Applications of Agent-Based Modeling and Simulation in Organization Management: A Quarter-Century Review through Bibliometric Mapping (1998–2022)

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Abstract

The purpose of this study is to review existing research on organization management that applied agent-based modeling and simulation (ABMS). First, we systematically identified 133 relevant articles published between 1998 and 2022 using the Web of Science (WoS) and EBSCOhost database. Second, we analyzed the characteristics of ABMS reported in the 133 articles. The results illustrated that ABMS becomes a means of theory development and demands enhanced transparency when extensively used by the focal research. Third, we used a bibliometric mapping approach to analyze the 133 articles visually. The results identified 36 key terms and four clusters: team behaviors under complex environment, organizational structure and design, knowledge management in organizations, and organizational decision-making. The analysis also showed which key terms are used as research fronts and which terms are emerging. Lastly, we suggest five promising research opportunities that should either be continued or be addressed in organization management.

Keywords: Agent-based modeling and simulation, bibliometric mapping, literature review, organization management.

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1 Introduction

Organizations often deemed as complex systems organize large numbers of highly interdependent parts to achieve their goals (Simon, 1962). In order to unpack such complex systems, most quantitative research follows a variable-based approach in social psychology (Smith and Conrey 2007) and equation-based modeling in management science (Sabzian et al. 2018). However, there has been growing demand for research design to advance towards more direct, dynamic, and flexible research methods, such as agent-based modeling and simulation (ABMS), to capture and understand the dynamics of phenomena that manifest among individual, group, and organization levels (Kozlowski and Chao 2012; Kozlowski et al. 2013).

ABMS is a bottom-up computational technique that is recognized and used by researchers from a variety of disciplines to study a range of emergent behaviors and phenomena (Hughes et al. 2012) and to simulate dynamic large-scale complicated systems (Abar et al. 2017). ABMS can simulate generative outcomes to yield higher level phenomena and can meet research purposes by building three core blocks: (a) agents (proxy for individuals, groups, or organizations), (b) environments (proxy for tasks, social networks, or organizational structures), and (c) interactions (proxy for self-governing or adaptive behavior due to learning from others; Sabzian et al. 2018). Agent-based model (ABM) and agent-based simulation (ABS) can be used interchangeably but strictly speaking, described in the following ways: ABM refers to “a model in which agents repeatedly interact” with a strong interest in a desired end-state, whereas ABS refers to “a model in which the dynamic processes of agent interaction are simulated repeatedly over time, as in systems dynamics, time-stepped, discrete-event, and other types of simulation” with an emphasis on simulating

dynamic processes of focal phenomena (Macal and North 2009, p. 88). However, ABMS will be used throughout this study because our research interest does not necessarily differentiate between ABM and ABS.

One of the main advantages of ABMS is that it allows researchers to create a theoretically-based model and to systematically vary numerous built-in parameters and assumptions that operate under different scenarios, which are challenging when one uses traditional approaches (e.g., field studies and lab experiments; Davis et al. 2007). Additionally, the process of emergent phenomena is rarely directly examined and is an inference based on cross-sectional data (Kozlowski 2015). ABMS offers advantages over traditional research designs for capturing such emergence.

In the field of organization management, ABMS has been used to explore certain aspects of research areas, such as leadership (e.g., Serban et al. 2015), team cognition (e.g., Dionne et al. 2010; Palazzolo et al. 2006), and organizational design (e.g., Rivkin and Siggelkow 2003). However, the adoption of ABMS in organization management is still in a nascent stage (Gómez-Cruz et al. 2017). As discussed in the method section below, this study analyzes papers that date from 1998 to 2022, which shows that the application of ABMS in organizational research is not necessarily new.

Furthermore, multiple relatively old papers were omitted from our analysis due to the article type (e.g., theoretical, review) or no explicit reference to ABMS. Several were related to ABMS in organization management, indicating that the benefits of ABMS in this field were noticed early on. For example, although the term ABMS was not explicitly used, Carley and Svoboda (1996) used multiple agents to simulate individual and structural learning and examined the emergence of organizational adaptation. This attempt made their work one of the earliest to address organization management issues through ABMS. In *Organization Science*, one of the journals that published the largest number of articles analyzed in this

study, Anderson (1999) argued that organization science research can be further advanced by constructing complex adaptive systems using multiple agents based on complexity theory, contributing to the subsequent proliferation of ABMS-related publications in this journal. Nevertheless, it is only in the last few decades that the use of ABMS in organization management has begun to spread. To further advance its application, it would be beneficial to clarify its current achievements and challenges. We believe that a systematic and data-driven review of the current status of ABMS applications in organization management is necessary and will offer insights into the direction that future research should follow.

In this study, organization is described as "a consciously coordinated social unit, composed of two or more people that functions on a relatively continuous basis to achieve a common goal or set of goals" (Robbins and Judge 2013, p. 5). For an organization like the one described above, organization management is defined as "coordinating and overseeing the work activities of others so that their activities are completed efficiently and effectively" (Robbins and Mary 2012, p. 8). The description's defining characteristics include the focus on management within organizations and the management of other people's work. When selecting literature for analysis, we followed Gómez-Cruz et al. (2017) and referred to the subcategories in management by the Academy of Management (2022); the details are described in the method section.

We use the bibliometric mapping technique to review the articles that applied ABMS in the organization management domain. Bibliometric mapping is defined as a quantitative study of bibliographic data; it is a method used to examine large volumes of literature and visually represent intellectual connections in a scientific knowledge (Cobo et al. 2011). Mapping bibliometric data through visualization and networking has experienced the large growth (Cobo et al. 2011; van Eck and Waltman 2009). Recent examples of this technique in related fields include Markoulli et al.'s (2017) study, which reviewed human resource

management articles and identified key topics and key themes for future research, and Byington et al.'s (2018) work, which analyzed articles published in the *Journal of Vocational Behavior* and created a co-citation and topic map.

This study contributes to the organization management literature in the following ways. First, our study specifically focuses on the review of ABMS in organization management topics and generates useful information for organization management researchers who want to apply ABMS in their future research. In this sense, our study complements other review studies of ABMS applications in related fields, including business process management (Halaška and Šperka 2018), human systems (Bonabeau 2002), management science (Sabzian et al. 2018; Wall 2016), organization science (Fioretti 2013), organizational psychology (Hughes et al. 2012), and organization and management research (Gómez-Cruz et al. 2017; Harrison et al. 2007).

Second, our study uses bibliometric mapping to identify the current status visually and to shed light on future research opportunities. In the end, our results reveal that the 133 focal articles consist of four clusters that range from team-level management to organization-level decision-making. Key research terms, such as *project*, *knowledge transfer*, and *decision-making*, have evolved into research fronts, whereas terms such as *team*, *information*, and *decision* are identified as emerging terms. Our analysis shows that each cluster has several specific research gaps, such as incorporating agent diversity and group interactions. We argue that integrating ABMS in organization management research can benefit and complement empirical studies and add precise measurements to existing theories. Our study also suggests that a well-described and replicable ABMS presentation is demanded because the use of ABMS helps overcome methodological challenges. Additional value will come from research that incorporates ABMS with influential constructs and associated theories in organization management.

2 Method

2.1 Sample

We conducted a similar process as Markoulli et al.'s (2017) four-stage process, which identifies target articles by searching the Web of Science (WoS) database, to identify the literature for our review (see Fig. 1). First, we searched the WoS and EBSCOhost database for articles that contained at least one of the relevant keyword to this study up to March 2022 (e.g., "multi-agent model," "multi-agent modeling," "multi-agent computational modeling," "multi-agent simulation," "multi-agent model," "agent-based model," "agent-based modeling," "agent-based computational modeling," "agent-based simulation").

