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This new journal series is the new face of two former journals:

- The *Scientific Bulletin of Politehnica University of Timisoara, Transaction on Economics and Social Sciences (ranked according to CNCSIS classification in Romania: D class);*
- *The Scientific Bulletin of Politehnica University of Timisoara, Transaction on Management. Economics Engineering. Transportation Engineering (ranked according to CNCSIS classification in Romania: C class).*

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The scientific papers in this issue were produced in the context of the implementation of the training program for future researchers (PhD and Master students) 1st Edition Connected Minds – Research and Co-Creation Exchange (https://connectminds2025.wixsite.com/home). The peer review process was carried out by tutors and trainers, and the quality of the research results, as well as the respect for ethics in the use of bibliographic resources, various Gen AI software or data was validated by them. The author groups are responsible for the content of each article.

We thank all contributors from:

- Instituto Politécnico de Setúbal, Portugal (host of the Connected Minds – Research and Co-Creation Exchange event, https://connectminds2025.wixsite.com/home).
- Politehnica University of Timisoara, Romania
- Fulda University of Applied Sciences, Germany

We would like to thank the university alliance E³UDRES² (https://eudres.eu/) for the favorable context of collaboration between the different partners in the field of education and research.

CONTENT

Scientific Bulletin
of Politehnica University of Timisoara, Romania

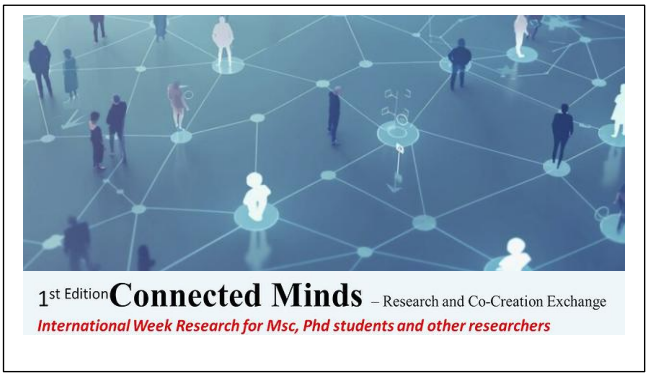
Transactions on ENGINEERING AND MANAGEMENT

Vol. 12 Issue 1, 2026

Editorial

Anca DRAGHICI[1] & Teresa COSTA[2]

The first issue in 2026 of the "***Scientific Bulletin of Politehnica University of Timisoara – Transaction on Engineering and Management***" (ISSN 2392-7364) has been developed with the contribution of the authors being participants at the 1st Blended Intensive Program "- Research and Co-Creation Exchange" (https://connectminds2025.wixsite.com/home), in-person Program, November 3 - 7, 2025, dedicated to young researchers. The initiative was supported by partners in the E³UDRES² alliance (https://eudres.eu/) as: Polytechnique University of Setubal, Portugal (host of the event); Politehnica University of Timisoara, Romania; University of Applied Science Fulda, Germany.



The Connected Minds intensive training research provides an opportunity for Master and PhD students engaged in social science research to learn from experts and their peers. Students and professors have participated in BootCamps, and workshops led by experts, with the objective of proposing and developing a research project for scientific paper development in a collaborative manner. The training was designed to enhance participants' research and co-creation skills, while also enjoying social and cultural activities, such as dolphin watching, a winery tour, and a guided visit to the city center.

Prior to the in-person gathering, participants attended an online kick-off session on October 14, followed by two online follow-up sessions in December 2025 and January 2026 with their assigned supervisors. These sessions aimed to support the improvement of the scientific papers that are published in this issue.

All articles of Connected Minds the ***Scientific Bulletin*** 12th volume, 1st issue of 2026 have been reviewed by the teaching staff / tutors involved in the Connected Minds programme; their professional and volunteer review work impact the quality content of the papers.

The first paper, "***Resilient Sustainable Systems for Urban Development. Literature Review and a Debate on the Situation in Romania and Portugal***" asserts that **urban resilience** is a fundamental **prerequisite for achieving long-term sustainability** goals. Utilizing the SETS framework (**Social – Ecological - Technological Systems**), the presented study advocates for a systemic approach that integrates human governance, natural ecosystems, and engineered infrastructure. Key strategic insights include the necessity of **integrated planning** to maximize the multi-functional co-benefits of urban interventions, a transition from traditional cost-benefit analysis to **holistic valuation** that internalizes the value of ecosystem services and social capital, and the careful management of **scale mismatches** between local actions and regional governance. Practical evidence from **Romania and Portugal** illustrates these concepts through successful implementations of **nature-based solutions (NBS)**, such as Oradea's geothermal heating and Guimarães' "Green Radial" cooling strategy, demonstrating that moving from fragmented to **systemic integration** is vital for transforming vulnerable urban centers into adaptive, thriving environments.

The second paper "***Designing Pre-/Post-Pandemic Comparisons in Japanese Pop Culture***

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Events: An Integrative Literature Review" develops an integrative framework to guide pre- and post-pandemic comparisons of participation in Japanese pop culture events. A central insight is that COVID-19 disrupted these events through **structural constraints (closures), consumption reconfiguration (digital shift), and psychological factors (perceived risk)**. Because this niche (encompassing anime, manga, and cosplay) relies fundamentally on **physical co-presence and intense socialization**, it was uniquely sensitive to pandemic shocks, with virtual alternatives often proving insufficient for highly participatory formats. The resulting framework establishes a structured research agenda that focuses on **measurement comparability** to determine whether changes in participation, profiles, and **contents/otaku tourism** mobilities are temporary coping strategies or permanent shifts in the fandom landscape. This approach clarifies the conceptual and analytical requirements for robust comparative designs in event studies.

The third paper presents "***The Role of Trustworthy Artificial Intelligence in Enhancing Managerial Decision Quality Under the Conditions Uncertainty***" investigate how **trustworthy Artificial Intelligence (AI)** enhances managerial decision quality under uncertainty, focusing specifically on autonomous UAV logistics and financial compliance. A fundamental insight is that technical accuracy is insufficient; systems must be **operationally trustworthy** to overcome managerial skepticism caused by "Black Box" opacity. The paper identifies **data integrity and explainability (XAI)** as critical pillars that transform raw probabilities into actionable managerial insights. Crucially, **managerial trust acts as a mediator** for organizational performance; efficiency gains, such as a 59% reduction in ship pollution detection times, occur only when managers trust the system enough to **reduce manual supervision**. The research emphasizes that AI failures are often driven by **data entropy and opacity** such as fragmented records or noisy sensors rather than algorithmic flaws.

The fourth paper ("***Mapping Sustainable Decisions: How Geographic Information Systems and Geographic Analytics Could be Integrated in the Infrastructure to Create Public Value. A Germany–Portugal Comparison***") examines the integration of **Geographic Information Systems (GIS) and Genetic Algorithms (GA)** to enhance sustainable infrastructure planning and generate public value. A primary insight is that combining GIS with **Multi-Criteria Decision Analysis (MCDA)** creates a transparent framework capable of balancing conflicting socio-economic and environmental factors. The study reveals distinct national strategies: **Germany** emphasizes **operational efficiency and economic optimization** for large-scale networks, utilizing advanced modeling and strict legal standards. Conversely, **Portugal** prioritizes **ecological resilience and social equity**, frequently employing **open-source platforms and participatory approaches** to address climate vulnerabilities and community needs. Ultimately, the research suggests that while methodological emphases differ, Germany focusing on systemic optimization and Portugal on local resilience, both countries recognize spatial decision-support systems as essential for addressing complex urban challenges like climate change and urbanization. This comparative framework provides a scalable model for evidence-based infrastructure development across diverse European contexts.

The fifth paper entitled "***Analysis of the Public Policies Evaluation at the Municipality Level and Their Contribution to Sustainable Development Goal 11*"** evaluates the alignment of public policies in Prudentópolis, Brazil, with Sustainable Development Goal 11 (SDG 11). Using document analysis of the 2022 State Court of Accounts (TCE-PR) report, the study determines that the municipality partially meets sustainability requirements. A core insight is the significant performance gap between sectors, with Health (8.16) and Social Assistance (7.13) performing well compared to the critically low Financial Administration (3.01). Notable strengths include School transportation (9.50) and Information availability (10.00), indicating effective logistical and technological infrastructure. The authors conclude that while social progress is evident, improvements in planning and monitoring are vital to fully achieving the 2030 Agenda's vision of a resilient, sustainable city.

Last paper ("***Open and Collaborative Innovation in SMEs: A Systematic Literature Review***") presents a systematic review (2021–2025) that reveals that **SMEs increasingly adopt open and collaborative innovation** to overcome structural constraints like limited financial flexibility and restricted R&D infrastructure. A primary insight is that while **digital transformation facilitates broader external searches**, performance gains are not automatic; success depends heavily on **internal readiness**, specifically absorptive capacity and dynamic capabilities. The authors identify significant **"costs of openness",** including cognitive overload, high coordination burdens, and intellectual property risks, which often force resource-constrained firms into cautious, shallow collaborations. Ultimately, the paper argues that **openness is a context-dependent strategic choice** rather than a universal "best practice". It highlights a critical need for **integrative, SME specific frameworks** that move beyond static variables to examine the temporal sequences through which collaboration creates value.

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TRANSACTIONS on ENGINEERING AND MANAGEMENT

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Resilient Sustainable Systems for Urban Development. Literature Review and a Debate on the Situation in Romania and Portugal

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Anca DRAGHICI[4], Teresa COSTA[5]

Abstract - This paper investigates the critical intersection between "urban resilience and sustainability", asserting that resilience (the capacity of a city to withstand, recover from, and adapt to shocks) is a fundamental prerequisite for achieving long-term sustainability goals. Utilizing the Social-Ecological-Technological Systems (SETS) framework, the study proposes a systemic approach to urban development that integrates human, natural, and engineered components. The research identifies four strategic pillars essential for this transition: (1) Integrated planning for multifunctionality, which seeks to maximize the co-benefits of urban interventions across social and ecological dimensions; (2) Holistic valuation and risk financing, arguing for a shift from traditional cost-benefit analysis (CBA) to a model that internalizes the value of ecosystem services and social capital; (3) Managing scale mismatches to align local interventions with regional governance and infrastructure; (4) Ensuring equity and justice, focusing on the fair distribution of resilience benefits to avoid issues like "green gentrification". The article further provides a comparative debate on the practical situations in Romania and Portugal. The paper concludes that moving from fragmented to systemic integration is vital for transforming vulnerable urban centers into adaptive and truly resilient sustainable systems.

Keywords: Resilience, Sustainability, Urban Development, SETS framework, Nature-Based Solutions (NBS).

I. INTRODUCTION

The global trend of rapid urbanization, coupled with the accelerating impacts of climate change, necessitates a fundamental shift in how cities are planned, governed, and developed. The traditional approach of pursuing sustainability, defined as the long-term persistence of a desirable urban outcome, is increasingly insufficient without an equal focus on resilience which is the capacity of a city's systems to withstand, recover from, and adapt to shocks and stresses (World Bank, 2013; Zen et al., 2022).

The presented strategic analysis in this article examines the critical nexus between these two concepts, identifying the frameworks and principles required to build truly resilient sustainable systems for urban development. The goal is to move beyond siloed planning and establish an integrated, systemic approach that ensures urban centers can thrive in the face of growing complexity and uncertainty. This paper investigates the critical intersection between "urban resilience and sustainability", asserting that resilience (the capacity of a city to withstand, recover from, and adapt to shocks) is a fundamental prerequisite for achieving long-term sustainability goals. Utilizing the Social-Ecological-Technological Systems (SETS) framework, the study proposes a systemic approach to urban development that integrates human, natural, and engineered components. The research identifies four strategic pillars essential for this transition:

(1) Integrated planning for multi-functionality, which seeks to maximize the co-benefits of urban interventions across social and ecological dimensions;

(2) Holistic valuation and risk financing, arguing for a shift from traditional cost-benefit analysis (CBA) to a model that internalizes the value of ecosystem services and social capital;

(3) Managing scale mismatches to align local interventions with regional governance and infrastructure;

(4) Ensuring equity and justice, focusing on the fair distribution of resilience benefits to avoid issues like "green gentrification".

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In the final part, the article provides a comparative debate on the practical situations in Romania and Portugal. The paper concludes that moving from fragmented to systemic integration is vital for transforming vulnerable urban centers into adaptive and truly resilient sustainable systems.

II. A BRIEF LITERATURE REVIEW ON THE RESEARCH FIELD

The strategic analysis of resilient sustainable systems for urban development is a multifaceted topic that integrates concepts of urban resilience, sustainability, and governance to address the challenges posed by rapid urbanization and climate change. This literature review synthesizes insights from various studies to explore how cities can enhance their adaptive capacity, mitigate environmental impacts, and foster social equity and economic prosperity. The review highlights the importance of integrating green infrastructure, resilient urban design, and community engagement strategies, while also addressing governance challenges and the role of critical infrastructure. The following sections delve into key aspects of this topic. Table 1 presents the relevant titles identified

Table 1: Relevant literature supporting the research approach – Analysis and synthesis

#	References	Brief analysis
1	Singh, A. (2024). Urban resilience and sustainability: A comprehensive review. *Journal of Sustainable Solutions*, *15*(2), 33-38.	
	The paper provides a comprehensive review of urban resilience and sustainability, emphasizing the integration of green infrastructure, resilient urban design, and community engagement strategies. It synthesizes current literature on how cities enhance adaptive capacity and mitigate environmental impacts while promoting social equity and economic prosperity. The review includes case studies showcasing innovative approaches and best practices, offering insights into the dynamics of urban resilience and sustainability, which are crucial for strategic analysis in urban development.	**Methods used:** - The review synthesizes current literature to examine the interplay between urban resilience and sustainability frameworks, highlighting the integration of green infrastructure, resilient urban design, and community engagement strategies as key methods for enhancing adaptive capacity and mitigating environmental impacts in urban settings. - Case studies from diverse urban contexts are utilized to illustrate innovative approaches and best practices in achieving sustainable development goals, providing empirical evidence and practical examples of how cities are addressing the challenges of rapid urbanization and climate change.
	Results: - The review synthesizes current literature to highlight the interplay between urban resilience and sustainability frameworks, emphasizing how cities are enhancing their adaptive capacity and mitigating environmental impacts while promoting social equity and economic prosperity. - Through case studies from diverse urban contexts, the paper illustrates innovative approaches and best practices in achieving sustainable development goals, providing insights into the complex dynamics of urban resilience and sustainability and offering recommendations for future research and policy implementation.	**Conclusions**: - The review highlights the importance of integrating green infrastructure, resilient urban design, and community engagement strategies as essential components for enhancing urban resilience and sustainability in the face of rapid urbanization and climate change. - It provides insights into the complex dynamics of urban resilience and sustainability by critically evaluating theoretical frameworks and empirical evidence and offers recommendations for future research and policy implementation to achieve sustainable development goals.
2	Zeng, X., Yu, Y., Yang, S., Lv, Y., & Sarker, M. N. I. (2022). Urban resilience for urban sustainability: Concepts, dimensions, and perspectives. *Sustainability*, *14*(5), 2481.	
	The paper conducts a systematic literature review on urban resilience and sustainability, emphasizing their interrelatedness in urban development. It identifies key indicators of urban resilience, categorized into adaptive, absorptive, and transformative capacities, alongside dimensions of urban sustainability (social, economic, environmental). The findings highlight the importance of understanding urban vulnerability and resilience dynamics, which are crucial for strategic analysis in developing resilient sustainable systems for urban development. This framework aids in addressing urban threats from rapid urbanization effectively.	**Methods used:** A systematic literature review guided by PRISMA was conducted using literature from 1 January 2001 to 30 November 2021 to clarify the concept and develop key indications of urban resilience and sustainability.
	Results: The paper conducts a systematic literature review on urban resilience and sustainability, emphasizing their interrelatedness in urban development. It identifies key indicators of urban resilience, categorized	**Conclusions**: A systematic literature review guided by PRISMA was conducted using literature from 1 January 2001 to 30 November 2021 to clarify the concept and develop key indications of urban resilience and sustainability.

	into adaptive, absorptive, and transformative capacities, alongside dimensions of urban sustainability (social, economic, environmental). The findings highlight the importance of understanding urban vulnerability and resilience dynamics, which are crucial for strategic analysis in developing resilient sustainable systems for urban development. This framework aids in addressing urban threats from rapid urbanization effectively.	
3	Wang, Y., Fang, H., & Liu, B. (2025). Obstacles and improvement strategies for urban resilience governance: A systematic literature review. *Advances in Engineering Technology Research*, *14*(1), 143-143.	
	The paper does not specifically perform a literature review on "strategic analysis of resilient sustainable systems for urban development". However, it identifies key obstacles to urban resilience governance, such as governance fragmentation and resource limitations, and suggests improvement strategies like NBS, stakeholder collaboration, and policy reforms. These insights can inform a strategic analysis by highlighting the need for integrated, adaptive, and participatory approaches to enhance urban resilience and sustainability in development efforts.	**Methods used:** - The paper employs a systematic literature review methodology to identify obstacles and improvement strategies for urban resilience governance. - It focuses on analyzing existing literature to extract key themes related to governance fragmentation, resource limitations, policy incoherence, social inequities, and technical constraints. - The review synthesizes findings from various studies to highlight primary obstacles and propose integrated strategies for urban resilience. - Central parameters include the identification of five primary obstacles and the evaluation of proposed strategies such as NBS and stakeholder collaboration. - The approach emphasizes the need for holistic, adaptive, and participatory methods to enhance urban resilience governance.
	Results: - The systematic literature review identifies five primary obstacles to urban resilience governance: governance and policy fragmentation, financial and economic barriers, social and equity challenges, technical and infrastructure limitations, and environmental and climate uncertainties. - It highlights the need for integrated strategies to overcome these obstacles, including NBS, stakeholder collaboration, policy reforms, technological innovations, and community-centric approaches. - The findings emphasize the importance of holistic, adaptive, and participatory approaches in building resilient urban systems. - The review underscores that urban resilience is essential for addressing environmental, social, and economic challenges. - There are no stated null or negative results in the provided context.	**Conclusions:** - The paper concludes that urban resilience governance faces significant obstacles, including governance and policy fragmentation, financial and economic barriers, social and equity challenges, technical and infrastructure limitations, and environmental and climate uncertainties. - It emphasizes the necessity for integrated strategies to overcome these obstacles, such as implementing NBS and fostering stakeholder collaboration. - Authors advocate for policy reforms and technological innovations as essential components for enhancing urban resilience. - Community-centric approaches are highlighted as vital for ensuring that urban systems are adaptable and participatory. - The findings underscore the importance of holistic approaches to build resilient urban systems capable of addressing contemporary complexities.
4	Umoh, A. A., Nwasike, C. N., Tula, O. A., Ezeigweneme, C. A., & Gidiagba, J. O. (2024). Green infrastructure development: Strategies for urban resilience and sustainability. *World Journal of Advanced Research and Reviews*, *21*(1), 020-029.	
	The paper emphasizes the significance of green infrastructure in urban resilience and sustainability, highlighting its ecological, social, and economic dimensions. It outlines holistic strategies for development that prioritize biodiversity and community engagement while integrating with existing urban structures. The literature review indicates that despite the benefits of green infrastructure, challenges such as limited space and maintenance issues must be addressed. This strategic analysis underscores the need for cities to embrace transformative approaches for sustainable urban development.	**Methods used:** - The research employs a literature review to elucidate the significance of green infrastructure by intertwining ecological, social, and economic dimensions, providing a comprehensive understanding of its role in urban resilience and sustainability. - A conceptual framework is outlined to develop holistic strategies for green infrastructure, emphasizing key elements such as biodiversity, community engagement, and the seamless integration of green infrastructure with existing urban structures.
	Results: - The research highlights the transformative potential of green infrastructure in fostering urban resilience and sustainability by emphasizing biodiversity, community engagement, and integration with existing urban structures.	**Conclusions:** - The paper highlights the transformative potential of green infrastructure in fostering urban resilience and sustainability. - It offers a roadmap for cities to overcome challenges such as limited space, maintenance issues, and

	- Despite the documented benefits, the paper also identifies challenges such as limited space, maintenance issues, and resistance to change that need to be addressed for successful implementation of green infrastructure strategies in urban environments.	resistance to change, ultimately promoting the coalescence of nature and urbanity for resilient and sustainable urban environments.
5	Saptono, Y., Rustiadi, E., Barus, B., & Pravitasari, A. E. (2025). Systematic Literature Review: Research Development of Urban Resilience in Metropolitan Areas. *Sustainability*, *17*(16), 7380.	
	The paper systematically reviews urban resilience research, highlighting significant themes such as environmental factors, urban planning, and social dimensions. It emphasizes the need for strategic analysis in developing resilient sustainable systems, particularly in metropolitan areas facing diverse shocks. The findings suggest that policies should focus on adaptive and sustainable management, considering not only urban cores but also peri-urban and rural settings. This approach is crucial for enhancing urban resilience and addressing the unique challenges faced by different metropolitan landscapes.	**Methods used:** - The study employs systematic review methodology using the PRISMA method. - It focuses on SCOPUS-indexed articles related to urban resilience in metropolitan areas. - The review identifies and clusters research into three main themes: environment, urban planning, and social–human dimensions. - Most studies included in the review apply quantitative methods at the city/metropolitan scale. - Multi-dimensional resilience indicators are utilized to measure urban systems' resilience against various shocks.
	Results: - The study shows a significant annual increase in urban resilience research in metropolitan areas. - Three main themes of urban resilience research are identified: environment, urban planning, and social–human dimensions. - Highly cited research focuses on urban concepts, resilience measurement of urban systems against various shocks, and resilience dimensions. - Metropolitan areas in Asia are leading discussions on urban resilience, particularly in response to frequent and diverse shocks. - Most studies utilize quantitative methods at the city/metropolitan scale, employing multi-dimensional resilience indicators.	**Conclusions:** - The study concludes that urban resilience research in metropolitan areas is experiencing significant growth, particularly in Asia, which leads discussions on resilience in response to various shocks. - It identifies three main themes in urban resilience studies: environment, urban planning, and social–human dimensions. - The research emphasizes the importance of measuring resilience across urban systems and highlights the need for multi-dimensional resilience indicators. - The findings suggest that resilience assessments should extend beyond urban cores to include peri-urban, desakota, and rural settings. - The authors stress the necessity of formulating policies that promote adaptive, sustainable, and local ecosystem management to enhance urban resilience across diverse metropolitan landscapes.
6	Ochoa, W. A. A., Iarozinski Neto, A., Vitorio Junior, P. C., Calabokis, O. P., & Ballesteros-Ballesteros, V. (2025). The theory of complexity and sustainable urban development: A systematic literature review. *Sustainability*, *17*(1), 3.	
	The paper conducts a systematic literature review linking Complexity Theory to urban sustainability, emphasizing cities as Complex Adaptive Systems. It identifies trade-offs in urban development, such as economic growth versus ecological preservation, and highlights self-organization and adaptive governance as key to resilience. The study showcases methods like fractal analysis and system dynamics models to enhance urban planning and align sustainable development goals. It advocates interdisciplinary collaboration and innovative policies to address the complexities of urbanization effectively.	**Methods used:** - A systematic literature review was conducted, analyzing 91 studies retrieved from Scopus that explicitly link Complexity Theory to urban sustainability. This method allowed for a comprehensive understanding of existing research and frameworks related to the application of Complexity Theory in urban contexts. - The study utilized concrete examples such as fractal analysis in urban planning to predict sprawl and optimize infrastructure, as well as system dynamics models to align smart city initiatives with the United Nations Sustainable Development Goals. These methods demonstrate practical applications of Complexity Theory in addressing urban sustainability challenges.
	Results: - The study reveals key trade-offs in sustainable urban development, such as the need to balance economic growth with ecological preservation and social equity, while highlighting the importance of self-organization and adaptive governance in enhancing urban resilience. - Concrete applications of Complexity Theory in urban planning include the use of fractal analysis to predict urban sprawl and optimize infrastructure, as well as system dynamics models that align smart city initiatives with the United Nations Sustainable	**Conclusions:** - The research concludes that embracing Complexity Theory allows for a holistic approach to urban sustainability, which fosters adaptable and resilient systems capable of better managing uncertainty in urban environments. - It emphasizes the necessity for interdisciplinary collaboration and the development of innovative policy frameworks to effectively address the complex challenges posed by modern urbanization.

