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A Systematic Review of the Viable System Model: Applications, Insights, and Future Directions

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ABSTRACT

The Viable System Model (VSM) is a foundational framework in organizational cybernetics, designed to manage complexity and ensure systemic viability in dynamic environments. Given the increasing importance of this model in addressing complex organizational challenges, the primary objective of this research is to conduct a comprehensive and systematic review of existing studies in the field of the Viable System Model. This review aims to identify and analyze the practical areas of this model, evaluate its challenges and opportunities in confronting contemporary systemic issues, and extract key insights from 21 peer-reviewed studies. By synthesizing and analyzing the findings of these studies, this paper intends to provide a clear and coherent picture of the Viable System Model's current state and future potential. The process of identifying relevant studies was conducted using the PRISMA method, which involved searching the Scopus database and performing manual searches. This study employs a bibliometric research design, utilizing a quantitative approach and combining bibliometric and network analysis to examine the landscape of VSM research. Key findings highlight VSM's role in enhancing organizational resilience, improving decentralized decision-making, and enabling systemic adaptability. The integration of VSM with emerging technologies—such as artificial intelligence, digital twins, and big data analytics—demonstrates its potential to address contemporary organizational challenges. However, critical gaps remain, including limited empirical validation, insufficient applications in underrepresented sectors such as agriculture and education, and scalability issues for small and medium-sized enterprises (SMEs). The study emphasizes the need for longitudinal research, hybrid frameworks, and sector-specific models to enhance the theoretical and practical utility of VSM. By synthesizing recent applications and identifying research opportunities, this paper reinforces the significance of VSM as a robust approach to managing complexity and outlines pathways for future research.

Keywords

Viable System Model, Systematic Review, Organizational Cybernetics, Complexity Management.

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1. Introduction

The Viable System Model (VSM), developed by Stafford Beer (1972, 1979, 1985), provides a cybernetic framework for understanding and managing organizational complexity. It also offers a theoretical and practical basis for analyzing and managing organizations as complex, self-regulating systems. Beer views organizations as "viable systems" capable of self-organization, self-regulation, and adaptation to changing environments. In this context, he developed the VSM based on a five-level model (System 1 to System 5), where each level (system) plays a distinct role in operational control, coordination, monitoring, strategy, and policy-making. Beer introduced the theoretical foundation of the VSM based on his tripartite approach—Company Brain (1972), Company Heart (1979), and System Diagnosis for Organizations (1985). Beer's work is inspired by cybernetics, particularly Ashby's law of requisite variety (1956), which emphasizes the need for internal complexity within a system to match the complexity of its external environment for survival. Beer's work emphasizes that viable systems, like living organisms, must achieve a balance between autonomy and control while continuously adapting to their environment. This adaptability relies on recursive structures, where each subsystem replicates the overall system's functionality at a smaller scale.

As mentioned, VSM at its core identifies five interconnected subsystems that are essential for ensuring viability (Beer, 1972). System 1 is responsible for the operational units that handle primary activities. System 2 ensures coordination among operational units. On the other hand, System 3 focuses on internal management, overseeing operations, and optimizing resources. Systems 4 and 5 are respectively focused on strategic functions related to environmental analysis, future planning, policy-making, and governance, thereby maintaining the organization's identity and overall coherence. These subsystems interact with each other through continuous feedback loops, enabling organizations to identify and address internal inefficiencies while responding to external pressures (Figure 1).

After Beer, several other scholars have expanded and interpreted the principles of the VSM. For example, Espejo and Harnden (1989) compiled a foundational collection titled "The Viable System Model: Interpretations and Applications," which included case studies and theoretical extensions, and published it as a book. In their work, Spath and Harnden emphasized the adaptability of the VSM to corporate and social systems. Schwaninger (2006) highlighted the diagnostic power of the VSM, describing it as a tool for achieving organizational viability through effective management of complexity. Hoverstadt (2008), in his book "The Fractal Organization," after explaining the concept of fractal systems, suggested that the principles of

the VSM be applied at different levels (micro, meso, and macro) within an organization to address complexities.

On the other hand, Espinosa and Walker (2011) incorporated sustainability concerns into the VSM and expanded its application to address complex ecological and social systems. Jackson (2003), focusing on the role of the VSM as part of broader systems methodologies, emphasized its importance in modern management challenges. The overall conclusion drawn from these studies is that the VSM aligns with the capability for systemic thinking, where organizational elements are viewed as interconnected and dynamic. However, some scholars and researchers held differing opinions regarding the VSM and presented their perspectives within a framework of criticism of the model. For example, Flood and Jackson (1991) noted that although the VSM provides a robust conceptual framework, its implementation can be challenging, particularly in organizations with low systems literacy. From their perspective, the VSM may oversimplify some of the organization's cultural and social dynamics. Checkland (1981) suggested that the abstraction of the VSM makes it difficult for practitioners to translate its principles into practical strategies without significant expertise. Despite the weaknesses noted by some authors, the application of the VSM has been important, and its use has expanded across various fields. Notable applications of the VSM in various areas of an organization include diagnosing organizational issues, streamlining operations, and managing complexity, such as organizational design and restructuring. In this context, Leonard (200٩) demonstrated the VSM's ability to identify inefficiencies in organizational structures and enhance coherence between operational and strategic levels. The public sector and governance represent another critical area for using the VSM model. According to Espinosa et al. (2007), who applied the principles of the VSM to public sector organizations, they argued that this model provides a strong framework for improving decision-making and aligning policies in large and complex institutions. Another application of the VSM is its role in knowledge management. One of the key studies in this area is by Hildreth and Kimble (2004), who used the VSM to analyze knowledge networks and communities of practice. These two researchers also emphasized the VSM's ability to enhance innovation and knowledge flow. Sustainability and complexity management can be introduced as one of the new areas that highlight the significance of the VSM application. For a deeper understanding, one can refer to the study by Espinosa et al. (2007). These authors expanded the VSM to address sustainability challenges by managing environmental and organizational complexity. Beer himself implemented the VSM in various

industries, particularly in the "Cybersyn" project in Chile during the 1970s, which aimed to create a real-time cybernetic control system for managing the national economy.

The increasing speed of globalization, technological advancements, and interconnected systems have brought an unprecedented level of complexity to organizations worldwide. As modern challenges such as globalization, digital transformation, and sustainability rise, there has been a renewed interest in the VSM, highlighting the growing need for robust and systemic approaches to maintain organizational efficiency and flexibility. As Hoverstadt (2008) argued, organizations must adopt the principles of the VSM to sustain agility and adaptability in more complex environments. Espinosa and Walker (2011) examined the impact of using the VSM to address systemic issues in areas such as environmental sustainability and large-scale governance, introducing it as a tool for tackling global complexity. Furthermore, the VSM has also been applied in digital transformation, helping organizations align their operational processes with strategic goals in dynamic and technology-driven environments. Therefore, this study provides a comprehensive overview of previous research on the VSM by focusing on its applications, implications, and prospects. This paper aims to systematically review the VSM literature, examining its contributions, limitations, and opportunities for future research. By synthesizing evidence from diverse domains, the review seeks to answer the following questions:

QR1: In what domains has the Viable System Model been applied?

QR2: What insights have emerged from these applications?

QR3: What challenges and opportunities exist for the VSM in addressing contemporary systemic issues?

2. Materials and methods

2.1. Research design

This study adopts a systematic review approach, adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The PRISMA flow diagram plays a crucial role in ensuring the transparency, rigor, and replicability of systematic reviews. By visually summarizing each phase of the study selection process, the flow diagram allows readers to assess the methodology and validate the comprehensiveness of the evaluation. It aligns with internationally recognized standards for systematic reviews, such as those established by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. The inclusion of the PRISMA diagram ensures that the study selection process adheres to systematic review standards, fostering greater confidence in the validity and reproducibility of the findings

(Moher et al., 2009). Therefore, this study evaluates the existing literature using a PRISMA-based structured methodology to highlight the enduring significance of VSM, identify research gaps, and propose future opportunities to advance the application of the model in a complex and digital world. This diagram includes four stages: identification, screening, eligibility, and inclusion (Tugwell and Tovey, 2021).

- *Identification:* This phase includes locating records through database searches (e.g., Scopus) and manual reference checks, ensuring comprehensive coverage of relevant literature.
- *Screening:* During this phase, duplicate records are removed, and the remaining studies undergo a title and abstract review to exclude irrelevant publications.
- *Eligibility:* Full-text articles that pass the screening phase are assessed against the predefined inclusion and exclusion criteria to determine their suitability for inclusion.
- *Inclusion:* This final stage identifies the studies that meet all criteria and are included in the qualitative synthesis.

By breaking down the study selection process into these stages, the PRISMA diagram enhances transparency, clarity, and replicability, ensuring that the review aligns with internationally recognized standards for systematic reviews (Figure 2). The Scopus database was the primary data source due to its comprehensive coverage of high-impact journals. It was supplemented by manual reference checks to capture seminal studies that might not be indexed within the primary database, ensuring completeness and credibility. A standardized data extraction framework was used to enhance methodological reliability, categorizing information into application domains, methodologies, key findings, limitations, and future research directions. To maintain reliability, a double-screening process was implemented to validate article selection, and researchers performed inter-coder reliability checks to minimize subjective bias. Validity was reinforced by including only peer-reviewed studies. Since this study is based entirely on secondary data, ethical concerns were minimal. Yet, academic integrity was upheld by ensuring proper citation of sources, methodological transparency, and the avoidance of selective reporting.

