerate defense innovation with rapid adaptability and iterative delivery
Absorptive capacity theory	Focuses on an organization's ability to acquire, assimilate, and apply external knowledge	May require a learning curve and internal adjustment to incorporate new knowledge	Organizations looking to enhance their ability to absorb external knowledge and technologies	Develop internal training programs to improve the absorption of external knowledge and promote strategic technology transfer partnerships
Technological forecasting	Identifies and monitors emerging trends and technologies to anticipate future opportunities and challenges	Can be affected by the uncertainty and imprecision of technological forecasting	Sectors subject to rapid and disruptive changes	Conduct tech trend analyses to identify key defense investment and research areas, anticipate emerging threats, and identify technological opportunities for enhancing national security and capacity
Technological criticality	Identifies the strategic importance and potential impact of specific technologies	Can be affected by uncertainties in technology assessment and future significance	Organizations aiming to prioritize innovation efforts on critical technologies	Conduct comprehensive analyses of existing and emerging technologies in defense, identifying those critical to security and operational capability
Intellectual property-based management	Protects, manages, and monetizes intangible assets like patents and trade secrets	May require significant legal and bureaucratic resources to protect and manage IP	Organizations with strong IP portfolios and innovations	Establish an IP management strategy to protect and maximize the value of intangible assets developed in the defense industry, including technology licensing and collaboration opportunities
Resource-based theory	Emphasizes the role of internal resources like knowledge, skills, and assets in gaining competitive advantage	Requires accurate assessment of internal resources and their innovation leverage potential	Organizations aiming to identify, develop, and leverage internal resources for innovation	Identify and utilize internal resources such as talent, tech capabilities, and strategic assets in the defense industry to foster innovation and develop advanced technological solutions
Stage-gate model	Offers a structured process with well-defined steps for evaluating and advancing innovation projects	Can result in a bureaucratic and time-consuming process if not managed efficiently	Organizations wanting a systematic, results-oriented approach to manage innovation project flow	Implement a stage-gate model to assess and prioritize defense innovation projects, ensuring only promising projects move forward, minimizing risks and maximizing invested resources

Table 1. (*Continued*).

Innovation management approach	Advantages	Disadvantages	Context of application	Potential of application in the defense sector of developing countries
Value chain analysis	Evaluates all activities in product or service delivery, identifying improvement and innovation opportunities	Requires detailed analysis of value chain activities	Organizations aiming to optimize operations and identify innovation opportunities across the value chain	Analyze and optimize the defense industry value chain, identifying improvement and innovation areas that can increase efficiency, quality, and responsiveness
Project management	Provides a structured approach for planning, executing, and monitoring innovation projects	Requires advanced project management skills and team coordination	Innovation projects involving new products, technologies, or services	Implement project management techniques for technological innovation initiatives in defense, ensuring projects are completed on time, within budget, and with expected outcomes
Bussiness incubation	Provides a nurturing environment and support for developing and validating innovative ideas	May require significant investment in resources and infrastructure to establish and maintain an incubation program	Entrepreneurs and startups seeking support in developing their ideas and technologies	Establish defense-focused tech incubators offering support, resources, and guidance for startups and entrepreneurs to develop innovative solutions for defense sector needs
Diffusion of innovation theory	Analyzes the process of innovation adoption and diffusion within an organization or society	May encounter resistance to change and difficulties in acceptance and adoption of new innovations	Organizations interested in understanding how innovations are adopted and spread in a specific environment	Analyze the diffusion and adoption of technologies and innovations in the defense industry, identifying key factors influencing acceptance and successful implementation. This can assist in devising effective implementation and communication strategies to promote the adoption of technological innovations in the defense sector
Disruptive innovation theory	Identifies and analyzes the occurrence of disruptive innovations that have the potential to transform existing markets and sectors	It can be challenging to predict the magnitude and impact of disruptive innovations	Sectors where technological disruption is a concern, and organizations looking to identify and respond to threats and opportunities arising from disruptive innovations	Identify disruptive technologies and innovations that may impact the defense industry, analyze their strategic implications, and develop strategies to leverage opportunities and mitigate associated risks. This may involve creating R&D programs targeted at disruptive technologies, as well as collaborating with innovative startups to explore new solutions

4.2. Contributions

This study offers significant contributions both to the academic literature and to practical applications in the field of innovation management in the defense sector of developing countries.