However, most of the literature was obtained through the WoS database; the EBSCOhost database was only used as a complement to WoS. This is because the Annual Meeting Proceedings of the Academy of Management, the largest academic society in the field of management, is not available on WoS, whereas they are available on EBSCOhost. In addition to screening the above keywords, EBSCOhost collects literature by limiting the target journals to Academy of Management Annual Meeting Proceedings. Words with different spellings between American English and British English (e.g., modeling/modelling) were searched using both spellings. Likewise, words that can be spelled with or without hyphens (agent based/agent-based) were searched using both spellings. This initial search returned 17,220 articles (17,126 from WoS, 94 from EBSCOhost) between May 1992 and March 2022.

INSERT FIG. 1 ABOUT HERE

Second, our review focuses on the journals, proceedings, and book sections broadly related to the organization management field. We used the screening function of the WoS

database and limited the search by selecting the relevant academic fields among the WoS categories, such as “Management,” “Operations Research Management Science,” “Business,” and “Psychology, Applied.” To accurately capture the trend of actual ABMS use in organization management, articles mainly focused on conceptual development and reviewing previous literature were eliminated using the article type function. This process resulted in 1,661 articles from the WoS database. Also, we decided to include proceedings papers in our review because they can confirm the latest ongoing research topics.

Third, we collected 1,755 articles by intersecting two sets of data that were derived from the above two steps. Fourth, we manually screened 1,755 articles, first by their titles, and then by their abstracts and contents. When reviewing individual papers, screening was conducted depending on whether the paper contained actual ABMS model or data generated through simulation and whether the content could be classified as organization management. Regarding the actual ABMS model and data, papers that do not contain any ABMS model and data such as conceptual papers and review papers were usually marked with a word such as “conceptual” or “review” in the title or abstract. If such a word was identified and no actual model or data were contained in the paper, it was excluded from the analysis. However, as an exception, a few conceptual/review papers were included in our sample when they offered detailed discussion of actual usage of ABMS or contains various actual simulation results from previous studies (e.g., Martell et al., 2012).

To determine whether a paper was classified as organization management, we followed the definition of organization management mentioned in the previous section. We made it a prerequisite for the papers to be about management within an organization and about managing people. Furthermore, to avoid subjectivity in judgment as much as possible, we followed Gómez-Cruz et al.’s (2017) approach and referred to the Academy of Management’s (2022) subcategories of management. To be more specific, topics classified as

micro- or meso-clusters in Academy of Management's (2022) classification were considered to fall within the topic of organization management. On the contrary, most of the macro topics in this classification were not necessarily categorized as intra-organizational or people management. For example, topics related to managing relationships with other companies outside the organization, such as supply chain management, are excluded. Likewise, other topics that are outside our scope include production management, which is usually within the organization but does not necessarily concern the management of people. Therefore, the authors of this study discussed and agreed to exclude the macro topics, unless the paper clearly dealt with issues related to people management in organizations. Some of the macro topics such as strategic leadership and strategy process are clearly concerned with people management although they technically fall within the macro category. If that is the case, we included them in our sample. As a result, given Gómez-Cruz et al.'s (2017) organizational management domain based on the Academy of Management (2022), this study mainly focused on domains such as organizational behavior, human resources, strategic management, and decision-making.

Using the above perspective, one of the authors checked the title of each paper to identify those that should clearly be excluded; 635 papers were extracted (562 from WoS and 73 from EBSCOhost). The author then checked the abstracts and contents of those 635 papers and extracted 136 papers that met the above criteria (105 from WoS and 31 from EBSCOhost). In the process of extracting the papers, the authors met multiple times to discuss whether to include several papers that were difficult to judge. Finally, we excluded duplicates (e.g., when a proceedings paper was later published as a journal paper, the entry for the journal version was retained), which yielded our final sample.

This final step retained 133 articles published between 1998 and 2022. In other words, only approximately 0.8% (133 of 17,220) of the published ABMS articles fell in the

field of organization management; most of the ABMS articles were related to computer science, engineering, and economics. This observation was consistent with Harrison et al.'s (2007), which concluded that computer simulation studies for management and sociology fields lag behind those in economics and political science fields. Nevertheless, the number of articles published per year has increased with a compound annual growth rate of 12.0% from 1998 to 2021 (see Fig. 2; note that 2022 publications were excluded from the growth rate calculations due to a shorter aggregation period than other years). The use of ABMS in organization management is still in the process of gradually expanding; the number of publications per year is not necessarily large (0–17 articles per year). Therefore, we need to be cautious when judging trends, though the graph does indicate that the number of publications has been increasing, especially since 2007. The most active discussions on this topic take place in the proceeding papers for the *Academy of Management Annual Meeting Proceedings* (i.e., 28 articles, 51.9% of total proceedings papers) and in the journal papers for the *Leadership Quarterly* (i.e., 7 articles, 9.2% of total journal papers) and *Organization Science* (i.e., 6 articles, 7.9% of total journal papers).

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2.2 Bibliometric mapping

To conduct a literature review, we employed the VOSviewer bibliometric mapping (van Eck and Waltman 2009). Bibliometric mapping is a method used to visualize the relationships among various studies based on more objective indicators, such as the co-citation index (Callon et al. 1983). This method complements our review, providing us with more solid basis to analyze the structure of current academic knowledge (Cobo et al., 2011). This approach also has advantages over prior review approaches, such as the capacity to (a)

visualize the relationship among existing papers, (b) allow for a larger volume and more comprehensive analysis, and (c) provide a more detailed and solid perspective on the position and context of existing research with less subjectivity from individual researchers (Andersen 2021; Byington et al. 2018). First, bibliometric mapping has the advantage of being visual. For example, VOSviewer bibliometric mapping can create bibliometric networks and provide overlay visualization to show literature developments over time (van Eck and Waltman 2009). Second, bibliometric mapping facilitates a broader scope of literature reviews. Markoulli et al. (2017) used this approach to review 12,157 human resource management articles and identified 100 topics for future research. Without a bibliometric mapping method, such a large volume of literature reviews and resultant implications would be difficult to achieve. Third, bibliometric mapping enables more detailed reviews with evidence-driven information (such as the co-occurrence of keywords) about the analyzed literature, which reduces the potential for a biased representation of the literature.

With the understanding of the relatively small volume of publications in our focal scope, we aim to provide researchers with data-driven insights into the current status and future trajectories of ABMS applications in organization management. One of the advantages of bibliometric mapping is that it can handle a large volume of literature; however, it is not always necessary to use a large volume of articles if the purpose of using this method is to visualize the relationships among existing studies, enhancing the objectivity of the review. Rocha et al. (2021) is an example of the use of bibliometric mapping from this perspective; by focusing on specific themes, a thematic synthesis was attempted to understand the relationships among existing studies. Similar with the present study, Rocha et al. (2021) focused on a relatively new area (leadership in the context of university 4.0) and analyzed a relatively small sample of 224 articles. Even if a study does not aim to analyze a large

sample, it can still be reasonable to employ the bibliometric mapping method from a perspective that provides a data-driven visualization of existing research.

