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Systematic Review

Knowledge Management as a Domain, System Dynamics as a Methodology

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Abstract: For decades, system dynamics has been utilised as a framework for evaluating and interpreting various types of systems with varying degrees of complexity and knowledge demands. Knowledge management is strongly related to system dynamics on a thematic level. We did a thorough review to identify potential applications and analysed system dynamics and knowledge management domains. The systematic review followed the PRISMA method. We identified two major groups and one subgroup of the combination of system dynamics and knowledge management after examining and categorising 45 papers. Articles were searched for on Web of Science, Scopus, and LENS. We then concentrated on the categorisation of articles by theme. We discovered that system dynamics models were used as a component of a decision support tool or a knowledge management system in some instances, or the integration of knowledge management processes into specific systems. This study contributes to the growth of system dynamics as a methodology capable of generating novel ideas, highlighting limitations, and providing analogies for future research in a variety of academic areas.

Keywords: system dynamics; system dynamics modelling; knowledge management; knowledge management processes; knowledge management systems; systematic review; PRISMA

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1. Introduction

System dynamics (SD) is a distinct methodological technique for modelling and simulating a variety of different types of systems. Interconnectedness, feedback, adaptive capacity/resilience, self-organisation, and emergence are all fundamental concepts in systems thinking that are applied in system dynamics to assist individuals in making better decisions in complicated settings [1–4]. The field provides a philosophy for modelling and evaluating dynamic systems as well as methodologies for modelling and analysing dynamic systems. Additionally, the discipline provides approaches and tools for probing current decision-making and aiding decision-makers in their learning. There are two types of diagrams in SD. While Causal-Loop Diagrams (CLD) are used in qualitative modelling, Stock-and-Flow Diagrams (SFD) are used in quantitative modelling to develop models that can be simulated and quantitatively interpreted. The number of applications of SD methods and models has increased dramatically across a wide variety of sectors. Zanker et al. [5] provide an overview of SD applications, whereas Darabi and Hosseinichimeh [6] or Shepherd [7] provide details on individual applications.

Knowledge management (KM) has become a significant problem over the last few decades, and the Knowledge Management community has developed a diverse set of tools and systems for academic research as well as commercial applications [8]. For instance, Al-Emran et al. [9] focus on knowledge acquisition and knowledge sharing in developing countries. In the educational realm, Arpaci [10] applies cloud computing as a platform for the development of KM, while Al-Sharafi et al. [11] used chatbots for the establishment of KM.

KM can be perceived from the perspective of two levels. While the first one apprehends knowledge as an object and is associated with the technological level where knowledge-oriented technologies such as expert systems are applied. Different types of knowledge are used here, for example, procedural and declarative knowledge. The second one focuses rather on knowledge processes and takes place at the organisational level [12]. KM uses a variety of processes, collectively referred to as Knowledge Management Processes (KMP). This study focuses on the latter. At this level, several definitions of KM exist. The example of the traditional definition is the one provided by Demarest [13] who understands KM as a process of systematic underpinning, observation, instrumentation, and optimization. Nonaka postulates KM as a transformation between explicit and tacit knowledge in a form of Socialization, Externalization, Combination, and Internalization. Current research defines KM as a multidisciplinary concept that deals with capturing knowledge and its distribution [14]. Moreover, the focus on KMP is intensified. There is no need to enumerate various types of KMP here. Systematic reviews in which KMPs are presented and classified can be found. For instance, Costa and Monteiro [15] use the innovation perspective and distinguish Knowledge acquisition, Knowledge sharing, Knowledge codification, Knowledge creation and Knowledge Application. Rollett [16] adds the following processes: Knowledge planning, Creating knowledge, Integrating knowledge, Organizing knowledge, Transferring knowledge, Maintaining knowledge and Assessing knowledge.

There is a plethora of methods, tools, or techniques associated with the application of KM. They belong to areas such as decision support, knowledge and expert systems, or evaluation of intellectual capital in an organisation [17–19]. KM is associated with models in various manners. For instance, conceptual maps, object-modelling diagrams, business process diagrams, or project-related schemas have been applied for quite a long time [20,21]. Even simulatable models have already been used. The development of multi-agent models is quite spread in the economic domain and can serve as an example [22]. KM and SD modelling and simulations share several principles and perspectives as well. From this point of view, SD constitutes the model-based knowledge-oriented approach as qualitative models are used as a knowledge base for decision support. Quantitative models represent knowledge which captures the dynamics of the analysed system. It can be simulated and single scenarios can be developed and tested. Indeed, SD models can be considered as a type of explicit knowledge as it comprises knowledge unreachable anywhere else [2]. SD requires scenario generation and hypothesis testing. A modeller is essentially attempting to generate information and knowledge about the system under inquiry through this activity. When examined through the same lens, concerning a specific situation, modelling can be called knowledge development, and group modelling can be considered knowledge sharing or knowledge integration.

SD models are used across disciplines. There are several systematic reviews addressing system dynamics applications with a focus on different sectors. Brent et al. [23] present how SD was applied to understand and evaluate societal and policy-related problems in Southern Africa. Zanker and Štekerová [24] describe the application of SD in the realm of tourism. A systematic review focusing on the uncertainty and hydrocarbon resources modelling is presented by Koul et al. [25]. Uriona and Grobbelaar [26] addressed the application of SD in the area of policy analysis. Zanker et al. [5] provide an extensive analysis of domains in which SD has been applied as a methodological approach, specifically the domains of Business, Environment, and Health, and conclude that the largest group of systematic reviews is focused on the health domain. A paper published by Cassidy et al. [27] can serve as an appropriate example as the authors focus on the use of system dynamics and agent-based models for modelling and simulating health system behaviour. Chang et al. address the use of system dynamics for health systems as well [28]. Davahli et al. [29] focus on the application of SD to all areas of the health care domain from the ageing population, through the understanding of diseases, to health systems, per se. Morshed et al. [30] explore obesity using system dynamics and agent-based models. Nguyen et al. [31] focused on the application of System Dynamics, Discrete event simulations, Agent-based models, and

Hybrid simulation models on infections. Apparently, SD applications in various domains are numerous. However, at the same time, there is no link in the scientific literature to knowledge management. The rationale for the development of this study is the fact that diagrams generally fulfill the function of a transformation medium for the conversion of tacit knowledge to implicit or explicit knowledge. Hence, a research gap arises, which this systematic review tries to close and outline the existing link between SD and KM. So far, no systematic review has been published on the concurrent usage of KM and SD. A systematic search has the potential to uncover new opportunities for combining SD and KM while also bolstering existing applications of SD and KM. Additionally, a systematic search can be a source of knowledge and a starting point for new studies based on the synthesis of previous work. Additionally, a systematic search can summarise the domain's best practices. In these disciplines, we discussed each study from the standpoints of SD and KM and the domains in which these disciplines have been used. We then concentrated on the bibliographic synthesis and documenting the area's publication activity. Thus, the main objectives of this systematic review include (1) summarising current studies integrating both domains, (2) classifying a set of acquired research papers, (3) presenting content orientation, and (4) outlining the main research gaps or challenges.

The structure of this manuscript is as follows: after a brief introduction, the Section 2 discusses the systematic review process, including the search method, the inclusion criteria, and the study selection. Section 3 describes the systematic review's findings, including a synthesis in the form of a table that summarises all included articles and their essential characteristics. The papers are then classified and briefly described. The last section concludes the paper.