For the literature, this study provides an original and comprehensive systematic review of 62 documents, identifying and categorizing 22 distinct innovation management approaches. This review offers valuable insights into their advantages, disadvantages, contexts, and potential applications. Additionally, the study develops a framework for analyzing and comparing different innovation management approaches, facilitating future research and scholarly inquiry in the defense sector.

Regarding practical applications, the study offers actionable recommendations for policymakers and defense strategists in developing countries to enhance their innovation capabilities and seek technological independence. It provides strategic insights into the application of various innovation management approaches, helping defense organizations make informed decisions about which strategies to implement. Furthermore, the study serves as a guide for developing tailored innovation management policies that consider the unique industrial, socio-economic, and technological circumstances of these nations.

4.3. Limitations

This study has several limitations that should be acknowledged, particularly concerning data sources and the volatile context of the defense sector. Firstly, the academic databases used were limited to Scopus and WoS, which may exclude relevant studies from other databases and potentially overlook significant research contributions. Secondly, the grey literature relied heavily on the availability of documents from government agencies in developing countries. This dependency on publicly accessible documents might result in gaps or biases, as not all pertinent information may be readily available or disclosed by these agencies. Additionally, the rapidly changing technological and geopolitical contexts in the defense sector can impact the relevance and applicability of the findings over time. These limitations underscore the need for cautious interpretation and the potential for future research to address these gaps by incorporating a broader range of data sources and considering the dynamic nature of the field.

4.4. Future research

Future research should address several areas to build on the findings of this study. Firstly, conducting longitudinal studies to track the impact of different innovation management approaches over time in the defense sector of developing countries would provide valuable insights into their long-term effectiveness. Additionally, detailed case studies of specific countries or defense projects could offer deeper insights and practical examples of successful innovation management. Given the limitations related to data sources, future research should strive to incorporate a broader range of databases beyond Scopus and WoS and seek alternative sources of grey literature to ensure a more comprehensive analysis. Finally, investigating the impact of emerging technologies, such as artificial intelligence and cybersecurity, will be crucial to

understanding how these advancements can be leveraged for strategic advantage. By addressing these areas, future research can provide a more robust understanding of innovation management in the defense sector of developing countries and contribute to the implementation of more effective and adaptable strategies.

5. Conclusion

This study investigated the application of innovation management approaches in the defense sector of developing countries through a systematic literature review. By analyzing 62 documents, it identified 22 distinct innovation management approaches, highlighting their advantages, disadvantages, contexts, and potential applications. These findings are crucial for defense policymakers and strategists in developing countries, providing a roadmap for enhancing innovation capabilities and seeking technological independence.

However, the study has limitations, particularly concerning the scope of data sources. The reliance on Scopus and WoS may have excluded significant research from other databases, and the availability of grey literature from government agencies in developing countries was limited. Additionally, the rapidly changing technological and geopolitical contexts in the defense sector can impact the relevance and applicability of the findings over time.

Future research should conduct longitudinal studies and detailed case studies to provide deeper insights into the long-term effectiveness and practical applications of innovation management approaches. Expanding the range of data sources and investigating the impact of emerging technologies will also be crucial. By addressing these areas, future research can provide a more comprehensive understanding and contribute to the development of more effective strategies.

In conclusion, this study fills a gap in the literature and offers valuable practical recommendations. By focusing on tailored innovation management strategies, developing countries can enhance their position in the global defense arena, ensuring sovereignty and continuous technological progress.

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References

Abdallah, A. B., Alkhaldi, R. Z., & Aljuaid, M. M. (2021). Impact of social and technical lean management on operational performance in manufacturing SMEs: the roles of process and management innovations. Business Process Management Journal, 27(5), 1418–1444. https://doi.org/10.1108/bpmj-06-2020-0252

Abdallah, Y. O., Shehab, E., & Al-Ashaab, A. (2022). Developing a digital transformation process in the manufacturing sector: Egyptian case study. Information Systems and E-Business Management, 20(3), 613–630. https://doi.org/10.1007/s10257-022-00558-3

Allahar, H. (2019). Innovation management and Value Chain Design: Case of a Small Professional Services Firm. International Journal of Innovation, 7(2), 192–209. https://doi.org/10.5585/iji.v7i2.380