2.3 Mapping procedure

To identify key terms, clusters, and trends in the sampled 133 articles, we uploaded the article records (titles, abstracts) into VOSviewer. Terms with similar meanings were grouped together and integrated into the same terms (e.g., "strategies" and "strategy"). VOSviewer applies an objective technique of natural language processing to identify the primary terms of 133 articles. More specifically, VOSviewer first identifies the central topic of each paper from the imported title and abstract of the paper. Nouns and noun phrases (e.g., nouns combined with adjectives) are then automatically extracted, and these extracted words are linked to each paper. The association strength (i.e., the degree to which those words are used in the same article) is then calculated for each pair of phrases, and a map is created reflecting the strength in distance for each word (Byington et al. 2019; van Eck and Waltman 2009; Waltman et al. 2010).

To ensure that term relations and network mapping were reliably assessed, we included a term that appeared in at least seven articles in our co-occurrence analysis. In VOSviewer's co-occurrence analysis, it is useful to set a threshold of at least 10 occurrences in the literature, which is also the default value in VOSviewer, to increase the reliability of the mapping and to prevent meaningless phrases from being extracted (e.g., Markoulli et al. 2017). Although we followed other studies' practice and initially set the threshold at 10, this resulted in 41 terms with the majority being extremely generic words and phrases because the sample used in this study was smaller than in other studies that used bibliometric mapping.

To deal with this issue, we lowered the thresholds and adopted seven as the criterion for co-occurrence because that is when almost the majority of terms could be interpreted as meaningful. This threshold resulted in 77 terms being identified. We excluded highly generic

noun phrases that do not constitute any specific research meaning (e.g., agent, framework), which resulted in 36 key terms. We then ran a VOSviewer co-occurrence analysis to identify (a) the number of times each of the 36 key terms occurred, and (b) the association strength to which these key terms co-occurred. The VOSviewer algorithm spatially drew relations between key terms; the distance between key terms in the map indicates their degree of co-occurrence (Waltman et al. 2010). Based on this bibliometric mapping, VOSviewer further identified four clusters, adopting the algorithm that maximizes the association strengths of each term pair in the same cluster while minimizing the size of the cluster Markoulli et al., 2017; Waltman and van Eck,2013). Fig. 3 shows the co-occurrence map of the 36 key terms referenced in the 133 articles and the four identified clusters.

INSERT FIG. 3 ABOUT HERE

Although we eliminated highly abstract terms in the analysis, the map still has several terms that are relatively ambiguous (e.g., organization) and can be used interchangeably with other terms in a different cluster. Since the network of the map is highly centralized and the change in these terms may alter the nature of the clusters, we checked the robustness of the network through a supplement analysis. More specifically, we created two additional bibliometric maps: in one map, the term “organization” and two other similar terms (i.e., “company” and “firm”) were combined into the word “organization,” and in the other, all these three words were removed. The two additional mapping results showed that all the terms originally categorized as cluster #2 and #3 remained in the same clusters.

The six terms among the eight terms labeled as cluster #1 belonged to the same cluster. The two terms moving from cluster #1 to cluster #4 are “member” and “team,” which are important terms characterizing cluster #1 because cluster #1 is mainly concerned with

team management as delineated in the next section. However, this change is understandable since cluster #4 originally contains papers regarding both team-level and organization-level phenomena and elimination of the term "firm" in cluster #4 makes "member" and "team" more relevant to cluster #4. Considering cluster #1 still contain team-management-related terms such as "manager", "task," and "employee," the core nature of the cluster is still consistent in the additional analysis.

Finally, seven out of nine original terms in cluster #4 moved to other clusters, suggesting that this cluster may not be as robust as other clusters. Nevertheless, the core terms in this cluster "decision" and "decision-making" were retained. Furthermore, in one of the two additional analysis, three of the seven terms labeled as another cluster generated a new cluster. This implies that there may be several categories within the original cluster #4 and this cluster is characterized by its proximal components (decision-making) and peripheral factors adding nuances to the cluster. Taken together, cluster #2 and #3 are robust across different conditions, cluster #1 slightly changed but did not show fundamental inconsistencies, and cluster #4 retained the core nature across different conditions although the peripheral characteristics of this cluster may not be as strong as those of other clusters. These additional analyses indicate that there is sufficient basis to believe that our bibliometric map is appropriate for further examination.

3 Results

3.1 Characteristics of agent-based modeling and simulation applications

In this section, we address how ABMS is applied in organization management. Although the development or assessment of ABMS itself is also an important topic, in the present paper, we focus only on the application of ABMS to the organization management context (for a detailed description of ABMS research itself, see Davis et al. 2007; Fioretti 2013; Harrison et al. 2007; Smith and Conrey 2007). We have observed three characteristics for how ABMS is

used in organization management. First, 86.4% (95 of 110 articles) of the examined articles applied ABMS to theory development, and there was a growing trend toward integrating ABMS with other analytic approaches (only the 110 articles whose contents could be confirmed through full papers and/or abstracts are included in the analysis. The same principle applies to the analyses below). Second, researchers have used different formats to describe the study models (e.g., equations, illustrations, and flowcharts), and there is much room for improvement. Third, while 15.1% (14 of 93 articles) of the reviewed articles used Kauffman's (1993) NK model to address organizational-level questions, researchers have developed customized models per research interest.

3.1.1 ABMS research objectives

In general, researchers aimed for either theoretical purpose (i.e., theory development and theory testing), methodological purpose (i.e., generalizability, precision in control and measurement, and authenticity of context), or mixed purpose (Turner et al. 2017). About 86.4% (95 of 110 articles) built a model to explain the behavior of agents (e.g., being proxy for individuals) and consequently extending the existing models and theories (e.g., Siggelkow and Levinthal 2003) for the purpose of theory development. For this objective, researchers essentially used ABMS to model hypothetical cases, to systematically vary the values of the parameters and assumptions, to conduct rigorous simulations, and to draw conclusions based on simulation results. As ABMS permits unconstrained simulations to generate rather than deduce the consequences of these processes (Harrison et al. 2007), it serves as an ideal tool for such an explorative study. Moreover, we noted a growing trend toward integrating ABMS with other analytical methods (e.g., case study, archival records, field data, or empirical studies) in organization management (e.g., Kogut et al. 2014; Levine and Prietula 2012). We highlight more details in the section on future directions.

3.1.2 Format of ABMS presentation

With regards to the format of the ABMS presentation, equations, illustrations, flowcharts, tables, pseudocode, "Unified Modeling Language" (UML; Huget 2002), and the "Overview, Design concepts, and Details" protocol (ODD; Grimm et al. 2010) are the most prevalently used techniques to describe a model representation. However, our review raised concerns about methodological transparency defined as "the degree of detail and disclosure about the specific steps, decisions, and judgment calls made during a scientific study" (Aguinis et al. 2018, p. 84). For example, approximately 26.1% (24 of 92 articles; 12 of these 24 articles are published within the last 10 years) of the examined articles did not clearly describe the initialization or the generative development of the model: What is the initial state (at time t = 0) of the model space? How do the values of variables vary during simulations and within what ranges? Without a clear explanation of the initial or boundary conditions of ABMS, other researchers cannot understand the processes properly; thus, the models and results cannot be accurately replicated and learned. Approximately 7.6% (7 out of 92) of the articles described the model in plain text, which may make it even more difficult to capture the precise sequence of the modeling procedures.

More importantly, it is critical to ensure that other researchers can replicate and further build upon the presented model. For example, Miller et al. (2006) extended March's (1991) classic model on exploration and exploitation to study organizational learning. We believe that the importance of a structured model presentation can equal the critical role of descriptive statistics in empirical studies, which enables researchers to present the data in a more meaningful and standardized way. We urge future organization management researchers to cautiously report the details and to increase the transparency of their computational models. We offer these recommendations in the section on future directions.