2. Materials and Methods

2.1. Research Questions

The main objective of this study is to address a specific research topic that occurred over the course of studying both fields. The first research question (RQ1) focuses on figuring out how knowledge management is captured in systems dynamics models. The second research question (RQ2) deals with the exploration of how system dynamics models can support knowledge management and its processes. The third research question (RQ3) investigates in what areas system dynamics models that capture knowledge management and its elements are used. Finally, the fourth research question (RQ4) tries to clarify in what areas system dynamics models are used as a knowledge management tool.

2.2. Search Strategy and Inclusion Criteria

We searched for papers using the PRISMA [32] approach. The PRISMA Checklist is available in Appendix A. The application of PRISMA methodology and related explicit criteria of eligibility enabled to avoid any bias associated with the process of article collection and selection. The search's primary purpose was to discover publications that combined system dynamics and knowledge management. We searched three scientific databases: Web of Science, Scopus, and LENS. The terms "System dynamics" and "Knowledge management" were used to execute the search. The article title, abstract, and keywords were all screened (for each database, these areas varied slightly, depending on the capabilities of the database). The search query included two constraints: language restrictions on articles written exclusively in English and publication type limitations on scientific papers published exclusively as articles in scientific journals. Table 1 summarises the various search queries and searched sections.

Table 1. Search commands.

Search Engine	Search Command
Web of Science	"system dynamics" AND "knowledge management" (Topic)
Scopus	TITLE-ABS-KEY ("system dynamics" AND "knowledge management") AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English"))
LENS	(title: ("system dynamics") OR abstract: ("system dynamics")) AND (title: ("knowledge management") OR abstract: ("knowledge management"))

After examining the databases, we eliminated non-English content that passed the search engines' language filter. We then combined all of the articles we discovered into a single collection and deleted duplicates. The final screening step was to eliminate articles based on their full-text analysis. We excluded one article here since it did not match the language criterion (the abstract did not show that the article was not written in English). Additionally, we rejected 33 articles for failing to include the SD diagram in the text or an appendix. In total, 45 articles were included in the review's synthetic section. Figure 1 illustrates the entire process.

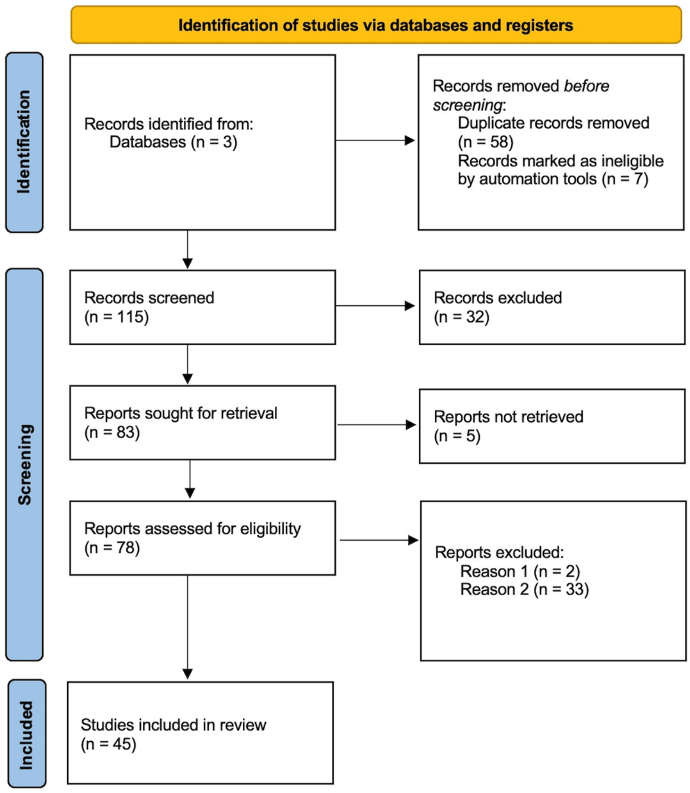

Figure 1. PRISMA flowchart (source: authors' work).

3. Results

There are two types of classifications that can be applied to the set of analysed papers. While the first one focuses on the interaction of SD methodology and KM concepts, the second one deals with content classification

Figure 2 summarises the former type of analysis, which represents the space of system dynamics and knowledge management interactions. There are three primary dimensions that can be identified in the published papers, namely:

- A type of SD modelling is categorised as the development of qualitative, or quantitative models (i.e., CLD or SFD diagrams)

- The knowledge lifecycle ranges from knowledge identification or creation to its application or replacement. The concrete design of this dimension depends on a model of the knowledge process, which is selected for the application.
- Work with either tacit or explicit knowledge.

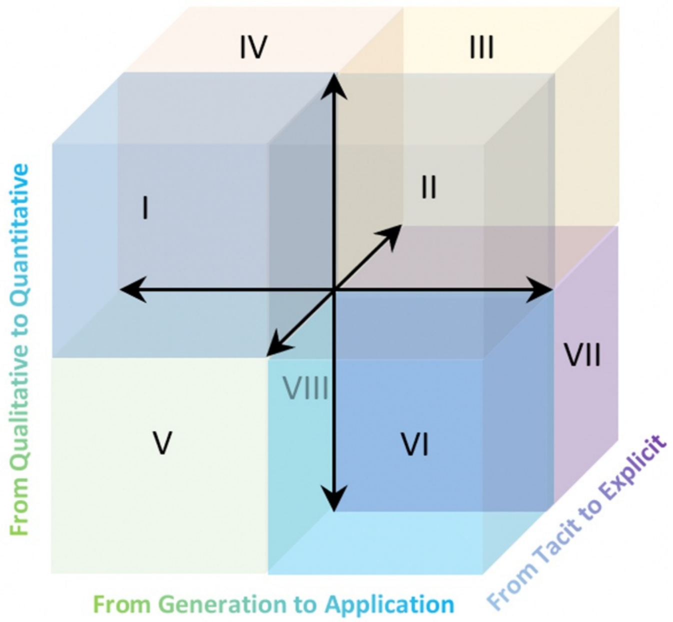

Figure 2. Identified systems dynamics and knowledge management space (source: authors' work).

Although the octant in Figure 2 consists of eight quadrants, the number can be increased based on the number of included knowledge processes or extension of the third dimension by implicit knowledge. The content of the quadrants is self-exploratory. For instance, quadrant V deals with using CLD diagrams to capture tacit knowledge in organisations as investigated, for example, in [33]. Quadrant I includes the studies focusing on quantitative modelling of knowledge identification or recognition, as presented for instance in [34]. Moreover, particular studies do not have to be located only in one quadrant. For instance, many papers deal with knowledge sharing, which can be associated more with the initial process, such as knowledge development or the application spectrum of the x-axis (e.g., [35]). Location can be thus a quite subjective task. There are also studies working with the whole spectrum of a single axis, for instance, applying both qualitative and quantitative modelling or focusing on all knowledge processes (e.g., [36]).

The full-text analysis confirmed the separation of the models into two major categories, namely:

- Group of SD models that deal with dynamic issues associated with knowledge management topics (knowledge management processes, application of knowledge, etc.)—Group A;
- A collection of SD models that are used as knowledge itself; the model is used to capture domain-oriented knowledge—Group B.

Additionally, the third group of models emerged from the full-text analysis, which fits into both preceding categories. While the previous two groups are associated with one-directional relationships, this category represents their mutual combination. The models contain elements of knowledge management, and, at the same time, the models capture knowledge about the modelled systems—Group C.

We classified 26 models as belonging to Group A, 18 as belonging to Group B, and 3 as belonging to Group C.