Allen, D. N. (1988). Business Incubator Life Cycles. Economic Development Quarterly, 2(1), 19–29. https://doi.org/10.1177/089124248800200103

Altuntas, S., Dereli, T., & Kusiak, A. (2015). Forecasting technology success based on patent data. Technological Forecasting and Social Change, 96, 202–214. https://doi.org/10.1016/j.techfore.2015.03.011

Alves, E. O., Fernandes, L. L., Pereira, R. B., & Silva, T. F. (2018). Framework for implementing knowledge management in

large organizations: the case of the Brazilian army's technological innovation and management agency (Portuguese). Final project for the Knowledge Management and Business Intelligence course (Portuguese). Universidade Federal do Rio de Janeiro.

Amann, E. (2002). Globalisation, industrial efficiency and technological sovereignty: Evidence from Brazil. Quarterly Review of Economics and Finance, 42(5). https://doi.org/10.1016/S1062-9769(02)00144-8 https://doi.org/10.1016/S1062-9769(02)00144-8

Atkinson, R. (1999). Project management: Cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. International Journal of Project Management, 17(6). https://doi.org/10.1016/S0263-7863(98)00069-6

Baierle, I. C., Benitez, G. B., Nara, E. O. B., et al. (2020). Influence of Open Innovation Variables on the Competitive Edge of Small and Medium Enterprises. Journal of Open Innovation: Technology, Market, and Complexity, 6(4), 179. https://doi.org/10.3390/joitmc6040179

Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. Journal of Management, 17(1), 99–120. https://doi.org/10.1177/014920639101700108

Bataev, A. V. (2018). Comparative Analysis of Cloud Computing Application in Russian and Foreign Financial Institutions. In: Proceedings of the 2018 IEEE International Conference "Quality Management, Transport and Information Security, Information Technologies" (ITandQMandIS). https://doi.org/10.1109/itmqis.2018.8525077

Beck, K., Beedle, M., Van Bennekum, A., et al. (2001). The agile manifesto. The Agile Alliance.

Blanchard, B. S., & Fabrycky, W. J. (1981). Systems engineering and analysis, 1st ed. Prentice-Hall.

Blanchard, B., & Fabrycky, W. (2011). Systems Engineering and Analysis, 5th ed. Prentice Hall.

Blanco, C., Lozada, N. E., & Arias, J. E. (2018). Technologies Capabilities and Innovative Performance: Mediating Effect of the Absorptive Capacity. IEEE Latin America Transactions, 16(11), 2775–2781. https://doi.org/10.1109/tla.2018.8795119

Brasil. (2020). MD40-M-01-Manual of good practices for life cycle management of defense systems (Portuguese). Ministério da Defesa. p. 177.

Briones-Peñalver, A. J., Bernal-Conesa, J. A., & de Nieves Nieto, C. (2019). Knowledge and innovation management model. Its influence on technology transfer and performance in Spanish Defence industry. International Entrepreneurship and Management Journal, 16(2), 595–615. https://doi.org/10.1007/s11365-019-00577-6

Brites, I. F. (2022). The development of innovations in the defense sector in Brazil: a study of the fx-2/gripen ng program (Portuguese). Universidade federal de santa maria.

Cepeda, J., & Arias-Pérez, J. (2019). Information technology capabilities and organizational agility. Multinational Business Review, 27(2), 198–216. https://doi.org/10.1108/mbr-11-2017-0088

Chang, Y. C., Chen, P. H., & Teng, M. J. (2021). How do institutional changes facilitate university-centric networks in Taiwan? The Triple Helix model of innovation view. Science and Public Policy, 48(3), 309–324. https://doi.org/10.1093/scipol/scaa076

Chege, S. M., & Wang, D. (2020). The impact of entrepreneurs' environmental analysis strategy on organizational performance. Journal of Rural Studies, 77, 113–125. https://doi.org/10.1016/j.jrurstud.2020.04.008

Chesbrough, H. W. (2003). Open Innovation: The New Imperative for Creating and Profiting from Technology. Harvard Business School Press.

Christensen, C. M. (1997). The innovator's dilemma: when new technologies cause great firms to fail. Harvard Business Review Press.