	Development Goals, leading to co-benefits like improved public health and reinforced social cohesion through participatory planning.	
7	Chin, C. P., Alias, A., & Alkharabsheh, O. H. (2025). Urban housing regeneration strategies for sustainable city development: a systematic literature review. *Discover Sustainability*, *6*(1), 1050.	
	The paper systematically reviews urban housing regeneration strategies within sustainable city development, addressing financial, social, regulatory, and environmental barriers. It highlights challenges like limited funding and gentrification while proposing opportunities linked to economic renewal and technological advancement. The study emphasizes the importance of community-driven initiatives, mixed-use developments, and inclusive housing strategies, advocating for cross-sector collaboration and smart technologies to enhance resilience. This holistic framework aids policymakers and urban designers in fostering equitable urban renewal and mitigating gentrification.	**Methods used:** - The paper employs the PRISMA framework (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) for systematic literature review. It utilizes thematic analysis to explore core challenges in urban housing regeneration. - The study examines financial, social, regulatory, and environmental barriers affecting regeneration efforts. It identifies regeneration opportunities linked to economic renewal, technological advancement, and collaborative models. - Practical approaches reviewed include community-driven initiatives, mixed-use developments, green infrastructure, and resilience-focused planning.
	Results: - The research identifies persistent financial and social challenges in urban housing regeneration. - Targeted interventions can significantly enhance regeneration outcomes. - Successful implementation relies on integrating smart technologies and encouraging cross-sector collaboration. - Embedding inclusive policies is crucial for promoting equitable urban renewal. - The study emphasizes the importance of mitigating gentrification and advancing affordable housing.	**Conclusions:** - The paper concludes that financial and social challenges in urban housing regeneration can be addressed through targeted interventions. - Successful regeneration outcomes depend on the integration of smart technologies and cross-sector collaboration. - The authors emphasize the importance of embedding inclusive policies to promote equitable urban renewal. - The research highlights the relevance of the findings in mitigating gentrification and advancing affordable housing initiatives. - The study contributes to the discourse on sustainable urban futures by advocating for participatory and inclusive planning processes.
8	Tong, B., Liu, H., Zhu, J., Wang, Y., Mei, T., & Kou, M. (2025). Exploring safety research progress and prospects for the sustainable development of resilient cities. *Buildings*, *15*(3), 505.	
	The paper provides a comprehensive literature review on resilient cities, focusing on disaster response, infrastructure resilience, community engagement, and big data technologies. It highlights the interdisciplinary integration necessary for sustainable urban development. The analysis of studies from 2000 to 2023 reveals core topics and emerging trends, offering a theoretical framework and data-driven decision support for governments. This research emphasizes the importance of strategic analysis in enhancing urban resilience and managing complex risks in the context of global climate change and urbanization.	**Methods used:** - The paper employs a literature review methodology to systematically analyze data from resilient city studies. - It focuses on studies published in the SCIE and SSCI databases from 2000 to 2023. - Bibliometric tools are utilized to examine the spatial-temporal distribution, collaboration networks, and knowledge foundations of literature. - The review identifies core topics and emerging trends in resilient city research, particularly from risk and safety perspectives. - The findings aim to provide a comprehensive theoretical framework and data-driven decision support for governments.
	Results: - The literature review reveals that contemporary research on resilient cities is primarily focused on key areas such as disaster response, infrastructure resilience, community engagement, and the integration of big data technologies, indicating a trend towards interdisciplinary collaboration in addressing urban safety and resilience. - The findings provide a comprehensive theoretical framework for the academic community and offer data-driven decision support for governments, highlighting essential directions for future research that aim to enhance urban resilience in managing complex risks and promoting sustainable urban development globally.	**Conclusions:** - The literature review reveals that contemporary research on resilient cities is primarily centered around key areas such as disaster response, infrastructure resilience, community engagement, and the integration of big data technologies, indicating a trend towards interdisciplinary collaboration in addressing urban safety and resilience challenges. - The findings of the review provide a comprehensive theoretical framework for the academic community and offer data-driven decision support for governments, highlighting essential directions for future research that aim to enhance urban resilience in managing complex risks and promoting sustainable urban development globally.
9	Schiappacasse, P., & Müller, B. (2018). One fits all? Resilience as a multipurpose concept in regional and environmental development. *Raumforschung und Raumordnung| Spatial Research and Planning*, *76*(1), 51-64.	

	The paper conducts a systematic literature review on resilience, analyzing 650 articles to explore its application in urban, regional, and environmental studies. It highlights the need for specificity, transdisciplinary approaches, and regional contextualization in resilience discussions, particularly in the global south. The review reveals a predominance of theoretical papers and emphasizes the influence of Holling's (1973) definition. It suggests that resilience research must evolve from theory to practice, incorporating diverse methodologies to enhance urban development strategies.	**Methods used:** - The methodological approach of the study consists of four steps, starting with the selection and classification of 209 peer-reviewed journals related to urban, regional, social, political, and environmental studies to identify relevant publications on resilience. This draft list was discussed within the framework of the doctoral programme of the Dresden Leibniz Graduate School, ensuring that participants were well advanced in their literature analyses. - A keyword-based search for the term 'resilience' was conducted, covering scientific articles published between 2000 and 2013. The search criteria required that the term 'resilience' or its variations be included in the title or keywords of the articles, and the publications had to be easily accessible to contribute meaningfully to the scientific discussion. Various electronic databases were utilized to identify the relevant papers.
	Results: - The paper provides a systematic literature review on resilience, analyzing 650 articles to highlight recent developments in thought and practice. It reveals that while resilience is defined and operationalized in various contexts, there is a notable lack of precision regarding its meaning, interests, and strategic options, particularly in urban and regional development studies. - The findings indicate a dominance of ecological and social-ecological perspectives in resilience studies, with a significant focus on ecosystems. However, there is a scarcity of empirical contributions addressing social, political, and economic dimensions of resilience, suggesting a need for more specificity, transdisciplinary approaches, and regional contextualization, especially in the global south.	**Conclusions:** - The paper concludes that resilience has become a prominent and often ambiguous term in academia, practice and policymaking, necessitating a clearer understanding of its conceptual and methodological frameworks. The systematic literature review of 650 papers highlights a significant focus on natural events over slow-paced anthropogenic, economic, social, or political stresses, indicating a need for a more holistic approach to resilience studies that encompasses various dimensions and scales of shocks and uncertainties. - It is noted that while there is a substantial body of theoretical contributions and empirical evidence regarding resilience, there remains a lack of precision in defining and operationalizing the concept. The dominance of ecological and social-ecological perspectives in resilience studies has overshadowed the exploration of social and political dimensions, particularly in the context of urban and regional studies in the global south, suggesting that future research should aim for greater specificity and regional contextualization in resilience discourse.
10	Serdar, M. Z., & Al-Ghamdi, S. G. (2023). Assessing Resilience in Urban Critical Infrastructures: Interdependencies and Considerations. *Sustainable Cities in a Changing Climate: Enhancing Urban Resilience*, 81-96.	
	The paper emphasizes the importance of resilience in urban development, particularly in critical infrastructures like transportation, water, and electricity. It highlights the interdependence among these systems and the need for a holistic approach to resilience assessments. By integrating resilience into urban planning, cities can enhance their adaptability to challenges such as climate change and political tensions. The chapter also includes case studies that illustrate the complexities of evaluating interrelated infrastructures, contributing to the strategic analysis of sustainable urban systems.	**Methods used:** - The chapter emphasizes a holistic approach to assessing resilience by considering the interdependencies and interactions between critical infrastructures such as transportation, water, and electricity. This approach is crucial as disruptions in one infrastructure can lead to cascading effects on others, impacting overall urban resilience. - Two case studies are included to illustrate the differences between assessing individual infrastructures and evaluating a system of interrelated infrastructures. These case studies highlight the complexities involved in resilience assessments and provide guidance on how to effectively evaluate both individual and interdependent infrastructures.
	Results: - The chapter emphasizes the importance of understanding the interdependencies between critical urban infrastructures such as transportation, water, and electricity, highlighting that disruptions in one infrastructure can lead to cascading effects on others, thereby impacting overall urban resilience. This understanding is crucial for developing effective urban development plans that integrate resilience considerations.	**Conclusions:** - The chapter emphasizes the importance of understanding the interdependencies between critical urban infrastructures such as transportation, water, and electricity, as disruptions in one can led to cascading effects on others, ultimately impacting overall urban resilience. A holistic approach to resilience assessment is necessary to effectively address these complexities. - By providing guidance on assessing both individual and interdependent infrastructures, the chapter aims to

	- Two case studies presented in the chapter illustrate the complexities involved in resilience assessments, demonstrating the differences between evaluating individual infrastructures and assessing a system of interrelated infrastructures. These case studies underscore the necessity of a holistic approach to resilience assessment that considers the interactions and dependencies among various urban systems.	enhance the understanding of urban resilience and support decision-making processes that improve the robustness and adaptability of critical urban systems, contributing to the development of more sustainable and resilient cities.

In the following analysis based on the literature, we will discuss the main components that should be considered in a proposed model approach.

2.1 Urban Resilience and Sustainability Frameworks

According to (Zeng et al., 2022), urban resilience and sustainability are interrelated paradigms that emphasize a system's capacity to move toward desirable development paths, focusing on preserving societal health and well-being within the context of environmental change. In addition, key indicators of urban resilience include adaptive capacity (education, health, food, and water), absorptive capacity (community support, urban green space, protective infrastructure, access to transport), and transformative capacity (communication technology, collaboration of multi-stakeholders, emergency services of government, community-oriented urban planning) (Zeng et al., 2022).

Furthermore, the integration of green infrastructure is pivotal in fostering urban resilience and sustainability, emphasizing biodiversity, community engagement, and seamless integration with existing urban structures (Umoh et al., 2024).

2.2 Governance and Policy Challenges

As supported by (Yan et al., 2025), urban resilience governance faces obstacles such as governance fragmentation, resource limitations, policy incoherence, social inequities, and technical constraints. Strategies to overcome these challenges include NBS, stakeholder collaboration, policy reforms, technological innovations, and community-centric approaches. Furthermore, the need for holistic, adaptive, and participatory approaches is emphasized to build resilient urban systems capable of navigating contemporary complexities (Yan et al., 2025).

2.3 Critical Infrastructure and Interdependencies

Resilience in urban development plans is crucial for addressing challenges from climate change, political tensions, and increasing complexity, particularly in critical infrastructures like transportation, water, and electricity (Serdar & Al-Ghamdi, 2023). In addition, understanding the interdependencies between these infrastructures is essential, as disruptions in one can have cascading effects on others, impacting overall urban resilience (Serdar & Al-Ghamdi, 2023). As supported by the case studies presented by (Serdar & Al-Ghamdi, 2023), they illustrated that complexities involved in resilience assessments and highlight the importance of a holistic approach that considers interdependencies and interactions

2.4 Complexity Theory and Urban Development

Complexity Theory frames cities as Complex Adaptive Systems (CAS), where dynamic social, economic, environmental, and technological interactions generate emergent behaviors. Same authors supported that their proposed approach emphasizes the role of self-organization and adaptive governance in enhancing urban resilience, with examples including the application of fractal analysis in urban planning and system dynamics models to align smart city initiatives with Sustainable Development Goals (Ochoa et al., 2024).

2.5 Urban Housing and Regeneration Strategies

Urban housing regeneration is a critical component of sustainable city development, addressing financial, social, regulatory, and environmental barriers. In addition, strategies include community-driven initiatives, mixed-use developments, green infrastructure, adaptive reuse, inclusive housing strategies, and resilience-focused planning (Chin et al., 2025). The same authors mentioned that successful implementation hinges on integrating smart technologies, encouraging cross-sector collaboration, and embedding inclusive policies to promote equitable urban renewal.

2.6 Preliminary Conclusions

While the strategic analysis of resilient sustainable systems for urban development offers a comprehensive framework for addressing urban challenges, it is important to consider the diverse contexts and unique challenges faced by different cities. The integration of resilience and sustainability into urban planning requires a nuanced understanding of local conditions, stakeholder dynamics, and governance structures. Future research and policy implementation should focus on fostering interdisciplinary collaboration and innovative frameworks to navigate the multifaceted challenges of modern urbanization.

III. CONCEPTUAL FRAMEWORK: RESILIENCE AS A PATHWAY TO SUSTAINABILITY

While often used interchangeably, urban resilience and urban sustainability represent complementary, yet distinct, strategic objectives. Understanding this relationship is the foundation of effective urban strategy (Zeng et al., 2022) and the following considerations need to be included:

- Urban sustainability focuses on the end state, a long-term equilibrium characterized by

intergenerational equity, resource protection, economic viability, and social well-being. It is concerned with reducing the city's overall environmental footprint and ensuring that resource consumption is compatible with the ecosystem's regenerative potential.

- Urban resilience focuses on the process, the dynamic capacity of a city's systems (social, ecological, and technological) to absorb disturbance, reorganize, and evolve. It is concerned with a city's vulnerability and its ability to "bounce back" or, more strategically, "bounce forward" into a more desirable state after a shock, such as a natural disaster or economic crisis.
- The strategic implication is clear: resilience is a prerequisite for sustainability. A city that lacks the capacity to withstand a major shock will see its long-term sustainability goals instantly undermined. Therefore, strategic urban development must integrate resilience-building measures into every sustainability initiative.

3.1 The Core Strategic Lens: Social-Ecological-Technological Systems (SETS)

To operationalize the resilience-sustainability nexus, a systems-thinking approach is essential. The Social-Ecological-Technological Systems (SETS) framework provides the most comprehensive lens for this integration, recognizing that urban areas are complex adaptive systems where human, natural, and engineered components are inextricably linked (McPhearson et al., 2022). Further details are given in Table 2.

Table 2: The SETS framework

Dimension	Core components	Strategic role in Resilient Sustainability
Social (S)	Governance, policy, planning, finance, institutional capacity, cultural norms, equity, and justice.	Provides the adaptive capacity, leadership, and inclusive decision-making necessary for transformation and equitable distribution of benefits.
Ecological (E)	Climate, biodiversity, ecosystem structure and function, and NBS, such as urban green infrastructure.	Provides essential ecosystem services (e.g., cooling, water filtration) that enhance the city's natural defence mechanisms and reduce reliance on gray infrastructure.
Technological (T)	Engineered infrastructure (gray and green), automated systems, data collection, and physical components (e.g., smart grids, water pipes, sensors).	Provides the physical backbone and operational efficiency, enabling rapid recovery and data-driven management of urban services.

As seen in Table 2, the SETS framework breaks down the urban environment into three interdependent dimensions, all of which must be managed concurrently to achieve resilient sustainability.

3.2 Strategic Pillars for Resilient Sustainable Urban Development

An effective strategy for resilient sustainable urban systems must address four cross-cutting challenges that emerge from the interaction of the SETS dimensions (McPhearson et al., 2022). These challenges form and define the strategic pillars for action:

1. Integrated Planning for Multi-functionality

A key strategic goal is to maximize the multi-functionality of urban interventions, ensuring that a single investment yields multiple co-benefits across the SETS dimensions. Traditional planning often results in siloed solutions (e.g., a park for recreation only, a pipe for drainage only). The integrated approach demands solutions that simultaneously address social, ecological, and technological needs.

For example, the implementation of NBS, such as green roofs or bioswales, should be evaluated not just for their ecological function (stormwater absorption, cooling) but also for their social function (creating community spaces, improving public health) and their technological function (reducing strain on gray infrastructure) (McPhearson et al., 2022). This requires a shift in planning metrics to account for synergies and trade-offs across all three dimensions.

2. Holistic Valuation and Risk Financing

The strategy must overcome the challenge of valuation, particularly the underestimation of the long-term value of ecological and social capital. Resilience-building requires significant upfront investment, which must be justified by a holistic valuation model that includes:

- Systemic Valuation - Assessing the value of ecosystem services (E) and the cost of social stewardship (S) and technological support (T) required to maintain them.
- Risk-Based Land Use Planning - Integrating risk assessment data into land-use policy to prevent development in high-hazard areas, a fundamental principle of urban resilience (World Bank, 2013).
- Risk Financing and Transfer - Developing economic and financial strategies, such as municipal insurance schemes, catastrophe bonds, and public-private partnerships, to finance recovery and transfer risk away from the public sector (World Bank, 2013).

3. Addressing Scale Mismatches

Resilience and sustainability are often undermined by scale mismatches, where local-scale provisions do not align with regional-scale needs or governance

structures (McPhearson et al., 2022). Strategic planning must coordinate actions across different scales:

- Local-to-Regional Coordination: Ensuring that local interventions (e.g., neighborhood cooling centers, community gardens) are supported by regional infrastructure (e.g., water supply, energy grid) and governance (e.g., metropolitan planning organizations) (World Bank, 2013).
- Temporal Alignment: Planning for both immediate shock response (e.g., disaster management systems) and long-term adaptive capacity (e.g., climate-resilient infrastructure upgrades) (World Bank, 2013). For instance, a green roof provides immediate cooling benefits locally, but city-wide cooling requires incentives and regulations (S) to ensure broad adoption (T) across the entire urban area (McPhearson et al., 2022).

4. Ensuring Equity and Justice

The most critical strategic pillar is ensuring equity and justice in the distribution of resilience and sustainability benefits. Historically, marginalized communities often face disproportionate exposure to hazards and have less access to protective services (McPhearson et al., 2022).

- Procedural Justice: Involving diverse community members and knowledge systems in the planning and decision-making process (S) (World Bank, 2013).
- Distributional Justice: Explicitly designing investments in ecological (E) and technological (T) infrastructure to benefit vulnerable populations. For example, failing to address this can lead to "green gentrification", where investments in green infrastructure increase property values, displacing the very low-income residents the resilience measures were intended to protect (McPhearson et al., 2022). A resilient sustainable system must be "just green enough" to provide benefits without causing displacement (McPhearson et al., 2022).

3.3 Preliminary Conclusion - A Call for Systemic Integration

The strategic analysis of resilient sustainable systems for urban development reveals that success hinges on a shift from fragmented, single-objective planning to a holistic, integrated approach guided by the SETS framework. Resilience is not merely an add-on to sustainability; it is the dynamic capacity that makes long-term sustainability possible in a turbulent world.

The path forward requires urban leaders to:

1 Adopt the SETS Lens - View all urban projects through the combined social, ecological, and technological dimensions.

2 Prioritize NBS - Invest in ecological infrastructure that provides multi-functional benefits and redundancy.

3 Embed Equity - Make social justice and equitable distribution of benefits a non-negotiable design constraint for all resilience and sustainability initiatives.

By strategically integrating these principles, cities can transform from vulnerable, resource-intensive centers into adaptive, thriving, and truly resilient sustainable systems.

IV. COMPARATIVE ANALYSIS: HOLISTIC VALUATION VS. TRADITIONAL COST-BENEFIT ANALYSIS (CBA)

The choice of valuation methodology is a critical strategic decision that determines the success of resilient sustainable urban development projects, particularly those involving Green Infrastructure (GI). Traditional Cost-Benefit Analysis (CBA) and the proposed Holistic Valuation approach differ fundamentally in their scope, metrics, and ultimate strategic goal.

4.1 Comparison of Methodologies for Green Infrastructure

Traditional CBA is a well-established economic tool that seeks to determine if the monetary benefits of a project outweigh its monetary costs (World Bank, 2013). However, its narrow focus often leads to the undervaluation of multi-functional, long-term, and non-market benefits inherent in resilient sustainable systems. Holistic valuation, by contrast, is designed to capture the full complexity of the Social-Ecological-Technological Systems (SETS) framework.

Table 3 below compares the two approaches in the context of a Green Infrastructure project, such as a city-wide network of bioswales and urban green spaces for stormwater management.

A discussion on the strategic implications is useful. The comparison reveals that traditional CBA is structurally biased against Green Infrastructure and other NBS. By focusing narrowly on the technological dimension (T) and externalizing the ecological (E) and social (S) co-benefits, CBA consistently undervalues GI projects, making them appear less financially viable than conventional gray infrastructure alternatives (e.g., concrete pipes and tunnels).

Holistic valuation, conversely, provides the necessary strategic justification for investing in resilient sustainable systems. By quantifying the full spectrum of multi-functional benefits - from reduced energy consumption due to urban cooling to improved public health from cleaner air and accessible green space, it demonstrates that the total return on investment for GI is often significantly higher than that of single-purpose gray infrastructure. This shift in valuation is not merely an accounting exercise; it is a strategic pivot that enables urban leaders to make decisions that prioritize long-term resilience and sustainability over short-term cost minimization (Zeng, et al., 2022; McPhearson, et al., 2022).

Table 3: Analysis of two approaches to Green Infrastructure project

Feature	Traditional Cost-Benefit Analysis (CBA)	Holistic Valuation (SETS-Based)
Scope of Analysis	*Narrow*: Primarily focuses on direct, quantifiable costs and benefits related to the project's primary function (e.g., stormwater capacity).	*Broad*: Integrates costs and benefits across all three SETS dimensions (Social, Ecological, Technological).
Key Metrics	Capital Expenditure (CapEx), Operational Expenditure (OpEx), and avoided costs of gray infrastructure replacement (e.g., new pipes).	CapEx, OpEx, avoided gray infrastructure costs, plus the quantified value of ecosystem services and social co-benefits.
Treatment of Ecological Value	*Externalized*: Non-market benefits like air filtration, biodiversity, and carbon sequestration are often ignored or treated as unquantifiable externalities.	*Internalized*: Systematically quantifies the monetary value of ecosystem services (E) and their contribution to resilience (e.g., wave attenuation, cooling).
Treatment of Social Value	*Externalized*: Social equity, public health improvements, and community cohesion are typically excluded.	*Internalized*: Explicitly values social co-benefits (S), including reduced heat-related illness, increased property values due to amenities, and the reduction of social vulnerability (equity).
Risk and Resilience	Focus on engineering reliability and cost-efficiency under normal operating conditions.	*Focuses on systemic resilience*: values redundancy, adaptability, and the reduction of long-term climate risk (avoided losses from extreme events).
Strategic Goal	To select the most cost-efficient project option.	To select the most value-maximizing and resilient sustainable project option.

4.2 Elaboration on Strategic Pillar 2: Holistic Valuation

The strategic pillar of Holistic Valuation is paramount for transitioning from conventional, cost-centric urban development to resilient sustainable systems. It addresses the fundamental challenge that traditional economic models often fail to capture the full spectrum of benefits and costs associated with urban infrastructure and planning decisions, particularly those related to ecological and social capital (McPhearson, et al., 2022).

Holistic valuation is a strategic approach that moves beyond simple capital expenditure (CapEx) and operational expenditure (OpEx) of engineered systems. It systematically integrates the value of the three SETS dimensions: Social (S), Ecological (E), and Technological (T), into the decision-making process.

This approach is necessary because resilience-building measures, such as NBS, often require significant upfront investment but yield long-term, multi-functional benefits that are difficult to quantify using standard metrics. By adopting holistic valuation, urban planners can justify these investments by demonstrating their full return on investment (ROI) in terms of avoided costs, enhanced ecosystem services, and improved social equity.

The core components of holistic valuation include:

1 Systemic Valuation - Quantifying the value of ecosystem services (e.g., carbon sequestration, air filtration, cooling) and social benefits (e.g., public health improvements, community cohesion, reduced social vulnerability).

2 Risk-Based Planning - Using advanced data analytics and risk modeling to calculate the value of avoided losses due to climate change impacts, which directly informs land-use and infrastructure investment decisions (World Bank, 2013).

3 Risk Financing and Transfer - Developing innovative financial mechanisms (e.g., resilience bonds, public-private partnerships) to manage residual risk and ensure that the long-term costs of maintenance and recovery are secured (World Bank, 2013).

4.3 Conceptual Examples of Implementation in Urban Planning

The implementation of holistic valuation is best illustrated by comparing its application to two contrasting infrastructure projects: an NBS and a traditional Gray Infrastructure project:

- Project 1consits of implementing a city-wide network of bioswales, permeable pavements, and urban wetlands (Green Infrastructure) to manage stormwater runoff and reduce flood risk. Details are given in Table 4. NBS projects are initiatives that protect, sustainably manage, and restore ecosystems to address societal challenges like climate change, disaster risk reduction, and biodiversity loss while providing human well-being co-benefits. Examples include restoring forests for carbon sequestration, creating urban green spaces for cooling, and restoring wetlands for flood management.

- Project 2 shows the construction of a new sea wall (Gray Infrastructure) combined with restoring coastal wetlands and dunes (NBS) to protect a low-lying urban district. Details are given in Table 5. Gray infrastructure projects involve human-engineered, structural solutions, such as dams, pipes, seawalls, and water treatment plants, designed to manage water, reduce flood risks, and support urban services. These traditional, often concrete-based systems are increasingly being combined with nature-based "green" solutions to enhance resilience, reduce pollution, and manage stormwater more effectively.

By implementing holistic valuation, urban planning shifts from a focus on minimizing initial cost to maximizing long-term value and resilience across the entire urban system. This is the strategic pivot required to build truly resilient sustainable cities.

Table 4: Example 1: Green Infrastructure (Nature-Based Solution)

Valuation Component	Traditional Valuation (T-centric)	Holistic Valuation (SETS-centric)
Technological (T) Cost	Cost of construction and maintenance of the green infrastructure assets.	Same as traditional but also includes the cost of smart sensors for monitoring soil moisture and water flow.
Ecological (E) Value	Often valued at zero or as a minor aesthetic benefit.	Quantified Value: Includes the monetary value of: (1) Avoided infrastructure costs - Reduced need for pipe upgrades and new retention tanks. (2) Ecosystem services - Value of water filtration, air quality improvement, and urban cooling (e.g., reduced energy demand for air conditioning). (3) Biodiversity - Value of new habitat creation.
Social (S) Value	Not considered.	Quantified Value: Includes the monetary value of: (1) Public health - Reduced heat-related illness and improved air quality. (2) Recreation/Aesthetics - Increased property values and community use of green spaces. (3) Equity - Targeted investment in low-income, flood-prone neighbourhoods, reducing social vulnerability and promoting environmental justice (McPhearson et al., 2022).
Strategic Outcome	Justified only if the construction cost is lower than a gray pipe alternative.	Justified by a significantly higher ROI, as the multi-functional benefits (E+S+T) far outweigh the initial investment, making it the preferred resilient sustainable solution.

Table 5: Example 2: Coastal Flood Defense (Hybrid Infrastructure)

Valuation Component	Traditional Valuation (T-centric)	Holistic Valuation (SETS-centric)
Technological (T) Cost	Cost of the concrete sea wall and its maintenance.	Cost of the sea wall, plus the cost of restoring and maintaining the ecological buffer (wetlands).
Ecological (E) Value	Not considered.	Quantified Value: (1) Wave attenuation - Value of the wetlands and dunes in absorbing wave energy, reducing the required height and cost of the sea wall (T); (2) Carbon sequestration - Value of the restored wetlands as a long-term carbon sink.
Social (S) Value	Not considered.	Quantified Value: (1) Risk reduction - Value of avoided economic damage to businesses and homes (Risk-Based Planning). (2) Social cohesion - Value of the restored coastline as a public amenity and recreational space. (3) Risk transfer - The cost-benefit analysis includes the premium savings from reduced insurance costs due to the combined E and T protection.
Strategic Outcome	Focuses solely on the engineering feasibility and cost of the wall.	Leads to a Hybrid Solution that is more resilient, as the ecological buffer provides redundancy and co-benefits that the sea wall alone cannot, ensuring a more sustainable and cost-effective long-term outcome.

4.4 A Debate About the Situation in Romania

In Romania, the push for resilient and sustainable urban systems is driven by a combination of EU funding (specifically the National Recovery and Resilience Plan - NRRP) and local municipal innovation. These systems focus on three main pillars: *climate adaptation, smart mobility, and energy efficiency*.

Table 6: Summary of Key Mechanisms

System Type	Key Technology / Strategy	Primary Goal
Blue - Green	Rainwater harvesting and Micro-forests	Flood and Heat mitigation
Digital	Smart Traffic Management and GIS	Congestion and Emission reduction
Energy	Geothermal and Photovoltaic integration	Energy independence
Structural	Combined Seismic + Thermal retrofitting	Safety and Efficiency

Here are specific examples of these systems in practice across Romanian cities (Table 6 presents a synthesis of key mechanisms):

1. Climate-Resilient Green Infrastructure - Urban centers are implementing NBS to combat the Urban Heat Island (UHI) effect and manage flash floods.