3.1. Categorisation of Articles

The following table introduces studies identified during the search in particular databases. The content of the tables corresponds with the presentation of the identified groups above. Table 2 contains all manuscripts which belong to Group A, Table 3 comprises studies from Group B and Table 4 introduces papers which are classified in Group C.

Table 2. Overview of papers of Group A.

Authors	Reference	Used Diagrams	Used Software	Modelled Parts of KM	Usage of SD Model
Ahuja et al.	[37]	CLD	Unspecified	Knowledge recognition capability, Knowledge acquisition capability, knowledge transformation capability, Knowledge application capability	To propose management strategies
Barforoush et al.	[38]	SFD	Vensim	Knowledge management, Knowledge sharing	To evaluate business strategies
Bi & Yu	[39]	CLD	Unspecified	Knowledge accumulation, Knowledge sharing, Knowledge conversion, Organization learning, Knowledge management capacity	To analyse the dynamic evolvement of IT absorptive capacity
Follador & Trabasso	[40]	CLD & SFD	Vensim	Knowledge generation, Knowledge sharing, Knowledge archiving, Knowledge transferring, Knowledge using	To represent KM system
Hong & Gao	[41]	CLD & SFD	Vensim	Knowledge gap, knowledge sharing and requiring related variables	To describe the knowledge-sharing process among internal members of the alliance
Honnutagi et al.	[42]	CLD	Unspecified	Knowledge management	To visualise and analyse quality assessment of undergraduate engineering education
Chen & Fong	[43]	CLD & SFD	Stella & Unspecified	Achieved knowledge management capability, Knowledge acquisition, the responsiveness of knowledge, Knowledge processes, Knowledge utilisation	To capture the best practice in learning developed knowledge management capability
Chen & Fong	[44]	SFD	Stella	The model is the same as the previous model from the same authors	To perform case analysis
Jonkers & Shahroudi	[45]	CLD	Vensim	Knowledge loss rate, Knowledge carrying capacity, Knowledge transfer rate, Knowledge generation rate	To affect decision-making by visualising causal relationships
Kundapur & Rodrigues	[46]	CLD & SFD	Vensim	Quality of knowledge management system, Knowledge worker satisfaction, Knowledge worker base	To understand benefits derived by knowledge workers
Kundapur & Rodrigues	[47]	SFD	Vensim	Knowledge workers and related variables	To understand the cycle of knowledge workers
Liu et al.	[48]	CLD & SFD	Vensim	Amount of knowledge transferred, Willingness to receive knowledge, Willingness to send knowledge, Knowledge stock	To model the practice of innovation in mega projects
Naseem & Shah	[49]	CLD & SFD	Stella	Knowledge management, Knowledge transferring, Knowledge sharing, Knowledge storage, Knowledge acquisition, Knowledge refinement, Knowledge alignment	To capture causality in the usage of knowledge management in organisations

Table 2. *Cont.*

Authors	Reference	Used Diagrams	Used Software	Modelled Parts of KM	Usage of SD Model
Nezafati et al.	[50]	CLD & SFD	Vensim	Individual tacit knowledge, Organization tacit knowledge, Individual explicit knowledge, Organization explicit knowledge	To monitor the level of knowledge inside an organisation
Otto	[35]	CLD & SFD	Vensim	New knowledge, Existing knowledge, Knowledge creation	To capture the willingness of knowledge sharing
Rich & Duchessi	[51]	CLD	Vensim	Organisational knowledge, Personal knowledge	To capture causality between personal and organisation knowledge
Sveen et al.	[52]	CLD	Vensim	Learning from events and incidents	As a tool for the development of sustainable knowledge and knowledge transfer
Weck et al.	[53]	SFD	Unspecified	Knowledge-based activities	To support decision-making toward knowledge management
Wu & Gong	[37]	CLD & SFD	Vensim	Knowledge recognition capability, Knowledge acquisition capability, Knowledge transformation capability	To propose management strategies
Xia et al.	[54]	CLD	Unspecified	Individual learning rate, Individual knowledge	To the model relationship between knowledge and tasks
Xiuhong	[55]	CLD	Unspecified	Knowledge stock of supplier, Rate of knowledge transfer, Knowledge stocks	To simulate knowledge transfer
Zaim	[36]	CLD	Vensim	Knowledge generation, Knowledge warehouse, Knowledge transferring and sharing, Knowledge utilisation	To capture the interaction between knowledge management processes
Zhai	[56]	SFD	AnyLogic	Student knowledge, Teacher knowledge, Knowledge gap, Knowledge transfer	To capture the transfer of knowledge between teacher and student
Zhang	[57]	CLD	Vensim	Explicit knowledge inventory and Tacit knowledge inventory of teachers and students	To capture the transfer of knowledge between teacher and student

Table 3. Overview of papers of Group B.

Authors	Citation	Used Diagrams	Used Software	Usage of SD Model
Armenia & Loia	[58]	CLD	Vensim	Part of the model for managing external and internal knowledge
Corben et al.	[59]	CLD & SFD	iThink	SD model development as part of the knowledge development process, to coordinate operational policy design
Edwards et al.	[60]	CLD	Unspecified	To prepare information for further analyses based on clinical and technology landscape inventories and to increase the effectiveness of knowledge management
Fernández-López et al.	[61]	CLD & SFD	Vensim	To capture knowledge management at universities
Jafari et al.	[62]	CLD & SFD	Vensim	To capture and understand complex social and economic behaviour of questions and answers market
Kopainsky et al.	[63]	CLD	Vensim	To capture local knowledge
Kristekova et al.	[64]	CLD & SFD	Powersim	To illustrate and convey the complex relationships between important constructs in the business process change
Labedz et al.	[65]	SFD	Vensim	As a tool to understand relationships between variables in the specific market
Miczka & Größler	[66]	SFD	Vensim	To explain the postmerger integration phase
Mishra & Mahanty	[67]	SFD	Stella	To capture knowledge in software development

Table 3. *Cont.*

Authors	Citation	Used Diagrams	Used Software	Usage of SD Model
Mishra & Mahanty	[68]	CLD & SFD	Stella	to capture knowledge in the outsourced industry of software development
Powell & Swart	[69]	CLD	Unspecified	To capture knowledge in several different parts of management
Rodrigues et al.	[70]	CLD & SFD	Vensim	To capture knowledge related to developing a new successful product
Schmitt	[71]	SFD	AnyLogic	As a part of the hybrid model of a knowledge management system
Swart & Powell	[72]	CLD	Unspecified	To capture knowledge requirements
Swart & Powell	[73]	None	None	To capture the behaviour of knowledge in the system
Yan	[74]	SFD	Vensim	As a decision support system
Yim et al.	[75]	CLD & SFD	Vensim	As a decision support system

Table 4. Overview of papers of Group C.

Authors	Citation	Used Diagrams	Used Software	Modelled Parts of KM	Usage of SD Model
Hafeez & Abdelmeguid	[76]	CLD & SFD	Vensim	Knowledge level, Knowledge in process, knowledge gap	To capture knowledge about human resource dynamics
Mishra & Mahanty	[77]	SFD	Stella	Knowledge transfer, Business knowledge level, Learning rate	To capture knowledge in a reengineering project
Spanemberg et al.	[33]	CLD & SFD	Stella	Knowledge sharing, Knowledge storage, Explicit knowledge, Knowledge creation, Knowledge utilisation	To understand the relationship between knowledge management processes and people management

3.2. Group A

3.2.1. Business

Business-related SD models are focused on various topics and applied in quite diverse economic sectors. The oil refining industry or airline industry can serve as an example. Barforoush et al. [38] used a combination of the Fuzzy Delphi and System Dynamics methods to capture the complexity of green company development in the **oil refining industry**. The SD model presented here is a hybrid of CLD and SFD with stated polarity constraints and SFD elements. The model is mainly composed of variables about the firm's performance, with a small portion devoted to knowledge management. The main outcomes reveal how the effectiveness of green business is affected by the green business budget. Focusing on **airlines**, Zaim [36] developed and presented a model with three interdependent components. The first section is devoted to knowledge management, with an emphasis on KMP and its inputs. The second section is devoted to business procedures in general. The final and least comprehensive section is devoted to aviation. The author forecasts the future evolution of the airline transformation using the model. This paper reveals that knowledge process-based activities have a mutual positive link. Moreover, organisational performance and activities show a positive relationship as well.