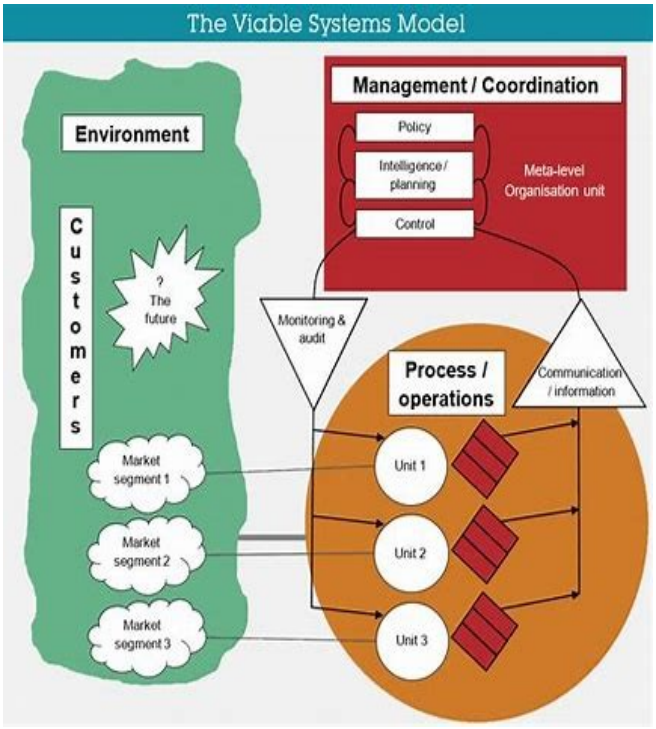

Figure 1. Structure and components of the VSM model (Beer, 1972)

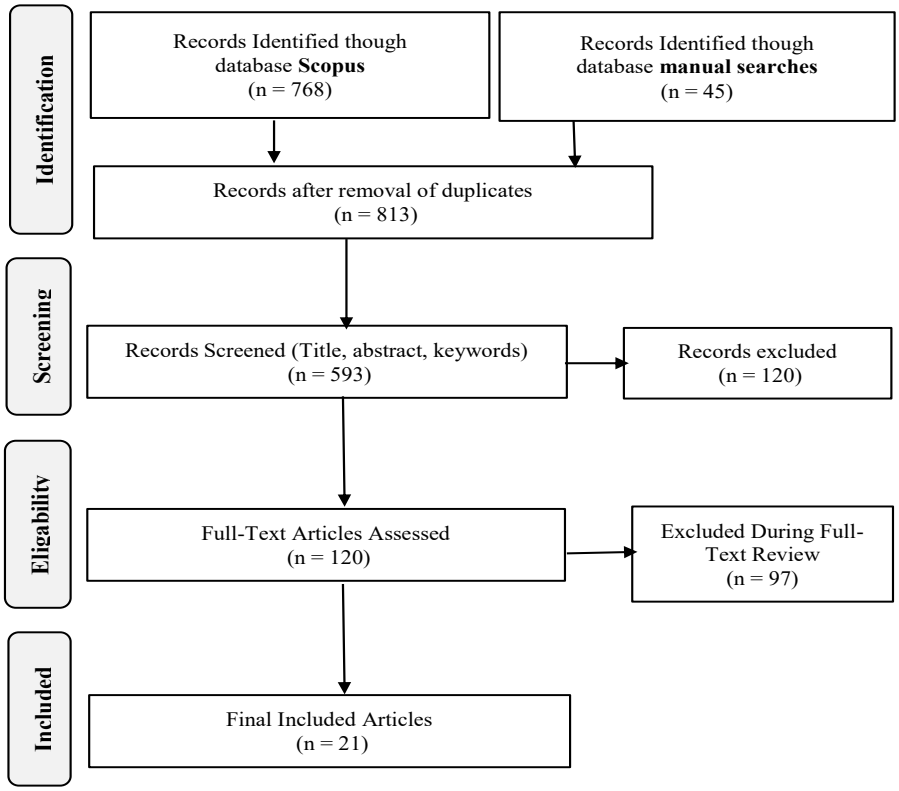

Figure 2. Process of selecting and screening articles

This study employs a bibliometric research design, utilizing a quantitative approach and combining bibliometric and network analysis to examine the landscape of VSM research. This methodology integrates descriptive bibliometric analysis, co-occurrence keyword analysis, and network clustering, ensuring a systematic and data-driven approach to identifying research trends, influential authors, and conceptual structures. In this regard, a purposive sampling technique was used, and relevant studies were selected from the Scopus database, complemented by a manual review of sources to ensure comprehensive coverage of key contributions. The dataset comprises 768 documents from 378 sources, encompassing a diverse and interdisciplinary research area. Data collection tools included the R Bibliometrix package for bibliometric analysis, which generated co-occurrence networks and thematic maps. The PRISMA framework structured the identification, screening, eligibility, and inclusion of studies, ensuring transparency and reproducibility. Standard data cleaning and preprocessing techniques were applied to guarantee reliability and validity, and duplicate cases and irrelevant publications were removed. Reliability checks among coders were conducted to classify and interpret keyword clusters, thereby minimizing bias and ensuring accuracy. Using Bradford's law and co-occurrence analysis further validated the robustness of the methodology. Ethically, this study is based entirely on secondary data, eliminating concerns about human participants, privacy, and consent. Scientific integrity was maintained through proper citation, transparent reporting, and adherence to bibliometric standards.

2.2. Search strategy

A comprehensive literature search was conducted using the Scopus database, supplemented by manual reference checks to identify additional relevant studies. The search query was designed to encompass the broad applications of VSM:

("Viable System Model" OR ("cybernetics" AND ("systemic approach" OR "organizational theory" OR "organizational management"))).

The inclusion of manual searches was deemed essential to ensure comprehensive coverage, as certain relevant studies may not be indexed in Scopus or could be missed due to variations in indexing terms. Manual searches also provided an opportunity to identify references from key articles, ensuring no significant contributions were overlooked. Additionally, to ensure effective communication and quality, the entry and exit criteria were applied as outlined in Table 1.

2.3. Data extraction and synthesis

A systematic and detailed data extraction process was applied to the 21 selected studies. A standardized extraction form was used to ensure consistency and completeness of the extracted information. The categories documented for each article, as shown in Figure 3, include: authors and year, application area, research focus, methodology, key findings, gaps and challenges, and future research directions.

The extracted data were synthesized using thematic analysis, which involved identifying patterns and grouping insights under relevant themes such as applications, challenges, and emerging opportunities.

Table 1. Entry and exit criteria in the context of searching for relevant scientific resources on vsm

Inclusion Criteria	• Studies that focus on the theoretical or practical applications of the Viable System Model (VSM). • Articles published in peer-reviewed journals. • Studies addressing organizational complexity, systemic approaches, or management challenges. • Articles published in English.
Exclusion Criteria	• Non-peer-reviewed articles, including editorials, book reviews, and opinion pieces. • Papers lacking empirical evidence or practical applications. • Duplicate studies were identified across sources. • Studies unrelated to VSM or its core principles.

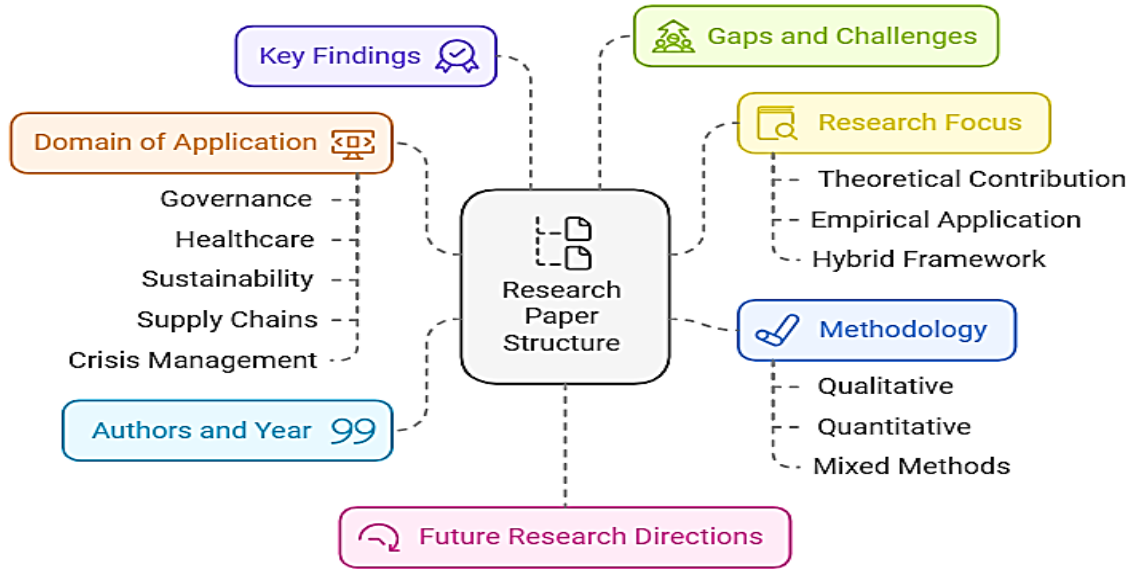

Figure 3. Selected categories for each article

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3. Results

The research results are presented in a structured format, utilizing tables, diagrams, and images to ensure clarity and comprehensibility. All visuals are clear and easy to interpret, and they include appropriate axes labels, captions, and references to the text. As mentioned in the previous section, a total of 21 articles were selected for a systematic review of the literature on VSM. Reviewing these studies indicates that the application areas of the VSM model are extensive. However, the six main areas of application for this model are governance, healthcare resilience, sustainability, supply chain optimization, crisis management, and technology integration (Table 2).

Chan (2011) explores organizational resilience in a small Hong Kong garment company by integrating the Viable System Model and Multi-Criteria Decision Analysis (MCDA) as a systematic decision-support tool. VSM diagnoses cybernetic weaknesses by assessing key organizational subsystems—operations, coordination, control, auditing, intelligence, and policy—identifying critical gaps in autonomy-control balance, internal coordination, and lack of auditing mechanisms. To address these vulnerabilities, MCDA, using the Superiority and Inferiority Ranking (SIR) method, is applied to evaluate four alternative structural arrangements based on corporate credibility and autonomy-control trade-offs. The findings indicate that outsourcing non-core functions such as quality control, shipping, and production enhances resilience by improving financial stability and stakeholder trust, despite leading to lower profit margins. A post-implementation evaluation over 15 months reveals increased adaptability, expanded product lines, and sustained client relationships. It confirms that the VSM-MCDA integration is a robust, data-driven framework to guide SMEs in strategic decision-making, organizational restructuring, and resilience-building in volatile business environments.

The study by Spyridopoulos et al. (2014) proposes a holistic cyber assurance framework for protecting critical infrastructure by integrating the VSM into cybersecurity risk assessments for Industrial Control Systems (ICSs), specifically Supervisory Control and Data Acquisition (SCADA) systems. Traditional risk management approaches often fail to address the systemic interdependencies, emerging cyber threats, and resilience needs of ICSs, necessitating a shift towards a system-of-systems perspective. The methodology applies VSM's cybernetic principles to model ICSs as hierarchical, self-regulating systems, identifying cyber assets, internal and external interactions, threats, and vulnerabilities through a recursive assessment process. The risk assessment framework categorizes threats affecting system viability, including Denial-of-Service attacks, data corruption, and unauthorized access. It maps them

across VSM's five subsystems: operations, coordination, control, strategic intelligence, and policy. The results demonstrate that VSM enhances cyber risk visibility, enables structured threat modeling, and fosters resilience by addressing technical and organizational cybersecurity gaps. The study concludes that VSM is a powerful diagnostic tool for critical infrastructure cyber assurance, offering a systemic, adaptive, and scalable approach to managing cyber risks across multiple organizational levels.