Christensen, J., Søndergaard, K., Serwanski, L., et al. (2018). A risk management framework for implementation of emerging technologies. In: Proceedings of the European Conference on Innovation and Entrepreneurship, ECIE; September 2018; pp. 199–207.

Coates, J. F. (1985). Foresight in federal government policy making. Futures Research Quarterly, 1(2), 29–53.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. Administrative Science Quarterly, 35(1), 128. https://doi.org/10.2307/2393553

Cooper, R. G. (1993). Winning at new products: Accelerating the process from idea to launch, 2nd ed. Basic Books.

Drucker, P. F. (1985). Innovation and Entrepreneurship: Practice and Principles. Harper and Row.

Erbay, H., & Yıldırım, N. (2022). Combined Technology Selection Model for Digital Transformation in Manufacturing: A Case Study from the Automotive Supplier Industry. International Journal of Innovation and Technology Management, 19(07). https://doi.org/10.1142/s0219877022500237

Erena, O. T., Kalko, M. M., & Debele, S. A. (2022). Organizational factors, knowledge management and innovation: empirical evidence from medium- and large-scale manufacturing firms in Ethiopia. Journal of Knowledge Management, 27(4), 1165–1207. https://doi.org/10.1108/jkm-11-2021-0861

Esquia, J. P. de V. (2021). National defense industry: opportunities from maintenance and procurement during the life cycle of military systems and materials (Portuguese). Universidade federal do rio grande do sul.

Ettlie, J., Muammer, O., & Murthy, R. (2023). R&D Dynamic Capabilities in a Changing Regulatory Context. IEEE Transactions on Engineering Management, 70(1), 98–111. https://doi.org/10.1109/tem.2020.3045650

Etzkowitz, H., & Leydesdorff, L. (1995). The triple helix: University-industry-government innovation in action. Routledge.

Etzkowitz, H., & Zhou, C. (2017). Triple helix: innovation and entrepreneurship university-industry-government (Portuguese). Estudos Avançados, 31(90), 23–48. https://doi.org/10.1590/s0103-40142017.3190003

Fakhreddin, F., & Foroudi, P. (2022). The impact of market orientation on new product performance through product launch quality: A resource-based view. Cogent Business and Management, 9(1). https://doi.org/10.1080/23311975.2022.2108220

Fakhreddin, F., Foroudi, P., & Rasouli Ghahroudi, M. (2021). The bidirectional complementarity between market orientation and launch proficiency affecting new product performance. Journal of Product and Brand Management, 30(6), 916–936. https://doi.org/10.1108/jpbm-03-2020-2824

Ferreira, J. J. P., Mention, A.L., & Torkkeli, M. (2020). Phrasing the giant: on the importance of rigour in literature search process. Journal of Innovation Management. 8(2): 1-10. https://doi.org/10.24840/2183-0606_008.002_0001

Ferreira, C. V., Biesek, F. L., & Scalice, R. K. (2021). Product innovation management model based on manufacturing readiness level (MRL), design for manufacturing and assembly (DFMA) and technology readiness level (TRL). Journal of the Brazilian Society of Mechanical Sciences and Engineering, 43(7). https://doi.org/10.1007/s40430-021-03080-8

Figueiredo, P. N. (2009). Technological Learning and Industrial Innovation in Emerging Economies: a Brief Contribution to the Design and Implementation of Empirical Studies and Strategies in Brazil (Portuguese). Revista Brasileira de Inovação, 3(2), 323. https://doi.org/10.20396/rbi.v3i2.8648901

França Junior, J. A., & Galdino, J. F. (2022). Acquisition of defense systems and products: reconciling short-and long-term objectives (Portuguese). In: Azevedo C. E. F., & Ramos C. E. D. F. (editors). Defense studies: innovation, strategy and industrial development (Portuguese). FGV. pp. 42–71.

Galdino, J. F. (2022). Machiavelli and the importance of national military power (Portuguese). Coleção Meira Mattos: revista das ciências militares, 16(56). https://doi.org/10.52781/cmm.a077

Girardi, R. (2024). Innovation management: a bibliometric review. Revista de Gestão e Secretariado, 15(3), e3589. https://doi.org/10.7769/gesec.v15i3.3589

Girardi, R., & dos Santos, M. (2023). Evaluation of Technologies to the Brazilian Army from the Application of the AHP-TOPSIS-2N Method with Patent Analysis. In: Proceedings of the 2023 3rd International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME). https://doi.org/10.1109/iceccme57830.2023.10252404

Girardi, R., & Passos, A. C. (2022). Analysis of the IME in the light of the concepts of entrepreneurial university and world-class university (Portuguese). In: Coletânea de artigos do Curso Executivo de Gestão da Inovação da AGITEC, 1st ed. BIBLIEx. pp. 57–76.