- Bucharest's "Climate Refuges" - Projects like the OPEN COOLSPOT Campus Tei and the Filipescu-Cesianu Garden use plant evapotranspiration and rainwater collection to create natural cooling zones in dense concrete areas.
- Urban Micro-Forests - The "Cool Bucharest" initiative is planting a network of 20 micro-forests across the city. These act as "carbon sinks" and air filters, increasing the city's biological resilience.
- Cluj-Napoca's Green Corridors - The city has pioneered the revitalization of riverbanks (e.g., Somes River) to create green-blue corridors that provide both flood protection and recreational public space.

2. Smart and Sustainable Mobility Systems - Romania is rapidly transitioning from diesel-heavy transit to integrated, low-emission transport networks.

- Cluj-Napoca (Smart City Leader) - It was the first city in Romania to introduce electric buses and currently operates a fleet that includes autonomous shuttles and electric ticketing systems.
- Recharge Networks: Under the NRRP, Romania is installing at least 30,000 electric vehicle (EV) recharging points by mid-2026 to decentralize fuel dependency and reduce urban air pollution.
- Intermodal Hubs in Oradea – The city has integrated its tram, bus, and regional rail systems with digitized GIS (Geographic Information System) databases to optimize routes and reduce idle times, significantly lowering the city's carbon footprint.

3. Energy Resilience and Circular Economy - Resilient systems in Romania are increasingly focused on energy independence and waste-to-resource loops.

- Geothermal Heating (Oradea and Beius) - Oradea is a national leader in using geothermal energy for district heating. By tapping into natural hot water reservoirs, the city provides sustainable, low-cost heat that is resilient to global fossil fuel price volatility.
- Seismic and Thermal Retrofitting - Throughout Bucharest and Iasi, integrated programs are combining seismic consolidation with thermal insulation. This "dual resilience" approach ensures buildings can withstand earthquakes while simultaneously reducing energy consumption by up to 60%.
- "Recycle in Romania" System - This national digital and physical infrastructure aims to standardize separate waste collection, moving cities toward a circular economy where waste is treated as a secondary raw material rather than a pollutant.

The information provided is based on official government strategies, European Commission reports, and local municipal project data as of early 2026.

Primary institutional sources are:

- European Commission (Recovery and Resilience Facility) - Details on the National Recovery and Resilience Plan (NRRP) for Romania, specifically the €2.7 billion allocation for energy efficiency and the "Renovation Wave" for seismic and thermal retrofitting.
- Government of Romania (Ministry of Investments and European Projects) - Implementation updates on the 30,000 EV charging points and national afforestation campaigns (urban micro-forests) scheduled for completion by June 2026.
- NetZeroCities (Horizon Europe) - Data regarding the "Mission 100 Climate-Neutral and Smart Cities by 2030", which includes Cluj-Napoca's "UrbanLab for Green Cities" and "Zero Move" initiatives.

Specific Municipal and Technical Sources include:

- Municipality of Oradea and Termoficare Oradea - Technical specifications for the Nufarul Geothermal Project (50 MW capacity) and the Iosia Nord district heating systems.
- Cluj-Napoca City Hall - Reports on the "Walkable City" (15-minute city) concept, the Digital Twin project for the Manastur neighborhood, and the 60km Green-Blue corridor along the Somes River.
- Bucharest Community Foundation (Environmental Platform for Bucharest) - Documentation on the "OPEN COOLSPOT" (Campus Tei) and "Filipescu-Cesianu Garden" climate refuges, and the "Cool Bucharest" micro-forest network.
- ThinkGeoEnergy and Transgex SA - Historical and technical data on geothermal exploration and CO_2 emission reduction statistics in the Bihor County region.

Formatting Tools and Infrastructure References - The conceptual framework for "Resilient Systems" in these examples follows the UEFISCDI (Executive Unit for Financing Higher Education, Research, Development and Innovation in Romania) research project: ReSURCe - Toolbox for assessing the resilience and sustainability of urban housing models in Romania (2025–2026), https://ccmesi.ro/?page_id=2807.

4.5 A Debate About the Situation in Portugal

Portugal's approach to urban resilience is defined by a deep integration of nature-based solutions with advanced digital and energy transitions. As the host of the 2026 European Urban Resilience Forum, the country has become a primary testing ground for "integrated resilience", where climate adaptation is woven into the cultural and social fabric of its cities. Here are the standout examples of resilient sustainable systems currently in place or being finalized in Portugal (a synthesis being presenting in Table 7):

1. Circular Construction and Heritage Regeneration - In Lisbon, the challenge of being one of Europe's oldest capitals is met with a "circularity-first" approach to building.

- Circular Construction Hubs (CCH) - Lisbon has implemented a hybrid system that combines a physical material bank with a digital marketplace. This system allows for the salvage and reuse of materials from urban demolition (like the iconic *azulejos* tiles or structural stone), significantly reducing carbon emissions from new material production.
- Affordable Housing and Retrofitting - Under the 2026 National Recovery and Resilience Plan (PRR) targets, Portugal is delivering 26,000 sustainable housing units. These projects use "energy-performance-certified" renovations, ensuring that social resilience (housing affordability) is paired with climate resilience (thermal efficiency).

2. The "Green - Blue" Urban Transformation - Portuguese cities are moving beyond traditional gray infrastructure to manage heat and water through natural systems.

- Guimarães – European Green Capital 2026: The city has pioneered a "Green Map" system that turns climate action into a citywide interactive experience. Its focus is on tree-based solutions to buffer microclimates, particularly important for Mediterranean landscapes prone to extreme heat and wildfires.
- Lisbon's Drainage Master Plan: One of Europe's most ambitious resilient engineering projects, this system uses massive underground tunnels to divert rainwater during extreme storms directly to the Tagus River, preventing the devastating flash floods that historically plagued the city's lower districts (Fig. 1).

3. Energy Independence - The "Green Hydrogen" Hubs. Portugal is leveraging its massive solar and wind capacity to decentralize its energy systems, focusing on Sines and Évora.

- Sines 100MW Green Hydrogen Unit - Recently completed in 2026, this industrial-scale system replaces gray hydrogen with green hydrogen, cutting over 110,000 tonnes of CO_2 annually.
- H2Évora - This pilot project is a pioneer in Solar-to-Hydrogen technology. It uses solar generators to produce hydrogen, which is then stored and converted back into electricity via fuel cells during peak demand, providing a resilient, off-grid power solution for urban functions.

4. Smart Mobility and Circular Waste:

- Deposit Return System (DRS) - In 2026, Portugal became the 19th European country to implement a nationwide DRS. This system uses "Smart RVMs" (Reverse Vending Machines) across urban centres to achieve a 90% collection rate for beverage containers, feeding directly into a circular manufacturing loop.
- Intermodal Mobility Hubs - Cities like Porto and Lisbon have synchronized their Sustainable Urban Mobility Plans (SUMPs) with real-time GIS data, prioritizing Multimodal Passenger Hubs that encourage a shift from private cars to a mix of rail, electric buses, and soft mobility (cycling/walking).

Guimarães, the 2026 European Green Capital, serves as Portugal's premier model for Nature-Based Solutions (NBS). Its strategy, the "Green Radial Strategy", is designed to cool the city and manage water by integrating natural ecosystems directly into the historic urban fabric.

Fig. 1. A visual overview of green stormwater infrastructure, a sustainable approach to managing urban stormwater runoff.

Table 7: Comparative Resilience Table for Portugal in 2026

System Sector	Key Innovation	Resilience Function
Construction	Digital Material Hubs	Resource independence and Waste reduction
Water	Deep Drainage Tunnels	Flood prevention in historic zones
Energy	Green Hydrogen Fuel Cells	Grid stability and Decarbonized transport
Forestry	Mediterranean Tree Diversity	Fire spread mitigation and Heat cooling

Table 8: Summary of Resilience Outcomes

NBS Intervention	Resilience Benefit	Data Metric
Green Corridors	Urban Heat Mitigation	-2°C temperature drop
Retention Basins	Flood Protection	23% fewer flood incidents
Miyawaki Forests	Air Quality & Biodiversity	97% "Good" air quality rating
River Restoration	Ecosystem Connectivity	High NDVI/WHO compliance

In the following there will be presented specific NBS examples being implemented for the 2026 program in Portugal (selection of relevant examples):

1. The "Green Radial" Strategy - This is the city's flagship cooling system, consisting of three expanding green belts that connect hilltop forests to the medieval city centre.

- Urban Cooling Corridors - 14 km of green corridors that drop ambient air temperatures by up to 2°C during heatwaves.
- Climate Refuges: Pockets of "Miyawaki" (micro) forests and community green spaces are strategically placed in dense areas to provide natural shaded "sanctuaries" for residents.
- Tree Canopy Expansion - A long-term commitment to plant thousands of trees (with a regional goal of 3 billion by 2030) to increase the Normalized Difference Vegetation Index (NDVI) above WHO recommendations.

2. Blue-Green Infrastructure for Water Resilience - Guimarães has moved away from concrete drainage in favour of systems that mimic the natural water cycle to prevent flash floods.

- Natural Irrigation Basins - Three newly established basins act as retention ponds. They capture peak rainfall to prevent flooding during winter and serve as water reservoirs for irrigation during summer droughts.
- Riverine Habitat Restoration - Rehabilitated riparian buffers along the Selho and Ave rivers now store peak rainfall. This "soft" engineering has slashed minor flooding incidents by an estimated 23% since 2022.
- Permeable Surfaces: Large-scale conversion of asphalt into permeable pavements in neighbourhoods like Bairro C, allowing water to soak into the soil rather than overwhelming the sewer system.

3. "Bairro C" – The Living Laboratory - A former industrial tanning district (Zona de Couros) has been transformed into a testing ground for zero-carbon and NBS policies.

- Regenerative Urban Design - Abandoned industrial buildings are repurposed with green roofs and vertical gardens that filter air and reduce noise pollution.
- Biodiversity Gardens - Small-scale urban gardens that use rain-fed meadows and native Mediterranean flowering plants to support local pollinators and improve urban soil health.

4. Data-Driven Nature Management - Unique to Guimarães is the Landscape Laboratory (Laboratório da Paisagem), which uses science to optimize these natural systems.

- Integrated Operations Centre - Planners use a "Decision Support System" that monitors urban heat islands and drainage levels in real-time. This allows the city to simulate the climate impact of a new park or a set of trees before they are even planted.
- Limp.AR Project - A specific intervention using urban vegetation to measurably reduce noise and air pollution, with 86% of residents now reporting improved acoustic comfort.

Guimarães is also the host of the 2026 European Urban Resilience Forum (EURESFO), where these "nature-first" strategies will be showcased to city leaders from across the continent.

The examples provided for Portugal's urban resilience are grounded in national strategy documents, municipal reports, and international climate mission data for 2026. The primary institutional sources considered in this documentation study were:

- European Commission (DG Environment) - Official documentation regarding the European Green Capital 2026 award for Guimarães, including technical assessment reports on its waste management and biodiversity strategies.
- Government of Portugal (PRR - Plano de Recuperação e Resiliência): The "Recuperar Portugal" portal, which tracks the delivery of 26,000 sustainable housing units and the €22.2 billion allocation for the climate and digital transition.
- ICLEI Europe (Local Governments for Sustainability): Program details for the 13th European Urban Resilience Forum (EURESFO26), hosted in Guimarães in June 2026.

In addition, we have used specific municipal and project sources as follows:

- Laboratório da Paisagem (Guimarães) - Scientific data and progress reports on the "Green Radial" strategy and the Limp.AR project, which monitors the air-cooling effects of urban vegetation.
- Lisbon Municipality (PGDL - Plano Geral de Drenagem de Lisboa) - Technical briefs on the 5.5-meter diameter drainage tunnels (specifically the Campolide–Santa Apolónia stretch) and the reuse of "Oli" the tunnel boring machine.
- NetZeroCities (Horizon Europe) - Case studies on Bairro C (District C) in Guimarães as a pilot for zero-carbon historical districts and the integration of the New European Bauhaus values.

- Galp Energia (Sines Green Hydrogen Production) - Press releases and EIB (European Investment Bank) project sheets detailing the completion of the 100MW electrolyser unit in Sines (January 2026).

Finally, some technological and engineering references have been considered for our documentation:

- Remote Sensing Applications: Society and Environment - A 2025 scientific study titled *"Impact of nature-based solutions (NBS) on urban surface temperatures in Guimarães,"* which provided the baseline for the observed $2°C$ temperature drop in green corridors.
- OECD Economic Surveys - Portugal 2026: Reports on the fiscal and structural impact of the National Recovery Plan on Portuguese urban infrastructure and energy resilience.

IV. CONCLUSIONS

Based on the provided study, here is a list of the primary conclusions regarding the development of resilient and sustainable urban systems:

- **Resilience as a prerequisite for sustainability -** The study concludes that while sustainability is the long-term goal (equilibrium), resilience is the essential process and capacity required to reach it. A city cannot achieve long-term sustainability if it lacks the capacity to withstand and "bounce forward" from shocks and stresses.
- **The necessity of the SETS framework -** Urban centres must be managed as **Social-Ecological-Technological Systems (SETS)**. This integrated approach recognizes that human governance, natural ecosystems, and engineered infrastructure are inextricably linked and must be addressed concurrently to ensure system-wide resilience.
- **Shift from traditional to holistic valuation -** A major conclusion is that **traditional Cost-Benefit Analysis (CBA)** is insufficient because it often externalizes and undervalues ecological and social benefits. The study advocates for a **Holistic Valuation model** that internalizes the value of ecosystem services and social capital to justify the upfront costs of resilient infrastructure.
- **Prioritization of Nature-Based Solutions (NBS):** The research highlights NBS (such as urban micro-forests, green corridors, and permeable surfaces) as critical tools. These solutions provide multi-functional benefits, including climate adaptation (cooling), stormwater management, and improved public health, often with a higher long-term return on investment than gray infrastructure alone.
- **Addressing scale and governance mismatches -** Effective resilience requires aligning local interventions (e.g., community gardens) with regional governance and infrastructure (e.g., energy grids). Overcoming governance fragmentation and policy incoherence is vital for navigating modern urban complexities.
- **Commitment to equity and justice -** A resilient system must prioritize **procedural and distributional justice**. Planners must ensure that resilience benefits reach vulnerable populations and intentionally design projects to avoid "green gentrification", where environmental improvements displace the residents, they were meant to protect.
- **Evidence from practical implementation -** Case studies from **Romania and Portugal** demonstrate that integrated strategies, such as Oradea's geothermal heating, Cluj-Napoca's green corridors, and Guimarães' "Green Radial" strategy, which are already yielding measurable results in energy independence, flood protection, and urban cooling.

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Designing Pre-/Post-Pandemic Comparisons in Japanese Pop Culture Events: An Integrative Literature Review

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Abstract – Research linking COVID-19 disruption to Japanese pop culture event participation remains scarce and fragmented, limiting pre-/post-pandemic comparative designs. This paper conducts a narrative integrative review, combining an exploratory Web of Science scoping search with targeted keyword searches and backward/forward citation tracing to broaden coverage beyond Web of Science indexing. Three streams are synthesized: crisis-related shifts in cultural event participation, motivations and profiling in cultural/creative events, and fandom-based dynamics, including contents/otaku tourism linkages. The main result is an integrative framework that clarifies mechanisms and outlines implications for comparative studies, including motivational comparability, cross-period assessment, segmentation, and risk- and constraint-related predictors.

Keywords: Japanese pop culture events; fandom; contents tourism; attendee motivations; comparative research design.

I. INTRODUCTION

The COVID-19 pandemic generated wide-ranging negative effects on tourism systems, with impacts that were simultaneously economic, social, and related to policy [1]. In the events area, restrictions and cancellations were especially salient, because events concentrate large numbers of people and required social-distancing policies and capacity limits, making large-scale formats difficult to sustain [2][8].

More broadly, pandemic impacts were shaped by travel restrictions, the need to implement security measures, and participation limitations across event contexts [22]. This context reinforces the importance of systematically observing cultural consumption and participation patterns during crises [25].

At the same time, crises introduce additional complexity into participation dynamics and behavioral change processes [27]. In event settings, perceived risk has been linked to situational and social factors, including the presence of other people [37].

Japanese pop culture events provide a relevant context for examining these dynamics, because they rely strongly on co-presence and socialization. They are described as thematically structured gatherings around Japanese popular culture contents, including anime, manga, cosplay, and videogames [14][36], which have gained international recognition and large fan followings [38]. During the pandemic, this event niche was described as particularly constrained by its socialization-based participation criteria [35][40]. In parallel, the literature has discussed technological alternatives for events, while noting that participatory formats may be difficult to reproduce with currently available technologies [15].

Despite the growing literature on cultural events and COVID-19, comparative designs explicitly addressing fandom-based pop culture events remain underdeveloped.

Against this background, the purpose of this review is to consolidate literature for informing comparative research designs on Japanese pop culture events, with a focus on potential differences between pre-pandemic and post-pandemic contexts in:

i) Attendee motivations;
ii) Sociodemographic profiles; and
iii) Participation/consumption behaviors.

The review is organized to synthesize three connected streams: crisis- and pandemic-related changes in event participation and cultural consumption; motivation and profiling approaches in

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cultural/creative events; and the specificities of Japanese pop culture events, including the motivational and experiential elements that shape participation.

II. METHODOLOGY

This study adopts a narrative integrative review to consolidate a conceptual basis for empirical research on Japanese pop culture events, with attention to pre-/post-pandemic comparative designs.

An exploratory scoping search was conducted in Web of Science (WoS) in December 2025 to map indexed coverage and refine both broad crisis-related terms (e.g., "COVID-19", "pandemic", "cultural events") and niche-related descriptors (e.g., "Japanese pop culture", "otaku culture", "anime convention", "cosplay event", "Comic-Con"). Searches and screening were conducted in English (Portuguese-language studies were also considered when identified through citation tracing and judged directly relevant), and editorials, opinion pieces, short commentaries, news items, and other purely promotional or non-academic materials were excluded. Boolean cross-searches indicated scarce direct intersections between the niche and pandemic framings, while broader event–pandemic combinations returned only limited results. Accordingly, the review expanded through targeted keyword searches and backward/forward citation tracing from conceptually central works to capture relevant scholarship beyond WoS indexing. Publications were retained only if they contributed directly to at least one of three analytic streams:

i) Crises/pandemic and event participation;
ii) Motivations and profiling in cultural/creative event settings; and
iii) Japanese pop culture events (or closely related fandom-oriented formats) and attendee motivations.

Relevance was assessed in two steps: an initial scan of titles and abstracts, followed by full-text appraisal of potentially relevant items. In total, 41 publications were retained and synthesized, with thematic integration focused on implications for pre-/post-pandemic comparisons, including construct comparability, segmentation logic, and the role of risk- and constraint-related mechanisms.

III. THEMATIC SYNTHESIS

A. *Crises, COVID-19 and shifts in cultural event participation*

Events have been discussed as mechanisms that can support destination competitiveness and attract visitors [10] and have also been conceptualized as temporal and spatial "concentrators" that connect creative networks and tourism dynamics [28]. Within this broader context, the contemporary events landscape has been repeatedly shaped by major disruptive episodes, including terrorist attacks, health outbreaks, financial crises, and the COVID-19 outbreak [2]. In this sequence, COVID-19 emerged as a particularly consequential shock, affecting multiple domains beyond tourism and imposing substantial constraints on cultural and creative sectors [11][25].

Within cultural events, the literature highlights that the experience is "inherently multifaceted", encompassing individual and collective forms, physical and virtual modalities, and both on-site and private settings [25]. During COVID-19, several experience modalities linked to collective and physical co-presence were disrupted, with festivals and event formats widely affected by restrictions and cancellations [8]. In parallel, digital/online and home-based forms became comparatively more salient, reflecting broader attempts to sustain engagement under physical distancing constraints [11][22].

Relatedly, cultural organizations expanded the use of online services and digitalized communication and delivery formats during this period [9]. Research on cultural consumption during the pandemic has further examined how motivations and engagement practices were reconfigured under conditions in which cultural venues and events were closed, cancelled, or operationally constrained, reinforcing the analytical relevance of assessing whether crisis-driven adjustments represent temporary coping strategies or more enduring shifts in consumption patterns [11][30].

The pandemic has also been framed as qualitatively distinct from economic crises due to layered disruptions, including the temporary or permanent closure of cultural infrastructure, the suspension of artistic activities, and heightened uncertainty at health, behavioral, and economic levels [27]. For example, in the Mexican context, evidence suggests that cultural participation during the pandemic was associated with specific participation profiles, notably age, education, and employment status [27]. More generally, reduced willingness to participate in events requiring physical presence has been associated with the perceived infection risk tied to the presence of other people [37]. Post-pandemic participation intentions may also remain influenced by psychological factors shaping social distancing preferences in outdoor event contexts [12]. At a broader level, cultural tourism participation has been described as remaining relatively stable in profile, with participants characterized as relatively well-educated individuals [30]. However, such macro-level profiling should not be treated as a direct proxy for niche events and fandom-oriented participation.

Overall, the literature converges on the view that COVID-19 can shape cultural event participation through three interrelated pathways: structural constraints (closures and capacity limits), consumption reconfiguration (greater salience of online and home-based modalities), and behavioral/psychological mechanisms (risk perceptions and distancing intentions), that can inhibit physical co-presence and condition participation intentions [12][25][27].

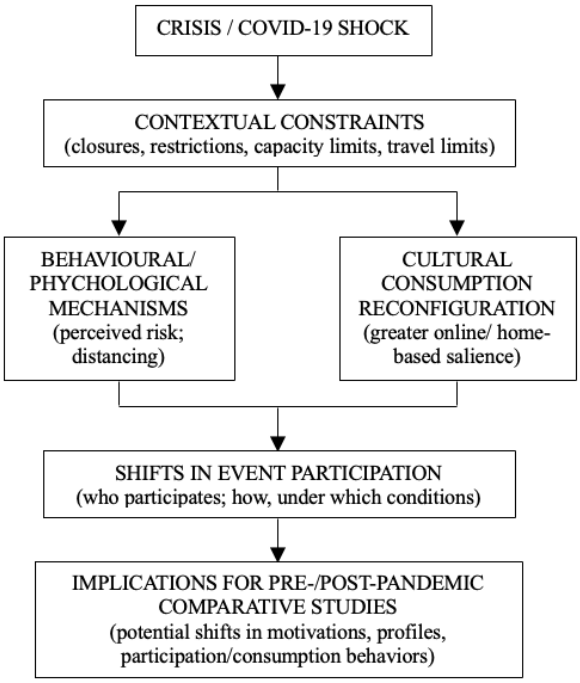

Fig. 1. Conceptual pathways linking COVID-19 disruption to cultural event participation shifts

Together, these mechanisms provide a grounded rationale for examining whether post-pandemic participation differs from pre-pandemic participation in terms of who participates, how participation occurs, and under which motivational conditions, thereby supporting comparative designs in specific event niches. Fig. 1 summarizes these linkages, and should be read top down, moving from the COVID-19 shock to contextual constraints and two mediating pathways that shape shifts in event participation and inform pre- and post-pandemic comparisons.

B. *Motivations and profiles in cultural and creative events*

Cultural tourism has been discussed as a growing segment associated with increasing tourist interest in the cultural aspects and history of destinations, with implications for the expansion and diversification of cultural attractions and experiences [29]. In the European context, cultural tourism has been described as a substantial component of tourism activity and as enabling visitors to understand and appreciate the essential character of places and their culture "as a whole" [13]. This positioning is linked to a broad aggregation of elements (culture, lifestyle and leisure activities, heritage, museums, and participation in cultural events), integrated within destination experiences [29]. Evidence from heritage contexts further illustrates the relevance of profiling and motivational assessment in cultural tourism, including analyses linking visitor motivations and destination image [26].

In parallel, creative tourism has been positioned as an evolution of cultural tourism, emphasizing more active and participatory forms of engagement [28][31]. Definitional approaches commonly associate creative tourism with active involvement in creative activities in the places visited and with opportunities for visitors to develop creative potential through courses and learning experiences characteristic of the destination [31]. More broadly, creative tourism is frequently framed as an experiential form of travel grounded in active participation and learning, and in closer interaction with local culture and everyday life, which reinforces its emphasis on engagement and authenticity [28]. Recent work has also continued to mobilize established motivational lenses (e.g., push–pull) in the study of creative tourism demand and choice processes, reinforcing the analytical relevance of treating motivations as structured, multi-dimensional drivers rather than as single reasons for participation [19].

From a motivational perspective, participation in events and festival settings has repeatedly been associated with social and experiential drivers, including spending time with friends and enjoying atmosphere and on-site offers [5]. Complementing this event-experience perspective, the broader festival motivation literature has identified recurring motive domains such as cultural exploration, novelty, and multiple socialization-related dimensions, while also showing that motive salience may vary by event type and context [7][23]. Evidence syntheses further indicate that commonly used motivational categories across festival studies include socialization, escape, excitement, learning, and shopping, while also noting that some motivational measures have historically been borrowed from general tourism motivation research rather than developed from festival-specific attributes [21].

Motivational variation is closely linked to profiling and segmentation. Empirical work in cultural-historical and festival contexts has long applied motivation-based segmentation to identify distinct visitor groups and relate them to demographic and behavioral characteristics [18][20]. Within creative tourism specifically, profiling remains analytically challenging because the "creative tourist" is not a narrow segment. Instead, participation can span multiple generations and reflect heterogeneous orientations (e.g., authenticity, exclusivity, skill improvement, and community contact) [28]. Segmentation evidence also points to multiple motivationally distinct groups in creative participation contexts (e.g., novelty seekers versus knowledge/skills learners), reinforcing the need to treat attendee profiles as an empirical outcome rather than a priori assumption [39].

Overall, literature supports two implications for comparative designs. First, participation in cultural and creative event contexts is typically explained through a combination of social/experiential drivers and development-oriented drivers linked to learning and self-development [5][31].