Espinosa et al. (2015) develop a systemic methodology for supporting strategy implementation in a Latin American multinational by integrating the VSM with a soft OR (Operational Research) approach to address the "implementation gap"—the challenge of aligning organizational structures with strategic goals. The study uses an action research methodology to enhance the "Methodology for Organisational Self-Transformation," incorporating mixed methods, including quantitative surveys, qualitative interviews, and participatory workshops. The VSM framework diagnoses structural weaknesses at different organizational levels, mapping complexity through five systemic functions (operations, coordination, control, intelligence, and policy). Findings reveal critical issues in decentralization, decision-making bottlenecks, and a lack of coordination mechanisms, particularly between corporate headquarters and regional branches. A structured redesign proposal emerges, striking a balance between autonomy and control by establishing collegiate decision-making bodies, innovation units, and decentralized accountability mechanisms. The results demonstrate that VSM enhances organizational learning and decision-making, fostering systemic adaptability, stakeholder engagement, and strategic alignment.

Panagiotakopoulos et al. (2016) examine the integration of sustainability management within organizations by applying the VSM to bridge the gap between adopting sustainability standards and their practical implementation. Focusing on the ISO 26000 Social Responsibility (SR) standard, the research employs a conceptual modeling approach using the hypothetical Widget Co. to illustrate how VSM can map sustainability functions across organizational governance systems. The VSM framework systematically aligns ISO 26000 clauses with the five core subsystems—operations, coordination, control, intelligence, and policy—to identify critical challenges in embedding sustainability into daily operations. The findings demonstrate that VSM clarifies SR responsibilities, enhances dynamic interrelations among governance structures, and facilitates a systemic approach to sustainability integration. The study highlights VSM's potential to serve as a strategic tool for organizational transformation, providing a structured method to align corporate governance, stakeholder engagement, and sustainability initiatives into a cohesive management framework.

Vahidi and Aliahmadi (2019) develop a multi-methodological approach that integrates the VSM with System Dynamics (SD) to enhance complexity management and decision-making within organizations, addressing the limitations of single-method frameworks. Traditional non-systemic management approaches often fail to tackle organizational complexity and adaptability, which requires holistic, dynamic methodologies. The research constructs a dynamic model that fuses VSM's cybernetic structure—focusing on autonomy, control, coordination, and viability—with SD's feedback loops, stock-flow structures, and simulation capabilities. It enables organizations to visualize systemic interdependencies and simulate the impact of decisions over time. Using a case study in a management consulting firm, the study demonstrates that the proposed model enhances problem-solving efficiency, knowledge management, and resilience to environmental changes. Results indicate that the integration of VSM and SD compensates for the weaknesses of each method individually, providing a structured yet adaptive approach to handling organizational complexity.

Gallego-García et al. (2019) present an integrated capacity management model for an automotive manufacturing plant, leveraging VSM and Digital Twin simulation to enhance decision-making in demand-driven production systems. The research addresses the challenge of matching supply capacity with fluctuating customer demand, proposing a systemic framework that combines cybernetic principles of VSM with real-time digital twin simulations for capacity adjustments. Using a case study approach, the methodology constructs a recursive VSM-based decision-making structure, enabling autonomous capacity adjustments based on real-time demand forecasting, production constraints, and investment decisions. A simulation model replicating different demand scenarios tests the reactivity, flexibility, and economic impact of decision-making strategies. The findings demonstrate that VSM-enabled capacity management reduces decision-making delays, enhances production efficiency, and minimizes financial risks through adaptive planning mechanisms, outperforming traditional static approaches. The research highlights the effectiveness of VSM-Digital Twin integration in creating a resilient, self-regulating production system, advocating for its adoption in high-variability industries to optimize operational responsiveness, cost efficiency, and long-term viability.

Cardoso Castro and Espinosa (2020) explore the integration of Social Network Analysis (SNA) with the VSM as a methodological advancement for diagnosing organizational pathologies, addressing limitations in existing VSM-based diagnostics. The research employs an action research approach within a European eco-community, using VSM to map systemic

functions (operations, coordination, control, intelligence, and policy) and SNA to analyze communication networks through centrality measures, connectivity structures, and information flow patterns. The results identify critical organizational dysfunctions, including weak decision-making hierarchies, fragmented coordination mechanisms, and communication bottlenecks, highlighting the misalignment between formal governance structures and informal influence networks. The study finds that integrating SNA enhances VSM diagnostics by offering a quantitative measure of interaction patterns, enabling the detection of hidden power structures, weak communication channels, and decision-making inefficiencies. The research contributes to organizational cybernetics and complexity management by demonstrating how VSM-SNA integration provides a robust framework for structural analysis, strategic reconfiguration, and resilience building, offering a novel, systemic, data-driven approach to diagnosing and mitigating organizational dysfunctions in complex, self-organizing systems.

Lowe et al. (2020) examine the difficulties of applying the VSM in practice and propose a set of constitutive rules to guide its implementation, ensuring theoretical rigor while allowing for flexibility in adapting to various organizational contexts. Recognizing that VSM's complexity often hinders its accessibility for practitioners, the authors develop a Hierarchical Process Model (HPM) to structure VSM engagements systematically. The research employs a cross-case analysis of three VSM interventions—in the UK Ministry of Defence, an Irish Ecovillage, and a Latin American Corporation—to examine how practitioners adapt VSM in diverse settings while maintaining methodological integrity. Using a performative epistemology, the study identifies key principles for VSM practice, including balancing problem structuring with systemic diagnosis, aligning interventions with organizational needs, and ensuring participatory engagement. Findings demonstrate that VSM remains a robust organizational design and resilience tool, but its application requires structured guidance to maintain conceptual fidelity.

Adham et al. (2020) apply the VSM to diagnose the halal industry in Taiwan, a Muslim-minority country aiming to integrate into the global halal market. Using qualitative research methods, including in-depth interviews with certification agencies, halal business owners, and consumers, as well as observations and online reviews, the study maps Taiwan's halal industry ecosystem onto the VSM framework. Findings indicate that while Taiwan has established multiple halal certification bodies and a supportive trade promotion unit (the Taiwan Halal Center), it lacks a formal halal industry development policy, resulting in the absence of key systemic functions, such as policy formulation, intelligence gathering, and coordination. The study highlights the central role of locally born Muslims and mosques in facilitating halal

certification, while also identifying fragmented governance, limited domestic awareness of the halal market, and inadequate international branding as challenges. Recognition from Malaysian authorities is deemed crucial for Taiwanese halal products to gain global market acceptance.

Pollock and Steen (2021) examine the Total Defence System (TDS) of Norway and the UK in the context of the COVID-19 crisis, using the Viable System Model (VSM) to assess its resilience and effectiveness. TDS is a civil-military cooperation framework designed to enhance national crisis response by integrating government agencies, military forces, health services, and private sector actors. The research employs a comparative case study approach, utilizing policy document analysis, media reports, and crisis response evaluations to assess the viability of TDS across five systemic functions: anticipation and monitoring, leadership and decision-making, collaboration and joint effort, coordination structure, and crisis communication. Findings reveal critical governance pathologies in both countries, including coordination inefficiencies, leadership inconsistencies, and communication failures, particularly in the UK's fragmented crisis response system. Norway's centralized and collaborative approach resulted in swift decision-making, higher public trust, and stronger resilience. In contrast, the UK's delayed lockdown, conflicting crisis messaging, and limited inter-agency cooperation led to higher mortality rates and public distrust.

Alves et al. (2021) employ the VSM to diagnose the development of fish farming policy in Tocantins, Brazil, assessing its systemic structure, governance, and operational challenges. The research follows a multi-stage systemic analysis, beginning with the identification of organizational identity and policy objectives, followed by the unfolding of vertical and horizontal complexity to examine how policy functions are structured across different governance levels. Using TASCOI analysis (Transformation, Actors, Suppliers, Customers, Owners, Interveners) and software-assisted VSM modeling, the study identifies key systemic weaknesses, including poor coordination, fragmented regulatory mechanisms, and inefficient decision-making structures within the State Fish Farming Development Council (CONEDEPISCI). Findings reveal gaps in systemic integration, characterized by unclear governance roles, inadequate enforcement mechanisms, and insufficient stakeholder collaboration, which hinder the effective execution of policies and the growth of the industry. The study highlights the importance of structured governance, cross-sector collaboration, and adaptive policy mechanisms in enhancing the viability of fish farming as a strategic economic activity. It concludes that VSM provides a robust framework for diagnosing policy failures and designing governance reforms, advocating for institutional restructuring, digital governance

integration, and participatory decision-making to ensure sustainable aquaculture development in Brazil.

Espejo (2021) extends the Viable System Model (VSM) by introducing the Enterprise Complexity Model (ECM) as a methodological framework for managing complexity in emerging organizational forms, particularly in highly interconnected and dynamic environments. Traditional VSM approaches focus on the viability of individual enterprises, whereas the ECM conceptualizes organizational networks as adaptive, collaborative systems that integrate multiple enterprises, digital technologies, and sustainability imperatives. Using the Viplan Methodology, the study examines how enterprises navigate complex ecological, social, and economic demands by structuring self-regulating systems that enhance resilience, autonomy, and coordination. Findings indicate that enterprises facing rapid environmental changes require distributed governance models, reflexive learning loops, and algorithmic decision-making tools to maintain systemic viability. The ECM facilitates reconfigurable organizational structures that align with real-time data analytics, artificial intelligence, and decentralized resource management, fostering continuous innovation and strategic adaptation.

Adham et al. (2022) employ the VSM as a diagnostic framework to analyze the evolution and viability of the Malaysian halal certification system, a globally recognized standard ensuring compliance with Islamic dietary laws. Using a qualitative research methodology, the study conducted in-depth interviews with 20 executives from key institutions involved in halal certification, alongside document analysis tracing policy development from the 1970s to 2020. Findings reveal that the system's development followed a staged progression, driven by crises and institutional responses, evolving from an unstructured, state-based approach to a centralized, highly regulated system under the Department of Islamic Development Malaysia (JAKIM). Systemic weaknesses were identified in policy integration, enforcement mechanisms, inter-agency coordination, and industry engagement, resulting in inconsistencies in governance and a lack of international recognition. The research highlights the necessity of adaptive governance, digital traceability, and stronger regulatory frameworks to enhance the system's viability and effectiveness. By integrating policy evolution with the principles of systemic viability, the study provides a blueprint for strengthening halal industry ecosystems, advocating for strategic alignment, cross-sector collaboration, and international standardization to sustain Malaysia's leadership in the global halal economy.