Girardi, R., Ferreira Galdino, J., & César Pellanda, P. (2024). The Front End of Innovation in Defense: A Comprehensive Literature Review. National Security in the Digital and Information Age. https://doi.org/10.5772/intechopen.1005191

Girardi, R., França Junior, J. A., & Galdino, J. F. (2022). Customizing technology readiness assessment processes based on the TRL scale: developing a methodology for the Brazilian Army (Portuguese). Coleção Meira Mattos: revista das ciências militares, 16(57). https://doi.org/10.52781/cmm.a084

Girardi, R., França Junior, J. A., & Galdino, J. F. (2024). Defense technology criticality in developing countries: concepts and criteria (Portuguese). Revista de Gestão e Secretariado, 15(4), e3618. https://doi.org/10.7769/gesec.v15i4.3618

Girardi, R., Galdino, J. F., Pellanda, P. C., et al. (2022). Bibliometric study on multi-criteria decision-making methods applied to life cycle management of defense systems. Procedia Computer Science, 214, 236–247. https://doi.org/10.1016/j.procs.2022.11.171

Goulart, L. C. (2022). Sources of funding for the Brazilian navy's strategic projects (Portuguese). Universidade de brasília.

Granstrand, O., & Sjölander, S. (1990). Managing innovation in multi-technology corporations. Research Policy, 19(1). https://doi.org/10.1016/0048-7333(90)90033-3

Grimaldi, M., Cricelli, L., Di Giovanni, M., et al. (2015). The patent portfolio value analysis: A new framework to leverage patent

information for strategic technology planning. Technological Forecasting and Social Change, 94, 286–302. https://doi.org/10.1016/j.techfore.2014.10.013

Gu, S. (1999). Implications of National Innovation Systems for Developing Countries: managing change and complexity in economic development. UNU/INTECH Discussion Papers.

Gupta, H., Kusi-Sarpong, S., & Rezaei, J. (2020). Barriers and overcoming strategies to supply chain sustainability innovation. Resources, Conservation and Recycling, 161, 104819. https://doi.org/10.1016/j.resconrec.2020.104819

Hafezi, R., Malekifar, S., & Akhavan, A. (2018). Analyzing Iran's science and technology foresight programs: recommendations for further practices. Foresight, 20(3), 312–331. https://doi.org/10.1108/fs-10-2017-0064

Henao-Garcia, E. A., & Cardona Montoya, R. A. (2023). Management Innovation in an Emerging Economy: An Analysis of Its Moderating Effect on the Technological Innovation-Performance Relationship. IEEE Transactions on Engineering Management, 70(1), 128–141. https://doi.org/10.1109/tem.2021.3052746

Hobday, M. (1998). Product complexity, innovation and industrial organisation. Research Policy, 26(6), 689–710. https://doi.org/10.1016/S0048-7333(97)00044-9

Huang, Y., Li, S., Xiang, X., et al. (2022). How can the combination of entrepreneurship policies activate regional innovation capability? A comparative study of Chinese provinces based on fsQCA. Journal of Innovation and Knowledge, 7(3), 100227. https://doi.org/10.1016/j.jik.2022.100227

Hwang, C. L., & Yoon, K. (1981). Multiple Attribute Decision Making. In Lecture Notes in Economics and Mathematical Systems. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-48318-9

IEDI. (2021). China's 14th Five-Year Plan: transforming China into an industrial and technological powerhouse (Portuguese). Carta Do Instituto de Estudos Para o Desenvolvimento Industrial - Edição 1094.

INCOSE. (2023). INCOSE Systems Engineering Handbook. International Council on Systems Engineering (INCOSE).

ISO. (2023). ISO/IEC/IEEE 15288-Systems and software engineering-System life cycle processes. International Organization for Standardization (ISO).