3.1.3 ABMS framework and platform

Although various ABMS models were used in our samples, approximately 15.1% (14 of 93 articles) of the reviewed articles used the NK model fitness landscapes (Kauffman 1993) to resolve the research questions. The NK model was first developed in evolutionary biology (Kauffman 1993) and then contributed greatly to the literature on organizational design (Davis et al. 2007). The NK model allows scholars to study complex organizations by defining two key parameters: the number of activity choices (N) and the number of interdependencies between activities (K) (Wu and Sekiguchi 2022). Common research questions can be suitable for applying the framework of NK fitness landscapes, such as "How long does it take to find an optimal point (e.g., high-performing strategy)?" or "What is the performance of the optimal point?" (Davis et al. 2007). In our review, we observed that most researchers applied the NK model to address organization-level questions—for example, "How should firms organize to explore and search such an altered performance landscape?" (Siggelkow and Levinthal 2003, p. 650) and "How do environmental turbulence and complexity affect the appropriate formal design of organizations?" (Siggelkow and Rivkin 2005, p. 101). Thus, the use of the NK model help scholars answer the question of how organizational managers make decisions or how they design organizations.

Researchers on organization management often need to conceptualize specific processes and to develop customized computational models to answer different research questions (e.g., "How does the pattern emerge and change over time?") or design environmental jolts (e.g., membership turnover). According to research needs, model development effort, and model scope, various ABMS platforms have been chosen to tackle complex research questions and overcome methodological challenges. Zhao et al. (2022) used the NetLogo toolkit (Wilensky 1999) to examine diffusion of helping behaviors in project teams. Wang et al. (2009) used the Repast toolkit (North et al. 2006) to model knowledge sharing. The Swarm toolkit (Minar et al. 1996) was applied for studying the effect

of power disparity on group performance (Tarakci et al. 2014). Although each toolkit is commonly used in ABMS (Abar et al. 2017), NetLogo is the most common toolkit in our sample (22.6%; 21 of 93 articles), and only a limited number of studies used Repast (3.2%; 3 of 93 articles) or Swarm (1.1%; 1 of 93). This may be attributed to the fact that NetLogo is much easier to implement models than other toolkits, due in part to its simple modeling language and nice graphics (Bajracharya and Duboz 2013; Hakrama and Frasheri 2016). A detailed comparison of various ABMS platforms can be found in Abar et al. (2017).

3.2 Characteristics of four clusters

To identify the theme in each of the four clusters, we first classified 133 articles that belonged to one of the four clusters. An article was deemed to belong to a certain cluster if (a) the majority of the key terms mentioned in an article's title and abstract belonged to a single cluster and (b) an article's title and abstract included at least one of 36 key terms (129 of the 133 articles contained at least one key term). When the same number of key terms belongs to different clusters or the contents of the paper are obviously misaligned with the assigned cluster based on the above-mentioned process, we manually assigned an appropriate cluster in accordance with the primary theme of the paper. We then labeled the four clusters based on the themes of the associated publications.

The first cluster, team behaviors in complex environments, focuses on individuals and teams, the smallest units of organizational management. This cluster is mainly related to the domain of organizational behavior and particularly addresses the use of ABMS to elucidate how managers and members are involved in the execution of tasks in a team. The second cluster, organizational structure and design, is also related to individuals and teams, but while cluster #1 deals with emergent phenomena and other micro-level behaviors mainly from the interactions at the individual level, the main research interest in this cluster is how organizational structure, design, and human resource management affect the behavior of

organizations. The third cluster, knowledge management in organizations, differs from clusters #1 and #2 in that it focuses exclusively on organization-level behaviors. In particular, it focuses on how knowledge and information relevant to strategy are created and shared within the organization. Finally, the fourth, organizational decision-making, involves how teams and organizations make decisions based on certain knowledge and information.

In Table 1, we show four clusters: the identified key terms in each cluster, beginning with the highest impact (i.e., the highest co-occurrence rate) terms; and the top three most cited articles belonging to each cluster. Fig. 4 reveals the comparative growth of each of the four clusters in terms of the number of articles published from 1998 to 2022. We noted that the overall literature has grown steadily during the past two decades at a compounding growth rate of 12.0% (also see Fig. 2); the body of research was characterized by continuously evolving and shifting perspectives, implying that no single cluster was completely predominant although the second cluster (i.e., organizational structure and design) is somewhat larger than other clusters; and there were several rounds of rapid turnaround for publications (e.g., 2005–2006, 2014–2016, 2020–2021), which could be attributed to a few highly cited review articles related to the applications of ABMS (e.g., Gómez-Cruz et al. 2017; Hughes et al. 2012; Kozlowski et al. 2013). We elaborated on the four clusters starting from teams to the level of the whole-organization.

INSERT TABLE 1 AND FIG. 4 ABOUT HERE

3.2.1 Cluster #1: Team behaviors in complex environments

The first cluster (i.e., team behaviors in complex environments) primarily consists of micro-organizational topics associated with teams, managers, and members, along with execution of tasks and complex environments. One of the featured articles associated with this cluster

examined how exploration conducted by lower levels in an organization can negatively impact exploration conducted by the entire organization, while focusing on interdependencies among low-level managers (Siggelkow and Rivkin 2006). Another article identified and verified three underlying assumptions related to whether groups with larger or smaller power differences achieve high performance, with a myopic focus on the static hierarchies, the competence of those at the top of the group, and the possibility of equality (Tarakci et al. 2016). Furthermore, another examined the impact of team functional diversity and worker interdependence on team performance in the context of project team member selection (Hsu et al. 2016. Although Fig. 4 shows that the publications in this cluster date back to 2006, the number of publications was limited up to 2016. This area of investigation has gained momentum since the publications in 2016, including a study on the impact of power disparity within groups on group performance using a combination of ABMS, field data, and laboratory studies (e.g., Tarakci et al. 2016), which resulted in multiple studies being published almost every year thereafter.

The studies in this cluster take advantage of the characteristics of ABMS that can specify micro-level dynamics, such as modeling individual behaviors or multiple agents working in complex environments (Sabzian et al. 2018). Over time, micro-level phenomena can exhibit emergent proprieties (e.g., a shared mental model or team trust) at either the meso- or macro-level because "emergence is the result of bottom up processes whereby phenomenon and constructs that originate at a lower level of analysis, through social interaction and exchange, combine, coalesce, and manifest at a higher collective level of analysis" (Kozlowski 2012, p. 267).

Most of the articles in this cluster involved different concepts and agents' interactions that could be used to model multiple agents working in complicated environments. However, this tendency requires researchers to create their own customized workflows, not just apply

existing models. Moreover, researchers began to integrate the ABMS method with empirical data. For example, along with the aforementioned data from Tarakci et al. (2016), Hsu et al. (2016) collected real-world data to validate their model and used ABMS to simulate how the functional diversity and interdependence of team members affect team performance under different economic conditions, particularly the selection process of project team members. Furthermore, they collected data from 116 construction projects to improve the validity of their simulations.