From the main focus perspective, developed models deal with business traits such as creativity, flexibility, knowledge-sharing capability, suitability, or profitability. Other associated "ities" are also included in models. For instance, Wu and Gong [34] established CLD and SFD with the goal of capturing the dynamics of **creativity** in the Ciaomi OIC's open community. Two SD diagrams are presented by the authors. The first is a subsystem devoted to broad knowledge management relationships, with the majority of variables committed to knowledge management and a smaller proportion to business operations. The authors then created SFD on top of the preceding CLD by extending the model's KMP-focused variables to include levels and flows concentrating on business processes. Based on the developed models and primary findings, the authors suggest the establishment and development of management strategies for open innovation communities. Ahuja et al. [37] investigated the relationship between knowledge management and **organisational flexibility**. To do this, the authors developed a CLD in which they concentrated on knowledge variables, distinct process stages, and the technology component of the business. The simulation model's result is the level of business performance under various scenarios with varying degrees of KM use. The authors state that CLD can be used for evaluating various long-term strategies for the effective implementation of organizational flexibility. Rich & Duchessi [51] specialised in knowledge management in consulting firms. The authors designed a CLD specifically for this topic that is devoted to KM, personal knowledge, and corporate knowledge. They work with variables related to Human Resources (HR) and work tasks in the diagram from a non-knowledge standpoint. The model's output is a prediction of the modelled company's **profitability**. Furthermore, Hong and Gao [41] concentrated on cloud computing's **knowledge-sharing capabilities**. The authors began by developing a CLD focused on KMP, KM, and the quality of inter-company partnerships. The authors constructed an SFD based on the created CLD, in which they characterised knowledge exchange and knowledge requirement as levels. The authors reported the level of knowledge sharing liquidation, the level of knowledge requiring barrier, and the level of knowledge gap as outputs from the simulation. Follador & Trabasso [40] assessed the Air Force's **suitability** for KM. The authors have produced a CLD describing the KMP. They then developed an SFD that primarily focuses on factors related to KM and KMP and includes variables related to human resources, workload, and employee training. The simulation results anticipate the organisation's total degree of knowledge and the level of knowledge transfer.

The intra-organizational set of KM activities can be presented as the last perspective which can be applied to the analysis of identified studies. The authors of these papers deal with activities, such as prediction of KM values, learning, knowledge sharing and exchange or measuring of knowledge. For instance, Chen and Fong [43] presented a CLD with a broad focus on KMP, which they then applied to SFD. The provided SFD is primarily comprised of KMP and knowledge work, with a tiny portion of the model devoted to **business processes**. Following that, the authors demonstrated how the generated SFD was used in three construction enterprises of varying sizes. The main output of the simulations represents the prediction of knowledge management values according to various scenarios in the six-year time duration. Otto [35] focuses on **inter-organisational learning** and has developed various SD diagrams to illustrate this concept. The first CLD examines two organisations' collaboration and the influence of their motivations and behaviours. The first SFD is based in part on the first CLD and is written from the perspective of a single business. The author then proposed a CLD concentrating on pharmaceutical company trust. Following that, the study presents many scenarios based on various amounts of trust and information. Simulation outcomes help to comprehend the main factors of the acquisition of knowledge in strategic alliances. Liu et al. [48] concentrated on **knowledge exchange** among many institutions in the context of megaproject innovation. The authors constructed a CLD model to represent the process of information exchange between research institutes, universities, and enterprises. The authors developed an SFD based on the CLD in which they classified the knowledge levels of the institutions stated previously as levels. Individual knowledge measures and the amount of knowledge transferred are the outputs of the simulation. The simulations produced various knowledge available for research institutions, universities, and other institutions. Nezafati et al. [50] created an SD model for **measuring knowledge** in businesses based on the Nonaka and Takeuchi model. Individual and firm-level knowledge are used as levels in the developed SFD. Following that, the authors discussed CLD, emphasising employee learning and incentive for individual learning. The authors then used the constructed model to data from 68 distinct firms. Models and related simulations capture different levels of knowledge, knowledge values, and the pace of knowledge transformation.

3.2.2. Education

In general, SD is applied in education widely. CLDs are used mostly in social science, business, or economics. However, from the KM perspective, the identified set of papers in this group was focused exclusively on education in the engineering domain. Honnutagi et al. [42] designed a CLD for this subject that is separated into seven major sections, one of which is KM. The author captures attributes and indicators of undergraduate engineering education. Zhang [57] developed an SD model with four subsystems (teaching subsystem, technological innovation subsystem, campus culture subsystem, and social service subsystem) that included KM and KMP variables. Following that, the authors detailed and interpreted each loop in the model. The primary outcomes of this study can support innovation processes by enhancing knowledge sharing and by providing resources among institutes. Zhai [56] concentrated on knowledge transmission in university-level **engineering and technology education**. The author developed SFD to facilitate information transmission between professors and students, and incorporated KMP into it. The simulation produces outputs, such as the level of the knowledge gap and the average level of knowledge. The author highlights possibilities of incentive and transfers thresholds to improve the effectiveness of teaching.

3.2.3. Managerial Disciplines

SD was applied in various managerial subdisciplines which were investigated both qualitatively and quantitatively. Namely, strategic management, human resources management, incident management, project management, management of supply chains, or IT management can be exemplified. For instance, Chen and Fong [44] examined assumptions concerning the performance of knowledge management systems. The authors created SFD with a focus on KMP based on the results of the generated analyses. This model is composed of seven interconnected tiers, the majority of which represent various aspects of KM and KMP. The authors created a model in which simulation enables the development configurations and settings of a KM **strategy** and the progress of KM performance over time. Naseem and Shah [49] concentrated on knowledge management in **human resource management**. They developed a CLD-specific KMP and HR that function as a self-reinforcing loop to validate this study methodology. The authors then developed a second CLD in which they elaborate on KMP and HR and the underlying business processes. The authors then introduced an SFD with two levels, one for employee productivity and one for employee knowledge. The simulation's result is the progression of the created levels' values. Sveen et al. [52] concentrated on **incident management** knowledge management. They accomplished this by creating a CLD composed of seven interconnected loops. While the majority of loops are centred on incident management, two are centred on knowledge acquisition from events and incidents. The simulation's result is the total number of incidents and their reporting over time. Jonkers and Shahroudi [45] constructed SD models with a focus on **project management** and, using these models, developed a project and product flight simulator. The authors began by introducing CLD through two loops that focused on the flight simulator in general. The authors then developed SFD in the area of strategies and hazards, based on the Predator-Pray paradigm. The resulting model is divided into many sections, one of which is devoted to KM and KMP in the context of strategy formulation and risk management. Bi and Yu [39] established a model concentrating on **information technology's** absorptive capability. The authors presented built CLD on this subject. The model is divided into six major sections, five of which are devoted to IT absorptive capacity and one to knowledge management and knowledge management processes. The developed model highlights that absorption of IT represents a dynamic circulatory process with an identifiable spiral trend. Xiuhong [55] discussed the transfer of knowledge throughout the **supply chain**. The author constructed a CLD in which KMPs and their relationship to various supply chain actors were explored. Simulation results enable an analysis of the amount of transferred knowledge inside a supply chain.