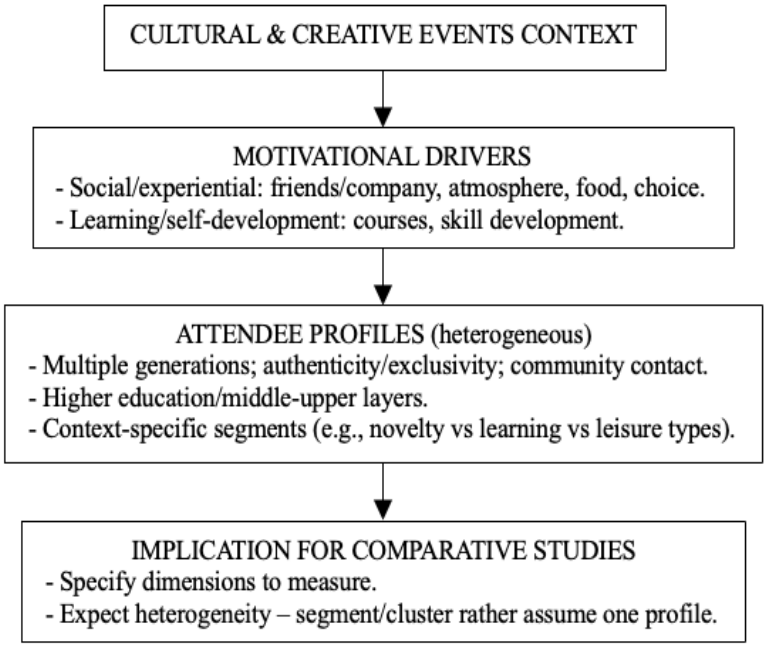

Fig. 2. Summary of motivations and attendee profile heterogeneity in cultural and creative events

Second, attendee profiles are consistently shown to be heterogeneous and context-dependent, and motivation-based segmentation is a well-established strategy for capturing that heterogeneity in event and festival research [18][21]. Fig. 2 summarizes the cultural and creative events context by linking motivational drivers and heterogeneous attendee profiles to the key dimensions that comparative studies should examine.

C. *Japanese pop culture events: fandom practices, contents tourism and attendee motivations*

Japanese pop culture events can be approached as fan meetings embedded within cultural events, typically organized as festivals or conventions [33], with these types of events being framed as concentrated thematic spaces that exhibit a strong mastery of cultural themes and content [36]. Their programming commonly integrates multiple Japanese popular culture components, such as anime (Japanese animation), manga (Japanese comics), music, fashion, cosplay (the art of masking and embodying characters), videogames, and further complementary elements (e.g., workshops, conferences, gastronomy, and lectures), which together support immersive and participatory experiences [14][36]. This thematic and experiential density is consistent with the internationalization of Japanese popular culture, which, although originating in Japan, has gained global recognition and attracted substantial fan communities worldwide [38].

A core feature of these events is their anchoring in fandom practices, where active participation (e.g., cosplay, contests, workshops, and performative engagement with recreated environments) is central to the event experience [35]. The literature also suggests that the audience is not limited to highly committed enthusiasts ("otakus"). Rather, participation may include a broader range of individuals interested in specific elements of Japanese popular culture [14]. Within this wider mobilities and consumption framework, Japanese popular culture has been positioned as relevant to contents tourism [32], with scholarship examining how media/popular culture contents connect to place-based visitation and community responses [41]. Closely related, otaku tourism has been defined as a form of travel in which fans of Japanese popular culture journey to engage with the cultural origins they value, typically through visiting emblematic sites and attending pop culture–related events [4][24][32][41]. In parallel, Japanese pop culture events have been positioned as potential attraction mechanisms not only for Japan, but also for destinations that invest in hosting such events, with implications for destination promotion and niche positioning, and with potential spillovers for local visitor economies [6][14][17].

Participation motivations and profiles in Japanese pop culture events appear to combine identity-related drivers with experiential and consumption-oriented considerations. Participation is frequently described as attracting both highly engaged enthusiasts and individuals who are curious about specific elements of Japanese popular culture [38]. For example, in the Portuguese context, motivations reported as salient include cosplay, event atmosphere, spending time with friends and socializing, as well as opportunities to purchase merchandising and access distinctive offers such as exclusive products, diverse guests/artists, and Japanese cuisine [35]. Beyond single-country evidence, pop culture fan travel motivations have been systematized into multidimensional sets that commonly include novelty, social enjoyment, brand visibility, value for money, exclusive merchandise, escapism, knowledge

acquisition, celebrity fandom, and event participation [4][16].

Finally, this event niche is particularly relevant for post-pandemic analyses because it depends strongly on co-presence and intense socialization. Japanese pop culture events were described as relatively constrained during COVID-19 due to their inherent socialization criteria, and were frequently cancelled or postponed, with limited editions occurring under restrictions and adaptations [3][34][40]. At the same time, the literature discusses the role of digitalization in sustaining or expanding event reach under physical distancing constraints, highlighting adaptations such as livestreaming, intensified social media communication, and other online/virtual formats used when on-site participation was not possible [9]. However, participatory formats, especially those requiring active attendee involvement, are reported as difficult to implement effectively with currently available technologies [15].

In essence, the literature reviewed in this subsection positions Japanese pop culture events as participatory, fandom-based cultural gatherings characterized by dense themed programming and strong reliance on co-presence and fan socialization.

This participatory core is analytically consequential because it links, on the one hand, to tourism-relevant mobilities associated with contents/otaku tourism and, on the other hand, to a multidimensional set of participation motivations (e.g., socializing, atmosphere, cosplay/participation, exclusive merchandise, guests/artists, and novelty-related drivers) [16][32][35].

The same reliance on co-presence also helps explain the niche's sensitivity to pandemic disruption and the limits of virtual alternatives for highly participatory formats [3][15][40]. These linkages provide a grounded rationale for examining whether post-pandemic participation differs from pre-pandemic participation in motivations, profiles, and participation/ consumption behaviors in comparative designs.

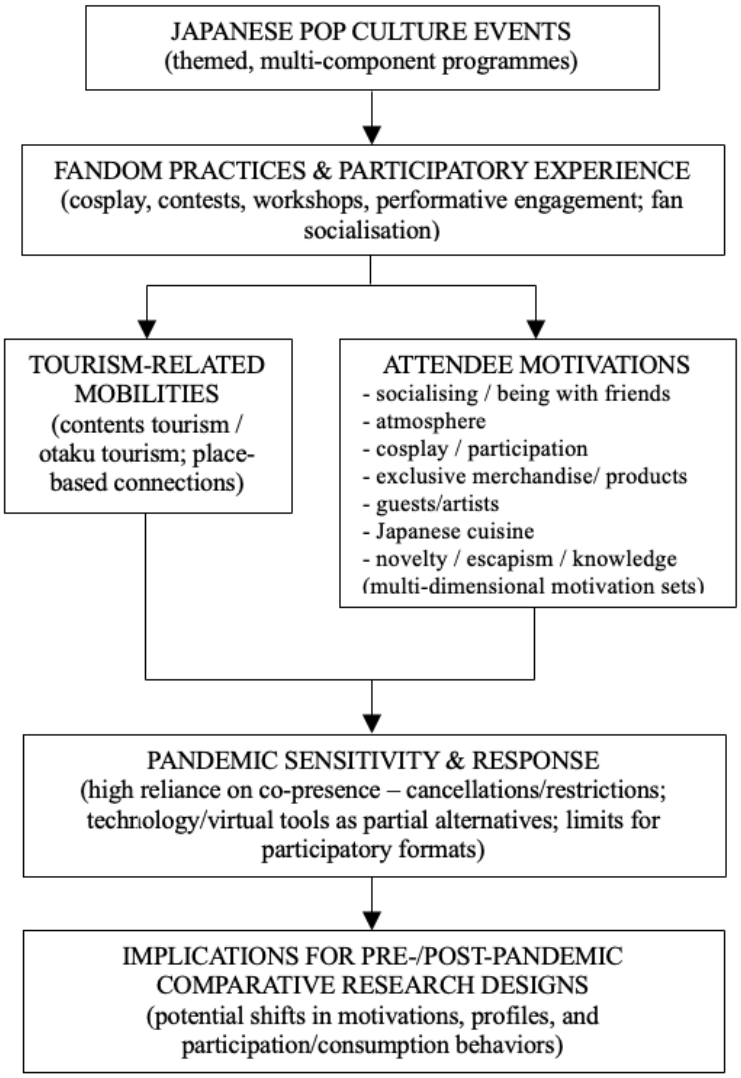

Fig. 3. Visual synthesis of Japanese pop culture events: fandom, tourism linkages, motivations, and pandemic sensitivity

Fig. 3 visually synthesizes these relationships, and should be read top down, starting from the participatory fandom experience and its links to tourism mobilities and attendee motivations, which together condition pandemic sensitivity and the implications for pre and post pandemic comparative research.

IV. CONCLUSION

The main theoretical contribution of this review lies in integrating crisis literature, event motivation research, and fandom-based tourism into a single comparative framework. Across three complementary thematic streams, this review clarifies why Japanese pop culture events constitute a relevant context for pre-/post-pandemic comparative research on event participation.

First, COVID-19 can shape cultural event participation through a combination of structural constraints (e.g., closures and participation restrictions), consumption reconfiguration (greater salience of online and home-based modalities), and risk- and psychology-related mechanisms affecting willingness to engage in physical co-presence.

Second, research on cultural and creative events indicates that participation is typically explained by two complementary motivational logics (social/experiential and development-oriented drivers), while attendee profiles remain heterogeneous and context-dependent, supporting explicit motivational operationalization and empirical profiling/segmentation rather than assumptions of a stable attendee type.

Third, Japanese pop culture events can be conceptualized as participatory, fandom-based gatherings in which themed programming and fan socialization are central, linking contents/otaku tourism mobilities to a multidimensional set of participation motivations, while also highlighting the niche's sensitivity to pandemic disruption and the limits of virtual substitutes for highly participatory formats.

Collectively, these insights provide a structured conceptual basis for comparative designs examining whether and how crisis-related mechanisms may be reflected in shifts in attendee motivations, profiles, and participation/consumption behaviors across periods. Methodologically, this implies:

i) Establishing motivational measurement comparability;
ii) Examining cross-period differences in motivations, sociodemographic, and behaviors;
iii) Using post-pandemic data for data-driven segmentation; and
iv) Assessing predictors of segment membership.

Fig. 4 integrates the three review streams into a single comparative research agenda, showing how they lead to design implications and to the four research questions from measurement comparability to segment prediction.

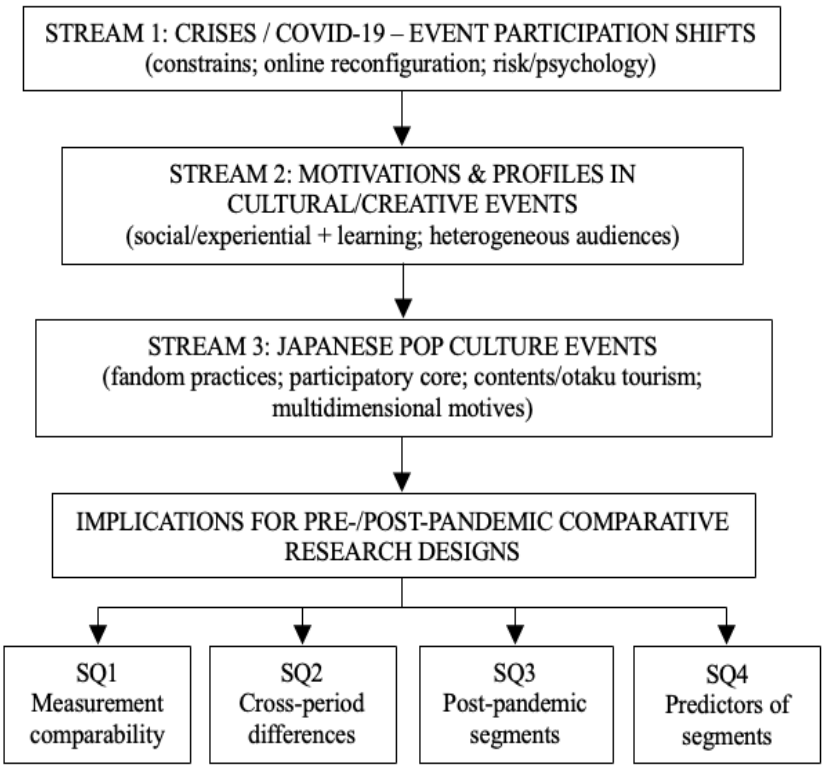

Fig. 4. Integrative framework linking the reviewed streams to implications for pre-/post-pandemic comparative research designs

Overall, this synthesis clarifies the conceptual and analytical requirements for robust pre-/post-pandemic comparison in Japanese pop culture event participation. It provides a compact basis for empirical studies seeking to explain cross-period differences in motivations, profiles, and participation/consumption behaviors.

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The Role of Trustworthy Artificial Intelligence in Enhancing Managerial Decision Quality Under the Conditions Uncertainty

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Abstract - This study investigates the role of trustworthy Artificial Intelligence (AI) in enhancing managerial decision quality under uncertainty within cyber-physical and financial systems. We analyze how data integrity, model explainability, and system complexity influence managerial trust in AI-generated risk insights. Specifically, we synthesize evidence from two distinct high-stakes environments: autonomous UAV logistics and banking compliance (Ultimate Beneficial Ownership). The research proposes a cross-domain conceptual framework defined by four central propositions, which explore the non-linear relationships between technical reliability and the acceptance of AI systems.

Keywords: Artificial Intelligence (AI), Management, Decision making process, Quality, Risk mitigation.

I. INTRODUCTION

The use of algorithmic decision-making systems has moved far beyond experimental pilots. Today, these systems are core operational necessities in sectors ranging from global finance to critical infrastructure (López-Solís et al., 2025). As Artificial Intelligence (AI) systems take on more autonomy, such as identifying Ultimate Beneficial Owners (UBO) in banking or navigating Unmanned Aerial Vehicles (UAVs) in maritime ports, the focus of managerial risk has shifted. It is simply not enough for a model to be statistically accurate anymore; it must be operationally trustworthy (Bedoya Sánchez et al., 2026).

Recent literature highlights a paradox. While technical sophistication has grown, managerial acceptance often lags because of the "Black Box" opacity of deep learning models. Decision-makers in high-stakes environments cannot afford to rely on unverified probabilities (Joshi, 2025). Whether the task is detecting financial crime or inspecting wind turbine blades, the cost of a false positive is operational inefficiency. Worse, the cost of a false negative can be a catastrophic failure (John, 2025).

This paper presents a cross-sectoral conceptual framework that reconciles technical reliability (data integrity, model robustness) with behavioral acceptance (managerial trust). We contend that “explainability” and “data lineage” are not merely technical attributes, drawing upon evidence from Cyber-Physical Systems (UAV logistics) and Data-Intensive Financial Systems. They are the most important factors that affect how well an organization does.

II. THEORETICAL BACKGROUND: THE DUALITY OF TRUST

Trustworthy AI is not a single, monolithic concept. Instead, it is highly context dependent. We analyze how trust requirements converge in two distinct domains: autonomous physical operations and financial compliance (Glikson & Woolley, 2020) (Fig. 1).

2.1 Entities that influence perception of the superior

The robustness of any AI model is strictly limited by the quality, or entropy, of its input data. In maritime logistics, this complexity is physical. Modern ports operate as "Space-Air-Ground-Sea" integrated networks where UAVs must fuse different data streams, including LiDAR point clouds, multispectral imaging, and underwater sensor data, to create a coherent Digital Twin of the harbor. Nomikos et al., (2023) show that without rigorous data integration protocols, the latency in these networks makes real-time decision-making impossible in remote offshore areas.

A similar complexity exists in the financial sector, though it is informational rather than physical. In UBO identification, AI models must traverse a labyrinth of global registries to "pierce the corporate veil". Just as a drone struggle with "urban canyons", financial

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algorithms struggle with "data canyons", which are fragmented, outdated, or deliberately obscured ownership records. Failure of the AI is rarely algorithmic. It is a failure of data integrity (López-Solís et al., 2025). We try to understand that improved algorithms alone do not automatically lead to better decisions. In high stakes settings, whether autonomous systems or financial controls, managers do not gradually become accustomed to AI simply because performance metrics improve. We believe that trust develops when authority becomes evident, when data can be monitored, when model uncertainty is openly discussed, and when its rationale is clear. From our own and collective previous experience, we noticed that there is a tipping point when reliability ceases to be a technical statistic and becomes something psychologically appealing. At this point, trust shifts from hesitation to acceptance, and the system begins to function as a true partner in decision-making, rather than as a tool constantly requiring control (Fig.2).

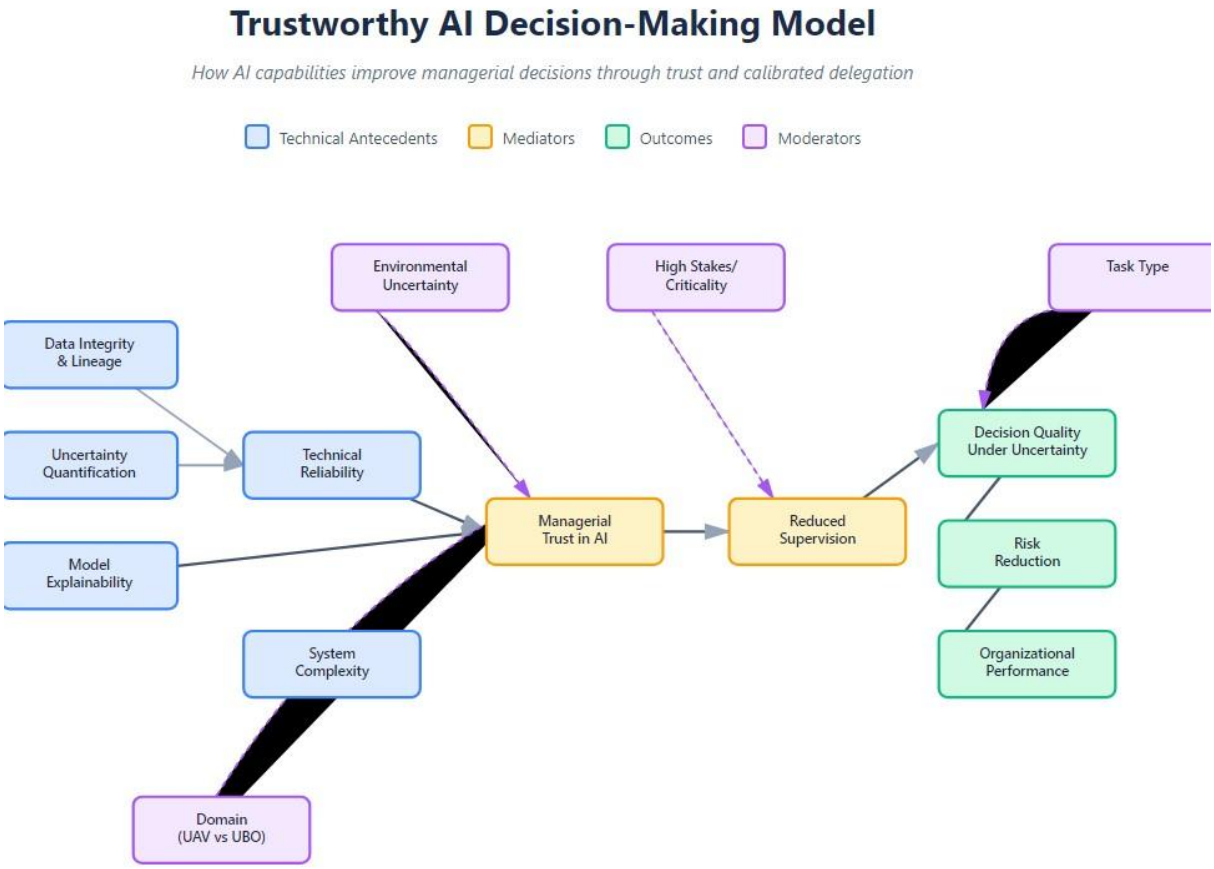

Fig. 1. Decision diagram of a trustworthy AI logical model

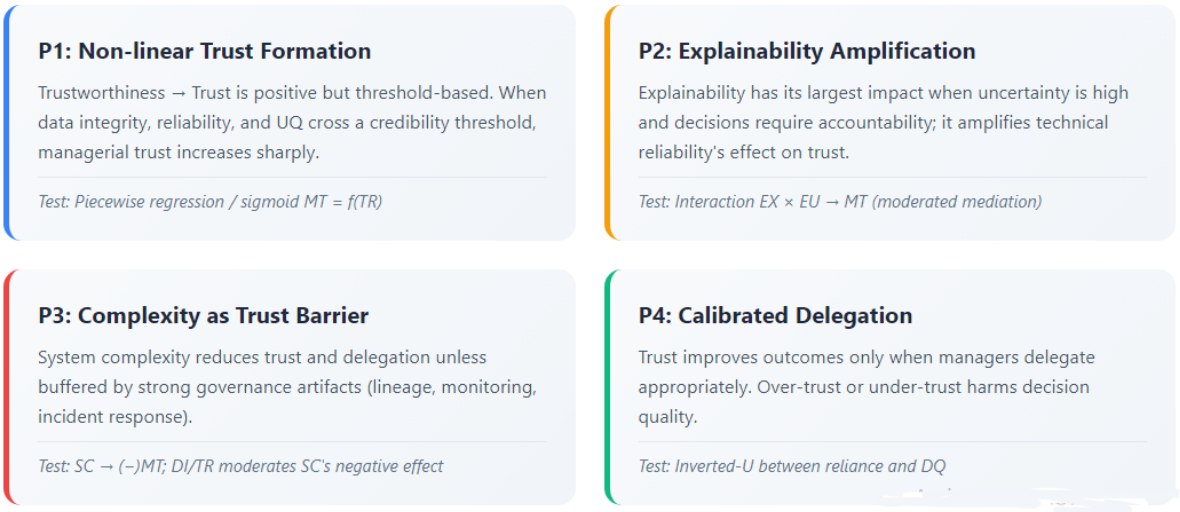

Fig. 2. Testable hypotheses that form the theoretical foundation

2.2 Algorithmic Sophistication as a Driver of Decision Quality

When data integrity is secured, the sophistication of the AI model correlates directly with the "velocity of information." Traditional manual methods, like boarding ships for pollution inspection or manually auditing transaction logs, are reactive and slow (Khalid et al., 2024).

In contrast, recent studies in UAV path planning reveal that dynamic "minimum ring" algorithms can reduce ship pollution detection times significantly, dropping from 4.23 minutes to just 1.71 minutes per vessel. This is not merely an efficiency gain. It represents a qualitative shift in decision-making power, allowing authorities to catch non-compliant vessels before they leave the jurisdiction (Lixin Shen et al., 2020). Similarly, in the energy sector, Deep Learning models (like YOLO architectures) have achieved mean average precision (mAP) exceeding 80% in detecting wind turbine defects, which outperforms human visual estimation.

However, sophistication alone does not guarantee adoption. Santos et al. (2024) highlight that for managers to trust a fully autonomous system, it must demonstrate "self-preservation" capabilities. An example is autonomous hot battery swaps on Unmanned Surface Vehicles (USVs). The system must prove it can operate continuously and recover from errors without human intervention.

2.3 The Imperative of Explainability (XAI)

The critical mediator between a sophisticated model and a human manager is explainability (XAI). In banking, a "high-risk" flag on a transaction is useless if the system cannot articulate why the flag was raised. "Black box" outputs lead to algorithm aversion, causing compliance officers to revert to manual checking. This negates the speed advantage of the AI (Joshi, 2025).

This holds true for physical systems as well. Operators need visual confirmation of why a drone chose a specific landing path. Research indicates that visual servoing techniques, which allow operators to "see" the drone's logic during centimetre-level landings, are essential for building the confidence required to remove the human pilot from the loop. Thus, XAI serves as the "audit trail" that validates the decision process. It transforms a statistical probability into an actionable managerial insight (Dissanayaka et al., 2024; John, 2025)

III. CONCEPTUAL FRAMEWORK

Based on the theoretical connection between cyber-physical reliability and data-intensive risk management, this study proposes a cross-domain framework defined by four central propositions. These propositions assert that managerial trust is not an inherent property of the AI. Rather, it is a dependent variable modulated by technical transparency and data governance, as shown in Fig. 3.

P1: Data Complexity and Integration Influence AI Model Robustness. The reliability of an AI outcome is inversely proportional to the entropy of unverified data sources, whether they are fragmented financial registries or noisy environmental sensors (John, 2025).

P2: AI Model Sophistication Improves Decision Quality. Advanced architectures (like Deep Learning, Dynamic Path Planning) transcend human cognitive limits. This enables "proactive" decision-making capabilities, like prediction and prevention, rather than "reactive" monitoring (Bedoya Sánchez et al., 2026).

P3: Data Integrity and Explainability Enhance Trustworthiness. Managerial acceptance requires a “chain of evidence”. Trust is generated only when the AI can demonstrate both the provenance of its data (Integrity) and the logic of its inference (Explainability/XAI) (John, 2025; Mittelstadt et al., 2019).

P4: Managerial Trust Mediates Organizational Performance. Technical superiority does not automatically yield operational gain. Only when managers psychologically trust the system enough to reduce manual supervision do organizations realize efficiency improvements such as reduced latency or cost savings (Nomikos et al., 2023).

IV. DISCUSSION: ALIGNING TECHNICAL RELIABILITY WITH MANAGERIAL TRUST

This section evaluates the proposed framework by synthesizing evidence from the UAV and Financial sectors. Our analysis shows that, despite the differences between these domains, the "Trust Architecture" needed for high-stakes decision-making remains structurally the same.

4.1 The Data Integrity Paradox (Addressing P1 & P3)

The primary barrier to decision quality in both analysed sectors is not algorithmic incapacity but data opacity. In the maritime domain, Nomikos et al. (2023) identify "jamming" and "identity forging" as critical threats to the Space-Air-Ground-Sea network. If a decision-maker cannot authenticate the source of a signal, verifying that a coordinate comes from a legitimate UAV and not a spoofer, the most sophisticated path-planning algorithm becomes a liability.

This is like the "Data Lineage" crisis in financial compliance. As mentioned in recent banking literature, UBO identification often fails not due to flaws in the Graph AI, but because the input data comes from places with unclear registries. In both cases, the "garbage in, garbage out" rule works with a lot of power (Joshi, 2025). So, trustworthiness (P3) is very important. A manager must have implicit faith in the source of the data before they can trust a prediction, such as "This ship is polluting" or "This transaction is money laundering." Without verifiable integrity mechanisms, like the lightweight authentication protocols suggested for maritime IoT, managers have no choice but to go back to manual verification. This slows down the speed of operations.