3.2.2 Cluster #2: Organizational structure and design

The cluster for "organizational structure and design" focused primarily on how and why certain organizational structures define employees' behaviors, interaction between members, and organizational processes over time that can exhibit nonlinear, nonequilibrium, or even surprising behavior at the organizational level. Highly cited articles published in this cluster include: Siggelkow and Levinthal (2003), who aimed to examine how firms should design their organizations and balance exploration and exploitation. They used ABMS to examine the impact of three different organizational structures: a centralized structure, a decentralized structure, and a structure that starts out as a temporarily decentralized structure that is later integrated. They also pointed out that temporary decentralized structures, which have not received much attention, could lead to high performance in some situations. Rivkin and Siggelkow (2003) used simulation to explain how and why various organizational design elements depend on each other to achieve both search and stability in organizations, with particular attention to vertical hierarchies. Rivkin and Siggelkow (2006) examined how firms organize themselves so that they can strategize well in the face of interactions among different decisions by ABMS.

Fig. 4 shows that the publications in this cluster emerged in the very beginning stage (i.e., the study examining the relationship between organizational design elements and

organizational performance in product development organizations [Lee and Chhajed 1998]). Although this cluster has published more than other clusters (49 publications, 38.0% of the total), the number of publications has been increasing, especially since 2012, with more than three publications almost every year. In addition, seven articles have been published in 2021, making it a category that is still being actively researched even in recent years.

ABMS suits the studies in this cluster well because, by defining the fundamental logic (e.g., when and how to trigger each event) that governs the interactions of the agents, ABMS can simulate generative outcomes to yield higher level and nonlinear phenomena (Billari et al. 2006). Gao et al. (2014) examined how organizational routines are generated through the bottom up interaction between human actors and non-human artifacts, suggesting that performance feedback loops between actors contribute to the formation of organizational routines, which may be further accelerated by imitation by individual actors. Such an impact on higher level phenomena (i.e., the generation of organizational routines) could be difficult to detect and verify through empirical study. In addition, simulation has been deemed a way of doing through experiments (Axelrod 1997), suggesting that ABMS can better facilitate experimentation processes, which can sometimes generate unintended results and challenge old wisdoms. In fact, Jamshidnezhad and Carley (2015) simulated the relationship between quality management and organizational performance by focusing on organizational factors and drew out implications that differ from previous findings, such as the idea that productivity does not necessarily decrease even when customer requirements are highly complex.

As delineated above, ABMS can incorporate all kinds of nonlinear effects or emergent relationships among members, teams, organizations, and environments that are technically difficult to handle within variable-based modeling (Smith and Conrey 2007). Hence, unpredictable and counterintuitive outcomes might occur to challenge the status quo.

For example, Rivkin and Siggelkow (2006) found that "unnecessary overlap across departments" can sometimes help an organization explore a broader range of choices, preventing premature lock-in for suboptimal performance.

3.2.3 Cluster #3: Knowledge management in organizations

This cluster focuses on the flow of knowledge and information related to organizational strategies, specifically the generation, acquisition, recall, sharing, and utilization. Multiple key topics were developed to understand strategy-related knowledge management in organizations, including the extension of March's (1991) model and three further modeled factors: face-to-face interpersonal exchanges, spatial dimension, and tacit knowledge in organizational learning (Miller et al. 2006). Miller et al. (2012) also modeled three forms of memory in individuals (i.e., procedural, declarative, and transactive memory), leading to a discussion of their roles in the formation of organizational routines and the resultant change due to loss of personnel or any environmental turbulence. Furthermore, Grand et al. (2016) utilized ABMS to understand how team-level knowledge dynamically emerges from individual-level interactions. According to Fig. 4, publications in this cluster date back to 2004, and from the beginning, there have been studies dealing with strategy-related knowledge/information and knowledge sharing in companies (i.e., Bae and Koo 2008; Miller et al. 2006; Yang and Wu 2008). The amount of publications peaked in the 2010s, but the last five years have seen fewer publications.

ABMS can unpack dynamic relationships not through deductive or inductive reasoning (Hughes et al. 2012), but through computations and simulations (Epstein 1999). In other words, ABMS can offer researchers deeper insight into the underlying mechanisms of research interest to answer questions on "why, how, and when." The studies in this cluster benefit from this characteristic of ABMS. For example, Yang and Wu (2008) used ABMS to explore why employees share or do not share their knowledge with their peers, how

interpersonal and organizational factors affect employees' knowledge-sharing behaviors, and when knowledge sharing behaviors increase. In addition, by systematically varying the parameters and assumptions in the model, ABMS can assist in conducting sophisticated conceptual experiments to help extend theories that are not fully developed yet (Epstein 1999), refine existing theories by offering specific boundary conditions (Levine and Prietula 2012), or provide models to balance conflicting effects (Knudsen and Srikanth 2014). Similar to cluster #1, several studies in this cluster combined empirical experiments by utilizing ABMS. For example, Levine and Prietula (2012) combined field data from a global consulting firm with ABMS. Grand et al. (2016) conducted a laboratory study to corroborate the simulation results on the emergence of knowledge in groups.

3.2.4 Cluster #4: Organizational decision-making

This cluster mainly addresses applying ABMS to the decision-making processes at the organizational level and identifying the factors that influence them. The major themes in the cluster are related to balancing speed and search in corporate activities to deal with the turbulence and complexity of the corporate environment, as well as the impact of department head-level authority over strategy and information in an organization (Siggelkow and Rivkin 2005). One theme is the entrepreneurial team's decision-making based on innovation risk, including the difference between such decision-making and traditional decision-making by individuals (Wu et al. 2010). Another theme is understanding the impact of setting a modest numerical quota for women directors on boards, which helps them have equality in their centrality and influence in the corporate decision-making (Kogut et al. 2014).

Fig. 4 shows that the publications in the cluster have a modest volume (28 articles in total), which gradually increased in recent years. Several articles in the cluster presented the organizational problems by adapting Kauffman's (1993) NK model. For example, Siggelkow and Rivkin (2005) adapted the NK model to determine the appropriate organization design in

response to unstable environmental parameters such as turbulence and complexity. Contrary to convention, their results showed that ample processing power at lower levels in multilevel organizations can reduce exploration by the entire organization.

ABMS offers two main advantages in researching organizational decision-making: the ability to examine phenomena at the collective level, and the identification of decision-making processes. According to McHugh et al. (2016), although the link between decision-making and leadership has been discussed for years, they have not been adequately examined at the collective level. This is primarily because collective decision-making research addresses relatively small groups, making it unsuitable for statistical analysis, and comparing multiple small groups is difficult due to data availability and methodological limitations. However, ABMS can artificially generate such data by simulating small-group decision-making. McHugh et al. (2016) took advantage of this feature to examine how individual intelligence affects the quality of collective decision-making.

The studies in this cluster utilize the uniqueness of ABMS to reveal not only the factors and outcomes of decision-making, but also the process of decision-making. In fact, Wu and Sekiguchi (2019) pointed out that intragroup conflict, which affects group decision-making, has not always been treated as dynamic in existing research and that the process has been black boxed. To address these issues, they examined how the nature of intragroup conflict changes over time by incorporating time into the analysis through ABMS. Due to its ability to model group-level phenomena and visualize processes related to decision-making, ABMS is a useful tool for generating new knowledge from a different angle from existing research.

3.3 The trend analysis

To follow a review study and its trend analysis by Ávila-Robinson and Wakabayashi (2018), we charted a similar analysis of 36 key terms (see Fig. 5) in terms of the growth rate of a

cumulative number of publications (x-axis), namely representing the level of quantity, and the growth rate of cumulative normalized citations (y-axis), namely representing the level of quality, between 1998–2017 and 2018–2022. Both publication and citation growth rates are calculated by comparing the 1998–2017 period to the most recent five-year period (2018–2022). The red dotted lines give the median values of both axes, and the size of the bubbles represents the total number of the publications associated with each of the 36 key terms.