Kalko, M. M., Erena, O. T., & Debele, S. A. (2022). Technology management practices and innovation: Empirical evidence from medium- and large-scale manufacturing firms in Ethiopia. African Journal of Science, Technology, Innovation and Development, 15(1), 107–123. https://doi.org/10.1080/20421338.2022.2040828

Kayabay, K., Gökalp, M. O., Gökalp, E., et al. (2022). Data science roadmapping: An architectural framework for facilitating transformation towards a data-driven organization. Technological Forecasting and Social Change, 174, 121264. https://doi.org/10.1016/j.techfore.2021.121264

Kleiner-Schaefer, T., & Schaefer, K. J. (2022). Barriers to university–industry collaboration in an emerging market: Firm-level evidence from Turkey. The Journal of Technology Transfer, 47(3), 872–905. https://doi.org/10.1007/s10961-022-09919-z

Kuo, T.-K., Lim, S. S., & Sonko, L. K. (2018). Catch-up strategy of latecomer firms in Asia: a case study of innovation ambidexterity in PC industry. Technology Analysis and Strategic Management, 30(12), 1483–1497. https://doi.org/10.1080/09537325.2018.1475642

Lakemond, N., & Holmberg, G. (2022). The quest for combined generativity and criticality in digital-physical complex systems. Journal of Engineering and Technology Management, 65, 101701. https://doi.org/10.1016/j.jengtecman.2022.101701

Lermen, F. H., de Moura, P. K., Bertoni, V. B., et al. (2023). Does maturity level influence the use of Agile UX methods by digital startups? Evaluating design thinking, lean startup, and lean user experience. Information and Software Technology, 154, 107107. https://doi.org/10.1016/j.infsof.2022.107107

Letaba, P. T., & Pretorius, M. W. (2022). Toward Sociotechnical Transition Technology Roadmaps: A Proposed Framework for Large-Scale Projects in Developing Countries. IEEE Transactions on Engineering Management, 69(1), 195–208. https://doi.org/10.1109/tem.2021.3050812

Lezama-Nicolás, R., Rodríguez-Salvador, M., Río-Belver, R., et al. (2018). A bibliometric method for assessing technological maturity: the case of additive manufacturing. Scientometrics, 117(3), 1425–1452. https://doi.org/10.1007/s11192-018-2941-1

Longo, W. P., & Moreira, W. de S. (2009). Access to "sensitive technologies" (Portuguese). Tensões Mundiais, 5(9), 73–122. https://doi.org/10.33956/tensoesmundiais.v5i9%20jul/dez.669

Madeu, F. C. B. (2019). Technology foresight using multicriteria analysis and bibliometric techniques: case studies for the defense sector (Portuguese). Instituto militar de engenharia-ime.

Magistretti, S., Dell'Era, C., & Verganti, R. (2020). Searching for the right application: A technology development review and research agenda. Technological Forecasting and Social Change, 151, 119879. https://doi.org/10.1016/j.techfore.2019.119879

Mamphiswana, R., & Sinha, S. (2019). Management of technological innovation in emerging economies: A conceptual framework. In: Proceedings of the Managing Technology for Inclusive and Sustainable Growth-28th International Conference for the International Association of Management of Technology, IAMOT 2019. pp. 20–31.

Mankins, J. C. (1995). Technology readiness levels—A White Paper. NASA.

Mankins, J. C. (2002). Approaches to strategic research and technology (RandT) analysis and road mapping. Acta Astronautica, 51(1–9). https://doi.org/10.1016/S0094-5765(02)00083-8

Mankins, J. C. (2009). Technology readiness assessments: A retrospective. Acta Astronautica, 65(9–10), 1216–1223. https://doi.org/10.1016/j.actaastro.2009.03.058

Mathiyazhagan, K., Agarwal, V., Appolloni, A., et al. (2021). Integrating lean and agile practices for achieving global sustainability goals in Indian manufacturing industries. Technological Forecasting and Social Change, 171, 120982. https://doi.org/10.1016/j.techfore.2021.120982

McQuivey, J. (2013). Digital disruption: Unleashing the next wave of innovation. Forrester Research.

Midler, C. (2019). Projectification. International Journal of Managing Projects in Business, 12(3), 545–564. https://doi.org/10.1108/ijmpb-07-2018-0126

Ministry of Defence. (2020). Defence Acquisition Procedure 2020. Ministry of Defence. p. 681.