A specific set of studies focused on individual knowledge workers and their work. For instance, Xia et al. [54] concentrated on KMP's application to individual knowledge. The authors first created a CLD model of individual learning to create an agent-based model of interpersonal communication. The output of the models is the level of acquired knowledge and task completion. Kundapur and Rodrigues [46] proposed a success model for Knowledge Management Systems (KMSs). They used CLD to capture the service quality aspect of the KMS. Following that, the authors discussed SFD with an emphasis on the knowledge worker base. The authors describe the potential of SD for KM systems. Another paper written by Kundapur and Rodrigues [47] focused on employee acceptance of KMS by developing a KMP focusing on SFD from an employee perspective. The outcome of this model's simulation is a prediction of the number of knowledge workers, both new and experienced.

3.3. Group B

Analogically to Group A, this group comprises studies from various sectors of the economy. The authors of these papers demonstrate that KM and SD can be interconnected in various environments and domains. For instance, SD was used by Corben et al. [59] to characterise knowledge processes in the oil industry. Where they initially used CLD to capture knowledge regarding oil extraction efficiency and then established SFD on the same subject. Following that, they incorporated knowledge into the generation of policy options. Kopainsky et al. [63] employed SD to document indigenous knowledge in a Zambian community **of smallholder farmers**. The authors of the paper formed CLDs in workshops with the assistance of local farmers. The authors iterated on the same concept using various workshops with diverse attendees. The main outcome is represented by an outline of the potential to capture knowledge in rural areas. Labedz et al. [65] employed SD to collect information about the **used and new vehicle markets**. In SFD, two levels are used: the number of used automobiles and potential purchasers. The second SFD focuses on the new automobile market; it is divided into four levels: prospective consumers, new car manufacturers, new cars, and used vehicles. Subsequently. The authors present the CLD intending to capture knowledge about environmental issues in the automobile sector. Fernández-López et al. [61] place a premium on strategic knowledge management and its impact on the **performance of universities**. The authors employ CLD to capture information about the application of KMP in universities, as well as the transition of data to knowledge and knowledge to data. The authors present SFD employing three stocks, ungrouped data, grouped data, and original knowledge, based on the produced CLD. With the help of simulation, the authors can simulate the evolution of the Spanish universities' scientific production.

3.3.1. Decision Making

There are studies dealing with decision-making or decision support. Yan [74] developed a standard for **decision support in knowledge management**. External resources, external factors, resource-based management decisions, performance, and an SD model comprise the proposed model. The SD model fulfills the function of transforming inputs for decision-making and performance in this framework. The offered portion of the model encapsulates knowledge regarding the developing stages of clients, from unaware to loyal. The model's outputs include the number of different sorts of clients and the level of sales to those consumers. Yim et al. [75] emphasised **knowledge-based decision-making** through the application of SD. The authors used CLD to acquire knowledge about profitability for a local telecoms firm. They developed SFD on this model, with levels capturing variables like customers, profit, service, and knowledge. The simulation's output is a forecast of the number of consumers.

3.3.2. Managerial Functions

Various managerial functions are included in the presented studies. They demonstrate that KM and SD reach topics from different managerial domains. For instance, Armenia and Loia [58] provided a **system for managing external and internal knowledge** that incorporates SD to manage extracted external knowledge as well as extracted tacit or implicit knowledge. This framework encompasses human beings, automated procedures, and data clusters. Schmitt [71] develops a knowledge management system using a hybrid model. The author employs system dynamics, discrete event modelling, and agent-based modelling. The author models a **personal knowledge management system** using the SD paradigm and captures it using SFD. The author of this SFD depicts the process of tacit knowledge development and acquisition. Furthermore, Kristekova et al. [64] consolidated insights from case studies on **business process improvement** using SD. The authors base their approach on a variable called staff morale. This variable serves as the anchor for other variables relating to business process change in CLD. Additionally, the authors present an SFD based on the model presented. The authors suggest using SD as a proper approach to demonstrate and convey complex relationships. Rodrigues et al. [70] demonstrate how to use SD to collect knowledge in **new product development's change management process**. The authors describe a CLD devoted entirely to new product development. The authors create an SFD based on this model, focusing on workflow and the income and revenue of the PS. The simulation's output is a forecast of the quantity of work to be completed, the number of completed projects, and the profit earned. Powell and Swart [69] present CLD in their work, in which the authors capture knowledge about the many components of **various types of management and their interaction**. The article divides each loop from the main picture into sections and describes them, for example, risk management improvement and service improvement. Based on the publication, the authors published another paper [72] in which they detail the functions of the separate loops. Both studies produce a proposal of a methodology for the application of SD in KM.

3.3.3. Miscellaneous Knowledge Areas

There are studies in this group, which are hard to classify as they deal with quite specific issues or represent an application in a domain. For instance, Edwards et al. [60] presented a process for **enhancing diabetes patient understanding** that includes a clinical landscape inventory, a technological landscape inventory, an SD model, and analyses. The SD model is subdivided into two subsets: clinical landscape inventory and technological landscape inventory. The SD model's outputs are further evaluated using techniques, such as leverage analysis. The authors propose a newly constructed CLD that captures connections between health problems and premorbidity in the article. Miczka & Größler [66] integrated a fractured knowledge base using SD. The authors of this article discuss many components of the SFD model. A subsystem dedicated to the post-merger capability transfer can be found among these components. Additionally, the authors introduce CLD, a concept that captures expertise in the field of motivation for multi-stakeholder collaboration. The main finding of this study is that SD has the potential to achieve a higher level of **consistency in the conceptual integration process**. Swart and Powell [73] develop a model of **how knowledge behaves in a system**. This article does not directly capture the model of system dynamics. However, the authors employ SD principles throughout the study, and the model presented is partially based on equations resembling those found in SFD's level equations. The suggested model is based on the flow of knowledge between nodes, which is characterised using derivatives, integrals, and linear equations. The authors model the KMP primarily utilising SD approximations and the SFD diagram in terms of the SFD's equation structure.

3.3.4. Software Engineering

The application of KM in the field of software development represents a common approach in the current business. There are also attempts to include SD in the game. For instance, Jafari et al. [62] concentrated on knowledge development via SD in the domain of **questions and answers**. The authors present the CLD-focused operation of a question & answer platform in this article; variables included in the model are consumer payoff and expert payoff. The authors developed SFD based on CLD, in which they employed levels to represent questions, answered questions, corporate profit, and training. The SFD simulation produces values for answered questions, response prediction, research reputation, and asker satisfaction. Mishra and Mahanty [67] employed SD to **document software development skills**. By outsourcing to low-cost destinations, the authors were able to control project costs, schedules, and quality. The authors offer SFD, emphasising the software development sector in this work, capturing some knowledge about this sector. Mishra & Mahanty [68] focus on the software outsourcing business in another piece. The authors collect expertise for this sector from a variety of sub-sectors, including human resource management, control and estimation, and software development.