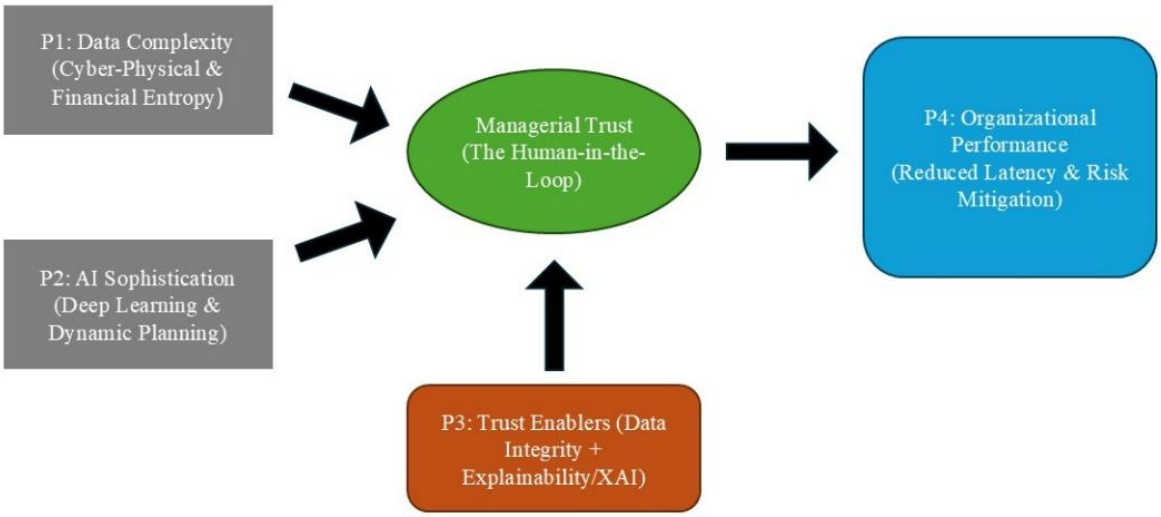

Fig. 3. Conceptual framework for Trustworthy AI in Decision Making

4.2 Explainability as the Trust Mediator (Addressing P3)

The literature confirms that "Black Box" models are incompatible with accountability. In the context of autonomous maritime operations, Santos et al. (2024) demonstrated that "visual servoing" was required to achieve centimetre-level landing accuracy (9.14 cm error). Crucially, this visualization serves a dual purpose. It guides the drone, but it also allows the human operator to "see what the drone sees," validating the logic of the descent.

This visual validation is the physical equivalent of Explainable AI (XAI) in banking. A compliance officer cannot legally justify freezing assets based on a neural network's silent probability score. They require an "explainable graph" that visualizes the ownership path through shell companies. Dissanayaka et al. (2024) argue that XAI frameworks are essential for navigation. We argue they are equally essential for regulatory defence. In both domains, XAI acts as the bridge that converts raw computational power into a "trusted advice" format that a human manager is willing to act upon.

4.3 From Trust to Organizational Performance (Addressing P2 & P4)

When technical reliability (P1) and explainability (P3) are satisfied, the transition to high-performance autonomous workflows (P4) becomes possible. L Shen et al. (2020) provide the clearest quantitative evidence of this shift. By trusting a dynamic multi-UAV system to plan its own routes, detection times for ship pollution dropped by 59% (from 4.23 to 1.71 minutes).

This efficiency gain is the direct result of removing the "human-in-the-loop" for routine tasks. In the banking sector, the equivalent gain is the reduction of "false positive" reviews. When managers trust the data lineage scores of the AI, they spend less time double-checking low-risk alerts and more time investigating complex financial crime networks. Thus, managerial trust is the mediating variable that unlocks the theoretical ROI of the technology. Without trust, the drone is flown manually, and the transaction is audited manually, rendering the AI investment redundant.

IV. CONCLUSION

This study proposed a cross-sectoral framework to address the "Trust Gap" in AI-driven decision-making. By juxtaposing the physical risks of UAV logistics with the regulatory risks of financial compliance, we identified that data integrity and explainability are universal prerequisites for managerial adoption.

Future research should focus on empirical validation of this model. Specifically, quantitative studies are needed to measure the "Trust Threshold," which is the specific level of XAI clarity or data accuracy required for a manager to cede control to an autonomous agent. As AI systems evolve from decision support to decision execution, solving the trust equation will become the definitive challenge for organizational leadership.

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Mapping Sustainable Decisions - How Geographic Information Systems and Geographic Analytics Could be Integrated in the Infrastructure to Create Public Value. A Germany–Portugal Comparison

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Abstract - This study examines how Geographic Information Systems (GIS) are integrated with social and economic dimensions in Sustainability Assessment (SA) in different territorial contexts, namely Germany and Portugal. Recent open access articles indexed on ScienceDirect were systematically reviewed (target corpus ≈ 174 records). Records will be coded for: (i) country coverage, with a focus on Germany and Portugal; (ii) infrastructure domain (transport, energy, water, health, digital); (iii) integration of social and economic variables (presence, operationalization and data sources); (iv) spatial scale; (v) GIS methods (e.g. map overlay, network analysis, spatial statistics, accessibility modeling); and (vi) the use of multi-criteria decision analysis (MCDA). The results are intended to inform infrastructure planning guidelines and education, support transparent trade-offs in public investments, and strengthen the evidence on impacts on public health and equity.

Keywords: Sustainability; Education; Business Analytics; Public Value; GIS; GA.

I. INTRODUCTION

This research investigates the integration of Geographic Information Systems (GIS) with social and economic dimensions in sustainability evaluations across varied territorial contexts, with a comparative focus on Germany and Portugal. It seeks to ascertain whether GIS-supported assessments transcend environmental considerations to systematically integrate socio-economic indicators and decision-support tools, while delineating methodological approaches conducive to public-value-driven infrastructure planning. Particularly, the study estimates how useful geographic intelligence would be for identifying preferred corridors for development projects and thus enhancement of alternative locational analysis stages. GIS and Geographic Analytics have become useful tools in the contemporary world, especially in public administration and urban planning, for offering environments the solution of difficult infrastructure problems (Attah et al. 2024).

This situation is particularly relevant in thorough sustainability assessments, where computer-model creators can better integrate diverse data sources, perform multi-criteria analyses, and create improved representations of spatial factors of significance to decision making (Bisello et al. 2023, Oliveira et al. 2023).Nevertheless, implementing GIS-supported Multi-Criteria Decision Analysis in urban planning frequently faces obstacles concerning the adaptability of context-dependent methodologies and an overdependence on basic linear aggregation techniques, which may inadequately represent the intricate interplay of social, environmental, technical, and economic facets of sustainability (Bousquet et al., 2023). Such intricacies often demand innovative modeling strategies that incorporate fuzzy logic via knowledge engineering and accommodate diverse, contradictory multicriteria perspectives from multiple stakeholders (Bill et al., 2022). The integration of Geographic Information Systems (GIS) with Multi-Criteria Decision Analysis (MCDA) represents an effective strategy for identifying optimal sites and developing plans that balance economic, environmental, social, and governance factors in urban settings (Setfane & Touhami, 2025). This combined approach not only assesses sustainability but also provides a transparent and auditable framework for decision-makers, facilitating deeper understanding of complex sustainability issues. The interdisciplinary nature of sustainability studies, which encompasses ecological,

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geophysical, societal, and environmental domains, underscores the necessity for advanced spatial analytics offered by GIS to efficiently manage and analyze large datasets (Gonçalves, 2021). Integrating GIS with artificial intelligence further enhances these capabilities, supplying urban planners with advanced tools for forecasting, risk assessment, and targeted interventions, particularly in land-use planning where traditional limitations are overcome through timely intelligence (Mkhitaryan et al., 2025). The spatial decision-support capacity of GIS, especially when combined with Multi-Criteria Decision-Making methods, is essential for evaluating multiple, often conflicting, criteria in urban planning, such as selecting infrastructure sites or formulating sustainable land-use strategies (Thapa et al., 2023). This integration is particularly valuable because urban planning challenges frequently involve multicriteria decisions with spatial dimensions, necessitating robust systems to process extensive geospatial and attribute data (Rahman & Szabó, 2022). As a result, this approach supports a comprehensive, evidence-based model for urban development, surpassing traditional methods that struggle to integrate diverse environmental, social, and economic factors simultaneously (Wang & Ren, 2025)

II. LITERATURE REVIEW

The literature review summarizes research on the integration of Geographic Information Systems (GIS), Artificial Intelligence (AI) and Multi-Criteria Decision Analysis (MCDA) in sustainable urban planning, with a focus on infrastructure development in Germany and Portugal. This paper presents the evolution of several methodologies, with a particular emphasis on the advantages of GIS for spatial analysis compared to traditional urban planning methods that rely on manual and transactional processes (Lartey & Law, 2025; Olawale et al., 2023). It is noted that the combination of GIS and AI improves analytical capabilities, allowing detailed assessments of land use patterns, demographic trends and environmental indicators. Through this combination, the accuracy of urban growth forecasts and sustainability assessments is improved (Anwar & Sakti, 2024). Developments in the geospatial field, driven by big data and AI, strengthen evidence-based planning and highlight the need for ethical guidelines in GeoAI applications (Marasinghe et al., 2024). Specifically, integrating genetic algorithms with GIS supports urban planning through multi-objective optimization. This is crucial for balancing competing development priorities in large-scale projects that require significant computational resources (Cheng et al., 2023). The synergy produced by these methods produces a set of Pareto-optimal strategies, allowing decision-makers to address trade-offs between objectives, such as alleviating traffic congestion or reducing construction costs, while respecting constraints, including affordable housing obligations. Geographic Information Systems (GIS) play a critical role in multi-criteria decision analysis (MCDA) and for urban planning this approach needs to be well documented, with applications covering land suitability assessment, environmental management and disaster risk reduction (Setfane & Touhami, 2025; Zhao et al., 2024). Furthermore, the integration of artificial intelligence (AI) and environmental sciences into urban planning represents a significant advance towards resilient urban ecosystems, by harnessing AI capabilities in predictive modeling and hazard assessment (Anwar & Sakti, 2024; Mkhitaryan et al., 2025).

2.1 Infrastructure Development through GIS and GA in Germany

This section critically assesses the current state and future applications of Geographic Information Systems (GIS) and Genetic Algorithms (GA) in German infrastructure projects, focusing on their contribution to public value creation. The research shows that Germany's advanced technological infrastructure and rigorous planning regulations provide an exemplary context for evaluating the synergistic potential of these tools in optimizing public utility networks and urban systems (Krügel et al., 2024). The analysis highlights how these computational methodologies support effective resource distribution, strengthen urban resilience, and increase citizen participation in smart city initiatives (Son et al., 2023; Wang et al., 2024). By integrating Artificial Intelligence into these systems, operational efficiency is improved through predictive maintenance and optimized resource allocation. The resulting benefits are tangible, such as energy savings and cost reductions in urban infrastructure (Almulhim, 2025). These synergies are crucial for addressing complex urban challenges, including rapid urbanisation and climate change, in line with the European Union's climate-neutrality objectives (Papantoniou et al., 2024). Technological advancements, particularly GeoAI, are instrumental in clarifying urban dynamics, fostering collaboration, and informing land-use and transportation strategies to promote sustainable, interconnected, and resilient communities in Germany (Mortaheb & Jankowski, 2022). The combination of AI and GIS, called GeoAI, is transforming urban planning and enabling advanced analysis of large-scale spatial datasets. This convergence also delivers accurate and predictive data, which streamlines decision-making and simplifies complex geospatial processes (Alastal & Shaqfa, 2022; He & Chen, 2024).

This integration supports innovative solutions for urban spatial optimization, resulting in more robust and adaptive planning data (Barr & Dawson, 2024; Cheng et al., 2023). Intelligent frameworks are increasingly essential for refining urban development scenarios, especially when navigating competing risks and sustainability requirements, which can be addressed through models based on genetic algorithms and Pareto optimization. For example, genetic algorithms have been successfully applied to optimize the location selection of mobility centers through iteratively evolving solutions that reduce travel times and increase location efficiency (Bencekri et al., 2024).

2.2 Infrastructure Development through GIS and GA in Portugal

This section critically assesses the application of Geographic Information Systems (GIS) and Genetic Algorithms (GA) in the development of infrastructure in Portugal, focusing on their roles in generating public value in the country's unique geographical and regulatory context. The analysis details how these computational approaches facilitate the optimization of key urban infrastructure, improve public service delivery, and strengthen emergency response systems in Portugal (Papantoniou et al., 2024). Research from a Portuguese perspective examines the impact of these technologies on smart city initiatives, supporting urban planning strategies that address urgent issues such as climate change adaptation and sustainable resource management (Marji et al., 2024; Vişan & Mone, 2023). Furthermore, the integration of GIS and GA in Portugal aims to increase the resilience of infrastructure to natural disasters and improve the efficiency of public services through data-driven spatial analysis (Boutayeb et al., 2024). This includes the use of GeoAI to support advanced urban governance, promoting environmental resilience and strengthening adaptation to climate change through robust monitoring and forecasting systems (Fauzi, 2024; Song et al., 2025). These integrated methodologies are crucial for the development of evidence-based frameworks that accurately identify optimal locations for active mobility infrastructure, such as bicycle lanes and pedestrian areas, thus promoting urban sustainability and public health (Calleo et al., 2024) (Table 1).

This study brings together public value frameworks for infrastructure planning, integrating multidimensional sensitivity analysis with a socio-technical systems perspective. The territorial context serves as a fundamental basis for developing indicators and translating empirical evidence into actionable planning decisions. The conceptual framework emphasizes equity, accessibility, and economic feasibility, alongside environmental sustainability, while also considering the influence of stakeholders and institutional contexts on the use of evidence.

Table 1: Summarizes research framework for both countries

Criterion	Germany	Portugal
Main Objective	Operational efficiency and sustained economic growth.	Environmental adaptability and social equity.
Technological Approach	Complex analytical frameworks, often based on strict legal standards.	Use of open source and bottom-up planning.
GIS/GA usage	Optimization of routes and maintenance schedules for vast networks.	Design of green infrastructure networks and conservation.

III. METHODOLOGY

A systematic review of recent open access articles indexed on ScienceDirect (targeting approximately 174 records) was conducted. Records were coded according to the following criteria: (i) country coverage, with a particular focus on Germany and Portugal; (ii) infrastructure domain, including the transport, energy, water, health and digital sectors; (iii) integration of social and economic variables, in particular their presence, operationalization and data sources; (iv) spatial scale; (v) Geographic Information Systems (GIS) methods, such as map overlay, network analysis, spatial statistics and accessibility modelling; and (vi) application of multi-criteria decision analysis (MCDA). The identified criteria are also evaluated to what extent these studies address the complex interactions between environmental, socioeconomic and cultural factors within planning procedures, a challenge that remains essential for critical infrastructure initiatives (Araújo et al., 2023). By synthesizing the findings, the systematic mapping review seeks to identify both best practices and key deficiencies in the application of GIS and genetic algorithms (GA) for sustainable infrastructure development in Germany and Portugal. This synthesis will provide insights into the regulatory and geographical determinants of public value generation. Additionally, the review will clarify how technological synergies contribute to urban resilience and public service provision within differing national contexts (Sofianopoulos et al., 2025). The comparative analysis will emphasize the varied implementations and impacts of these computational tools across distinct regulatory and geographical environments, focusing on how Germany and Portugal utilize GIS and GA to address unique infrastructural challenges and leverage emerging opportunities (Aydın & Erdoğan, 2024; Burlacu et al., 2023). Furthermore, the review will examine methodologies for assessing street walkability, highlighting the integration of objective metrics with subjective evaluations to inform infrastructure planning for improved community welfare (Huang et al., 2024; Maragkotidou et al., 2025). It will also analyze approaches for evaluating the multicriteria aspects of infrastructure projects, including environmental impacts, social equity, and economic feasibility (Boix-Cots et al., 2025; Fusco et al., 2023). This includes a detailed investigation into how Geographic Information Systems support strategic infrastructure planning through advanced capabilities such as spatial suitability modelling, network optimization, and impact assessment (Kurniawan et al., 2023). Notably, the review will assess the effectiveness of these tools in optimizing road alignments and siting photovoltaic-powered electric vehicle charging stations, given their importance for sustainable urban development and the achievement of UN Sustainable Development Goal 9 on resilient infrastructure (Abdullah et al., 2026; Agrawal et al., 2025; Aziz et al., 2025).
The subsequent analysis, based on the systematic mapping review of ScienceDirect-indexed literature,

delineates the essential components of an effective model for integrating GIS and GA in sustainable infrastructure planning. These components include country coverage with a focus on Germany and Portugal, infrastructure domains such as transportation, energy, and environmental systems, the integration of social and economic variables to ensure equitable public value, spatial scales ranging from micro-urban to regional levels, GIS methods including spatial, network, and geostatistical analysis, and multicriteria decision analysis techniques. These techniques are frequently enhanced by genetic algorithms to optimize conflicting objectives within complex socio-technical contexts (Araújo et al., 2023; Crippa & Ugaya, 2024; Perez & Fusco, 2025).

The methodology further examines how these components enable the identification of critical knowledge gaps in current research, particularly regarding the systematic documentation of planning frameworks, governance structures, and planning tools for achieving urban resilience (Varzeshi et al., 2025). This approach provides a comprehensive analysis of how GIS and GA are applied within the distinct regulatory and geographical contexts of Germany and Portugal. It identifies best practices and highlights opportunities for methodological enhancement in both countries. Ultimately, this comparative assessment reveals broadly applicable insights for integrating GIS and GA to advanced sustainable infrastructure, thereby deepening the understanding of smart urban planning across diverse European settings. (Table 2)

Table 2: Analysis and synthesis GIS-GA framework for both countries

#	Germany	Portugal
1	**(i) Country coverage**	
	GIS are deeply integrated into public administration, urban planning, and environmental management. This extensive adoption enables robust, data-informed decision-making for infrastructure initiatives, spanning transportation networks and renewable energy installations. Such pervasive utilization underpins holistic urban development strategies, frequently leveraging advanced spatial analytics to optimize resource distribution and mitigate environmental impacts (Gorjian, 2025).	GIS serve as pivotal tools for national infrastructure development, environmental management, and public administration. The country implements a hybrid approach by combining proprietary leading-edge software, such as ArcGIS, with robust open-source solutions like QGIS and PostGIS. This strategy enables versatile and economical deployment across diverse governmental tiers and research institutions, thereby improving data accessibility and interoperability for sophisticated geospatial analyses (Aljobaly et al., 2025).
2	**(ii) Infrastructure domain (transport, energy, water, health, digital)**	
	Infrastructure domain sees significant application of GIS in planning and managing extensive transportation networks, including high-speed rail and autobahns, as well as optimizing renewable energy grids and urban utility systems (Çelik, 2023). **Administration and Infrastructure:** Geo-topographic data is mainly managed at the state level, according to the German constitution. Large infrastructure projects, such as the maintenance of the extensive railway system, rely on GIS for strategic planning and cost optimization. **Renewable Energy:** GIS is essential for analyzing the technical potential of local renewable energy, including for agrivoltaics (solar panels over crops) and selecting agro-economic sites. **Urban Planning and Environment:** GIS-based tools are used to monitor urban sprawl, detect infill development potential, and manage sustainable heritage. **Public Participation (PPGIS):** There are initiatives to use web-based interactive maps to allow citizens to participate in urban planning processes (e.g. in the Wilhelmsburg district of Hamburg).	GIS is instrumental in coastal zone management, water resource allocation, and the strategic deployment of smart city technologies, particularly for enhancing urban resilience and disaster preparedness (Karleuša et al., 2013; Rezvani et al., 2023). **Public Administration & Census:** The Statistics Portugal (INE) utilized GIS for the 2021 Census, integrating web mapping applications to streamline data collection and transition toward a register-based census. **National Infrastructure:** The Centro Nacional de Informação Geográfica (CNIG) manages the National System of Geographical Information (SNIG), providing central access to mapping data, including CORINE land cover and administrative boundaries. **Environmental & Hazard Management:** Flood Risk: GIS-based multicriteria decision analysis is used to identify "hot spots" for flooding in municipalities like Vila Nova de Gaia. Conservation: The Lisbon University Botanical Garden employs GIS for plant conservation programs and ecological interaction analysis. **Economic Sectors:** Tourism: Regional platforms, such as in the Aveiro region, use GIS to inventory resources and develop sustainable marketing strategies. Natural Resources: The Direção-Geral de Energia e Geologia (DGEG) maintains geographical registers of minerals, solar power plants, and wind turbines.
3	**(iii) Integration of social and economic variables (presence, operationalization, and data sources)**	
	In Germany, the incorporation of social and economic factors into GIS-GA frameworks typically employs advanced econometric models integrated with demographic datasets to assess the wider societal repercussions and economic feasibility of major infrastructure projects, thereby promoting equitable access and balanced regional development.	In contrast, Portugal integrates social and economic variables through participatory GIS methodologies and multi-criteria decision analysis, aligning infrastructure development with community priorities while prioritizing social inclusion and sustainable economic progress across urban and rural landscapes. This strategy particularly harnesses GIS to redress socio-economic disparities via targeted infrastructure

		interventions in regions prone to environmental vulnerabilities or economic marginalization, thereby advancing inclusive growth and reducing regional inequities (Dasí et al., 2024).
4	**(iv) Spatial scale**	
	In Germany, GIS applications encompass a broad spectrum of spatial scales, from intricate micro-urban analyses that optimize pedestrian flows and public transport networks to comprehensive national-level evaluations of inter-regional infrastructure development and environmental impact assessments. At the municipal level, the precise application of GIS further supports the optimization of utility corridors and informs land-use planning, thereby enhancing resource allocation efficiency and advancing sustainable urban growth.	In Portugal, GIS applications span diverse spatial scales, extending from localized urban planning—such as the optimization of public spaces and utility networks—to expansive regional analyses addressing resource management and coastal protection ("Proceedings of the 20th Conference on Computer Science and Intelligence Systems (FedCSIS)," 2025). These implementations further encompass smart city initiatives at the local level alongside broader regional evaluations of agricultural land use and national environmental conservation efforts (Masson, 2024).
5	**(v) GIS methods (e.g., map overlay, network analysis, spatial statistics, accessibility modelling)**	
	In Germany, GIS methods commonly integrate advanced spatial modelling, remote sensing, and three-dimensional visualisation to model intricate urban development scenarios and evaluate environmental effects with elevated accuracy. These advanced approaches enable thorough examinations for infrastructure planning, spanning fine-grained micro-urban designs to extensive regional evaluations. Germany's strategy further involves creating advanced digital platforms that consolidate spatial data, thereby facilitating transparent access and collaborative planning across diverse stakeholders.	In Portugal, GIS methodologies predominantly employ open-source platforms to perform spatial data analyses, emphasising hydrological modelling, ecological mapping, and participatory planning to support resilient infrastructure development, especially in regions vulnerable to climate change effects (Salvador & Julião, 1999). These approaches incorporate sophisticated spatial analytical techniques to delineate susceptible areas, optimise resource distribution, and position infrastructure strategically, thereby bolstering adaptive capacities in the face of extreme weather events and sea-level rise (González & Pisabarro, 2024; Malick et al., 2025).
6	**(vi) use of multi criteria decision analysis (MCDA)**	
	In Germany, multi-criteria decision analysis is routinely coupled with GIS to address intricate infrastructure initiatives, exemplified by route selection for emerging transportation corridors, thereby permitting an exhaustive assessment of environmental, economic, and social dimensions. This synergy fosters transparent decision-making by methodically balancing multifaceted criteria and stakeholder preferences to yield superior solutions (Alogayell et al., 2024). The methodological precision moreover enables rigorous sensitivity analyses, augmenting the robustness of selected infrastructure alternatives via quantification of criterion weight fluctuations' effects on project viability.	Conversely, Portugal employs multi-criteria decision analysis integrated with GIS frameworks chiefly for land-use planning and environmental management. This integration routinely incorporates citizen science contributions and local expert insights to advance sustainable development priorities and shape policy formulation (Hilbers et al., 2023). The methodology proficiently amalgamates varied data sources to confront multifaceted spatial planning dilemmas, especially in locales vulnerable to climate change effects (Sutrisno et al., 2021).

Preliminary scoping of the corpus indicates: predominant reliance on environmental layers, coupled with partial or proxy integration of social variables; inconsistent operationalization of economic dimensions; and selective, often inadequately documented, application of MCDA. German studies are anticipated to exhibit more robust infrastructure datasets and sophisticated network analyses, whereas Portuguese contributions may prioritize territorial cohesion and accessibility metrics. The comprehensive analysis will quantify these patterns and spotlight exemplary integrative investigations. Furthermore, GIS appears underutilized in supporting decision-making and resource allocation planning. Future research should prioritize the development of integrated information systems for identifying and ranking infrastructure projects within specified administrative boundaries (Tryhuba et al., 2025), complemented by the incorporation of varied geospatial datasets to improve the transferability of predictive models (Gundogdu et al., 2025).

IV. DISCUSSION

Comparative analysis of GIS and genetic algorithms (GA) applications in infrastructure development in Germany and Portugal breaks down into distinct but complementary strategies shaped by national contexts. Germany uses advanced modeling techniques and robust analytical frameworks to support complex urban and regional planning, while Portugal prioritizes open-source software and participatory approaches to enhance resilience in ecologically sensitive regions (Hall et al., 2024).

Contrasts are observed that reflect divergent national priorities and resource allocations: Germany focuses on operational efficiency and economic optimization, while Portugal emphasizes social equity and environmental adaptability (König & Wenzelburger, 2021; Rodríguez-Fernández et al., 2025).

It is noteworthy that both countries recognize the critical role of spatial decision support systems in addressing contemporary infrastructure challenges,

although their methodological emphases differ (Thorsson et al., 2025). Sensitivity analysis within the systems is vital for evaluating infrastructure decisions, when evaluating alternative configurations or optimizing resources under multi-criteria conditions (Păunescu et al., 2021).