One potential issue upon our trend analysis was that the citation counts of the articles extracted from EBSCOhost (i.e., proceedings papers of Academy of Management Annual Meetings) were not available. Although we also explored Google Scholar, another database containing citation counts, only 39.3 % of these articles (11 of 28 articles) were registered in the database, and hence, the citation values for the remaining 17 articles were still missing. Nevertheless, we decided to include those articles in the trend analysis so we can at least capture the trend of the number of publications (x-axis) in this outlet. As for the citation counts (y-axis), we used the values from Google Scholar for the 11 articles whose citation data were available in the database. The citation values for the other 17 articles were set as zero to prevent them from affecting the analysis. We believe this procedure is reasonable because citing proceeding papers is not a common practice among management scholars. In fact, the average citation counts of the 11 articles we could obtain from Google Scholar was 1.73, and those of other proceedings papers in our sample were as small as 1.2. To verify the robustness of the analysis, the same trend analysis was conducted, completely omitting the 17 articles whose citation counts were not available. The additional analysis provided almost an identical result with the original analysis except that one term (“process”) originally categorized as a “hot” topic turned to be a “traditional” topic, supporting the overall reliability of the analysis.

Three main blocks can be discerned from Fig. 5. First, in the "hot topics" block, there are 11 research terms with an above-median level of growth rate in both quantity and quality dimensions, such as "project," "knowledge transfer," and "decision-making." The sizes of the bubbles (i.e., the total publications as of 2022) of 11 terms are not necessarily small, implying that a certain number of studies have already been conducted. Also, the relatively high number of cluster #2 terms (4 terms, 36.4%) is consistent with the recent proliferation of cluster #2 publications (see Fig. 4). Second, in the "emerging topics" block, a group of seven research terms are displayed, such as "team," "information," and "decision." In contrast to the hot topics, only one of the seven items in the emerging topics belong to cluster #2, which is probably because the research related to cluster #2 is entering the maturity stage. Third, 18 research terms are in the "traditional topics" block, implying a below-median level of growth rate in the quantity dimensions. In general, the research terms (or topic areas) associated with this block mature. Meanwhile, we acknowledge that the most identified key terms are highly interlinked and are less likely to stand alone. For example, the term "communication" in the "traditional topics" block had a total of 22 linkages connecting to other terms, such as "project" in the "hot topics" block and "decision" in "emerging topics" (see Fig. 3). However, we believe that the trend analysis can be used as a roadmap for the promising research direction.

INSERT FIG. 5 ABOUT HERE

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4 Future directions and limitations

Despite a still small number of publications on the applications of ABMS in organization management, the results show that the associated research has grown steadily during the last two decades, particularly the research in cluster #2. In examining our systematic review to

elicit “where we are,” scholars can infer which directions to productively follow in the future. For example, this review analyzed the trend of 36 key terms to reveal what the hot and emerging topics are. In this section, we provide five inferences drawn from the analyses above, depict “what is missing” in the existing research, and offer alternatives from the perspective of creating an impact on the organization management field.

4.1 Research gap by clusters

Our results revealed the following research gaps for each cluster. First, for cluster #1, team behaviors under complex environment, the diversity of team members must be more explicitly incorporated into the simulation models in the future. As management is practiced on a more global scale, managing diversity in teams is an important issue in organization management (Horwitz and Horwitz 2007). In cluster #1, however, research incorporating team members’ diversity into simulation remains limited. An exception is Carraro and Furlan (2021), who examined the impact of a key employee exerting initiative in team problem-solving with individuals holding diverse mental models. Arrieta (2020) also examined how the diversity of preferences within a group affects the group’s exploratory behavior in an uncertain environment. Thus, future research can incorporate the diverse nature of agents into their model, which will lead to the understanding of teams’ complex nature.

In addition, although the focus of cluster #1 to date has been primarily on the phenomena occurring within teams, it would be very fruitful to consider the effects of team interactions and external factors. In other words, studying teams as open rather than closed systems (Dong et al. 2021) will allow for a more realistic understanding of team dynamics. This line of investigation started to be seen in the study of project team member selection by Hsu et al. (2016), who pointed out that although previous studies have focused on teams’ work capacity, such as individual skills and performance, the interaction between team members and the social environment has not been sufficiently examined. Therefore, they also

examined in their analysis the impact of external factors, such as differences in the economic conditions. Although previous studies have also assumed the complexity of team external factors as the context of their study (e.g., Kiel et al. 2013), explicitly including them in the analysis allows for a more refined observation of team dynamics.

Next, in cluster #2, organizational structure and design, feedback loops and multiple levels of hierarchy will be key terms for future research directions. A feedback loop is a phenomenon where the result of a factor has a cyclical effect on the causing factor itself (e.g., Gao et al. 2014). Early research in this cluster has focused on how organizational factors affect organizational performance and members. Thus, the interest there was the impact of structural aspects in organizations on other factors in organizations, and structural factors were treated as causes. However, in reality, the organizational-level factors are not necessarily stable, and their structure may change depending on organizational performance and feedback from members. Zhang et al. (2021), based on this perspective, examined the principle of coevolution of business and information systems in organizations. Although most of the studies in this cluster focus on relatively stable organizational factors such as organizational structure, this cluster is also concerned with more fluid organizational factors such as organizational culture (Meluso et al. 2021), organizational routines (Gao et al. 2014), and human resource management (Kim and Shim 2017). For these areas, it would be useful to examine the interaction between institutions and agents.

It is also important to consider models that assume multiple hierarchies within an organization. Organizations addressed in management studies usually have multiple hierarchies, and different layers have different characteristics (e.g., Baumann et al. 2021). Many studies in this cluster have examined how organizational factors affect agents, but few have assumed there are multiple hierarchies. In one study that will serve as a touchstone for future research in this regard, Baumann et al. (2021) assumed that managers' decision-

making authority differs depending on their position in the organizational hierarchy and pointed out that the effectiveness of resource allocation for corporate exploration depends on organizational structure.

For cluster #3, knowledge management in organizations, research on micro-foundations for strategic management will be fruitful. Micro-foundations are a research area that aims to understand strategy-related topics from the perspective of individual behavior and interaction, and it seeks to deepen our understanding of organizational strategy by focusing on individual behavior and psychological mechanisms that underlie phenomena at the organizational level (Foss 2011). Although early studies in this cluster dealt with corporate behavior in complex environments (e.g., Siggelkow and Rivkin 2005), more recent studies have focused on the connections between micro- and macro-level phenomena. Uli (2015), for example, pointed out that although business processes were traditionally thought to be formed primarily as a result of decisions by the top management team, the actions of lower levels of the organization explain the creation and change of business processes. This connection between micro- and macro-levels is compatible with the methodological advantages of ABMS and will provide a useful perspective for future discussions of micro-foundations.

Finally, for cluster #4, organizational decision-making, collective decision-making emerging from diverse individuals rather than organization-level decision-making is a research gap that needs to be filled in the future. Recent papers in cluster #4 have gradually focused on the nature of collective decision-making. McHugh et al. (2016), for example, pointed out that although there has been much discussion about decision-making and leadership, not enough has been made at the collective level. In other words, the research on decision-making by multiple individuals has not been sufficient. Saenz-Royo et al. (2022) also examined how the performance of decision-making in groups with fallible members

changes under different organizational structures. Similar to the studies in cluster #1, using ABMS to model multi-person decision-making will allow future studies to examine how member diversity affects group decision-making.