3.4. Group C

This subset of models is characterised by the fact that they employ KM KMP expressions while encapsulating domain knowledge. As evidenced by the distribution of articles, this group is quite small in comparison to the other two. These articles belong to the category where system dynamics is employed for KM or KMP modelling purposes; nevertheless, given the groupings, it was necessary to construct a separate sub-group for these articles, as they formally belong to both. Spanemberg et al. [33] examined the **shop floor workforce's expertise**. They captured the knowledge connected with this activity using CLD, where they employed KM and KMP ideas to define the variables; additionally, this model includes variables associated with shop floor labour. An SFD was constructed based on the CLD model to capture more knowledge about the research issue. The model simulation produces predictions about the states of variables, such as costs associated with employee training, profit, or employee autonomy. Hafeez and Abdelmeguid [76] emphasised the importance of **documenting knowledge about human resource dynamics**. The authors established CLD with an emphasis on knowledge management inside an organisation and SFD with an emphasis on personnel level and training. The authors presented employee skills per unit of time and employee behaviour using this model. Mishra & Mahanty's paper [77] is conceptually related to their previously published articles. The authors of this article discussed how to use CLD to capture knowledge work throughout a **reengineering project**. Following that, the authors propose SFD with an emphasis on the software reengineering sector, with the levels representing already developed tasks and misdeveloped tasks.

3.5. Synthesis

3.5.1. Bibliographic Synthesis

We conducted a bibliographic synthesis of the publications in Table 2 using Vosviewer [78]. We changed the keyword "systems dynamics" to "system dynamics" in three instances for two reasons. The first reason was the keyword's definition and the fact that both phrases had the same meaning in the context of the articles. The second reason for the adjustment was the bibliographic synthesis's predictive value; if the original term was retained, two nodes with the same meaning would be formed, rendering the bibliographic synthesis useless. Three articles were omitted from the bibliographical synthesis due to their lack of keywords. The result of the bibliographic synthesis is depicted in Figure 3. As illustrated in the figure, the most often used keywords were SD and KM. The right-hand side of Figure 3 illustrates the use of the keyword "modelling," which is associated with knowledge management. We can view it as a word at a higher level of abstraction than SD in the bibliographic synthesis we have constructed. The following articles are examples for selected clusters: Systems thinking [59,63]; Simulation [41,61]; Strategic planning [65,69]; Modelling [38,63,66,67] Knowledge management [42,59,65,67,69,76,79]; System dynamics [38,41,42,59,63,76].

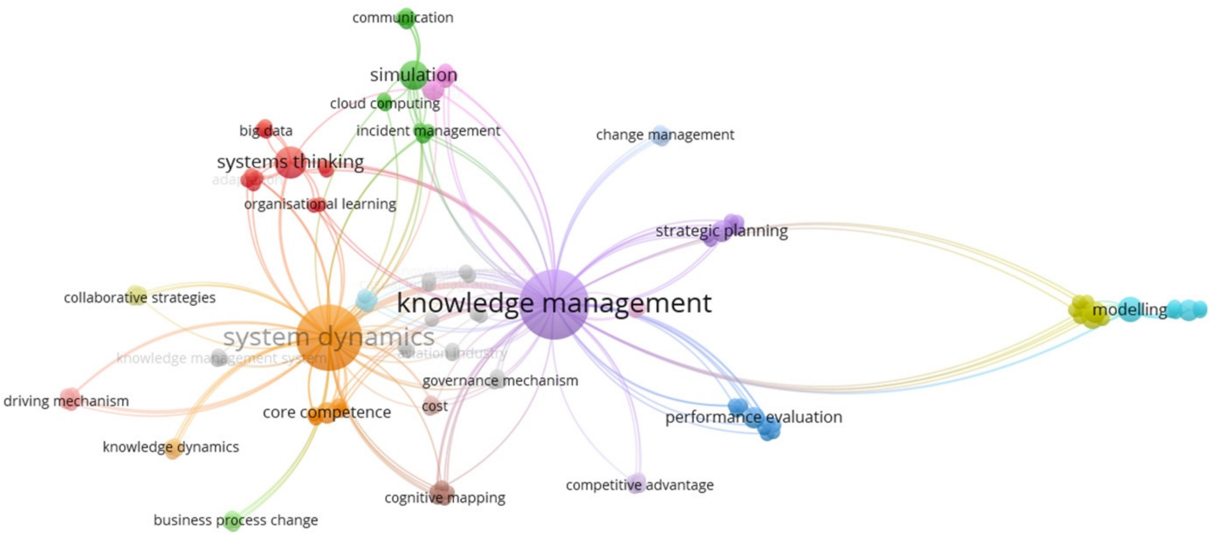

Figure 3. Conceptual network (source: authors' research).

As indicated by the intersection of system dynamics and knowledge management links, keywords such as "incident management", "simulation", "governance mechanism", "cognitive mapping", and "organisational learning", among others, continued to appear in articles devoted to SD and KM. We can classify the mutual use of SD and KM into two categories based on this intersection and Table 2. The first group comprises the industries in which SD and KM were applied in the papers examined. The second group encompasses the disciplines of knowledge management in which SD is applied. The domains covered by these categories should also be considered from the perspective of Table 2, as the subject matter of both categories is rather extensive, and not all intersections can be recorded through bibliographic synthesis.

3.5.2. Number of Contributions

The annual number of publications represents another outcome of the synthesis. The *y*-axis in Figure 4 indicates the number of publications, the *x*-axis indicates the year of publication, the blue column indicates articles in which SD is used as a tool for knowledge management, and the orange column indicates articles in which KM and KMP concepts are incorporated into SD models, and the grey column indicates the total number of publications. Three times in the graph, the sum of the blue and orange columns is less than the total for the grey column; this is because three articles fit into both categories thematically but are not counted in either. As illustrated in Figure 4, the combined SD and KM area has been very steady since 2008. The more significant outliers are identifiable in 2012 and 2013, when the number of articles published reached an all-time high. Between 2020 and 2021, a slight upward tendency can be observed.

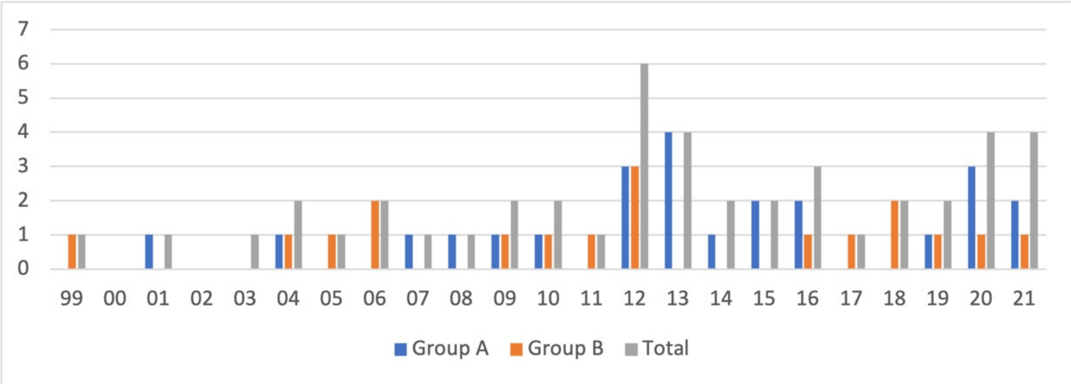

Figure 4. The of contributions (source: authors' research).

3.6. Research Questions

This section highlights the major findings of the study.