Multi-criteria decision analysis integrated into GIS allows public authorities and planners to accelerate complex infrastructure projects by incorporating diverse criteria into comprehensive assessments, thus promoting sustainable development and efficient use of resources (Kere and Molla, 2024). The integration of GIS and GA further improves infrastructure asset management and fund allocation, especially for existing road networks, by identifying vulnerabilities and guiding investments through rigorous risk assessments (Mohamed et al., 2025).

Future research can strengthen these frameworks by incorporating real-time traffic data and predictive maintenance algorithms to anticipate deterioration, thereby improving the accuracy and responsiveness of infrastructure management (Nugraha et al., 2025). Applications of genetic analysis (GA) in this context extend to optimizing maintenance and rehabilitation programs, taking into account climatic factors and network criticality to support the development of more resilient infrastructure systems (Madushani et al., 2024).

A comparative analysis of the application of GIS (Geographic Information Systems) and Genetic Algorithms (GA) in Germany and Portugal highlights approaches that are aligned with each country's economic structures and environmental priorities. While both countries integrate these technologies to optimize resources, Germany tends towards large-scale operational efficiency, while Portugal focuses on ecological resilience and participatory planning:

Table 3: Future perspectives for both countries

Criterion	**Germany** Systemic Optimization and Efficiency	**Portugal** Local Resilience and Sustainability
Focus	Developing a robust Spatial Data Infrastructure (SDI) at federal and regional level to support large-scale projects (airports, rail networks, offshore wind farms).	Prioritizing open-source software and methodologies that integrate ecological and social components in green infrastructure planning.
Data Model	Digital Twin at the national level (federal standards).	Flexible GIS frameworks, often based on regions/municipalities.
Technology	High-resolution LiDAR, massive cloud processing.	Geospatial AI integration and open-source solutions.
GIS/GA Applications	Using advanced modeling to identify potential for urban development ("infill development") and optimize transport networks (e.g. hydrogen pipelines).	Implementing multi-criteria decision-making methods to design resilient networks in sensitive areas, such as the Setúbal region.
Priority	Operational efficiency and climate change adaptation.	Ecological resilience, sustainable tourism and social urbanism.
Key Infrastructure	5G/Fiber optic networks, hydrogen networks.	Coastal areas, port and tourist infrastructure.
Economic Impact	Managing delays and costs in megaprojects through digital solutions that improve governance and trans-parency.	Investments in critical infrastructure (railways, ports, telecommunications) are evaluated through the prism of production multipliers and tax revenues generated in the long term.

V. CONCLUSIONS

The comparative analysis highlights the critical contributions of Geographic Information Systems (GIS) and Genetic Algorithms (GA) to infrastructure decision-making. The results indicate that Germany uses advanced modeling techniques to maximize efficiency, while Portugal uses open-source platforms and participatory approaches to enhance environmental resilience (Hall et al., 2024). The research shows that the existence of methodological differences reflects distinct national priorities: Germany focuses on operational efficiency and economic optimization, while Portugal prioritizes social equity and environmental adaptability (König & Wenzelburger, 2021; Rodríguez-Fernández et al., 2025). Despite these contrasts, both countries recognize the essential function of spatial decision-support systems in addressing the complex challenges of modern infrastructure development (Thorsson et al., 2025). Further research is warranted to assess the applicability of these diverse methodologies in other national contexts, with particular attention to the influence of varying regulatory frameworks and technological capabilities on the integration and effectiveness of GIS and GA in infrastructure planning (Gundogdu et al., 2025; Tryhuba et al., 2025). Subsequent research should focus on refining genetic algorithms to optimise resource allocation for road infrastructure maintenance and to enhance evacuation route planning during natural disasters, thereby strengthening infrastructure resilience and public safety (Mohamed et al., 2025). Specifically, integrating genetic algorithms with GIS may support dynamic network optimisation under changing conditions, enabling proactive adjustments to infrastructure strategies and real-time responses.

Research suggests that both countries are moving towards predictive management. Integrating real-time traffic data with GA algorithms will allow authorities to anticipate road infrastructure degradation and

allocate funds more efficiently through rigorous risk assessments.

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Analysis of the Public Policies Evaluation at the Municipality Level and Their Contribution to Sustainable Development Goal 11

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Abstract - Public Policies are developed by governments as a way of contributing to the development of municipalities and improving the population's quality of life, as well as achieving the Sustainable Development Goals (SDGs), objectives established by the United Nation's Agenda 2030. The main objective of the study was to analyse, from the perspective of Document Analysis, using the TCE 2022 database from the municipality of Prudentópolis-PR, to highlight the most positive and negative aspects of public policies and SDG 11, in the municipality under analysis. The methodology used was document analysis. The following steps were used to collect information from the Court of Auditors of the State of Paraná - TCE (Assessment of Government Performance 2022): verification of the Public Policies of the municipality of Prudentópolis-PR and SDG 11, as well as analysis of the report prepared by the TCE. The results considered the positive and negative aspects of the Public Policy evaluations of the TCE PR report of the municipality of Prudentópolis-PR and its relations with SDG 11, it was observed that in large part it partially meets the requirements and also meets the SDGs. The results of the TCE 2022 report present the need to improve Public Policies, to become a Sustainable City, for the benefit of society and compliance with the requirements of the 2030 Agenda.

Keywords: Municipal Public Policies, Sustainable Cities, SDG 11.

I. INTRODUCTION

The evaluation of municipal public policies has gained increasing relevance in the academic field and in public administration due to its importance for local development and for improving the population's quality of life. In recent decades, there has been an expansion of studies in the field of public policies, driven both by the strengthening of funding agencies and by the expansion of funding lines aimed at the analysis of governmental policies (Trevisan & Bellen, 2008; Arretche, 2003). Furthermore, society has increasingly demanded greater transparency and impact research to ensure that governmental actions promote effective social, environmental, economic, and institutional transformations (Nicli et al., 2020; Sehnem et al., 2022).

In this context, public policies play a fundamental role in achieving the Sustainable Development Goals (SDGs), established by the United Nations (UN) in 2015 through the 2030 Agenda. Considered one of the largest global agreements for sustainable development, the 2030 Agenda represents an action plan focused on people, the planet, and prosperity, involving 193 member countries. Among its 17 goals, SDG 11 stands out, aiming to make cities and human settlements inclusive, safe, resilient, and sustainable (UN, 2015; 2016). This goal emphasizes, among other aspects, the reduction of the negative per capita environmental impact of cities, with particular attention to air quality and solid waste management.

Urban development, although associated with economic and social progress, also generates significant environmental impacts, requiring public authorities and civil society to adopt strategies capable of minimizing such effects (Ferreira et al., 2015). Thus, the integration between municipal public policies and the principles of the 2030 Agenda becomes essential to promote a more balanced and sustainable development model.

In this context, the present study focuses on the municipality of Prudentópolis, located in the State of

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Paraná, with an estimated population of 49,393 inhabitants (IBGE, 2022). This research is justified by the need to evaluate municipal public policies and their relationship with SDG 11, identifying their main strengths and weaknesses. The research problem consists of analysing the strengths and the fragilities of public policies in the municipality of Prudentópolis, Paraná, regarding SDG 11. The main objective is to examine, through a documentary analysis based on the 2022 database of the State Court of Accounts (TCE), the elements that demonstrate the municipality's performance in relation to the guidelines of SDG 11.

The following section presents the theoretical framework that supports this research.

II. CONCEPTUAL AND THEORETICAL FRAMEWORK

2.1 Evaluation of Municipal Public Policies

First, it is necessary to understand the concept of public policies. According to Marostica et al. (2021), public policies are important instruments for promoting changes in current paradigms, such as mitigating the effects of climate change and achieving urban and regional sustainability and development. This occurs insofar as public policies modify or maintain the behaviour of citizens or organizations to achieve specific outcomes.

Silva et al. (2016, p. 1436) further state that "government public policies represent an organized set of governmental actions and decisions, generally aimed at solving societal problems." However, the concept is not free from controversies that reveal different worldviews. It may also be understood as a field of investigation that originates from political science, particularly concerning studies of government, public administration, international relations, and political behaviour (Melazzo, 2010 apud Silva et al., 2016).

Dias and Matos (2012) explain public policies as a form of managing collective problems and demands using methodologies that identify priorities, rationalize the allocation of investments, and employ planning to achieve previously defined objectives and goals.

Regarding the stages involved in the process of public policy development, Viana (1996), Dias and Matos (2012), and Secchi (2013), cited by Silva et al. (2016), note that there is no consensus concerning the exact number of phases, stages, or cycles in the policy process.

Dias and Matos (2012) also state that there is no agreement regarding the number of phases or stages. Based on a review conducted with fourteen authors, the number of stages ranges from four basic steps to up to seven phases or stages. These generally include problem identification; formulation of solutions; decision-making; implementation; and evaluation. Viana (1996) proposes a set of phases, as presented in Table 1.

Regarding public policy analysis, Souza (2009) highlights differences between public policy evaluation and public policy analysis. Policy analysis focuses on the study of the causes and consequences of government actions, whereas evaluation refers to the impacts or processes associated with policies. Labra (1999) further emphasizes that public policy analysis constitutes a complex, dynamic, and evolving field that requires both theoretical knowledge and sufficient empirical data to understand and explain government actions.

Concerning the evaluation of public policies, Secchi (2013) defines this phase as the stage in which the implementation process and the performance of public policies are examined to better understand the status of the policy and the degree to which the original problem has been reduced. At this stage, feedback is generated for the preceding phases. Evaluation includes the definition of criteria, indicators, and standards. According to the same author, indicators are used to operationalize evaluation criteria and function as proxies that can measure inputs, outputs, and outcomes. Input indicators (system inputs) are related to financial expenditures, human resources employed, or material resources utilized.

Output indicators are associated with the productivity of services or products, such as the quantity of waste collected. Outcome indicators refer to the effects of public policy on policymakers (citizens) and to the policy's capacity to solve or mitigate the problem for which it was originally designed (Secchi, 2013).Regarding the concept of an index, it is defined as a more refined measure derived from the aggregation of a set of indicators or variables, which can be used to interpret the reality of a system. It is also applied as a pretreatment of original data (Siche et al., 2007). The following section discusses the concept of Sustainable Cities.

Table 1: Phases of the Public Policy Development Process (Research data (2023), based on Viana (1996))

#	**Phases description**
1	Agenda setting (development of the agenda; specification of alternatives; selection of an alternative by the President, Legislative branch, or other competent authority; and implementation of the decision);
3	Policy formulation (three sub-phases: first, when a mass of data is transformed into relevant information; second, when values, ideals, principles, and ideologies combine with factual information to produce knowledge oriented toward action; and third, when empirical and normative knowledge is transformed into public actions in the present context);
3	Policy implementation (definition of the problem regarding its normative and causal aspects; decomposition of the problem into its constituent parts; demonstration that parts of the problem can be addressed and identification of alternative solutions; preliminary estimates; and definition of implementation strategies);
4	Policy evaluation (impact evaluation – measures policy effectiveness; evaluation of implementation strategies – identifies the most productive approach; monitoring – measures managerial and operational efficiency).

2.2 Sustainable Cities

The process of urbanization intensified in recent decades has transformed predominantly rural societies into largely urban populations (Bento et al., 2018), increasing challenges related to infrastructure, mobility, sanitation, waste management, and environmental quality. In this context, the need for new urban planning models has emerged. The concept of a sustainable city is associated with the integration of environmental, economic, and social dimensions into public policies and management practices (Nalini & Silva Neto, 2017), including initiatives such as sustainable procurement, green construction, public transportation powered by renewable sources, and proper waste management, as well as efforts to reduce socioeconomic vulnerabilities. Stefani et al. (2022) emphasize that sustainable cities are among the most resilient forms of human settlements because they aim to ensure quality of life without compromising ecosystems. Similarly, Nam and Pardo (2011), cited by Kniess et al. (2019), highlight the challenge of balancing economic growth, social equity, and environmental preservation.

In the Brazilian context, the consolidation of sustainable cities depends on the formulation and effective implementation of public policies related to sanitation, mobility, education, water management, solid waste management, and land regularization (Souza & Albino, 2018). This process requires structured planning and coordination between government and society. Global concern for sustainable development has also stimulated the creation of an international agenda coordinated by the United Nations, culminating in the establishment of the Sustainable Development Goals (SDGs), organized around the five "Ps": People, Planet, Prosperity, Peace, and Partnerships.

2.3 SDG 11 and Cities

In 2015, the United Nations established the 2030 Agenda, a global action plan approved by 193 countries with targets to be achieved by 2030. The agenda is structured around 17 Sustainable Development Goals (SDGs, Fig. 1) that address essential dimensions of human and environmental progress. Among these, Sustainable Development Goal 11 (SDG 11) aims to make cities and human settlements inclusive, safe, resilient, and sustainable. This objective emphasizes reducing the negative per capita environmental impact of cities, with particular attention to air quality, urban mobility, adequate housing, and solid waste management.

Inadequate management of urban waste represents one of the most significant contemporary environmental challenges, generating considerable impacts on both the environment and public health (Ferreira, 2018). This scenario highlights the need for intersectoral public policies capable of integrating economic development, social inclusion, and environmental preservation.

In this context, Roma (2019) argues that achieving the targets of the 2030 Agenda depends on effective collaboration among governments, the private sector, and civil society.

Fig. 1. The 17 Sustainable Development Goals established by the United Nations (United Nations, 2023).

Similarly, Moreira et al. (2020) emphasize that sustainability is no longer a concern limited to environmental groups but has become a shared responsibility across different sectors of society. Therefore, the integration between municipal public policies and the guidelines of SDG 11 is fundamental for building more sustainable, resilient, and inclusive cities. The evaluation of these policies plays an important role in identifying progress, limitations, and opportunities for improvement, promoting alignment between local actions and global sustainable development goals. Among the 17 Sustainable Development Goals established by the 2030 Agenda, SDG 11 specifically addresses Sustainable Cities and Communities (Stéfani et al., 2022).

SDG 11 seeks to promote inclusive, safe, resilient, and sustainable cities and human settlements, reinforcing the importance of integrated urban planning and efficient resource management. One of the main challenges for achieving this goal is the management of urban solid waste, considered one of the most critical environmental issues today, with significant impacts on environmental quality and human health (Nascimento, 2013, cited in Ferreira, 2018). This issue has mobilized public managers in both developed and developing countries, highlighting the urgency of strategies that combine urban development with environmental sustainability.

To achieve the established targets, it is essential to formulate and implement public policies and intersectoral actions supported by legal instruments that simultaneously promote economic development, social inclusion, and environmental protection (Ferreira, 2018). As noted by Roma (2019), the achievement of the objectives of the 2030 Agenda requires coordinated engagement between governments and society. In this sense, the conservation of natural resources and the proper management of waste generated by consumption have become shared responsibilities among public authorities, the private sector, and citizens, rather than concerns limited only to environmental activists (Moreira et al., 2020).

III. METHODOLOGIES

3.1 Methodological Design

This research was conducted between June and July 2023. The methodology adopted for data collection and analysis was documentary analysis. According to

Lüdke and André (1986, p. 38), documentary analysis is a valuable approach for qualitative data research, as it both complements information obtained through different techniques and reveals new aspects of a given theme or problem. Cechinel et al. (2016) further explain that documentary analysis begins with a preliminary evaluation of each document collected for the study. This involves examining and critically assessing each document by considering elements such as context, authorship, the interests involved, the reliability of the information, the nature of the text, and the key concepts relevant to the development of the research.

For the analysis itself, the following steps were adopted for data collection from the Tribunal de Contas do Estado do Paraná (TCE) – *Evaluation of Government Performance 2022*: verification of the public policies implemented by the municipality of Prudentópolis (PR) and their relationship with Sustainable Development Goal (SDG) 11, as well as an analysis of the report prepared by the TCE.

The report obtained from the official website of the Tribunal de Contas do Estado do Paraná – TCE (*Evaluation of Government Performance 2022*) aimed to present the results achieved by the municipality regarding the evaluation of governmental performance in implementing public policy actions, in accordance with Article 217-A of the Internal Regulations of the TCE/PR. The technical note issued by TCE/PR (Annex I) was sent in 2022 to public officials from municipalities in the state of Paraná to collect responses. The objective of the evaluation in each area was divided into evaluation questions, which are further subdivided into sub-questions called verification items, which in turn are divided into questionnaire items. Table 2 presents the conceptual definitions of these instruments.

Table 2: Evaluation Questions of Government Performance (2022) (TCE (2023)).

Level of Question/ Sub-question	Concept
Evaluation Question (EQ)	Refers to the main question to be answered through the evaluation process. The set of EQs within a specific area of municipal public management aims to achieve the overall objective of evaluation in that area.
Verification Item (VI)	The division of an EQ into sub-questions results in VIs. The set of VIs seeks to answer the EQ from which they originated.
Questionnaire Item (QI)	The division of a VI into sub-questions results in QIs. The set of QIs seeks to answer the VI from which they originated.

Table 3: Government Areas and Evaluation Objectives (TCE (2023)).

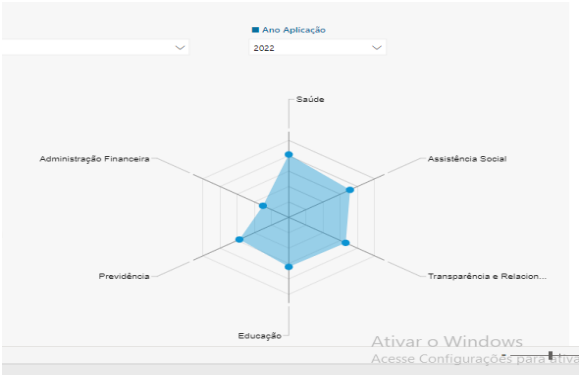
Area of Municipal Public Management	Evaluation Objective
Financial Administration	To evaluate government actions that contribute to sustainable financial conditions to ensure the continuity of adequate public service provision.
Social Assistance	To evaluate the degree to which government actions identify and prevent situations of vulnerability and social risk through the provision of Basic Social Protection services.
Education	To evaluate government actions aimed at improving the quality of education and expanding access to and permanence in early childhood education and the early years of elementary education offered by the municipal education system.
Social Security	To evaluate government actions that contribute to the financial and actuarial solvency of the Municipal Social Security System.
Health	To evaluate government actions aimed at improving the quality of primary health care services according to the needs and demands of the population in each territory.
Transparency and Citizen Engagement	To evaluate government actions that ensure transparency and strengthen the relationship with citizens in order to promote social accountability.

According to TCE (2022), the preparation of the report used the following evaluation criteria: the degree of compliance in each area of municipal public management ranges from 0 (zero) to 10 (ten) and is calculated by the simple average of the compliance level of the evaluation questions, multiplied by ten. The compliance level of each evaluation question is calculated through the simple average of the compliance levels of the verification items. The compliance level of each verification item is calculated through the simple average of the compliance levels of the questionnaire items. Finally, the compliance level of each questionnaire item is determined through the simple average of the responses provided for each item.

Regarding the areas of municipal public management evaluated in the Municipal Mayor's Accountability Reports submitted to the Tribunal de Contas do Paraná, TCE (2022) identifies the following areas: financial administration, social assistance, education, social security (in municipalities with their own pension systems), health, and transparency and citizen engagement. Table 3 presents the evaluation objectives for each area of municipal public management.

Table 4: Criteria for the Registration of Municipal Interlocutors (TCE (2023)).

Area of Municipal Public Management	Position(s) Held by the Interlocutor(s) (or equivalent position)
Financial Administration	Municipal manager responsible for the financial area.
Social Assistance	Municipal social assistance manager; coordinator of a municipal Social Assistance Reference Center.
Education	Municipal education manager; director of a municipal school or municipal early childhood education center; pedagogical coordinator; nutritionist responsible for the municipal school feeding program.
Social Security	Municipal administration manager; municipal manager of the social security system.
Health	Municipal health manager; coordinator of a municipal basic health unit; pharmacist responsible for the dispensing of primary care medications.
Transparency and Citizen Engagement	Municipal administration manager.



Legend: 0 – very poor to 10 – excellent.

Fig. 2: Evaluation of Government Performance (Research data (2026), based on TCE (2022)).

Regarding the criteria for registering municipal interlocutors, according to TCE (2022), the interlocutors referred to in §1 of Article 8 of Normative Instruction No. 172 (2022) must be appointed by the Mayor and must occupy the positions defined as in Table 4, or equivalent positions, according to the corresponding area of municipal public management.

Regarding the updating of the registration, TCE (2023) states that the Mayor must indicate and maintain an updated registry of all public officials occupying the positions described in the previous table or equivalent positions, in accordance with Articles 8 (§1) and 13 of Normative Instruction No. 172 (2022). If the absence, partial or total, of the registration of municipal interlocutors is identified, the public policy evaluation forms will be made available exclusively to the Mayor, in accordance with §2 of Article 8 of Normative Instruction No. 172 (2022). The complete set of evaluation forms used to assess the degree of implementation of public policies is included in the annexes of the technical note.

The research universe consists of the municipality of Prudentópolis, Paraná, which, according to data from the IBGE census (2022), has a population of 49,393 inhabitants. Additionally, bibliographic research was used. According to Rodrigues (2006), bibliographic research is conducted using secondary sources such as scientific articles, dissertations, and theses, among others.

The next section presents the data obtained from the research, along with the corresponding analysis and discussion

IV. RESULTS

This section presents the analysis and discussion of the results through tables prepared from data extracted from the report *"Evaluation of Government Performance 2022"* obtained from the Paraná State Court of Accounts (TCE). The objective is to examine the public policies of the municipality of Prudentópolis, Paraná, and their relationship with the Sustainable Development Goals (SDGs).

Fig. 2 presents the six areas that composed the evaluation of governmental performance within the municipality's annual accountability process. The overall results obtained from the TCE 2022 report were: Health (8.16); Social Assistance (7.13); Transparency (6.62); Education (6.43); Social Security (5.75); and Financial Administration (3.01). Table 5 summarizes the consolidated results of the municipal government performance evaluation according to data from the Paraná State Court of Accounts (TCE, 2022), organized by area of municipal public management.

The "Health" sector presented the highest overall average (8.16), indicating satisfactory performance, particularly in planning instruments and service provision. This result aligns with Sustainable Development Goal 3, which seeks to ensure healthy lives and well-being for all. However, workforce management showed limitations, possibly related to insufficient staffing levels.

In "Education", the overall average was 6.43, with a positive highlight for school transportation services (9.50), demonstrating efficient logistical organization. Nevertheless, pedagogical practices received the lowest score (4.60), suggesting weaknesses in evaluation processes and learning monitoring. Barreto (2001), cited by Cipriani, Moreira, and Carius (2021), argues that qualitative evaluation should consider the learning process and students' experiences. These findings relate directly to Sustainable Development Goal 4 and to Sustainable Development Goal 11, as educational quality is linked to sustainable urban development.

Table 5: Summary of Municipal Governance Evaluation (Research data (2026), based on TCE (2022)).

Management Area	Highest Average (Factor)	Score	Lowest Average (Factor)	Score	Overall Average
Education	School transportation services	9.50	Pedagogical practices	4.60	6.43
Health	Planning instruments	9.50	Workforce management	7.00	8.16
Social Assistance	Territorial and intersectoral coordination	9.70	SCFV and home-based basic protection services	3.90	7.13
Financial Administration	Tax revenue collection	5.10	Budget planning review	0.00	3.01
Social Security	Social security legislation / investments	10.00	Transparency and work processes	0.00	5.75
Transparency and Citizen Relations	Information availability	10.00	Regulation of communication channels	2.50	6.62

The "Social Assistance" sector obtained an overall average of 7.13, with strong performance in territorial and intersectoral coordination (9.70), indicating integration among policies and the existence of a structured socio-territorial diagnosis. However, the Service for Coexistence and Strengthening of Bonds (SCFV) and the Home-Based Basic Social Protection Service presented low scores (3.90), revealing gaps in the provision of specific services. Roma (2019) highlights that the 2030 Agenda emphasizes actions directed toward people and prosperity, reinforcing the importance of strengthening social assistance policies in alignment with SDGs 3 and 11.

"Financial Administration" recorded the lowest overall average (3.01), revealing structural weaknesses, particularly in the review of budget planning (0.00). Although tax revenue collection achieved a moderate score (5.10), the data indicate deficiencies in the consolidation of fiscal monitoring and review instruments. According to Silva et al. (2016), public policies represent organized decisions aimed at solving social problems, which requires consistent budget planning. Such limitations compromise financial sustainability and, consequently, the achievement of SDG 11.

In the "Social Security" area, the overall average was 5.75, with maximum performance in social security legislation and investments (10.00), indicating regulatory adequacy and structured resource allocation. However, the absence of transparency and formal governance processes (0.00) reveals administrative weaknesses. Ferreira (2018) notes that structured public policies supported by legal instruments contribute to economic and social development, reinforcing the need to improve governance in this sector.

Finally, in "Transparency and Citizen Relations", the overall average was 6.62, with strong performance in the availability of information (10.00), demonstrating adequate technological infrastructure and access to information. However, the regulation of communication channels scored only 2.50, indicating the need for more formalized procedures. Moreira et al. (2020) emphasize that sustainability requires participation from all sectors of society, while Viante et al. (2021) highlight the central role of cities in sustainable transformation. Therefore, transparency represents an essential element for strengthening social control and aligning governance practices with SDG 11.

Overall, the results indicate satisfactory performance in social sectors (health and social assistance), intermediate performance in education and transparency, and more significant weaknesses in financial administration and social security governance. The analysis shows that the municipality has achieved important progress; however, it still needs to strengthen planning, monitoring, and control mechanisms to consolidate public management aligned with the Sustainable Development Goals, particularly SDG 11.

V. CONCLUSIONS

This study aimed to analyse, from a documentary analysis perspective, the data from the *Government Performance Evaluation Report* (TCE/PR, 2022) of the municipality of Prudentópolis, Paraná, in order to identify the main positive and negative aspects of municipal public policies and their relationship with Sustainable Development Goal 11 (SDG 11).

The results indicate that, overall, the municipality partially meets the evaluated requirements, presenting relevant progress in social areas, particularly Health (8.16) and Social Assistance (7.13), followed by Transparency (6.62) and Education (6.43). Social Security showed an intermediate average (5.75), while Financial Administration presented the lowest performance (3.01), revealing weaknesses in budget planning and monitoring. These findings suggest that although there are initiatives aligned with the guidelines of the 2030 Agenda, structural improvements are still necessary, especially in financial management, to strengthen municipal sustainability.