Rodriguez-Ulloa (2022) presents a systemic approach to reforming Peru’s governance, utilizing Stafford Beer’s VSM to address its structural inefficiencies, bureaucratic rigidity, corruption, and lack of strategic foresight. By diagnosing Peru’s governance across four key

perspectives—sectoral (government functions), regional (territorial administration), river basins (environmental sustainability), and macroregional (integrated national development)—the research illustrates how a cybernetic governance framework can enhance adaptability, efficiency, and resilience. The methodology employs VSM in two modes: Diagnosis Mode, which identifies Peru's governance dysfunctions, and Design Mode, which proposes a cybernetic transformation leveraging real-time data integration, process automation, and intelligent decision-support systems. The study integrates systemic methodologies, including soft systems methodology (SSM), business process management (BPM), dynamically balanced scorecards, agent-based modeling (ABM), and social network analysis (SNA), to enhance the management of governance complexity. Findings indicate that Peru's governance must transition from a hierarchical, reactive model to a cybernetic, process-oriented system, emphasizing real-time monitoring, automation, and strategic adaptability. The proposed cybernetic governance model advocates for state reform through process automation (robotic process automation, AI-powered chatbots, and expert systems), intelligent policy execution (utilizing real-time dashboards and data-driven decision-making), and increased funding for science, technology, and innovation (ST&I) to enhance Peru's technological and economic resilience. Additionally, decentralized governance frameworks focused on regional and river basin-based policy execution are recommended to improve localized adaptability. This pioneering application of VSM to national governance provides a blueprint for resilient, technology-driven governance transformation, making it highly relevant for other developing nations seeking systemic reforms in the digital era.

Adamides et al. (2023) present a cybernetic approach to addressing the challenges of municipal waste management by utilizing Stafford Beer's VSM and the VIPLAN methodology to design a more adaptable and resilient waste management organization. The research highlights the increasing complexity of municipal waste management systems (MWMS), driven by evolving consumption patterns, climate change, new waste-processing technologies, and socio-technical transformations, which demand greater organizational flexibility and systemic resilience. Using the Municipality of Patras in Greece as a reference case, the study applies the VSM framework to diagnose inefficiencies and redesign municipal waste governance for enhanced adaptability and sustainability. The methodology follows a structured, three-phase approach: (1) Defining the system's identity and stakeholders through the TASCOI framework, (2) Unfolding organizational complexity by identifying primary waste management activities, regulatory functions, and decision-making structures, and (3) Testing the viability of

the redesigned system through simulated scenarios that evaluate its response to environmental disturbances. The findings reveal rigidities in current municipal waste governance, particularly in resource allocation, decision-making, and environmental scanning, which hinder responsiveness to unforeseen disruptions such as pandemics or changes in waste composition. To enhance resilience, the proposed VSM-based organizational model redistributes decision-making power across five interconnected cybernetic systems: System 1 (operational waste collection and disposal), System 2 (coordination mechanisms), System 3 (resource allocation and performance monitoring), System 4 (environmental scanning and innovation), and System 5 (policy and strategic oversight). The study concludes that a decentralized, recursive structure—where municipal waste units operate autonomously yet interdependently—ensures greater flexibility, efficiency, and integration into a circular economy model. The proposed model demonstrates practical applicability by integrating advanced waste management technologies, predictive analytics, and participatory governance mechanisms, offering a scalable framework for municipalities worldwide seeking to enhance sustainability and resilience in urban waste management.

Adamides et al. (2023) present a systemic cybernetic framework to enhance the resilience of oil refineries against climate-induced disruptions, utilizing Stafford Beer's VSM. Given the increasing vulnerability of critical oil infrastructure to extreme weather events—such as heatwaves, storms, flooding, and wildfires—this research develops a Viable Climate Resilience Providing Organisation (CRPO) to ensure uninterrupted operations and adaptive capacity within a Greek oil refinery. The methodology is based on an action research approach, employing the VIPLAN method to diagnose, design, and test a distributed resilience-providing organizational model. The research follows a three-phase process: (1) Defining the refinery's resilience identity and stakeholders using the TASCOI framework, (2) Mapping organizational complexity by identifying climate vulnerabilities, operational interdependencies, and decision-making structures, and (3) Designing a cybernetic governance model using VSM to distribute resilience-related functions across five systemic levels—System 1 (operational resilience implementation), System 2 (coordination of resilience activities), System 3 (resource allocation and performance monitoring), System 4 (climate foresight and strategic adaptation), and System 5 (policy and governance oversight). Findings reveal that existing refinery resilience strategies are reactive, safety-centric, and fragmented, lacking real-time environmental scanning, decentralized decision-making, and adaptive recovery mechanisms. The proposed CRPO model integrates climate scenario analysis, predictive risk assessments, knowledge-based decision-making, and distributed resilience responsibilities across refinery units, ensuring proactive

adaptation, rapid recovery, and integration of sustainability. This cybernetic resilience framework provides a scalable and transferable model for climate-proofing industrial infrastructures, making a significant contribution to organizational cybernetics, climate resilience governance, and risk-adaptive industrial management.

Perko (2023) presents a systemic and cybernetic examination of data-sharing frameworks, addressing the ethical, social, and governance concerns surrounding current data collection practices, which are predominantly centralized and controlled by data scientists, corporations, and AI developers. The research explores an alternative data-sharing model that grants data producers ownership and governance rights over their data, allowing for a more transparent, ethical, and participatory digital ecosystem. The methodology employs a conceptual and theoretical approach, utilizing literature analysis, system dynamics modeling, and the VSM to assess the viability of a decentralized data-sharing ecosystem. The study contrasts the dominant centralized data collection paradigm—where biometric and behavioral data are amassed in large-scale data lakes for AI-driven analysis—with a proposed data-sharing model in which data producers maintain control, negotiate sharing conditions, and leverage AI-driven agents for intelligent governance. Findings suggest that transitioning from passive data collection to active data governance would significantly enhance transparency, security, and ethical accountability, thereby mitigating risks such as data misuse, exploitation, and privacy violations. The study also reveals technical and structural challenges, including the need for distributed storage, intelligent negotiation protocols, and trust-based regulatory mechanisms. By applying VSM, the research diagnoses the systemic feasibility of this transition, outlining the functional requirements for a resilient, participatory, and AI-enhanced data governance framework.

Espinosa et al. (2023) explore how the VSM and the Self-Transformation Methodology (STM) can be applied to enhance organizational resilience within public healthcare systems. Amidst the challenges posed by the global pandemic, economic instability, and resource constraints, the research focuses on a case study within an English Local Health Trust's (ELHT) Breast Care Unit (BCU), diagnosing systemic inefficiencies and designing a more resilient, adaptable operational structure. The methodology employs a participatory action research approach, utilizing VSM as a diagnostic tool to evaluate the effectiveness of organizational structures and decision-making mechanisms. The study is structured into three key phases: (1) Boundary critique and stakeholder mapping, which defines the system's identity and constraints; (2) VSM-based diagnosis, which identifies governance weaknesses, decision-

making bottlenecks, and operational inefficiencies across five cybernetic levels—System 1 (clinical operations), System 2 (coordination mechanisms), System 3 (performance management), System 4 (innovation and environmental scanning), and System 5 (strategic oversight); and (3) Implementation of self-transformation initiatives, co-designed with participants to address key organizational vulnerabilities. The findings highlight that excessive centralization, rigid financial controls, and a lack of local autonomy hinder real-time responsiveness and adaptive learning within the healthcare unit. The proposed self-transformation interventions emphasize greater decision-making autonomy for clinical teams, a restructured performance management system that prioritizes patient-centric indicators, improved resource allocation processes, and a shift toward a culture of participatory innovation. The study concludes that decentralized governance, empowered frontline staff, and real-time decision-support systems are critical to enhancing resilience and sustainability in public health organizations.

Steen (2024) investigates the role of inter-organizational collaboration in enhancing the viability of disaster response systems by applying Stafford Beer's VSM to analyze the 2020 Gjerdrum landslide crisis response in Norway. The research highlights the impact of effective communication, coordination, and decision-making processes on the resilience and adaptability of emergency response efforts, particularly in disasters induced by climate change. Using a qualitative research design, the study employs document analysis, semi-structured interviews, and thematic analysis to systematically diagnose the structural, communicational, and functional inefficiencies within the Norwegian Search and Rescue (SAR) system. The findings highlight key pathological issues that hinder effective disaster response, including imbalances between centralized and decentralized decision-making, communication breakdowns, inefficient resource allocation, and unclear role distribution among emergency responders. Specifically, the study reveals that while collaboration among police, fire brigades, medical services, and voluntary organizations was essentially practical, the lack of clear leadership transitions, inadequate infrastructure for crisis coordination, and inconsistent information-sharing mechanisms created significant challenges. By applying the VSM framework, the research identifies systemic dysfunctions across five organizational levels—System 1 (operational response), System 2 (coordination), System 3 (resource allocation and performance monitoring), System 4 (environmental scanning and strategic foresight), and System 5 (policy and governance oversight)—and provides targeted recommendations to improve the resilience, efficiency, and long-term adaptability of disaster response networks. The study highlights the

significance of pre-existing inter-organizational relationships, trust-based communication protocols, and dynamic role allocation in establishing a robust crisis management system.

Perko et al. (2024) present a systemic approach to sustainable supply chain (SSC) management, integrating systems thinking, stakeholder theory, and the VSM to create a holistic framework for sustainability. Given the increasing global pressure for responsible and ethical business practices, the research highlights the complex interdependencies between supply chain (SC) members and their economic, social, and environmental contexts, emphasizing the necessity for a holistic approach in sustainability strategies. The methodology employs a structured, conceptual, and empirical approach, combining system dynamics modeling and VSM diagnosis to analyze the systemic viability of SSCs. The research develops two models: (1) a basic holistic model that integrates sustainability as an embedded goal within SC operations and (2) a requisite holistic SSC model that extends sustainability beyond SC members to include regulatory bodies, societal stakeholders, and environmental frameworks. Findings indicate that low-tier SC members, such as suppliers and small-scale producers, lack the autonomy and capacity to engage in sustainability-driven decision-making, necessitating external support mechanisms from regulatory frameworks, incentive structures, and policy reforms. The study also reveals systemic pathologies within SC structures, including profit-driven incentives that conflict with long-term sustainability goals, inefficient regulatory adaptation, and a lack of real-time feedback mechanisms from environmental and societal actors. By applying VSM analysis across five systemic levels—System 1 (operations), System 2 (coordination), System 3 (resource management and performance control), System 4 (strategic foresight and environmental scanning), and System 5 (policy and governance oversight)—the study proposes structural changes that ensure adaptive, resilient, and ethically responsible SC operations.