The answer to RQ1 is based on Tables 2 and 4, which outline six fundamental categories of variables related to knowledge management and its components. The first category encompasses both individual and collective knowledge (e.g., Individual explicit knowledge, Individual tacit knowledge, Organization tacit knowledge). The second collection of factors includes those pertaining to warehouses, capacity, and inventory (e.g., Knowledge carrying capacity, Knowledge stock, Knowledge storage). The third category comprises knowledge processes (e.g., Knowledge accumulation, Knowledge refinement, Knowledge transfer). The fourth category is knowledge capability (e.g., knowledge transformation capability, knowledge acquisition capability, achieved knowledge management capability). The fifth category comprises notions pertaining to the state of knowing (e.g., Knowledge gap, Knowledge level). The sixth category includes all remaining undeclared variables (e.g., Willingness to send knowledge, new knowledge, Existing knowledge)

As illustrated in Figure 5, the knowledge processes group is the largest. The next largest category is made up of the remaining variables. It encompasses a variety of KM-related topics for this group. This group might be further subdivided into smaller subgroups, such as the status of knowledge workers, which would include employee satisfaction and their desire to share and receive knowledge. Another subgroup would be concerned with knowledge in general (e.g., existing knowledge, new knowledge). Additionally, this group encompasses a subset of knowledge that often has its own category; however, in this case, this subgroup closely resembles the group devoted to individual and group knowledge. The following articles are examples for each category in Figure 5: knowledge processes [38,39,43]; knowledge warehouse, capacity, and inventory [37,43,48]; individual and group knowledge [46,48,50]; knowledge capability [37,43]; state of knowledge [41,56,76]

In relation to RQ2, SD was frequently employed to extract domain-specific information. Mostly, it was about capturing knowledge about a particular process, such as software development or establishing a new successful product. Additionally, this group includes the collection of indigenous knowledge, which was based on a questionnaire survey.

As illustrated in Figure 6, the second largest group is the use of others; this is a broad collection of small SD for KM applications. This category encompasses the application of SD from the earliest postmerger integration phase, through the capturing of knowledge requirements, to the coordinated formulation of operational policies.

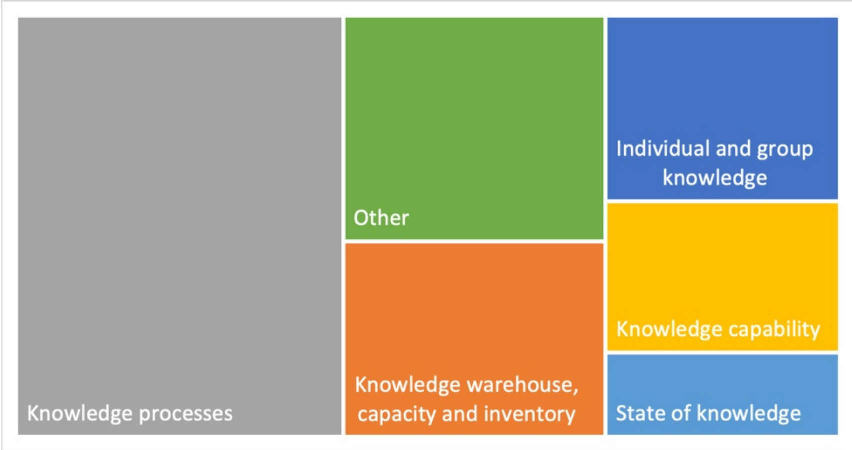

Figure 5. Types of knowledge management variables (source: authors' research).

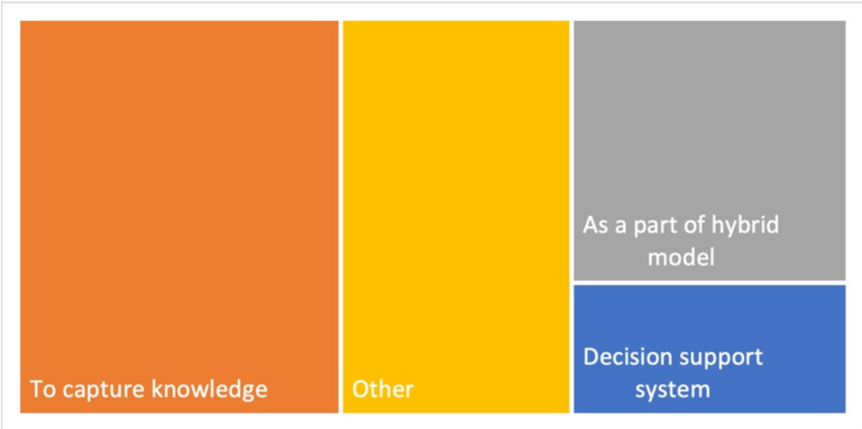

Figure 6. Usage of system dynamics in knowledge management (source: authors' research).

Another thematically distinct group is the one that includes the SD model as a component of the hybrid model. SD is primarily responsible for two tasks in this category, namely the transformation of information and knowledge and the capturing of correlations between the system's primary variables. The smallest group comprises SD models that provide decision support functions. The following articles are examples for each category in Figure 6: to capture knowledge [61,62,62]; as a part of a hybrid model [59,71]; decision support system [74,75].

SD modelled KM and its components in the following domains: business, education, general, knowledge management system, miscellaneous knowledge areas, miscellaneous management disciplines, other, product-related area, and software development. Figure 7 illustrates the distribution ratio (RQ3). According to Table 3, the SD was utilised as a tool for knowledge management in the following domains (in ascending order): business, miscellaneous management disciplines, software development, general, food system, health, miscellaneous knowledge areas, other, and product-related area (RQ4). The following articles are examples for each category in Figure 7: business [35,37,38,43,50]; miscellanies management disciplines [49,52,53]; miscellanies knowledge area [41,48,54]; education [42,56,57] knowledge management system [46,47]; general [40,44,58]; product-related area [45,70]; software development [62,77].

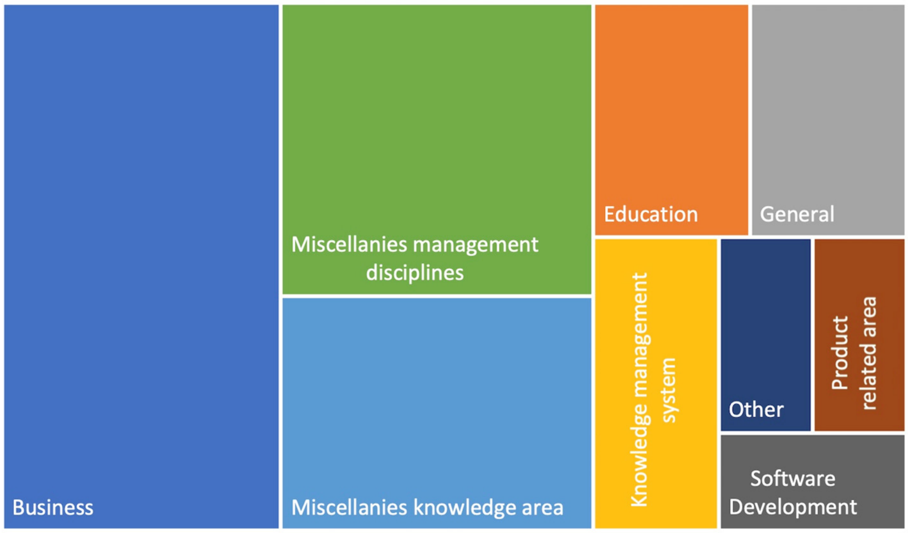

Figure 7. Distribution of fields where SD was used for KM and its elements (source: authors' research).