Moreira, W. de S. (2013). Science and Power: Technological Curtailment and the Implications for National Defense (Portuguese). Universidade Federal Fluminense (UFF).

Nagar, A. K., Jat, D. S., Marín-Raventós, G., & Mishra, D. K. (2022). Intelligent Sustainable Systems. In: Lecture Notes in Networks and Systems. Springer Nature Singapore. https://doi.org/10.1007/978-981-16-6369-7

Nguyen, H. T., Hoang, T. G., Nguyen, L. Q. T., et al. (2021). Green technology transfer in a developing country: mainstream practitioner views. International Journal of Organizational Analysis, 30(3), 699–720. https://doi.org/10.1108/ijoa-11-2019-1941

Niosi, J., & Zhegu, M. (2010). Multinational Corporations, Value Chains and Knowledge Spillovers in the Global Aircraft Industry. International Journal of Institutions and Economies, 2(2), 109–141.

Nonaka, I. (1994). A Dynamic Theory of Organizational Knowledge Creation. Organization Science, 5(1), 14–37. https://doi.org/10.1287/orsc.5.1.14

Page, M. J., McKenzie, J. E., Bossuyt, P. M., et al. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ, (71). https://doi.org/10.1136/bmj.n71

Pandit, D., Joshi, M. P., Sahay, A., et al. (2018). Disruptive innovation and dynamic capabilities in emerging economies: Evidence from the Indian automotive sector. Technological Forecasting and Social Change, 129, 323–329. https://doi.org/10.1016/j.techfore.2017.09.035

Pereira, A. L. (2022). The role of military organizations in innovation ecosystems: an analysis in the Brazilian context (Portuguese). Universidade do vale do rio dos sinos-unisinos.

Phaal, R., Farrukh, C. J. P., & Probert, D. R. (2004). Technology roadmapping-A planning framework for evolution and revolution. Technological Forecasting and Social Change, 71(1–2), 5–26. https://doi.org/10.1016/S0040-1625(03)00072-6

Pisano, G. (2006). Profiting from innovation and the intellectual property revolution. Research Policy, 35(8), 1122–1130. https://doi.org/10.1016/j.respol.2006.09.008

Porter, M. E. (1985). The Competitive Advantage: Creating and Sustaining Superior Performance. Free Press.

Reddy, N. M., & Zhao, L. (1990). International technology transfer: A review. Research Policy, 19(4). https://doi.org/10.1016/0048-7333(90)90015-X

Reed, F. M., & Walsh, K. (2002). Enhancing technological capability through supplier development: a study of the UK aerospace industry. IEEE Transactions on Engineering Management, 49(3), 231–242. https://doi.org/10.1109/tem.2002.803379

Robles, M. G. (2018). Management Control Systems: The use of the Stage-Gate Process in an environment of innovation. Contabilidad y Negocios, 13(25). https://doi.org/10.18800/contabilidad.201701005

Rogers, E. M. (1962). Diffusion of innovations. Free Press of Glencoe.

Saaty, T. L. (1979). Optimization by the Analytic Hierarchy Process. Defense Technical Information Center. https://doi.org/10.21236/ada214804

Saksupapchon, P., & Willoughby, K. W. (2019). Contextual Factors Affecting Decisions About Intellectual Property Licensing Provisions in Collaboration Agreements for Open Innovation Projects of Complex Technological Organizations. In: Proceedings of the 2019 IEEE International Symposium on Innovation and Entrepreneurship (TEMS-ISIE).

https://doi.org/10.1109/tems-isie46312.2019.9074359

Santos, G., Félix, M. J., Doiro, M., et al. (2020). On the concept of an integrated and lean model of product development proposed for intellectual property creation and competitive economies. International Journal of Intellectual Property Management, 10(4), 409. https://doi.org/10.1504/ijipm.2020.112412

Sauser, B., Gove, R., Forbes, E., et al. (2010). Integration maturity metrics: Development of an integration readiness level. Information Knowledge Systems Management, 9(1), 17–46. https://doi.org/10.3233/iks-2010-0133

Schilling, M. A. (2013). Strategic Management of Technological Innovation, 4th ed. McGraw-Hill.