Sydelko et al. (2024) explore a systemic and participatory approach to enhancing interagency collaboration in tackling wicked problems using Stafford Beer's VSM. Wicked problems, such as international organized crime and its intersection with local gang activity, are highly complex, interdependent, and resistant to traditional reductionist problem-solving methods. The research presents an innovative board game-based application of the VSM designed to facilitate interagency learning, trust-building, and collaborative organizational design. By applying the VSM framework within a game-based intervention, the study demonstrates how agencies can overcome siloed decision-making, interdepartmental rivalries, and inefficient coordination structures, which often hinder responses to large-scale, multi-stakeholder crises. The

methodology follows a systemic intervention approach, integrating boundary critique, systemic perspective mapping, and a facilitated VSM board game workshop to co-design an interagency meta-organization (BlueNet). The research is structured into three key phases: (1) stakeholder mapping and boundary critique, where participants identify the structural barriers to collaboration; (2) systemic perspective mapping, which helps agencies build a shared understanding of interdependencies and overlapping responsibilities; and (3) deployment of the VSM board game, where participants simulate and negotiate the design of an adaptive, cybernetic interagency structure. Findings indicate that pre-existing interagency collaboration is often informal and reliant on personal networks ('I know a guy' approach), leading to inefficiencies in intelligence-sharing, decision-making, and coordinated resource allocation. By structuring BlueNet's organizational design across VSM's five systemic levels—System 1 (operational units), System 2 (coordinating functions), System 3 (resource management and performance oversight), System 4 (strategic foresight and environmental scanning), and System 5 (policy and governance oversight)—the study demonstrates that interagency responses to wicked problems can be optimized through recursive, self-organizing governance structures that enhance adaptability, resilience, and information flow.

Table 2. Key trends across the 21 studies

key trends	Explanations
Governance Applications	• VSM enhances decentralized decision-making by identifying systemic inefficiencies and improving hierarchical communication (Lowe et al., 2020; Espinosa et al., 2023). • Applied to national and local government systems to optimize policy implementation and coordination (Rodriguez-Ulloa, 2022).
Healthcare Resilience	• VSM strengthens resource allocation, emergency response, and resilience in healthcare systems, particularly during crises like the COVID-19 pandemic (Espinosa et al., 2023; Gallego-García et al., 2019). • Improves coordination between departments to maintain operational stability under pressure (Pollock and Steen, 2021).
Sustainability	• VSM aligns organizational processes with sustainability frameworks like ISO 26000 and the UN Sustainable Development Goals (SDGs) (Panagiotakopoulos et al., 2016). • VSM supports sustainable supply chain management, balancing economic and environmental demands (Perko et al., 2024).
Supply Chain Optimization	• VSM minimizes supply chain disruptions by identifying structural weaknesses and implementing systemic solutions. • Enhances stakeholder alignment and systemic flexibility for global supply chains (Espinosa et al., 2023).
Crisis Management	• VSM improves multi-agency responses to crises, such as natural disasters and pandemics (Espinosa et al., 2015). • Provides a robust framework for addressing "wicked problems" requiring inter-organizational coordination (Gallego-García et al., 2019).
Technological Integration	• Emerging technologies such as artificial intelligence, big data analytics, and digital twins are increasingly integrated with VSM to enhance real-time monitoring and decision-making (Lowe et al., 2020; Espinosa et al., 2023). • VSM frameworks demonstrate adaptability for digital transformation and predictive analysis.

Table 3. Summary of key findings across the 23 studies

Authors	Target Country	Research Focus	Research Objectives	Methodology	Key Findings	Future Recommendations
Chan (2011)	Global	SME viability frameworks	Enhance SME systems resilience through VSM analysis.	Case study	VSM supports SME adaptability during crises.	Extend VSM resilience strategies to global SMEs.
Spyridopoulos et al. (2014)	Netherlands	Infrastructure resilience	Use VSM for system adaptability in infrastructure.	Systems analysis	VSM enhances coordination to improve critical systems resilience.	Apply VSM frameworks to healthcare systems.
Espinosa et al. (2015)	Multi-country	Policy adaptability	Use VSM to develop flexible policy systems.	Mixed methods, policy study	VSM improves policy alignment and decision-making adaptabilit.	Extend VSM policy frameworks for global urban development systems.
Panagiotakopoulos et al. (2016)	UK	Sustainability management using VSM	Analyze VSM's role in achieving sustainability.	Case study	VSM fosters systemic alignment with sustainability objectives.	Refine VSM rules for broader organizational adaptability.
Gallego-García (2019)	Spain	Simulation of VSM	Assess VSM efficiency in systems design.	Simulation-based modeling	VSM improves system efficiency and energy optimization.	Apply VSM models in energy industries for real-world testing.
Vahidi and Aliahmadi (2019)	Global	Hybrid VSM approaches	Combine VSM with other methods for systemic analysis.	Conceptual study	Hybrid approaches improve problem-solving efficiency in complex systems.	Explore VSM hybrid frameworks across multiple industries.
Adham et al. (2020)	Taiwan	Diagnosis of Halal industry systems	Identify inefficiencies in Halal certification.	VSM-based analysis	VSM reveals structural gaps and improves coordination processes.	Extend VSM applications to similar certification systems globally.
Shaw et al. (2020)	Global	Disaster management systems	Propose frameworks for VSM-based disaster response.	Action research	VSM improves systemic disaster risk coordination and mitigation processes.	Apply VSM globally to national disaster risk reduction initiatives.
Cardoso Castro and Espinosa (2020)	European Eco-Community (EEC)	Organizational pathologies, complexity management, and diagnostics	To combine Social Network Analysis (SNA) and the Viable System Model (VSM) for identifying and addressing structural pathologies in organizations.	Action research involving participatory workshops - Data collection via questionnaires, interviews, and field observations	- Integration of VSM and SNA identified weak communication channels, lack of systemic feedback, and poorly aligned operational groups - Provided a robust diagnostic approach for organizational pathologies - The methodology highlighted key actors and structural deficiencies.	- Use advanced computational tools for real-time analysis (e.g., meta-networks and ORA) - Expand the combined framework to other types of organizations - Investigate additional metrics and tools for enhancing diagnostics of structural complexity..

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Authors	Target Country	Research Focus	Research Objectives	Methodology	Key Findings	Future Recommendations
Espejo (2021)	UK	Complexity management	Address enterprise complexity with systemic models.	Conceptual study	VSM reduces complexity by improving coordination among organizational layers.	Develop frameworks for enterprise-scale implementation of VSM.
Alves et al. (2021)	Brazil (specifically the state of Tocantins)	Application of the Viable System Model (VSM) to analyze and improve fish farming development policy in Tocantins.	- To diagnose organizational weaknesses in fish farming development policy using VSM. - To enhance socio-economic and environmental sustainability through systemic governance and cybernetic approache.	- Adaptation of VSM for policy analysis. - Use of TASCOI framework to define system identity.	- Identified systemic inefficiencies such as poor coordination and lack of standards for operational units.	- Development of a more integrated framework involving public, private, and academic stakeholders. - Establishment of clear governance structures and technical standards. - Exploration of additional cybernetic models for systematic policy monitoring and management. - Promote stakeholder education and capacity-building initiatives.
Rodriguez-Ulloa (2022)	Peru	Cybernetic governance	Implement VSM to optimize governance frameworks.	Qualitative analysis	VSM improves decision-making processes and reduces inefficiencie.	Test VSM in other public governance models in developing nations.
Adham et al. (2022)	Malaysia	Certification system analysis	Identify gaps and strengths in Halal certification.	Case study, VSM diagnosis	VSM improves operational gaps and stakeholder alignment in certifications.	Apply VSM frameworks for other policy-based certifications globally.
Adamides et al. (2023)	Global	Climate change resilience	Apply VSM to improve systemic climate resilience.	Case study	VSM fosters decision-making in critical infrastructure resilience.	Extend frameworks for climate resilience in vulnerable industries.
Perko (2023)	Germany	Circular economy systems	Align VSM with circular economic sustainability.	Case study	VSM supports resilience and sustainability in circular systems.	Expand VSM frameworks for environmental sectors.
Adamides et al. (2023)	Italy	Municipal systems design	Enhance municipal waste systems efficiency using VSM.	Case study, VIPLAN	VSM improves flexibility in managing urban waste systems.	Apply VSM to other urban public service systems globally.
Espinosa et al. (2023)	Multi-country	Organizational resilience	Assess VSM's role in building resilient organizations.	Case study	VSM improves adaptability and long-term resilience in crises.	Scale resilience frameworks using VSM globally.
Steen (2024)	Norway	Investigating the role of interorganizational collaboration in enhancing the viability of	. To identify systemic pathologies and propose improvements to enhance the	- Conducted nine semi-structured interviews with stakeholders. - Document	Identified challenges such as inefficiencies in communication, coordination, and resource allocation.	- Enhance communication and knowledge-sharing mechanisms across agencies. - Develop clearer roles and responsibilities for

Authors	Target Country	Research Focus	Research Objectives	Methodology	Key Findings	Future Recommendations
		disaster response operations, specifically in the context of the Gjerdrum landslide.	overall viability of disaster response systems.	analysis of public reports, media, and evaluation documets.	- Highlighted structural and functional pathologies, including tensions between centralization and decentralization.	interorganizational collaboration.
Sydelko et al. (2024)	Multi-country	Interagency collaboration	Improve multi-stakeholder coordination using VSM.	Mixed-methods, simulation	VSM improves problem-solving across inter-organizational systems.	Develop scalable collaboration tools using VSM principles.
Perko et al. (2024)	Germany	Supply chain management	Develop sustainable supply chains using VSM.	Case study	VSM ensures holistic supply chain sustainability and resilience.	Test VSM in supply chain disruptions caused by crises.

Table 4. Identified research gaps and opportunities

Research Gap	Description	Future Opportunities
Lack of real-world validation	Most studies rely on simulations or conceptual models without real-world testing.	Conduct empirical studies implementing VSM in real-world organizations and industries.
Limited scope of applications	Studies focus on specific sectors (e.g., sustainability, governance).	Explore VSM's scalability across sectors like AI, smart cities, and digital systems.
Reliance on single case studies	Findings are often based on single case studies, limiting generalizability.	Conduct multi-case studies across diverse organizations and geographical regions.
Integration with other methodologies	Few studies explore hybrid approaches combining VSM with systemic tools.	Combine VSM with system dynamics, quantitative modeling, and AI-based methods.
Limited attention to implementation challenges	Practical barriers like resistance and cultural gaps are underexplored.	Identify and address challenges to VSM implementation through empirical studies.
Scalability of VSM frameworks	Focus on SMEs or single organizations, not larger systems.	Develop scalable VSM frameworks for multinational corporations and global networks.
Absence of longitudinal studies	Studies provide cross-sectional analyses without long-term impact assessments.	Conduct longitudinal studies to assess the long-term effectiveness of VSM.
Policy integration challenges	VSM's integration into broader policy ecosystems remains unexplored.	Explore VSM applications in public policy frameworks, especially in developing nations.
Resilience during prolonged crises	Limited focus on prolonged disruptions like pandemics or economic crises.	Evaluate VSM performance in prolonged crises and complex emergency systems.
Data limitations	Lack of quantitative data and metrics in VSM studies.	Incorporate quantitative metrics to improve evaluation and impact measurement.
Circular economy integration	Few studies apply VSM in circular economy initiatives.	Design VSM models for circular economies, waste management, and industrial ecology.
Interdisciplinary research	Limited exploration in interdisciplinary fields like AI and digital systems.	Combine VSM with emerging technologies to address complex and dynamic systems.
Stakeholder engagement processes	Limited focus on stakeholder engagement in VSM implementation.	Develop frameworks to improve stakeholder buy-in and systemic adoption of VSM.