Regarding SDG 11 specifically, the analysis indicates that certain public policies contribute to promoting more inclusive and sustainable cities, such as the provision of school transportation in the education sector and the guarantee of access to basic health services.

These actions demonstrate a commitment to improving the population's quality of life and strengthening local governance. However, the results also highlight the need to improve planning, control, and transparency mechanisms, particularly in areas with lower performance.

This research contributes to the academic field by presenting a structured diagnosis of the reality of public policies in Prudentópolis, Paraná, expanding the discussion on municipal governance evaluation and sustainable development. For future studies, it is recommended to conduct comparative analyses among different municipalities to identify best practices and propose planning strategies capable of improving performance indicators and strengthening alignment with the goals of the 2030 Agenda.

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Open and Collaborative Innovation in SMEs: A Systematic Literature Review

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Abstract - This study synthesizes the academic knowledge published in recent years of open and collaborative innovation in small and medium-sized enterprises (SMEs) through a systematic literature review, with the aim of identifying the main thematic clusters, theoretical contributions and opportunities for future research. A structured search was conducted in the SCOPUS database, focusing on open access journal articles published between 2021 and 2025. Following the Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, 185 articles were initially identified, 174 of which were included in the review. Descriptive analysis and thematic coding were applied to identify methodological models, conceptual frameworks, and new research clusters. The results show five major themes: the drivers and facilitators of open innovation; structural and behavioral barriers; collaborative strategies involving clients, universities and intermediaries; innovation results; and digital infrastructures that facilitate open innovation. Most studies use quantitative methodologies, especially PLS - SEM, and the theoretical approach is varied, based primarily on the Resource Based Approach, the Theory of Dynamic Capabilities, and the Theory of Social Capital. Despite the growth in publications, literature is divided and there is a lack of integrative models specifically adapted to the context of SMEs. This review is limited by the fact that it is based on articles indexed in SCOPUS and open access; future studies may extend database coverage and adopt longitudinal or comparative views. The findings provide practical insights for SME managers who wish to leverage external partnerships and policy makers who want to strengthen innovation ecosystems through direct support. By unifying the body of scattered knowledge, this review contributes to theoretical integration and proposes a research agenda for the study of collaborative innovation in SMEs.

Keywords: Open Innovation; Collaborative Innovation; SMEs; Systematic Literature Review.

I. INTRODUCTION

In today's global economy, innovation is seen as the main engine of competitiveness, adaptability and sustainable growth for companies of all sectors and sizes. Especially in small and medium-sized enterprises (SMEs), innovation is a fundamental lever for strengthening sustainable performance, resilience and competitive advantage, especially when associated with eco-innovation, service innovation and continuous innovation performance (Carrasco-Carvajal et al., 2023; Nuryakin et al., 2022; Valdez-Juárez & Castillo-Vergara, 2021; Wang et al., 2025; Yulianto & Supriono, 2023). However, SMEs often innovate with structural constraints – low financial flexibility, limited internal capacities and restricted access to formal R&D infrastructure – which makes the search for external knowledge and complementary assets particularly important (Almeida, 2024; Dubouloz et al., 2021; Priyadarshini et al., 2024).

In response to these constraints, more SMEs are adopting models of open innovation and collaboration to increase innovation potential through external alliances, shared knowledge and inter-organizational collaboration. The concept of open innovation proposed by Chesbrough (2003) states that companies can and should use external and internal ideas, channels and collaborations to develop technology and market offerings. In this paradigm, SMEs are not isolated innovators; more network participants in innovation ecosystems are collaborating with universities, research institutions, suppliers, customers, startups and even competitors (Audretsch et al., 2023; Bertello et al., 2022; Carlos et al., 2025; Livieratos et al., 2022). At the same time, studies emphasize that openness is not binary; it has different levels and forms, and can be

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operationalized through input (inbound), output (outbound), and combined (coupled) views (Marullo et al., 2021).

From the point of view of implementation, open innovation in SMEs depends on skills and routines for the identification, absorption and exploitation of external knowledge, including absorption capacity and partner selection logic (Dubouloz et al., 2021; Manosalvas Vaca et al., 2023). Open and collaborative innovation is increasingly associated with broader strategic outcomes, such as innovation in the business model and performance effects, often dependent on complementary capabilities and strategic opportunities (Albats et al., 2023; Carrasco-Carvajal et al., 2023). Similarly, collaborative innovation emphasizes the shared resolution of problems, the development of co-creation and joint value creation; for example, the research grant consortia, the development of import-export partnerships, and triple helix collaboration (Grimpe et al., 2022; Kantaruk Pierre et al., 2024; Khan et al., 2022).

These dynamics are particularly visible in rapidly changing digital contexts, where technology adoption costs and capacity gaps can increase constraints, which encourages SMEs to collaborate to access resources that they cannot develop internally (Ayamga et al., 2025). The following lines of research also show how knowledge management supports the trends of digital transformation of SMEs (Hafeez et al., 2025) and how trust and inter-organizational collaboration can shape the results obtained in cross-border relations (e.g. supply chains) (Kankam & Dza, 2025). Moreover, open innovation mechanisms can extend beyond technical collaboration to funding and the involvement of stakeholders, such as equity crowdfunding as an open innovation tool related to sustainability objectives (Perotti et al., 2025). Empirical work also suggests that sharing knowledge can lead to innovation performance through open innovation mechanisms (Zan et al., 2024).

Although interest has increased in how SMEs carry out open and collaborative innovation, literature is fragmented, multidisciplinary and methodologically diverse. The contributions include strategic management, innovation studies, entrepreneurship and organizational theory, with different definitions, analysis units and contextual differences (Akjou & Idrissi Fakhreddine, 2024; Audretsch & Guenther, 2023). Bibliometric synthesis and systematic revisions also indicate the rapid expansion of research fronts and the heterogeneous thematic clusters in open innovation associated with SMEs (and surrounding concepts) (Carvalho et al., 2021; Chigori et al., 2024; Ragazou et al., 2022; Sabando-Vera et al., 2022). Consequently, this review synthesizes the factors, facilitators, obstacles and results that drive open and collaborative innovation in SMEs, including management decisions and implications for policy support (Srisathan et al., 2023a, 2023b).

Consequently, this work provides a systematic review of the literature of research on open and collaborative innovation in SMEs. By identifying, classifying and critically analysing publications, we intend to provide a comprehensive map of the knowledge base, to highlight the main thematic clusters and methodological trends, and to highlight the research gaps that can feed recommendations based on future theories and implications.

The rest of the structure of the article is as follows: Section 2 presents open and collaborative innovation and a theoretical basis for its importance to SMEs. Section 3 describes the systematic review methodology. Section 4 contains the results, including the main themes and trends. Section 5 discusses the findings considering theory and practice. Section 6 contains conclusions with implications, limitations and suggestions for future research.

II. THEORETICAL FRAMEWORK

As the landscape of innovation evolves, there has been a paradigm shift from the closed innovation models (internally guided) to more permeable and collaborative frameworks, where companies deliberately use external knowledge and partners. For SMEs, this change is particularly significant: openness can offer advantages, but at the same time creates managerial and resource-related tensions. Recent studies on SMEs show that openness cannot be treated as a simple option "open vs. closed", while SMEs exhibit different levels of openness, conditioned by innovation objectives, activities and investments (Priyadarshini et al., 2024). Similarly, open innovation can create risks which SMEs must compare with the expected benefits, considering their resource limits (Livieratos et al., 2022). While open innovation generally refers to the purposive inflow and outflow of knowledge across organizational boundaries, collaborative innovation places greater emphasis on joint processes of co-creation among multiple actors. In the SME context, these two concepts are closely related and often overlap, but distinguishing them analytically helps clarify the different mechanisms and outcomes associated with each. This section summarizes the basic concepts of open and collaborative innovation, their importance to SMEs, and the challenges and opportunities present at this intersection.

2.1 Open Innovation: Definitions and Dimensions

Open innovation (OI) was first formally conceptualized by Chesbrough (2003) as a paradigm in which firms purposively manage knowledge flows across organizational boundaries to advance technology and market offerings. In contrast to vertically integrated innovation models, OI is commonly articulated through inbound, outbound, and coupled modes. This tripartite framing is not merely conceptual: empirical SME research has explicitly examined how barriers differ in intensity depending on whether SMEs adopt inbound, outbound, or coupled OI (Dubouloz et al., 2021).

- Inbound OI refers to integrating external ideas, technologies, or competencies into internal innovation processes.

- Outbound OI involves leveraging internal knowledge through licensing, external commercialization, or other transfer mechanisms.
- Coupled OI combines inbound and outbound logic through alliances and collaborations.

Beyond the classification of modes, recent literature stresses that the central strategic question for SMEs is not only which mode they adopt, but how open they are in practice. Priyadarshini et al. (2024) show that prior research frequently treated OI as a binary distinction, and they move beyond this by analyzing the extent of openness across European SMEs, finding that overall openness is low and is associated with firm objectives (e.g., product/process innovation), internal R&D, acquisition/licensing of external knowledge, and financial commitment to innovation (Priyadarshini et al., 2024). Complementing this perspective, Marullo et al. (2021) directly address the measurement challenge ("how open are firms?") by conceptualizing openness as a decision pattern shaped by managers' evaluation of OI benefits and concerns, identifying different levels of OI maturity required to broaden external partnerships and shift from relationship-based to more transaction-based practices (Marullo et al., 2021).

Crucially, OI in SMEs is increasingly framed as a dynamic and managerial process rather than a static arrangement of knowledge inflows/outflows. Livieratos et al. (2022) introduce the concept of "OI moves", a granular unit of analysis describing a set of managerial decisions and actions executed within a collaboration with a single partner. They argue SMEs evaluate OI at the level of partner choice ("who innovates with whom") and exploitation mode ("who exploits the result"), revealing distinct configurations of benefits and risks across OI moves (Livieratos et al., 2022). Digitalization-related phenomena also shape this search behavior: Ferrigno et al. (2025) find that Big Data characteristics (Volume, Velocity, Variety) can influence SMEs' OI breadth (i.e., increasing external collaborations), while not necessarily affecting OI depth, suggesting that digital resources may expand collaboration scope without automatically deepening partner engagement (Ferrigno et al., 2025).

2.2 Collaborative Innovation: From Dyads to Ecosystems

While open innovation emphasizes the permeability of organizational boundaries, collaborative innovation (CI) focuses on the joint creation of value through inter-firm or inter-organizational collaboration. It encompasses activities such as co-development, co-design, co-patenting, and shared experimentation. Collaboration may occur in dyadic partnerships, within value chains, or in broader innovation ecosystems involving multiple, heterogeneous actors (Audretsch & Guenther,2023; Ferrigno et al., 2025).

Collaborative innovation is particularly relevant in uncertain and dynamic environments where innovation requires complementary capabilities, distributed knowledge, and shared risk-taking. The rise of digital platforms, knowledge-intensive business services (KIBS), and open-source communities has further expanded the scope and strategic relevance of collaborative innovation.

Recent literature underscores that innovation collaboration in SMEs is multifaceted, spanning formal partnerships, informal networks, and dynamic innovation ecosystems. A bibliometric and systematic review by Sabando-Vera et al. (2022) reveals a growing scholarly emphasis on open innovation in SMEs, particularly in relation to external knowledge integration, collaborative experimentation, and the role of intermediary agents. Their findings highlight how SMEs increasingly adopt open innovation practices not only to overcome internal limitations but also to position themselves more competitively within regional and global innovation networks.

This trend aligns with broader research that conceptualizes innovation ecosystems as complex adaptive systems, where SMEs participate in interdependent knowledge flows, resource exchanges, and co-creation platforms that transcend traditional industry boundaries. Although ecosystem approaches have deep roots in innovation studies, recent empirical contributions stress their applicability and relevance to resource-constrained SMEs seeking external complementarities.

2.3 SMEs and Innovation: Constraints and Adaptative Logics

SMEs are often typified by their resource constraints, including limited financial capital, R&D infrastructure, and managerial capacity. These structural limitations have traditionally placed them at a disadvantage relative to larger firms in innovation races. However, their agility, informality, and closer customer proximity can enable faster decision-making and responsiveness.

Open and collaborative innovation offers SMEs a strategic means to overcome internal limitations by tapping into external sources of knowledge, funding, and technical expertise. For instance, partnerships with universities or participation in government-supported innovation programs may provide access to research infrastructure or subsidized R&D initiatives. Additionally, alliances with suppliers or customers can drive user-centric innovation, while participation in clusters or consortia may foster collective learning.

Recent empirical work by Almeida (2024) investigates the causes of open innovation failure in SMEs, revealing that resource limitations and management processes are critical barriers that differentiate SMEs' innovation challenges from those of larger firms.

Equally, the literature suggests that SMEs' innovation strategies are shaped by resource orchestration and strategic sequencing – where firms may begin innovation activity internally before progressively engaging external partners – emphasizing that timing, partner selection, and value capture strategies are integral to successful OI adoption (Livieratos et al., 2022).

In sum, these recent developments indicate a shift in how innovation scholars understand SME innovation: away from static models of openness toward

processual, strategic, and networked perspectives tailored to SMEs' unique conditions.

2.4 Theoretical Lenses in Literature

The literature on open and collaborative innovation in SMEs has drawn on an increasingly diverse set of theoretical lenses – many of which bridge traditional innovation theory with insights from strategy, management, and organizational behavior:

- Dynamic Capabilities – Research frames open and collaborative innovation in SMEs through dynamic capabilities, i.e., the ability to sense opportunities, seize them, and reconfigure competences under change. Empirical studies link these capabilities to SMEs' ability to translate openness into innovation and performance outcomes, particularly when open innovation is combined with eco-innovation and capability renewal (Valdez-Juárez & Castillo-Vergara, 2021; Lepore et al., 2023).
- Resource-Based and Composition-Based Views – SMEs innovate by acquiring external knowledge/resources and recombining them with internal assets. Evidence shows that the extent of openness relates to SMEs' innovation objectives, R&D activity, and investment in external knowledge acquisition/licensing, while competitive outcomes also depend on complementary mechanisms such as IP protection and continuous innovation performance (Priyadarshini et al., 2024; Wang et al., 2025).
- Network Theory – highlights how SMEs' relational ties and positions shape knowledge flows and innovation outcomes. Studies emphasize collaboration in multi-actor arrangements (e.g., university–industry–government, consortia) as channels for accessing complementary capabilities and coordinating innovation efforts beyond firm boundaries (Bertello et al., 2022; Grimpe et al., 2022).
- Processual and Adaptive Theories – A processual and adaptive lens treats openness as evolving decisions, routines, and sequences rather than a static attribute. Work on "open innovation moves" explains SMEs' partner-specific choices and attention/risk trade-offs, while other studies show how barriers vary across inbound/outbound/coupled modes, reinforcing the need to study timing, partner engagement, and implementation routines (Livieratos et al., 2022; Dubouloz et al., 2021).

This multiplicity of lenses reflects both the complexity of the innovation phenomenon in SMEs and the interdisciplinary nature of the field. However, it also introduces fragmentation and a need for theoretical synthesis – one of the goals of this systematic review.

2.5 Knowledge Gaps and Opportunities

Although recent studies have expanded the debate on open and collaborative innovation in SMEs, the literature remains fragmented across themes, theoretical perspectives, and methodological approaches. This makes it difficult to develop an integrated understanding of how these innovation practices are conceptualized, implemented, and linked to SME-specific outcomes. These include:

- Limited integration of open and collaborative innovation concepts into unified frameworks tailored to SMEs.
- Varied methodological approaches with insufficient consensus on best practices for measuring collaboration outcomes.
- A need for more longitudinal and comparative studies to understand how open and collaborative innovation evolves over time within SMEs.

By systematically reviewing recent empirical and theoretical contributions, this article aims to clarify these emerging contours and outline directions for future research.

III. METHODOLOGY

This study follows a systematic literature review (SLR) methodology grounded in established academic protocols to ensure transparency, reproducibility, and methodological rigor. The objective is to map and synthesize recent scholarly contributions on open and collaborative innovation in SMEs published between 2021 and 2025.

3.1 Review Design and Protocol

The review was structured according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021), which outline a four-phase process: identification, screening, eligibility, and inclusion. A protocol was developed in advance to define the inclusion and exclusion criteria, search strategy, and data extraction process. This review aims to synthesize recent research on open and collaborative innovation in SMEs to identify the main forms of collaboration, key drivers and barriers, principal outcomes, and the dominant theoretical and methodological approaches in the field.

To guide the review, we pose the following research questions:

1. What forms and practices of open or collaborative innovation are most frequently adopted by SMEs?
2. What are the main barriers and enablers that influence collaborative innovation in SMEs?
3. What are the observed outcomes and performance implications of engaging in open innovation for SMEs?
4. What theoretical frameworks and methodological approaches have been employed in the study of this topic?

3.2 Search Strategy

The literature search was conducted using the SCOPUS database – recognized for its comprehensive coverage of peer-reviewed journals in business,

management, and social sciences. The query was constructed to capture publications that explicitly address open or collaborative innovation within the context of small and medium-sized enterprises. The final search string was constructed based on the following aspects:

- **Keyword combination** (Title/abstract/keywords): ("collaborative innovation" OR "open innovation") AND ("SME*" OR "small and medium-sized enterprise*" OR "small and medium enterprise*");
- **Range:** 2021–2025;
- **Subject areas**: Business, Management and Accounting; Social Sciences;
- **Language:** English;
- **Access type:** Open Access.

3.3 Inclusion and Exclusion Criteria

According to the literature review process guidelines in Information Systems field (Kitchenham, 2004, 2007; Templier & Paré, 2015), inclusion and exclusion criteria were applied, screening the articles identified in the search phase. The selection criteria were defined to ensure conceptual relevance and methodological consistency, as presented in Table 1.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	**Exclusion Criteria**
Peer-reviewed journal articles	Book chapters, or editorials
Published between 2021–2025	Articles outside the specified year range
Written in English	Articles in other languages
Focused on SMEs and open or collaborative innovation	Studies focused on large firms, startups, or unrelated innovation
Empirical, conceptual, or theoretical in nature	Articles lacking substantial relevance to innovation topics

3.4 Screening and Selection Process

The selection process unfolded in two stages:

1) Title and Abstract Screening: All 185 articles were initially screened based on title and abstract to assess conceptual alignment with the research objectives.
2) Full-Text Review: Eligible articles were then assessed in full to verify relevance, rigor, and thematic fit. Non-conforming studies were excluded based on the criteria in Table 1.

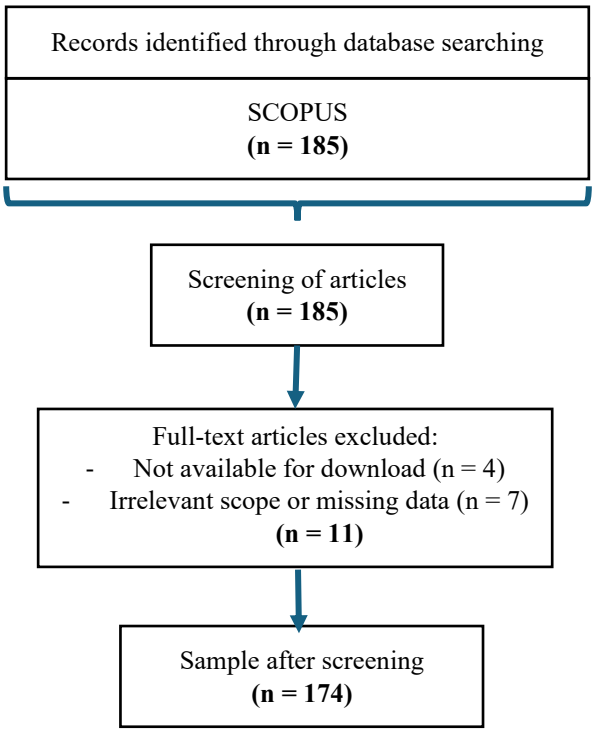

Fig. 1. Search Process

3.5 Data Extraction and Coding

To prepare the analysis, data from the 174 eligible articles were organized using a structured coding protocol in Microsoft Excel. Each article was reviewed in full, and relevant information was extracted across multiple analytical dimensions. The goal was to ensure consistency and depth in comparative analysis while allowing inductive pattern identification.

IV. RESULTS

This section presents the key findings derived from the analysis of 174 peer-reviewed articles retrieved from the SCOPUS database, published between 2021 and 2025. The analysis explores publication trends, methodological orientations, theoretical frameworks, and thematic emphasis to uncover how the academic field is currently engaging with open and collaborative innovation in SMEs.

4.1 Publication Trends Over Time

Table 2 presents the number of publications (articles) identified using predefined criteria, in the period 2021 – 2025. The dynamics of the publications are presented in Fig. 2. The results are discussed in the following sections.

4.2 Methodological Approaches

Table 3 summarizes the study types with calculations of relevant indicators that will be debated later.

Quantitative work often operationalize open innovation and collaboration as measurable constructs (usually through surveys and SEM/PLS - SEM or regression/econometric designs). In this sense, open innovation is often modeled as a antecedent (or mediator) of

innovation and performance results, and studies focus on estimating effect sizes and boundary conditions (boundary conditions).

The expression of open innovation is usually expressed as:

(i) the degree of openness,

(ii) the practice of OI or

(iii) the breadth/depth of external search.

For example, the determinants of the degree of openness in European SMEs are related to the objectives of innovation, internal R&D and investment in the acquisition/licensing of external knowledge (Priyadarshini et al., 2024).

Table 2. Publications overtime

Methodology	**2021**	**2022**	**2023**	**2024**	**2025**	**Total**	**% of papers**
Quantitative empirical	17	18	22	24	22	103	59.2
Qualitative empirical	8	14	11	9	5	47	27.0
Mixed methods	5	3	2	1	1	12	6.9
Review / bibliometric	1	2	1	3	2	9	5.2
Conceptual / theoretical	0	0	1	0	2	3	1.7
Total	**31**	**37**	**37**	**37**	**32**	**174**	**100.0**

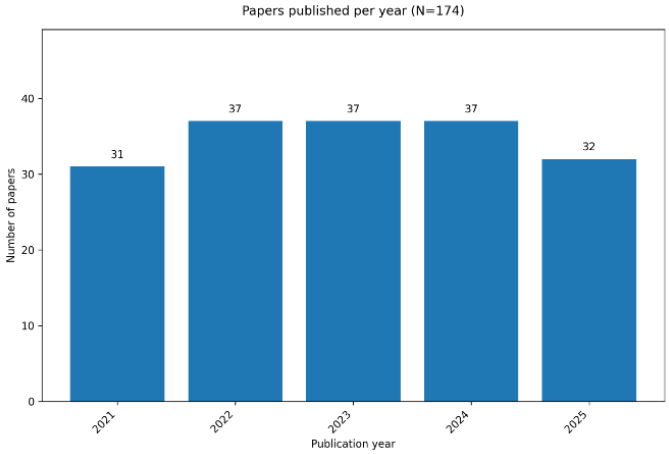

Fig. 2. Publications over years (2021-2025).

Table 3. Study types

Study type	**Papers (n, % of total)**	**Open innovation (OI)**	**Collaborative innovation (CI)**	**SMEs & innovation**	**OI+CI+SME**
Quantitative empirical	103 (59.2%)	94 (91.3%)	37 (35.9%)	103 (100%)	28 (27.2%)
Qualitative empirical	47 (27.0%)	42 (89.4%)	25 (53.2%)	46 (97.9%)	20 (42.6%)
Mixed methods	12 (6.9%)	11 (91.7%)	1 (8.3%)	12 (100%)	0 (0.0%)
Review / bibliometric	9 (5.2%)	8 (88.9%)	4 (44.4%)	9 (100%)	3 (33.3%)
Conceptual / theoretical	3 (1.7%)	2 (66.7%)	1 (33.3%)	3 (100%)	0 (0.0%)
Total	**174 (100%)**	**157 (90.2%)**	**68 (39.1%)**	**173 (99.4%)**	**51 (29.3%)**

Other works relate OI to outcomes associated with dynamic capabilities, such as eco-innovation and performance (Valdez-Juárez & Castillo-Vergara, 2021) or service innovation and sustainable competitive advantage (Wang et al., 2025). Studies focused on digitization also examine how the characteristics of Big Data affect the bredth and depth of OI (Ferrigno et al., 2025).

In quantitative designs, collaboration is often depicted as a collaborative intensity/strategy, inter-organizational collaboration or relational mechanism based on trust. Large sample studies assess how collaboration strategies affect the innovation performance of SMEs (Audretsch et al., 2023) and how collaboration/trust mechanisms influence performance in cross-border contexts (Kankam & Dza, 2025). Some models explicitly associate the sharing of knowledge with innovation performance as an OI mediator (Zan et al., 2024).

In SMEs, many innovations are treated as performance variables (e.g. innovation performance, environmental innovation, or sustainability-oriented results) and OI/CI is explained by revenue and organizational capabilities. Implementation strategy studies examine how OI practices contribute to the development of ambidextrous innovation in SMEs (Srisathan et al., 2023a). Quantitative studies of failure in OI indicate that resource constraints and limitations in management processes are key factors explaining why initiatives frequently fail in SMEs, highlighting differences from the challenges encountered by larger organizations (Almeida, 2024).

Quantitative works often operationalize open innovation and collaboration as measurable constructions (usually through surveys and SEM/PLS - SEM or regression/econometric designs). In this sense, open

innovation is often modeled as a precedent (or mediator) of innovation and performance results, and studies focus on estimating effect sizes and boundary conditions (boundary conditions).

Qualitative works usually represent open and collaborative innovation as processes and practices (and not as static variables), emphasizing decision-making, routines, partner selection and boundary conditions. They are particularly powerful to highlight mechanisms that are difficult to capture by simple survey designs.

The expression of open innovation is often viewed as a practice associated with modes (inbound/outbound/coupled) and through obstacles encountered by SMEs in establishing openness. A view based on obstacles shows that the intensity and type of obstacles vary according to OI modes and highlights internal restrictions and frictions of partner fitness (Dubouloz et al., 2021). Processional lenses such as "open innovation movements" decompose OI into groups of specific partners to strike a balance between opportunity and risk (Livieratos et al., 2022).