4.2 Integrating ABMS to complement studies and add precision to existing theory

Our results show that ABMS applications in organization management is mainly for theory development, along with a growing trend of integrating ABMS with other analytic methods. ABMS allows the simulations to generate, rather than deduce, the consequences of these processes (Harrison et al. 2007). Nevertheless, despite the contrasting conceptions between computational methodology and traditional techniques, in most cases, both can be complementary (Hughes et al. 2012; Smith and Conrey 2007) and integrated into research designs (Kozlowski et al. 2013). As delineated above, we confirmed the trend of interlinking ABMS with traditional techniques in the organization management field.

For example, Levine and Prietula (2012) combined field data from a global firm with ABMS to examine how knowledge transfer impacts performance. Kogut et al. (2014) used the estimates from the Norwegian experiment and applied it to build parameters in ABMS to simulate American board data. Serban et al. (2015) used ABMS and proposed that the degree of team virtuality moderates the relationships of cognitive ability, personality, and self-efficacy to leadership emergence. Also, the researchers conducted the quasi-experimental study to support the moderating role of network ties' density. Chandrasekaran et al. (2016) designed a multimethod study: multiple case studies for theory development and ABMS for theory augmentation and theory refinement.

In addition, Turner et al. (2017) argued that computer simulation was well suited for enhancing precision in the control and measurement of variables and could serve as an effective tool in maximizing generalizability (i.e., for the external validity). For example, in Rivkin and Siggelkow's (2003) work about organizational design using the NK model, they

extended the conventional wisdom about interdependencies among organizational design elements by identifying the boundary conditions, such as when vertical hierarchies lead to inferior long-term performance. Levine and Prietula (2012) set boundary conditions to answer when the performance benefits of knowledge transfer decrease.

4.3 Continuing to enhance the transparency of model representation

As indicated above, our analysis noted that some deficiencies of the model representation exist in the reviewed literature—for example, an insufficient transparency regarding the model design concepts, model initialization, or generative stages. Low methodological transparency has a negative impact on the credibility of research results and is deemed as a "research performance problem" (Aguinis et al. 2018). Therefore, to advance knowledge by building on the works of others, organization management researchers should continue to enhance the transparency of model representation, allow their computational models to be well understood and analyzed by other researchers involved in similar work, and learn new model representation methods from other areas of expertise.

A good example of high transparency regarding model representation is the study by Grand et al. (2016), who examined a process-oriented theory of team knowledge emergence. The authors systematically specified how they identified key concepts and mechanisms of emergence within teams; translated the narrative theory into a computational model with procedural rules and algorithms; instantiated the model and conducted simulations to generate insights; and, finally, tested the theoretical predictions and insights from simulation with real data. In addition, they were highly transparent about what they coded to develop by not only detailing necessary assumptions, flowcharts, and figures but also programming logic and pseudocode for inferential reproducibility (Goodman et al. 2016). In another study, Raveendran et al. (2022) examined the conditions under which the self-selection-based division of labor can outperform the traditional work allocation by managers. Besides their

good description, Raveendran et al. (2022) effectively combined pictograms with a table to elaborate on each of the simulated task allocation cases and simulated change of the allocation over time. We believe their work will be paid off by allowing future researchers to replicate and build on their efforts to extend the knowledge.

Moreover, we recommend that organization management researchers, who are interested in applying and reporting ABMS in their work, refer to the ODD protocol (Grimm et al. 2010). The primary purpose of ODD is to standardize the published descriptions of ABMS, thus making writing and reading model descriptions more efficient and easier to replicate (Grimm et al. 2010). Specifically, ODD refers to overview, design concepts, and details, respectively, and includes the following seven elements: purpose, state variables and scales, process overview and scheduling, design concepts, initialization, input, sub-models (Grimm et al. 2006). The main goal of the ODD protocol is to further increase the transparency and consistency among simulation research by clearly describing these seven elements in the papers, regardless of the field (Grimm et al. 2006). Although the ODD protocol may seem daunting to use in the beginning, we strongly believe that doing a rigorous reporting to communicate ABMS in a common way can facilitate future researchers to reach a better understanding of model usage and its potential applications in the organization management field. In addition, to improve transparency in model representation, the ABMS research community is promoting the OpenABM initiative, and the details of various ABMS models are published on their website (Janssen et al. 2008). We believe that ABMS researchers in organization management could learn the better practice in promoting transparency of model representation from this community.

4.4 Continuing to apply ABMS to overcome methodological challenges

Organization management researchers are confronted with many methodological challenges, such as incorporating the multiple waves of data collection in a longitudinal study or

implicitly fine-tuning team compositions and interactions. ABMS is deemed a potential approach to overcome certain methodological challenges, particularly (a) when time factor is considered to be critical in generating behavior and (b) where getting it wrong is costly or there are operational restrictions (e.g., for ethical reasons) associated with carrying out the empirical studies (Hughes et al. 2012).

First, the time construct plays as the catalyst for emergent phenomena to be manifested at a higher level (Kozlowski and Klein 2000), yet many studies have been conducted in the setting of a cross-sectional manner (Cronin et al. 2011; Kozlowski 2015). Recently, researchers have inadequately dealt with time and dynamics (Kozlowski 2015). As Jehn and Mannix (2001) concluded in their longitudinal study on intragroup conflict and group performance, "If we had used a one-time measure of conflict, the results and their interpretation would have been very different" (p. 248). As a consequence, researchers may neglect the fact that any small effects triggered by certain phenomena that are potentially magnified over time have a longer impact on team and organizational functioning (Kozlowski and Klein 2000). Nevertheless, while building ABMS, most research already requires inclusion of the time factor (e.g., being proxy for days, months, years, or any virtual periods) and explores the development of research interest over time. ABMS allows researchers to directly observe or trace the phenomena of interest over a period of time and to overcome the issues of inadequate sampling rates (Kozlowski 2015), daunting data collection, and the processing faced in multiperiod research (Humphrey and Aime 2014).

Second, ABMS simulates in a virtual setting, where it provides a "safe" environment to be modified without worrying about causing risks and sensitivities for individuals, teams, and organizations. For example, Mizgier et al. (2012) studied the influence of local processes on the global economic behavior of the system. They modeled defaults of companies in supply chain networks, which would be risky to conduct in practice. Likewise, it is

challenging to operationalize the research regarding team membership change, although today's workforce is becoming more mobile and team members in dynamic organizations can frequently move in and out of project teams. ABMS can help researchers directly study the research of interest so that they can unpack such team and organizational dynamics operating under various scenarios (e.g., different team sizes and diverse demographic compositions). For example, Miller et al. (2006) considered the implications of personnel turnover on learning over time to extend March's (1991) conclusions and modeled a simulation for the formation of organizational routines and its changes due to downsizing 20 personnel.

4.5 Focusing on the influential constructs in organization management

Based on our review and previous studies (e.g., Gómez-Cruz et al. 2017), the applications of ABMS in organization management remain underutilized; thus, its coverage of existing constructs and theories is limited. For example, only few constructs in organization management (e.g., organizational structure, knowledge transfer) were identified as key terms through bibliometric mapping. To add value to the organization management field and leverage the potential power of the ABMS method, we suggest that researchers start with applying ABMS to address the "most influential constructs in organization management."