The bibliometric summary (Figure 4) highlights a moderate annual growth rate (1.45%), indicating a steady but not exponential expansion of the research domain. With 768 documents published across 378 sources, the field demonstrates a diverse publication landscape, supported by 1,110 authors, yet a relatively low international co-authorship rate (16.8%), suggesting limited global collaboration. The average number of citations per document (9.151) reflects a reasonably strong impact, although the document's average age (12.2 years) suggests reliance on older foundational works. The high number of unique keywords (1,778) indicates a broad thematic scope, making this research area interdisciplinary and evolving.

The bibliometric visualization of Annual Scientific Production in Figure 5 reveals an initial slow growth phase (1977–1999), followed by a rapid expansion (2000–2010), indicating an increasing scholarly interest and theoretical advancements. The period from 2010 to 2022 reflects peak productivity, albeit with fluctuations, likely driven by funding cycles, policy changes, and emerging interdisciplinary integrations. The sharp decline after 2023 is likely due to incomplete data for recent years, rather than an actual drop in research output. This pattern aligns with Price's Law of Scientific Growth, suggesting a field that has matured but may now be transitioning into new research directions.

Figure 4. The bibliometric summary

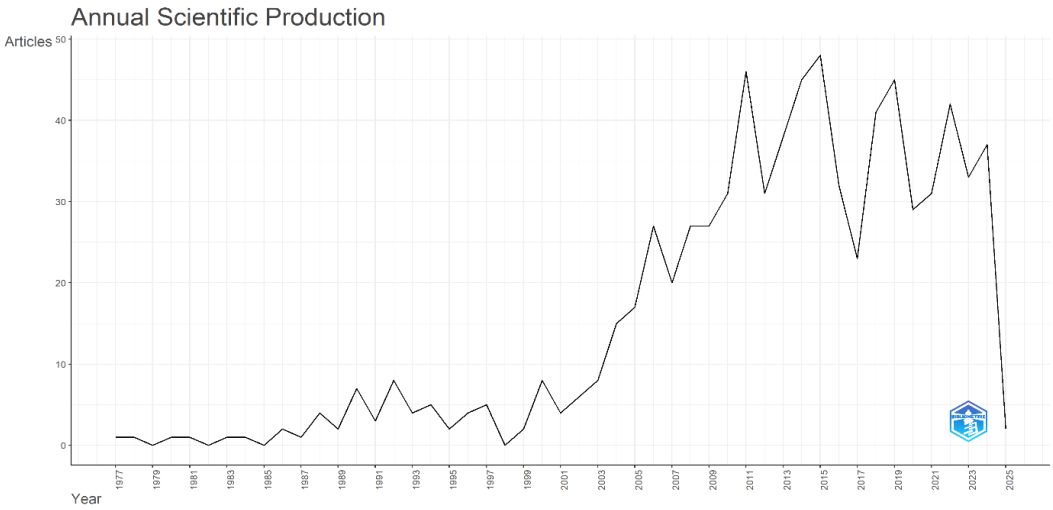

Figure 5. The bibliometric visualization of annual scientific production

The bibliometric visualization of document types in Figure 6 reveals that journal articles (55.6%) dominate scholarly contributions, indicating a strong emphasis on peer-reviewed research. Conference papers (31%) represent a significant portion, reflecting the dynamic and evolving nature of the field through the rapid dissemination of knowledge. Book chapters (6.1%) and reviews (3.2%) suggest ongoing theoretical advancements and conceptual synthesis. The presence of editorials, errata, and short surveys (≤0.1%) is minimal, indicating limited engagement in opinion-based or corrigendum literature. This distribution aligns with scientific communication trends, where journal articles serve as the primary medium for rigorous academic discourse, while conferences act as platforms for emerging innovations.

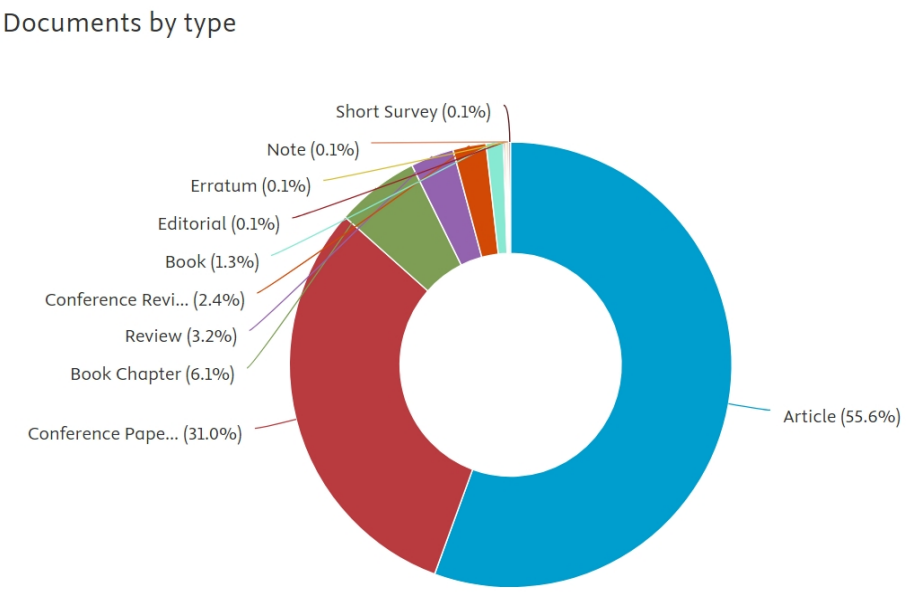

Figure 6. The bibliometric visualization of document types

The bibliometric analysis of documents by subject area in Figure 7 reveals a strong interdisciplinary nature, with Computer Science (21.9%), Engineering (18.6%), and Business, Management (16.1%) being the dominant fields, indicating a technological and managerial research focus. Social Sciences (12.9%) and Decision Sciences (9.4%) suggest significant engagement with policy-making and strategic decision-making frameworks. The presence of Mathematics (9.1%) implies a quantitative or computational approach to problem-solving. The lower representation of Economics (2.6%), Arts and Humanities (1.5%), and Medicine (1.5%) suggests that while peripheral, these disciplines contribute theoretical, ethical, or applied insights. This distribution aligns with modern research trends where digital transformation, engineering solutions, and managerial decision-making are interlinked.

The bibliometric analysis, using Bradford's Law, identifies the core journals that contribute the most significant volume of research in the field, highlighting their central role in disseminating knowledge. The shaded area represents the most influential sources, including journals like Kybernetes, Systemic Practice and Action Research, and Systems Research and Behavioral Science, which are foundational to this domain. The steep decline beyond the core zone indicates a long-tail distribution, suggesting that while many peripheral sources exist, their contribution is minimal compared to the core sources. It aligns with Bradford's Law, which states that a small set of journals accounts for the majority of relevant literature. Identifying these core sources is crucial for researchers aiming to publish in high-impact venues and track emerging scholarly debates (Figure 8).

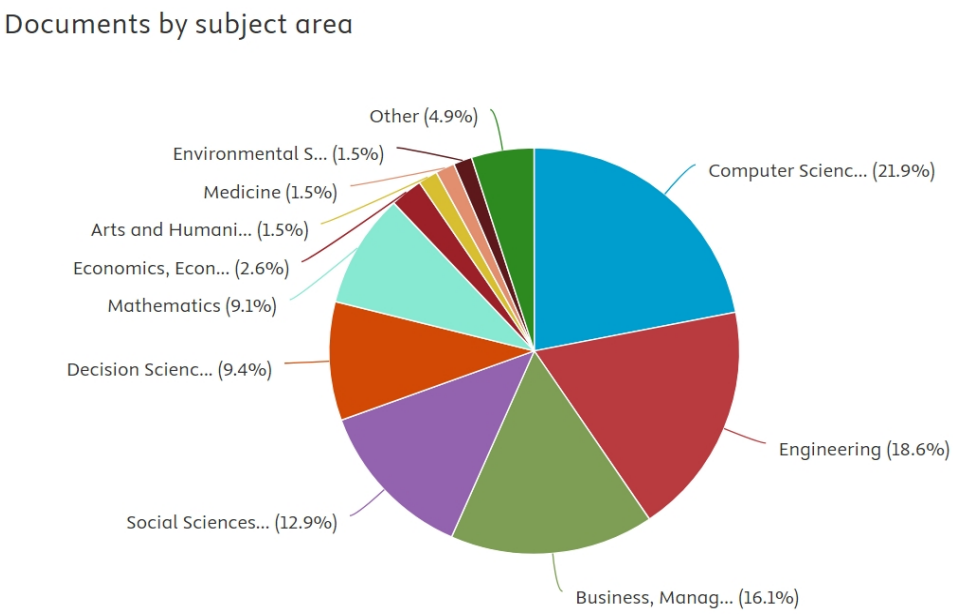

Figure 7. The bibliometric visualization of document types

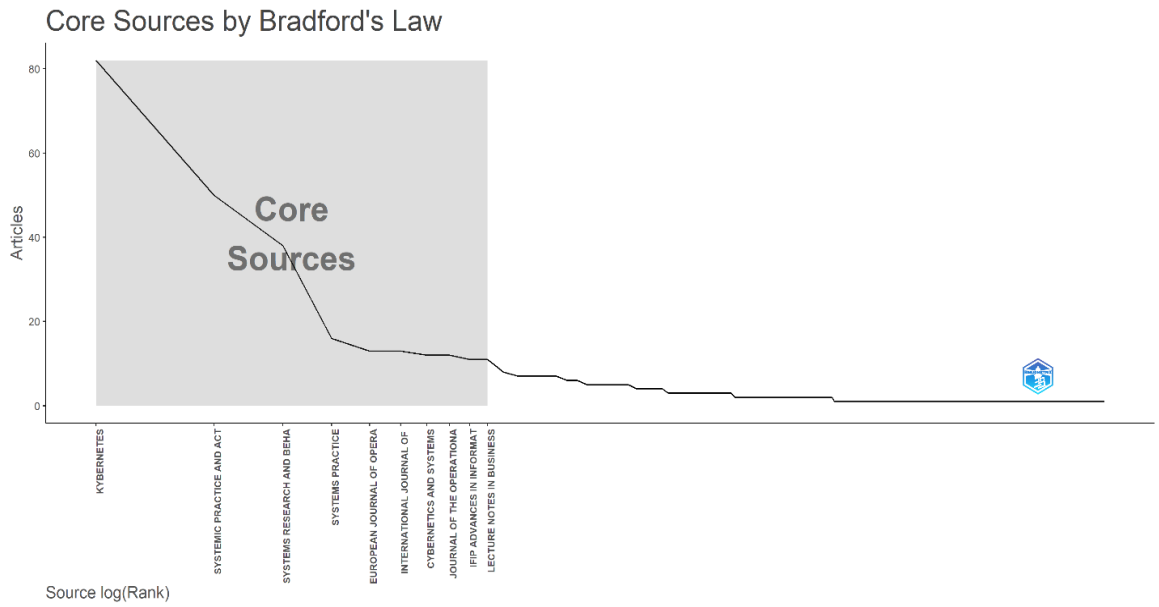

Figure 8. The bibliometric analysis using bradford's law

The word cloud visualization (Figure 9) highlights "Viable System Model" and "Cybernetics" as the dominant research themes, indicating a strong conceptual foundation in systems thinking and organizational viability. Keywords such as "decision-making," "information systems," and "sustainable development" suggest interdisciplinary applications, particularly in management, governance, and technology-driven solutions. The presence of "design/methodology/approach" implies a focus on theoretical and practical frameworks, supporting methodological advancements. Including "Stafford Beer" and "systems modeling" reinforces the field's theoretical lineage and continued evolution. This keyword analysis reflects a dynamic research landscape that integrates systems science, decision theory, and digital transformation.