Collaboration is represented in concrete interactions (e.g. development, partnerships and multi-actor projects) and through relational governance/rules that enable value creation. Longitudinal and multi-actor contexts (e.g. university – industrial – government projects) raise coordination and institutional challenges for traditional SMEs (Bertello et al., 2022). The relational rules which shape the development of the exporter/importer product are studied through multi-case designs based on interviews (Kantaruk Pierre et al., 2024).

Innovation in SMEs is usually explained as an adaptation route under resource constraints; openness/collaboration is used to acquire complementary capacities. Case studies in Industry 4.0 highlight how SMEs manage dependencies and collaboration among stakeholders to enable innovation in digital transformation (Khan et al., 2022).

Mixed method designs combine measuring components (e.g., surveys, modelling, social media analysis) and qualitative evidence (e.g., interviews, thematic analysis) to triangulate the functioning of openness and collaboration in SMEs. The expression of open innovation is often regarded as a multidimensional phenomenon; quantitative models identify the pattern, and qualitative elements explain the underlying logic of decision. For example, cognitive configurations associated with the adoption of open innovation are studied with the combination of PLS - SEM and configuration analysis (Marzi et al., 2023). In high-risk sectors, mixed methods emphasize the tension between open innovation for SMEs and value capture (appropriability/value capture) (Barrett et al., 2025).

Mixed methods are often used to link the structure and meaning of collaboration: analysis of social networks quantifies network position (e.g. centrality), and interviews explain how structure influences openness and innovation results (Woods et al., 2022). Living - lab contexts are also explored through sequential mixed designs to understand how SMEs collaborate with multiple actors in experimental environments (Alexandrakis et al., 2022). Innovation results in SMEs are considered multidimensional (performance + process) and mixed methods are used to explain heterogeneity: similar results can be obtained from different combinations of OI practices, collaborative routines and internal capacities (Marzi et al., 2023; Woods et al., 2022).

Revisions and bibliometrics studies represent open and collaborative innovation as an evolutionary course of research, with priority given to conceptual unification, thematic map and identification of gaps. Bibliometric maps and systematic synthesis illustrate how open innovation research in SMEs has spread, which subjects are predominant, and which are less studied (Sabando-Vera et al., 2022; Ragazou et al., 2022).

The reviews also analyze the role of management and leadership factors in OI adoption and propose structured future research agendas (Akjou & Idrissi Fakhreddine, 2024). Many collaborative innovations are treated as part of broader ecosystems and network logic; revisions place collaborative innovation as one of the main research topics for SMEs along with internationalization (Audretsch & Guenther, 2023).

Bibliometric studies identify clusters associated with collaboration (e.g., integration of external knowledge, ambivalence, agility) that link OI and collaboration in SMEs (Ragazou et al., 2022). Innovation studies emphasize the specific limitations of SMEs, policy/management implications and how innovation management in MSMEs has been addressed in the most prominent literature (Carvalho et al., 2021). They also link innovation to current transformations, such as digital transformation and knowledge management in SMEs (Hafeez et al., 2025) and map the trajectories of ambivalent innovation (Chigori et al., 2024).

Conceptual and theoretical works represent OI and collaboration as formal mechanisms (e.g. incentives, strategic interaction, platform design), usually producing verifiable proposals and not direct empirical estimates. The expression OI is often presented as a problem of mechanism design; the behavior of the participants depends on incentives and the structure of the competition. For example, theoretical modelling examines how the rules of collective presentation in open innovation competitions influence participation and results (Candogan et al., 2025).

Other works theorize incentive structures for companies to adopt emerging technologies that can enable openness (Xin et al., 2025). Collaboration is represented by strategic interaction and the alignment of incentives (e.g., formulations of principal agent and game theory). Celebrity based incentives are modeled to encourage participation and effort in open innovation contexts (Zhang & Li, 2023). SMEs usually appear as contexts in the area where these mechanisms could be applied; theoretical works offer general predictions that must then be empirically validated in SME samples (Candogan et al., 2025; Zhang & Li, 2023).

4.3 Theoretical Foundations

Table 4 presents the theory of family type which will be debated and commented on in the following sections.

OI is the main basis of your data set and is commonly used to formalize intentional knowledge flows across organizational boundaries (inbound /outbound /coupled; width/depth), in accordance with the foundational framework of Chesbrough (Chesbrough, 2003). In the context of SMEs, the articles often treat OI as a strategic response to resource shortages and market turbulence, but also emphasize implementation frictions (capacity gaps, cost burdens, coordination constraints). This can be seen in works dealing with OI in crisis and B2B contexts (Markovic et al., 2021), obstacles and restrictions on traditional SMEs (Bertello et al., 2022), and explicit approaches to "cost/challenge" (Costa et al., 2023).

The most common family theory is Resource-based/knowledge-based approaches, which relate openness and collaboration with value creation and performance through strategic resources, knowledge assets and recombination logic (Hervas-Oliver et al., 2021; Audretsch et al., 2023). In this logic, SMEs collaborate because their partners provide additional assets (knowledge, market access, technology, legitimacy) that SMEs cannot effectively build internally. Next, dynamic capabilities explain how SMEs turn the result into openness: detecting external opportunities, taking advantage of partner opportunities, and reconfiguring routines/processes to absorb and exploit knowledge (Giudice et al., 2021; Valdez-Juárez & Castillo-Vergara, 2021; Priyono & Hidayat, 2022; Lepore et al., 2023). A significant cluster suggests that SMEs are integrated into networks and ecosystems, where the results of collaboration depend on structural position, trust and interdependence. For example, network location and the logic of social networks are used to link centrality/relational structure with openness and innovation results (Woods et al., 2022).

Theories of trust/collaboration are used to explain performance effects through inter-organizational collaboration, especially in supply chain contexts (Kankam & Dza, 2025). Some works explicitly formulate ecosystem logic through the creation of value, often aligned with service/value logic (Carlos et al., 2025). Others combine networking theory with behavioral exchange mechanisms (e.g. Actor - Network Theory + Social Exchange Theory) to explain the dynamics of involvement and collaborative innovation in SMEs (Annamalah et al., 2022).

Behavioral lenses explain why decision makers and organizations choose openness, and how internal attitudes/intentions are transformed into action. The usual pattern is to combine behavioral theory with aptitude or resource logic to link motivation + ability. For example, the Planned Behavior Theory (TPB) appears with RBV in the determinants of the openness of SMEs (Priyadarshini et al., 2024). SOR has been used to model resistance/obstacles and response mechanisms for SMEs in their openness (Ryoba et al., 2025). Social Exchange Theory is used to explain how relational rules, perceptive reciprocity and engagement mechanisms support inbound OI (Cera et al., 2024). The logic of cognitive processing (dual process) goes one step further, describing how cognitive configurations shape strategic choice and openness behavior (Marzi et al., 2023).

A remarkable theoretical signal is the rise of dynamic and process-based explanations of OI and collaboration: how SMEs sequence openness, how they rebalance exploration/exploitation, and how they routinize collaboration over time. This appears, among others, in the following:

- Supported the idea of open innovation “moves” and attention allocation (Attention-Based View) (Livieratos et al., 2022);
- Debate of the process view linking OI to business model innovation (Albats et al., 2023);
- Study the coordination and participation logic in research consortia via attention/selection mechanisms (Grimpe et al., 2022);
- Large study on ambidexterity to manage tensions between exploration and exploitation in OI strategies as supported by (Srisathan et al., 2023);
- Quasi-causal evidence on the effect of subsidized R&D collaboration on SME outcomes (Kleine et al., 2022).

Another line is that openness/collaboration is shaped by institutions, restrictions on governance and alignment of incentives. Upper Echelons Theory supports the fact that the cognition of managers and the characteristics of the management team can influence the way SMEs seek and collaborate abroad (Messeni Petruzzelli et al., 2022).

Table 4. Theory family type

Theory family	Papers (n)	%	Mean cited-by	Median year
Other / niche theories	8	4.6	14.9	2021
Open innovation models	14	8.0	38.6	2022
Resource-based / knowledge-based views	31	17.8	14.1	2024
Dynamic capabilities	24	13.8	41.0	2024
Institutional and governance / information economics	7	4.0	14.1	2022
Behavioral / psychological theories	32	18.4	19.7	2023
Processual and adaptive theories	6	3.4	30.5	2022
Network / ecosystem perspectives	14	8.0	14.9	2022
Sustainability / CSR frameworks	10	5.7	42.0	2022
Transaction cost economics	6	3.4	33.2	2022
Absorptive / desorptive capacity	8	4.6	32.8	2023

Service-dominant logic	5	2.9	2.6	2024
Not specified	3	1.7	11.3	2024
No explicit theory / method-driven	3	1.7	0.7	2025
Digitalization / data lenses	3	1.7	8.7	2025
Totals	**174**	-	-	-

Institutional theory marks how rules, social norms, and pressures of legitimacy shape the OI and circular innovation pathways (Rahmat et al., 2024). Information economy lenses appear through signaling (how SMEs reliably communicate quality/innovation potential in digital contexts) (Schrank & Kijkasiwat, 2025) and principal agent/justice approaches (how to structure incentive systems for openness and knowledge sharing) (Zhang & Li, 2023).

The transaction cost economy explicitly marks the costs of coordination, contracting and monitoring, which may make it difficult for SMEs to open (Costa et al., 2023); it also applies to emerging digital infrastructures (e.g., distributed ledger to enable/reduce transaction frictions) (Hashimy et al., 2021).

Absorption capacity acts as a bridge mechanism to explain why external knowledge (or not) becomes innovation – appearing in empirical works and in revision-bibliometrics synthesis (Messeni Petruzzelli et al., 2022; Sabando-Vera et al., 2022; Woods et al., 2022). It should be noted that absorption capacity is often accompanied by behavioral lenses, which suggests that literature implicitly treats it as "capacity + willingness". A smaller but growing cluster explicitly pursues sustainability results through OI and collaborative organizations (e.g., OI for sustainability) (Kurniawati et al., 2022); and lenses of dynamic capabilities associate openness with innovation capacity under turbulence and competitive pressures (Valdez-Juárez & Castillo-Vergara, 2021). The logic of service superiority also contributes by redefining collaboration as a value creation and emphasizing the design of platforms/service systems (Osorno-Hinojosa et al., 2023).

4.4 Journal and Disciplinary Landscape

In Table 5 there are presented the journals and the number of published papers within their content. Following there will be a debate on this finding.

Table 5. Number of papers by journal

Journal Title	**Papers (n)**
Journal of Open Innovation: Technology, Market, and Complexity	41
Sustainability	20
Technological Forecasting and Social Change	8
R&D Management	7
Technovation	6
Administrative Sciences	5
Cogent Business and Management	4
Journal of Innovation and Knowledge	4
International Journal of Innovation	3
Journal of Business Research	3
SAGE Open	3
Journal of Small Business and Entrepreneurship	2
Others	68
Total	**174**

4.5 Thematic Clusters and Key Findings

Building on the thematic coding captured in the Excel database (n = 174 screened and coded articles), we identified five dominant thematic clusters that structure recent research on open and collaborative innovation in SMEs. This clustering complements the descriptive evidence reported earlier in this section (e.g., prevalence of quantitative designs and the dominance of open innovation relative to collaborative innovation). The findings could be strengthened by clarifying how the thematic clusters were derived and by presenting the results in a more consolidated way. This would help the reader better understand the analytical logic of the review and the significance of the main patterns identified.

The clusters reflect how the literature currently explains (i) why SMEs open up, (ii) what prevents them from doing so effectively, (iii) how they configure external partnerships, (iv) what outcomes they achieve, and (v) how digital infrastructures shape openness.

Based on the primary thematic clusters, the distribution is as follows:

- Digital infrastructures & data-enabled openness: 42 papers (24.1%);
- Innovation outcomes & performance effects: 42 papers (24.1%);
- Drivers & enablers (capabilities, culture, leadership): 39 papers (22.4%);
- Collaboration strategies & partner configurations: 34 papers (19.5%);
- Barriers, risks & constraints (costs, IP, resistance): 17 papers (9.9%).

4.5.1 Digital infrastructures facilitating openness (n=42; 24.1%)

This cluster captures the acceleration of SME openness through digital transformation, platforms, data analytics, Industry 4.0, and emerging technologies. The empirical literature suggests digital resources expand SMEs' collaboration scope (more potential partners; faster search and coordination), but do not automatically produce deeper collaboration or superior outcomes without complementary capabilities (data governance, skills, routines). This resonates with your paper's observation that digital contexts amplify both opportunities and capability gaps. Key findings synthesized across studies:

- Digital transformation frequently appears as an enabler of broader external search and faster partner coordination.
- Technology adoption introduces second-order challenges: skills gaps, cybersecurity/privacy risks, and integration costs can weaken realized benefits.

- Digital openness often requires "new governance" (data-sharing agreements, platform rules, interoperability) that many SMEs struggle to formalize.

4.5.2 Innovation outcomes and performance effects (n=42; 24.1%)

This is the most outcome-driven cluster, typically linking openness/collaboration to innovation performance, competitive advantage, business model innovation, international performance, and (in a growing subset) sustainability-related outcomes. The dominant empirical pattern is conditionality: openness tends to correlate with positive outcomes, but effect sizes and directions often depend on mediators (knowledge sharing, absorptive capacity) and moderators (environmental turbulence, digital maturity, firm capabilities).

Key findings synthesized across studies:

- Openness is frequently modelled as an antecedent of innovation performance and competitiveness, often through mediating mechanisms such as knowledge recombination.
- Evidence increasingly links collaborative/open practices to broader strategic outcomes (e.g., business model innovation), consistent with your theoretical background.
- Sustainability outcomes are present but still less consolidated conceptually (more "applied" than theory-integrated in many papers).

4.5.3 Drivers and enablers of open and collaborative innovation in SMEs (n=39; 22.4%)

This cluster explains openness as an enabled strategic behavior grounded in resources, capabilities, leadership and organizational context. A dominant finding is that SMEs rarely benefit from openness "by default"; rather, performance effects depend on internal readiness, typically operationalized through absorptive capacity, learning orientation, dynamic capabilities, managerial cognition, and innovation culture. This stream also repeatedly shows that "openness" is heterogeneous: SMEs differ in depth vs breadth of external search and in how they mobilize relational assets (e.g., social/relational capital) to access external knowledge.

Key findings synthesized across studies:

- Capability-based enablers (absorptive capacity; dynamic capabilities) are recurrent mechanisms translating external knowledge into innovation outputs.
- Managerial and behavioral factors (orientation, cognition, leadership) condition whether openness becomes systematic practice or remains opportunistic.
- Complementary internal practices (knowledge management routines; agility/ambidexterity) strengthen the conversion of external collaboration into results.

4.5.4 Collaboration strategies and partner configurations (n=34; 19.5%)

This cluster focuses on with whom SMEs collaborate and how they govern inter-organizational relationships. Literature increasingly treats SMEs as ecosystem participants rather than isolated innovators, documenting collaboration with customers, universities, suppliers, intermediaries, clusters, and multi-actor consortia. Importantly, findings converge on the idea that partner choice is strategic and contingent: SMEs vary their configurations depending on uncertainty, resource gaps, and value capture strategy.

Key findings synthesized across studies:

- Collaboration is multi-modal (dyadic partnerships, supply-chain collaboration, ecosystem platforms, triple-helix and consortium projects), and outcomes depend on governance fit and partner complementarity.
- Intermediaries such as clusters, innovation agencies, living labs, often reduce transaction/coordination costs and help SMEs access specialized knowledge.
- Trust and relational norms appear as central coordination devices, especially where formal contracting capacity is limited.

4.5.5 Barriers, risks, and constraints (n=17; 9.9%)

Although smaller in volume, this cluster provides the clearest articulation of why openness fails in SMEs. Barriers are rarely purely external; studies emphasize internal resource scarcity, coordination burdens, and organizational/behavioral resistance, frequently framed as cognitive overload, limited governance capacity, and difficulties in appropriability/value capture. This aligns with the broader conclusion in your paper that SME openness is neither binary nor frictionless and that implementation tensions are central.

Key findings synthesized across studies:

- SMEs face disproportionate "costs of openness" (search, contracting, coordination, monitoring), which reduces sustained engagement in partnerships.
- Appropriability concerns and weak IP/governance capabilities can shift firms toward cautious, shallow collaboration rather than deep co-development.
- Cognitive and organizational resistance (including overload and change fatigue) emerges as a practical limiting factor in adopting OI routines.

4.6 Research Gaps and Opportunities

The "Future Research Lines" field in the coded database shows a consistent pattern: authors repeatedly call for more context-sensitive, process-aware, and causally robust research designs, alongside theoretical integration. This aligns with your paper's claim that the field remains fragmented and lacks integrative SME-specific models.

4.6.1 Most frequently signaled gaps

Across the 174 coded articles, the most common gap categories are:

1. Longitudinal and temporal dynamics (flagged in 72 papers). Need to explain how openness evolves (sequencing, learning curves, path dependence), rather than treating OI/CI as static "levels".

2. Cross-country, cultural, and context comparisons (flagged in 64 papers)
3. Calls to test boundary conditions across regions, institutional environments, and stages of ecosystem maturity.
4. Sector- and technology-specific evidence (flagged into 54 papers). Strong demand for studies in specific sectors (including high-tech and regulated domains) and for technology-centered openness (platforms, Industry 4.0).
5. Measurement refinement and construct clarity (flagged in 23 papers). Repeated requests for improved operationalization of openness, collaboration quality, and collaboration outcomes.
6. Causal inference and stronger identification strategies (flagged in 10 papers). Need for quasi-experimental designs, field experiments, panel approaches, and better handling of endogeneity.
7. Governance/IP/appropriability and trust safeguards (flagged in 8 papers). Particularly salient as SMEs scale openness into deeper co-development arrangements.
8. Network/ecosystem methods and multi-level designs (flagged in 7 papers). More work is needed linking micro-level managerial decisions to ecosystem structure and institutional support.
9. Sustainability/circularity integration (flagged in 9 papers). Calls to move beyond "sustainability as outcome" into sustainability as a design principle shaping collaboration governance and value capture.

4.6.2 Opportunity areas for a consolidated research agenda

The main areas discovered are:

1. Synthesizing these gaps, future research opportunities cluster around four agenda priorities:
2. Toward integrative SME-specific frameworks: unify capability-based lenses (RBV/dynamic capabilities) with behavioral micro-foundations and governance/appropriability mechanisms into a single explanatory architecture.
3. Processual models of openness: shift emphasis from "whether openness matters" to "when, how, and in what sequence openness creates value" (including partner switching, learning, and routinization).
4. Digital openness with governance: examine data-sharing, platform rules, cybersecurity/privacy, and interoperability as conditions for realizing digital collaboration benefits.
5. Ecosystem/policy alignment: study the effectiveness of intermediaries, cluster programs, and public instruments in reducing collaboration costs and enabling high-quality partnerships.

V. DISCUSSION

5.1 Theoretical Contributions and Conceptual Tensions

This review consolidates a rapidly growing but conceptually fragmented literature. Descriptively, the dataset is dominated by quantitative empirical studies (59.2%), and conceptually the theoretical landscape spans multiple families, with strong representation of capability-based and behavioral lenses.

A first theoretical contribution of this review lies in reframing SME openness not as an intrinsic "best practice", but as a capability-conditioned strategic choice. The evidence consistently shows repeated complementarities between (i) internal readiness (capabilities, culture, leadership), (ii) external configuration (partner choice, governance), and (iii) realized outcomes (innovation/performance). A second contribution is highlighting a set of persistent conceptual tensions that explain mixed empirical findings:

- Openness vs. appropriability: deeper collaboration increases learning potential but heightens leakage and governance burdens – especially for resource-constrained SMEs.
- Breadth vs. depth: digital tools can expand breadth (more partners), but depth requires managerial attention, routines, and governance capacity.
- Value creation vs. coordination costs: SMEs often face higher marginal coordination/transaction costs than large firms, which can invert expected benefits.
- OI dominance vs. CI under-integration: open innovation is substantially more prevalent than explicit collaborative innovation framing (OI appears in most papers, while CI is present in a smaller subset), suggesting a need to better integrate co-creation and governance perspectives.

Overall, the review supports an integrative view: SME innovation benefits from openness when capability readiness and governance design jointly enable knowledge absorption and value capture.

5.2 Strategic and Managerial Implications for SMEs

The synthesis yields actionable implications for SME owners and managers aiming to translate openness into performance:

1. Treat openness as a managed capability, not an ad-hoc activity. Invest in absorptive capacity (skills, routines, knowledge management) and define internal roles for partner management.
2. Adopt a portfolio logic for partners. Combine quick-win collaborations (customers/suppliers) with longer-horizon ties (universities, intermediaries) to balance exploration and exploitation.
3. Design governance proportional to collaboration depth. Use lightweight agreements for shallow search collaborations, but formalize IP, data sharing, and decision rights for co-development.

4. Use digital tools to reduce search/coordination costs – then build the routines to exploit them. Digital platforms and analytics can expand opportunity sets; realization value depends on internal processes and integration capacity.

5.3 Policy and Ecosystem Considerations

The results imply that policy should not only subsidize R&D but also reduce the transaction and coordination costs of collaboration for SMEs. Priorities include the following aspects.

Intermediaries and brokers: strengthen clusters, living labs, and innovation agencies that match SMEs with credible partners and support contracting/governance. Digital public infrastructure: support interoperability, cybersecurity readiness, and accessible digital training so SMEs can collaborate safely and efficiently. Furthermore, targeted programs for capability building: complement funding with managerial and absorptive-capacity support (partnering skills, IP/data governance). Also, ecosystem-level evaluation: measure not only project outputs but ecosystem learning and repeated collaboration effects over time.

5.4 Methodological Reflection and Research Gaps

Methodologically, the evidence base is skewed toward cross-sectional quantitative designs, with frequent reliance on PLS-SEM, to model linear relationships between openness and performance. However, the thematic synthesis suggests that the relationship between openness and innovation outcomes is rarely direct. Instead, it is mediated and moderated by organizational and environmental conditions. For this reason, the inclusion of the subsections below is theoretically and empirically justified.

5.4.1 Mediators

Across quantitative studies, open and collaborative innovation rarely exert direct performance effects. Instead, the impact is transmitted through intermediate mechanisms. The most recurrent mediators identified in the dataset include:

- Absorptive capacity (knowledge acquisition, assimilation, transformation, exploitation).
- Knowledge sharing and recombination.
- Dynamic capabilities (sensing, seizing, reconfiguring).
- Business model innovation.
- Innovation ambidexterity.

These mediating mechanisms clarify that openness increases access to knowledge, but performance emerges only when firms successfully internalize and reconfigure that knowledge. This mediating logic aligns strongly with capability-based theories and helps reconcile mixed findings in the literature. Studies that fail to account for mediating processes often report weak or inconsistent direct effects.

5.4.2 Moderators

The literature also demonstrates significant boundary conditions that alter the strength or direction of openness–performance relationships. The most recurrent moderators include:

1. Firm-level moderators:
   - Firm size within SME category.
   - Digital maturity.
   - R&D intensity.
   - Managerial orientation and cognition.
   - Governance sophistication.
2. Environmental moderators:
   - Environmental turbulence.
   - Institutional quality.
   - Ecosystem maturity.
   - Competitive intensity.
   - Industry technological dynamism.

These moderators explain why similar openness practices produce heterogeneous outcomes across contexts. The evidence suggests that openness pays off most strongly when:

- Environmental turbulence is high (increasing value of external knowledge).
- Digital infrastructure supports coordination-
- SMEs possess sufficient absorptive capacity to manage complexity.

This reinforces the argument that openness is contingent, not universally beneficial.

5.4.3 Toward an Integrative Research Framework

Synthesizing these insights, the field would benefit from an integrative SME-specific framework structured around:

1. Antecedents (drivers & readiness) – Capabilities, leadership, culture, digital maturity
2. Collaboration configuration – Partner portfolio, governance design, ecosystem positioning
3. Mediating mechanisms – Absorptive capacity, knowledge recombination, business model innovation
4. Moderating conditions – Environmental turbulence, institutional context, firm-level capabilities
5. Outcomes – Innovation performance, competitive advantage, sustainability outcomes

Such a framework would reduce fragmentation and support cumulative theory building.

5.5 Toward a Consolidated Research Agenda

Future research should prioritize:

- Longitudinal and panel designs.
- Multi-level ecosystem approaches.
- Stronger causal identification strategies.
- Governance and appropriability modeling.
- Integration of sustainability as structural design principle rather than outcome variable.
- Comparative cross-country SME ecosystem studies.

This agenda moves the field from descriptive expansion toward explanatory consolidation.

The discussion could be developed further by linking the findings more explicitly to the research questions and by highlighting the main conceptual tensions

emerging from literature, such as the balance between openness and control, collaboration and coordination costs, or capability constraints and innovation outcomes in SMEs.

VI. CONCLUSIONS AND FINAL REMARKS

This systematic review synthesizes 174 open-access journal articles (2021–2025) retrieved from SCOPUS, mapping a fast-growing literature at the intersection of SME innovation and openness. It contributes by:

- Providing an integrated thematic map of the field across five dominant clusters (drivers/enablers; barriers/risks; collaboration strategies; outcomes; digital infrastructures).
- Consolidating what is known about the conditions under which openness pays off for SMEs, emphasizing capability readiness and governance design.
- Surfacing a structured research agenda that prioritizes temporal/process perspectives, stronger causal designs, and ecosystem/policy alignment.

The presented review has limitations consistent with its protocol: it is restricted to SCOPUS-indexed open-access journal articles, English language, and a 2021–2025 window, which may omit relevant work published in other outlets, languages, databases, and paywalled venues.

In addition, thematic synthesis relies on coded interpretations (even with structured extraction), and heterogeneity in how studies operationalize openness and collaboration constrain direct comparability.

Future research should therefore:

- Expand coverage across databases and access types, and test whether the identified thematic structure holds across broader corpora.
- Develop integrative SME-specific frameworks that jointly model capabilities, governance/appropriability, and ecosystem conditions.
- Study how openness evolves over time (sequencing, routinization, partner switching) using longitudinal and comparative designs.
- Advance digital openness governance (data-sharing, platform rules, cybersecurity) as a core explanatory layer.
- Deepen evidence on sustainability-oriented openness and on under-studied contexts (industries, regions, highly regulated sectors).

Overall, the review shows that open and collaborative innovation in SMEs should not be understood as universally beneficial practices, but rather as context-dependent processes shaped by internal capabilities, governance arrangements, and external ecosystem conditions.

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