Shahrbabaki, A. A., Sakkaki, S., Parsa, P., et al. (2020). Strategic reactions to information content of dividend change: applying BCG growth share matrix when signalling hypothesis identified. Entrepreneurship and Sustainability Issues, 8(2). https://doi.org/10.9770/jesi.2020.8.2

Shuguang, L., Xingxing, Z., Wuyang, C., et al. (2021). The Path of University Collaborative Innovation Mechanism Based on the Triple-Helix Model. In: Proceedings of the 2021 10th International Conference on Educational and Information Technology (ICEIT). https://doi.org/10.1109/iceit51700.2021.9375561

Silva Queiroz, G. L., de Oliveira Paula, F., & da Silva, J. F. (2021). The role of alliance portfolio diversity on firm innovation and performance: the case of Colombia. Technology Analysis and Strategic Management, 35(4), 365–379. https://doi.org/10.1080/09537325.2021.1975036

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. Strategic Management Journal, 18(7). https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z

Teh, P. L., Adebanjo, D., & Kong, D. L. Y. (2021). Key enablers and barriers of solar paver technologies for the advancement of environmental sustainability. Heliyon, 7(10), e08189. https://doi.org/10.1016/j.heliyon.2021.e08189

Thomé, A. M. T., Scavarda, L. F., & Scavarda, A. J. (2016). Conducting systematic literature review in operations management. Production Planning and Control, 27(5), 408–420. https://doi.org/10.1080/09537287.2015.1129464

Tidd, J., & Bessant, J. (2020). Managing Innovation: Integrating Technological, Market and Organizational Change, 7th ed. Wiley.

Ul Haq, I., Ali, S. M., & Nawaz, M. T. (2019). An Analysis of the Critical Success Factors in ICT Sector of Pakistan. In: Proceedings of the 2019 5th International Conference on Information Management (ICIM). https://doi.org/10.1109/infoman.2019.8714666

United Kingdom. (2022). The Defence Capability Framework. Ministry of Defence (MoD). p. 51.

United States. (2016). Manufacturing Readiness Level Deskbook. In: OSD Manufacturing Technology Program. Department of Defense (DoD). p. 71.

United States. (2018). CJCSI 5123.01H-Charter of the Joint Requirements Oversight Council (JROC) and Implementation of the Joint Capabilities Integration and Development System (JCIDS). Department of Defense (DoD).

United States. (2020a). Defense Space Strategy Summary. Department of Defense (DoD).

United States. (2020b). Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects. Available online: https://www.gao.gov/products/gao-20-48g (accessed on 2 April 2024).

United States. (2022). Critical and Emerging Technologies List Update. National Science and Technology Council (NSTC).

Valdez-Juárez, L. E., Ramos-Escobar, E. A., & Borboa-Álvarez, E. P. (2023). Reconfiguration of Technological and Innovation Capabilities in Mexican SMEs: Effective Strategies for Corporate Performance in Emerging Economies. Administrative Sciences, 13(1), 15. https://doi.org/10.3390/admsci13010015

Voltan, J. L. N., Girardi, R., Galdino, J. F., & Goldschmidt, R. R. (2024). A review and classification of technology readiness assessment techniques based on the TRL scale (Portuguese). Coleção Meira Mattos: revista das ciências militares, 18(61), 49–76. https://doi.org/10.52781/cmm.a121

Wu, A., & Li, T. (2019). Gaining sustainable development by green supply chain innovation: Perspectives of specific investments and stakeholder engagement. Business Strategy and the Environment, 29(3), 962–975. Portico. https://doi.org/10.1002/bse.2410

Xavier Jr, A., Veloso, A., Souza, J., et al. (2020). AEB Online Calculator for Assessing Technology Maturity: IMATEC. Volume 12, 12. Internet Archive. https://doi.org/10.5028/jatm.v12.1098

Zhang, J., Tian, J., Alcaide, A. M., et al. (2023). Lifetime Extension Approach Based on the Levenberg-Marquardt Neural Network and Power Routing of DC–DC Converters. IEEE Transactions on Power Electronics, 38(8), 10280–10291.

https://doi.org/10.1109/tpel.2023.3275791

Zhang, J., Tian, J., Yan, P., et al. (2024). Multi-hop graph pooling adversarial network for cross-domain remaining useful life prediction: A distributed federated learning perspective. Reliability Engineering and System Safety, 244, 109950. https://doi.org/10.1016/j.ress.2024.109950