Figure 9. The word cloud visualization

The trend topic analysis (Figure 10) highlights the evolution of research themes over time, with cybernetics, system theory, and viable system models (VSM) emerging as foundational concepts. The growing interest in big data, complex networks, decision-making, and sustainable development has led to a shift toward technological and governance-oriented applications in recent years. The increasing frequency of terms like energy management, behavioral research, and innovation suggests an interdisciplinary expansion of VSM into environmental and organizational domains. The presence of wicked problems and problem structuring reflects a contemporary focus on complex, systemic challenges. This trajectory aligns with the digital transformation of systems science, bridging theoretical advancements with real-world problem-solving.

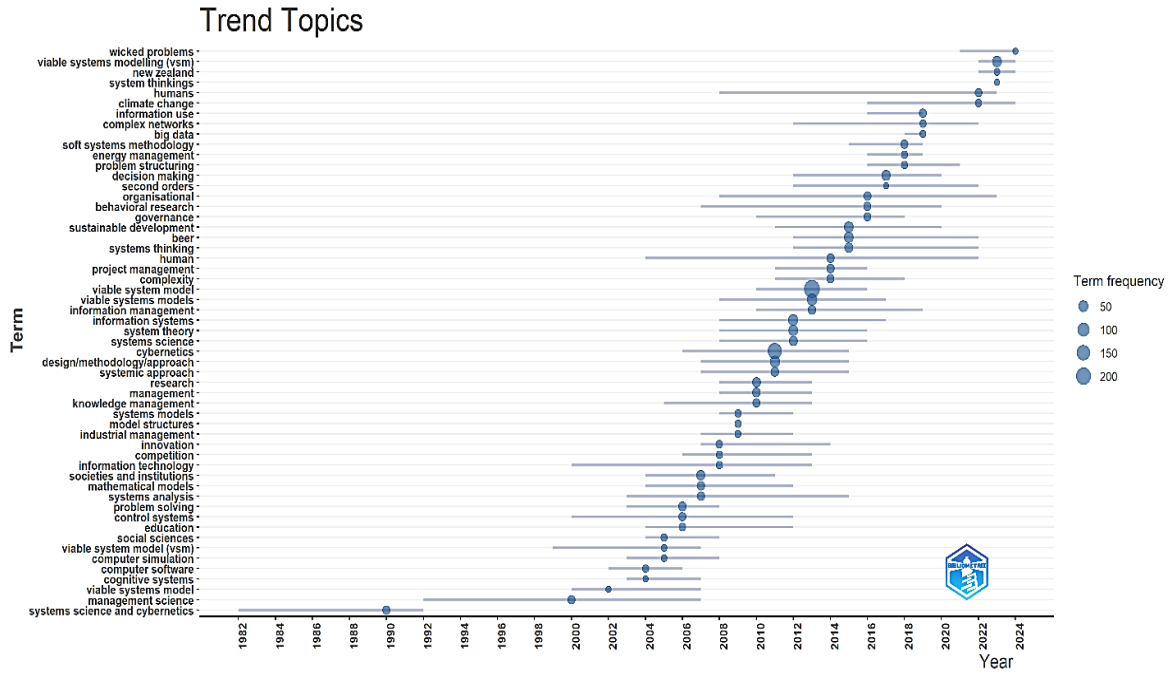

Figure 10. The trend topic analysis

The co-word network clustering analysis in Figure 11 illustrates the conceptual landscape of VSM research, with "cybernetics" and "methodology/approach" as dominant themes, reflecting strong theoretical underpinnings. The red cluster focuses on decision-making, complexity, and systems dynamics, indicating applications in organizational strategy and problem structuring. The blue cluster links VSM to management science, governance, and knowledge management, emphasizing its role in institutional decision-making. The green cluster, containing climate change and complex networks, suggests emerging interdisciplinary applications in sustainability and digital ecosystems. The purple cluster, encompassing operations research and mathematical modeling, highlights quantitative and computational methodologies that support

VSM. The network structure confirms VSM's expanding interdisciplinary relevance, integrating systems thinking, decision theory, and computational modeling. This analysis underscores VSM's adaptability, positioning it at the intersection of organizational resilience, systemic governance, and digital transformation.

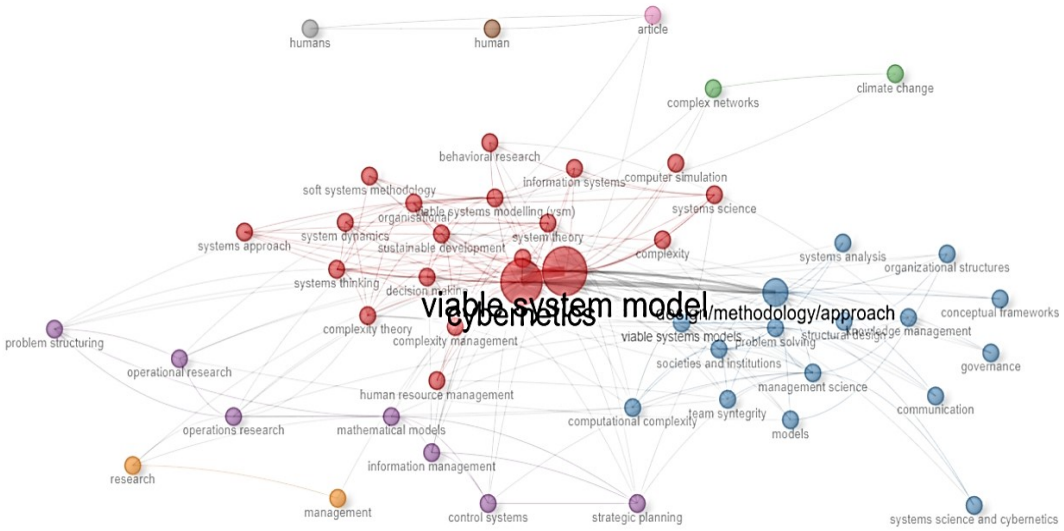

Figure 11. The co-word network clustering analysis

The thematic map analysis in Figure 12 categorizes research themes based on development (density) and relevance (centrality), providing insights into the VSM research landscape. The motor themes (upper-right quadrant), including VSM, cybernetics, and organizational process, indicate well-developed and highly relevant topics driving the field. The basic themes (lower-right quadrant), such as systems science, system theory, and system dynamics, form the conceptual foundation of the domain. The niche themes (upper-left quadrant), including wicked problems, crime, and government agencies, suggest specialized but less influential areas. The emerging or declining themes (lower-left quadrant), such as sustainability, organizational framework, and virtual reality, indicate potential future directions or declining interest. The map highlights VSM’s strong interdisciplinary integration, connecting governance, healthcare, and digital transformation. Complex networks and adaptive systems signal growing applications in computational and artificial intelligence-driven systems thinking. Future research may benefit from expanding interdisciplinary collaborations to integrate decision sciences, sustainability, and digital governance frameworks.

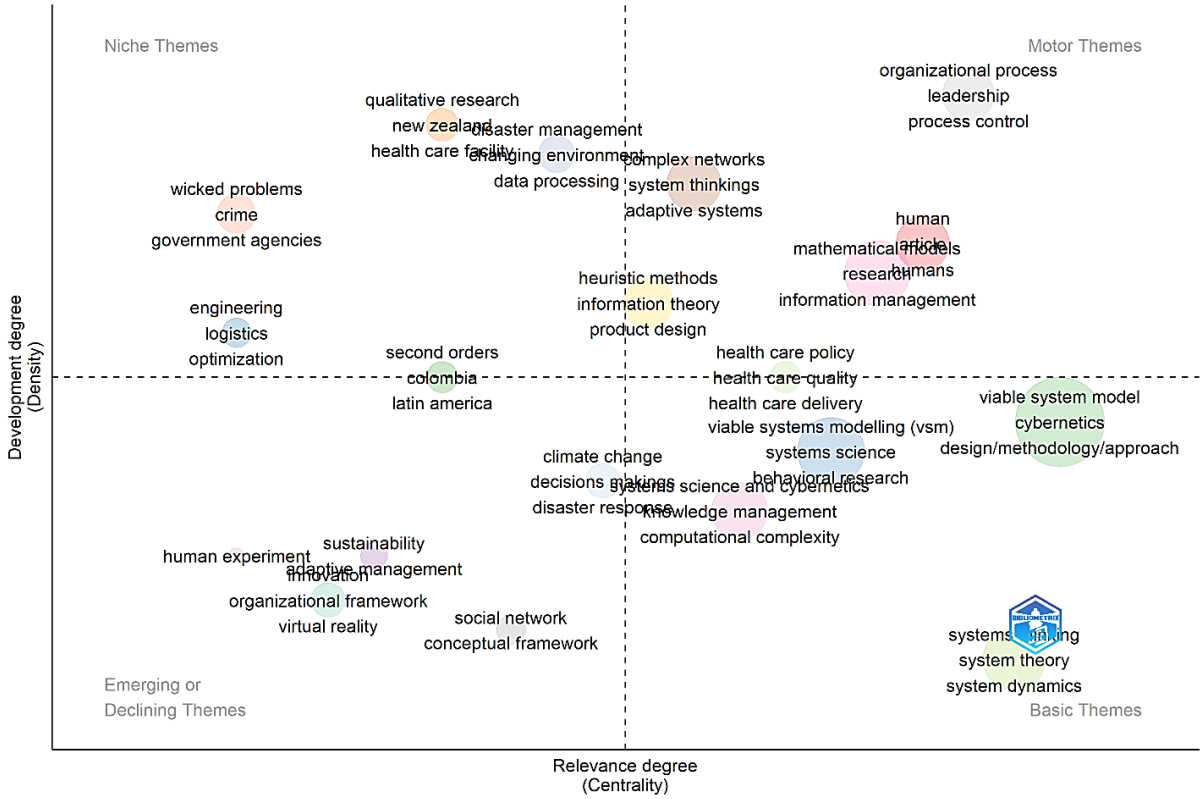

Figure 12. The thematic map analysis

4. Discussion and conclusion

This systematic review evaluates the breadth and depth of the VSM applications across various domains, synthesizing findings from 21 studies. By critically analyzing the role of VSM in managing complexity, the study highlights its contributions to improving systemic resilience, enhancing decision-making, and facilitating organizational adaptability across various domains, including governance, healthcare, sustainability, supply chains, and crisis management. Subsequently, based on the findings from the research, we will examine and address the research questions.