4. Conclusions

This is the first systematic review of the application of system dynamics techniques to knowledge management. We discovered 45 papers that combine system dynamics models and knowledge management. We classified papers according to two main perspectives. While the first one focuses on the conceptual level of KM and the nature of SD models, the second one focuses on the content analysis. In the former, three primary domains were identified, creating eight dimensions of SD and KM interrelationship. In the latter, two broad categories were identified, those that incorporate concepts from KM and KMP into SD models (i.e., knowledge as a subject of SD models) and those that serve as a tool for KM (SD models are used as particular knowledge in KM). This classification is perfectly aligned with the theoretical concept of knowledge levels, which differentiate knowledge management as a managerial discipline and the management of knowledge as a technical discipline [12]. Furthermore, there is a subgroup of models that fall into both categories. We demonstrate that the adoption of SD models increases in both groups based on the articles retrieved. The developed conceptual network reveals the existence of several clusters. Apparently, SD and KM represent two of the most significant ones. The connection is either directly or indirectly mediated by smaller clusters, such as simulations, incident management, systems thinking, or cognitive mapping. However, there are topics that stay separately in the network or are not connected with both primary clusters, e.g., strategic planning or knowledge dynamics. These clusters are characterized by the connection with one main cluster only, which is associated with the next main cluster via another small cluster.

Numerous research gaps were observed in our investigation. The first of them is based on the first group of models, namely those in which SD models capture the causal relationship between KMP and the industry variables being studied. Recently, the application of knowledge management has become a necessity in both the private and governmental sectors [79]. The SD tools can be advantageous in this regard. As this systematic study demonstrates, the application of SD in KM implementation is a relatively unexplored area compared to other soft disciplines [22]. At the same time, this approach to knowledge management implementation has the potential to communicate the benefits of knowledge management better while also comprehending the complexities of knowledge management integration, thereby making this method of implementation both more effective and easier to implement.

Second, our analysis demonstrates the relevance of SD to KMP requirements. As our study reveals, this convergence of the two disciplines is not yet a well-researched subject. Thus, our work opens new research pathways for both the application of SD for knowledge management and the implementation of SD for knowledge management, an example of which is the work of Edwards et al. [60]. Simultaneously, this study outlines the feasibility of creating methodological ways for applying SD in knowledge management. Additionally, this work demonstrates the feasibility of embedding system dynamics directly into knowledge management and/or into specific knowledge management components. Our review noted that this group of models included both SFD and CLD, with some CLDs being fairly similar to system archetypes. Several studies in this group adopted a holistic perspective, which is a necessary component of system thinking [80].

A third research need was discovered in the general application of KM and SD in combination. Given that SD is employed in a wide variety of fields [5]. Simultaneously, it is used in domains that place a high premium on knowledge and knowledge management [6]. Thus, this combination of SD and KM enables development into new domains and intensified application in existing fields. A case in point is healthcare, which is a knowledge-intensive profession [81], even though SD is already well-established [6]. While we discovered only one study [60] in this area, it is a topic with a lot of potential for application, as SD and KM are already widely utilised individually.

Our review suggests that the application of systems dynamics in knowledge management is not very widespread. However, it is gradually becoming more widely used in this field. As such, systems dynamics have a significant potential to support the creation of new knowledge through the creation of models, either SFD or CLD, and through simulation. Furthermore, SD has the potential to generate new knowledge or capture existing knowledge, and other knowledge management processes. Furthermore, this review points to the possibility of using system dynamics to implement knowledge management systems in the field of business. This possibility stems from the potential to capture implementation using CLD, where it is possible to identify key workers and then define implementation strategies. Despite the information stated above, some companies' implementation and work with knowledge management systems do not apply a comprehensive approach. As a result, system dynamics have the potential to alter this. The SD models and their simulations are associated with time. It means, that these models enable acquiring knowledge associated with a time horizon. This type of knowledge is quite hard to capture. This study reveals how knowledge coexist in the KM space, i.e., identifies relevant studies and put them into KM-oriented and SD-based context. Consequently, for instance, knowledge managers can learn how to apply CLDs to get tacit knowledge from experts and transform it into an explicit form.

There were a few limitations associated with this review. The first constraint was the risk of missing important studies if the term "system dynamics" or "knowledge management" was not included in the title, abstract, or keywords. We initially attempted to circumvent this limitation by altering the way we searched for articles. However, this alteration resulted in a disproportionate increase in the number of articles that did not match the systematic review's intended content, which, from a systematic review methodological standpoint, resulted in an improperly configured search query. This limitation is also associated with the exclusion of topics, which would be normally considered as a part of knowledge management-related initiatives such as intellectual capital [82,83], treasury management [84–86], or research and development management [87,88]. Furthermore, other analytical methodologies, such as text-mining [89] or Ambient Intelligence techniques and tools [90] were excluded. Second, we did not retrieve all studies; however, this was a minor constraint given the small number of papers that were not analysed (5 out of 84). Finally, more resources and record repositories can be accessed. This constraint, however, was overcome using three scientific search engines (WoS, Scopus and LENS), which collect products from various publishers. Adding additional scientific databases is unlikely to result in a significant increase in the number of unique papers but rather in a significant increase in the number of duplicate publications.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. PRISMA Checklist.

Section and Topic	Item #	Checklist Item	Location Where Item Is Reported
TITLE			
Title	1	Identify the report as a systematic review.	p. 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	p. 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	p. 2, para. 3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p. 3, para. 2.
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	p. 3, paras. 3
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Table 1
Search strategy	7	Present the full search strategies for all databases, registers, and websites, including any filters and limits used.	Table 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	p. 4, para. 1, Figure 1
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	p. 5, para. 1
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g., for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	p. 4, paras. 1,2; list, p. 5, para 1
	10b	List and define all other variables for which data were sought (e.g., participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	N/S

Table A1. *Cont.*

Section and Topic	Item #	Checklist Item	Location Where Item Is Reported
Study risk of bias assessment	11	Specify the methods used to assess the risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	p. 4, para. 1
Effect measures	12	Specify for each outcome the effect measure(s) (e.g., risk ratio, mean difference) used in the synthesis or presentation of results.	Tables 2–4
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g., tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	p. 5, list, paras. 2,3
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling missing summary statistics, or data conversions.	p. 14, para.1,3
	13c	Describe any methods used to tabulate or visually display the results of individual studies and syntheses.	N/S
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	p. 4, para. 1
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g., subgroup analysis, meta-regression).	N/S
	13f	Describe any sensitivity analyses conducted to assess the robustness of the synthesized results.	N/S
Reporting bias assessment	14	Describe any methods used to assess the risk of bias due to missing results in a synthesis (arising from reporting biases).	p. 3, para. 3
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	N/S
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Figure 1, Table 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	N/S
Study characteristics	17	Cite each included study and present its characteristics.	Tables 2–4, pp. 9–13
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	N/S
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g., confidence/credible interval), ideally using structured tables or plots.	Tables 2–4
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	p. 14, para. 1
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g., confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	N/S
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	N/S
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/S
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	p. 18, para. 3
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	N/S

Table A1. *Cont.*

Section and Topic	Item #	Checklist Item	Location Where Item Is Reported
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	p. 17, para. 1
	23b	Discuss any limitations of the evidence included in the review.	p. 18, para. 3
	23c	Discuss any limitations of the review processes used.	p. 18, para. 3
	23d	Discuss implications of the results for practice, policy, and future research.	p. 17, paras. 2,3p. 18, para. 1
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	N/S
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	N/S
	24c	Describe and explain any amendments to the information provided at registration or in the protocol.	N/S
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	p. 19, paras. 2,3
Competing interests	26	Declare any competing interests of review authors.	p. 19, para. 4
Availability of data, code, and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	N/S

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