RQ1: In what domains has the Viable System Model been applied?

The systematic review identifies six major domains where VSM has been widely applied: governance, healthcare, sustainability, supply chain optimization, crisis management, and technological integration. In governance, VSM has improved public administration decision-making, coordination, and policy alignment. It has strengthened resilience, resource allocation, and systemic coordination in healthcare, particularly during crises like the COVID-19 pandemic. Sustainability applications include their role in aligning organizational processes with environmental and social sustainability goals, particularly in circular economy models and sustainable supply chain management. VSM enhances stakeholder integration, system

flexibility, and risk management in supply chains. In crisis management, VSM has proven effective in multi-agency collaboration, systemic coordination, and disaster resilience. Technological integration highlights VSM's adaptability in AI-driven decision-making, big data analytics, and digital transformation initiatives.

VSM, as highlighted in the document, has been applied in a wide range of interdisciplinary fields, such as VSM in management and governance (in organizational strategy, decision-making, and governance, particularly in knowledge management and institutional decision-making), cybernetics and systems science (for system modeling and complexity management), information systems and digital transformation (in digital ecosystems, information systems, and emerging technologies like artificial intelligence and big data), sustainability and environmental sciences (for analyzing climate change, energy management, and sustainable development), operations research and computational methods (mathematical modeling, complex networks, and quantitative approaches to problem structuring), and public policy and government organizations (in governance structures, policy-making, and addressing social challenges such as crime prevention and organizational resilience).

RQ2: What insights have emerged from these applications?

A key finding is that VSM enhances systemic resilience, adaptability, and decentralized decision-making across different industries. The review highlights its effectiveness in identifying systemic inefficiencies, reducing complexity, and improving multi-layered governance structures. Integrating emerging technologies, such as digital twins and AI, demonstrates the model's ability to evolve with modern challenges. In sustainability, the alignment of VSM with UN Sustainable Development Goals (SDGs) suggests its growing relevance in addressing environmental and organizational difficulties. However, despite its conceptual strengths, the study reveals a gap in empirical validation, as many studies rely on theoretical and simulation-based models rather than real-world implementation.

Several key insights have emerged from applying VSM across domains: Interdisciplinary Nature, Adaptability and Resilience, Decision-Making and Complexity Management, Digital Transformation and Innovation, Sustainability Applications, and Integration with Systemic Governance.

RQ3: What challenges and opportunities exist for the VSM in addressing contemporary systemic issues?

The study identifies several key challenges in VSM implementation. One of the primary concerns is scalability, particularly in small and medium enterprises (SMEs) and large

multinational organizations. Another challenge is the lack of empirical studies, as most research remains conceptual or simulation-based, limiting real-world validation. Resistance to change and low systems literacy in organizations also hinder the widespread adoption of VSM. However, there are significant opportunities for further research, particularly in interdisciplinary fields such as AI, smart cities, and digital governance. The study suggests the development of hybrid frameworks that integrate VSM with quantitative modeling, AI, and predictive analytics. Future research should also focus on longitudinal studies to assess the long-term impact of VSM applications in various industries.

Our analysis identifies key challenges associated with the Viable System Model (VSM), including the complexity of implementation, the lack of extensive empirical validation, limitations in international collaborations, and the need to adapt to emerging technologies. At the same time, there are potential opportunities for developing and applying this model, particularly in digital applications, to enhance sustainability and resilience, strengthen the connection between governance and decision science, and leverage significant computational modeling.

4.1. Theoretical contributions and key insights

The findings reaffirm VSM's foundational relevance as a systemic approach for organizational management, while extending its utility to address contemporary challenges. These insights contribute to both the theoretical evolution of VSM and its practical adaptability.

4.1.1. Governance systems: Enhancing coherence and adaptability

Governance remains the most prominent domain of VSM application. Studies such as Espinosa et al. (2015) and Pollock and Steen (2021) illustrate VSM's capacity to address systemic inefficiencies, fragmentation, and communication barriers in public administration. By promoting decentralized decision-making, VSM provides a mechanism for striking a balance between central oversight and local autonomy. This approach enhances policy coherence and institutional adaptability in multi-level governance systems, offering a robust solution to governance challenges in both developing and developed economies. The systemic properties of VSM align with emerging needs in governance, particularly in complex, inter-agency collaborations. Gallego-García et al. (2019) demonstrate how VSM can foster trust, transparency, and systemic coordination in addressing wicked problems, such as regional development and disaster response. It highlights VSM's role as a tool for facilitating adaptive governance frameworks that can address multifaceted societal challenges.

4.1.2. Sustainability: Aligning organizational goals with environmental objectives

The review highlights VSM's increasing relevance to sustainability, where it enables organizations to align operational processes with long-term environmental goals. Espinosa et al. (2023) and Perko (2024) demonstrate how VSM frameworks incorporate circular economy principles, enabling systemic solutions to sustainability challenges. These studies highlight VSM's potential to support the United Nations' Sustainable Development Goals (SDGs) by fostering adaptive systems that can balance ecological, economic, and social demands. The application of VSM in sustainable supply chains further underscores its value. By identifying structural inefficiencies and fostering stakeholder integration, VSM enables organizations to build resilience against disruptions and maintain operational alignment with sustainability targets. It extends VSM's utility to globalized supply chain networks, particularly in industries characterized by resource constraints and environmental pressures.

4.1.3. Healthcare systems: Building resilience and operational efficiency

Although underexplored compared to governance and sustainability, healthcare emerges as a key domain for VSM applications. Studies such as Espinosa et al. (2023) and Pollock and Steen (2021) demonstrate how VSM enhances healthcare resilience during crises, including pandemics and resource shortages. By improving systemic coordination, resource allocation, and communication, VSM provides a robust framework for managing complex healthcare networks. The review reveals VSM's ability to optimize patient care pathways, reduce systemic waste, and enhance operational stability under pressure. These findings highlight VSM as a valuable tool for addressing healthcare challenges in both developed and resource-constrained settings, particularly as healthcare systems face growing demands and complexity.

4.1.4. Supply chain systems: Managing complexity in dynamic environments

The results demonstrate VSM's applicability to modern supply chains, where it minimizes disruptions, improves systemic flexibility, and enhances stakeholder alignment. Perko et al. (2024) and Pollock and Steen (2021) illustrate how VSM enables organizations to respond to supply chain variability through feedback mechanisms and systemic redesigns. This positions VSM as a critical tool for improving supply chain resilience, particularly in light of global uncertainties such as pandemics, geopolitical risks, and technological disruptions.

4.1.5. Crisis management: Multi-Agency collaboration and systemic resilience

Crisis management emerges as a key area of VSM application, where its systemic principles enable multi-agency collaboration, adaptive decision-making, and the building of resilience. Studies, such as those by Gallego-García et al. (2019), highlight VSM's ability to enhance systemic coordination during natural disasters, governance crises, and other disruptions. By fostering real-time information flows and dynamic feedback loops, VSM improves organizational responses to unpredictable challenges, making it an indispensable tool for managing systemic risks.

Our review of the studies conducted found that the diversity in the VSM areas is highly flexible and provides systemic solutions to existing challenges in governance, healthcare, sustainability, supply chains, and crisis management. Its principles align with the growing need for resilient and adaptable systems that respond to contemporary organizational challenges. Our findings emphasize the applicability of VSM in enhancing decentralized decision-making, improving systemic resilience, and enabling multi-agency collaboration. Integrating VSM with emerging technologies further strengthens its applicability in technology-driven and data-centric environments. Another finding is that theoretical advancements can extend the exploration of the theoretical boundaries of VSM and demonstrate its relevance to emerging fields such as sustainability and crisis management. This review highlights the role of VSM as a systemic tool for aligning organizational structures with the dynamic needs of the environment.

While the findings of this study provide valuable insights into the distribution and applications of VSM, several limitations must be acknowledged. Firstly, the study relied exclusively on the Scopus database for data extraction. It may have omitted relevant studies indexed in other databases, such as Web of Science, IEEE Xplore, or discipline-specific repositories. As a result, the findings may not fully reflect the global landscape of VSM applications, potentially introducing selection bias. Another significant limitation is that the study covers multiple domains (governance, healthcare, sustainability, supply chains, and crisis management), but it does not profoundly explore sector-specific challenges. The applicability of VSM in education, agriculture, and digital governance remains underexplored, limiting insights into its full interdisciplinary potential. A significant limitation is the lack of empirical validation for many reviewed applications.

Several studies are conceptual or simulation-based, making it difficult to assess the real-world impact of VSM in dynamic environments. Future research should conduct longitudinal and

multi-case studies to validate the model's effectiveness. Despite its theoretical robustness, the practical implementation of VSM poses challenges, including organizational resistance, low systems literacy, and adaptation difficulties in complex structures. These factors may hinder adoption in real-world settings, requiring simplified models or hybrid approaches. Most studies lack quantitative validation, relying instead on qualitative assessments that may be subject to bias. There is an absence of standardized metrics to measure the impact of VSM interventions, making it challenging to compare effectiveness across different contexts. Future research should expand data sources, conduct multi-case and longitudinal studies, explore interdisciplinary applications, and develop scalable VSM models for SMEs to address these limitations. Integrating quantitative metrics and hybrid approaches will enhance the practical relevance and adoption of these methods. Lastly, the study does not assess the long-term impacts or sustainability of VSM applications. Future research could focus on measuring the tangible and intangible outcomes of VSM over extended periods, such as cost savings, process improvements, and organizational cultural transformations. By addressing these limitations, future research can build on the insights presented here to provide a more comprehensive and nuanced understanding of VSM's potential across diverse contexts.

Disclosure statement

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