In the aforementioned trend analysis, we pointed out where to shift the research agenda by targeting 18 identified hot and emerging terms. Moreover, in their research of construct mixology, Newman et al. (2016) conducted a systematic method, including a survey of all the micro-oriented Academy of Management Journal editorial board members, to compile a provisional list of the 26 most influential constructs in OB and HR. Further, they categorized these into seven cardinal construct domains. Even though the list is not meant to be exhaustive (Newman et al. 2016), we believe it can provide a good starting point for future work on the following: which relevant influential constructs and the associated theories can

be connected, modeled, simulated, and explored to create an impact on the organization management field.

To properly conceptualize and model the influential constructs and theories in ABMS, ABMS requires researchers to explicitly specify their assumptions and integrate likely data from different sources (Hughes et al. 2012). This implies that the existing academic research has adequately described or established the selected constructs and theories (Hughes et al. 2012). In other words, when fewer assumptions or ambiguous judgment calls are made, the validity of the established model improves. Out of 26 constructs compiled by Newman et al. (2016), many are well established by the existing academic research and empirical studies. Such constructs can then be relatively straightforward when translated into ABMS applications. For example, by searching the keyword "organizational structure" in the WoS database, there are more than 39,000 articles returned, whereas only 14 papers were extracted for this study as articles addressing this topic with ABMS. Nevertheless, some latent variables in the list, such as job satisfaction, self-esteem, and the Big Five personality traits would be difficult to directly model into ABMS, unless the constructs could be inferred by observable individual characteristics, dyadic interactions, or team processes.

4.6 Limitations

Although this paper has several strengths such as the adoption of bibliometric mapping to provide more evidence-driven review and actionable recommendations stemming from analysis of the four clusters and detailed manual inspections of focal articles, the present review is not free from limitations. Firstly, the sampling process was not entirely based on an objective standard. To reduce the subjectivity in the sampling procedure, we followed the approach by Gómez-Cruz et al. (2017) and utilized the subcategories in management by the Academy of Management (2022). In addition, authors met several times to determine which topics should be included or excluded, discussing several specific articles in our potential

sample pool. Nevertheless, the inclusion criteria was not completely objective, which may have caused potential bias in our sample.

Secondly, our bibliometric mapping results need to be interpreted with caution due to their several limitations. Although we believe the bibliometric mapping method is still useful for a small sample, our relatively small sample size may have affected the mapping results. For example, there were several ambiguous terms in the map (i.e., organization, firm, company). If our sample size were bigger, we might have clearer and more specific terms in the map, which can add more meanings and nuances to each cluster. In addition, partially because of the small sample size, our bibliometric map was highly centralized and somewhat affected by our robustness check (i.e., elimination/integration of several words). Since it did not essentially change the nature of each cluster, we concluded that the map was robust enough to be further analyzed. However, as this field expands even more, future research can benefit even more from bibliometric mapping by using a larger sample.

Finally, our trend analysis using the number of publications and citations has several issues. One issue would be that the citation counts for 17 of the focal proceedings articles were not public. As we confirmed through additional analysis, it is not likely that the general results from trend analysis drastically change by including the citations counts for these 17 articles. Nevertheless, since many of proceedings articles are expected to be concerned with relatively new research topics, we may not have fully captured some of the latest trend in this field. Furthermore, as in the bibliometric mapping result, some of the terms in hot and emerging topics still remain somewhat ambiguous and hence less helpful.

Having stated that, these limitations mainly stem from our relatively small sample size, which indicates applications of ABMS in organization management is still on the nascent phase. We believe that our review will further stimulate organizational scholars who is attempting to utilize ABMS and move the field forward, by which future review following

the similar approach with this paper will be able to base their analysis on a larger sample pool and more nuanced terms and clusters.

5 Conclusion

The applications of ABMS in organization management have experienced growth in the number of articles published each year, suggesting that ABMS has moderately gained scholarly acceptance and has added value in organization management. In reviewing 133 articles through a systematic analysis (i.e., using the WoS and EBSCOhost database search and a bibliometric mapping technique), we offer researchers the current status of the research with three characteristics of ABMS applications, four clusters, and 36 key terms, as well as the trend of hot and emerging key terms. More importantly, we provide five directions for future work to depict a promising possibility of ABMS applications in the field.

Among the potential future directions, we suggest that researchers further fill in the research gap in each cluster, such as modeling the diversity of agents and incorporating interaction between groups; continue to utilize ABMS to complement empirical studies; enhance the transparency at each stage of modeling and simulation; apply ABMS to overcome methodological challenges faced in empirical studies; and focus on the influential organization management constructs to create an impact. In presenting these findings, we aim to encourage more researchers to embrace this exciting paradigm shift, which synthesizes the technique of computational modeling and simulation with the existing approaches, in order to answer tougher and more complex questions in the organization management field.

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Table 1 A summary of four clusters (*Note: Key terms are presented in order, beginning with the highest co-occurrence term.*)

No.	Cluster	Representative key terms	Key features of the cluster	Top three most cited articles belonging to each cluster
1	**Team behaviors in complex environments**	Eight key terms: team; environment; manager; member; resource; task; complexity; employee	- Consists of micro-organizational topics - Focuses on emergent nature of micro-level phenomena - Increasing publications since the 2016 publications - Some studies combine ABMS with empirical data	Siggelkow and Rivkin (2006). When exploration backfires: Unintended consequences of multilevel organizational search. Tarakci, Greer, and Groenen (2016). When does power disparity help or hurt group performance? Hsu, Weng, Cui, and Rand (2016). Understanding the complexity of project team member selection through agent-based modeling.
2	**Organizational structure and design**	Ten key terms: organization; process; dynamic; behavior; interaction; management; project; organizational structure; company; case study	- Contains meso-oraganizational topics related to oraganizational structures and designs - Explores the effects of oraganizational factors on its members - Biggest cluster in terms of publications - Often produces non-linear or counter intuitive results	Siggelkow and Levinthal (2003). Temporarily divide to conquer: Centralized, decentralized, and reintegrated organizational approaches to exploration and adaptation. Rivkin and Siggelkow (2003). Balancing search and stability: Interdependencies among elements of organizational design. Rivkin and Siggelkow (2006). Organizing to strategize in the face of interactions: Preventing premature lock-in.
3	**Knowledge management in organizations**	Nine key terms: knowledge; time; role; strategy; individual; search; knowledge transfer; complex system; organizational learning	- Adresses meso/macrolevel phenomena - Examine the flow of knowledge and information in an organization - Often connected to strategy-related topics - Fewer publications in the last five years than the early-middle 2010s	Miller, Zhao, and Calantone (2006). Adding interpersonal learning and tacit knowledge to March's exploration-exploitation model. Miller, Pentland, and Choi (2012). Dynamics of Performing and Remembering Organizational Routines. Grand, Braun, Kuljanin, Kozlowski, and Chao (2016). The Dynamics of Team Cognition: A Process-Oriented Theory of Knowledge Emergence in Teams.
4	**Organizational decision-making**	Nine key terms: performance; network; system; decision; work; firm; decision making; communication; information	- Focuses on meso/macro-organizatinoal issues regarding decision-making - Steadily published but gradually growing since 2016 - Explore the collective and temporal nature of decision-making	Siggelkowand Rivkin (2005). Speed and search: Designing organizations for turbulence and complexity. Wu, Xie, Hua, Shi, and Olson (2010). Modeling technological innovation risks of an entrepreneurial team using system dynamics: An agent-based perspective. Kogut, Colomer, and Belinky (2014). Structural equality at the top of the corporation: Mandated quotas for women directors.

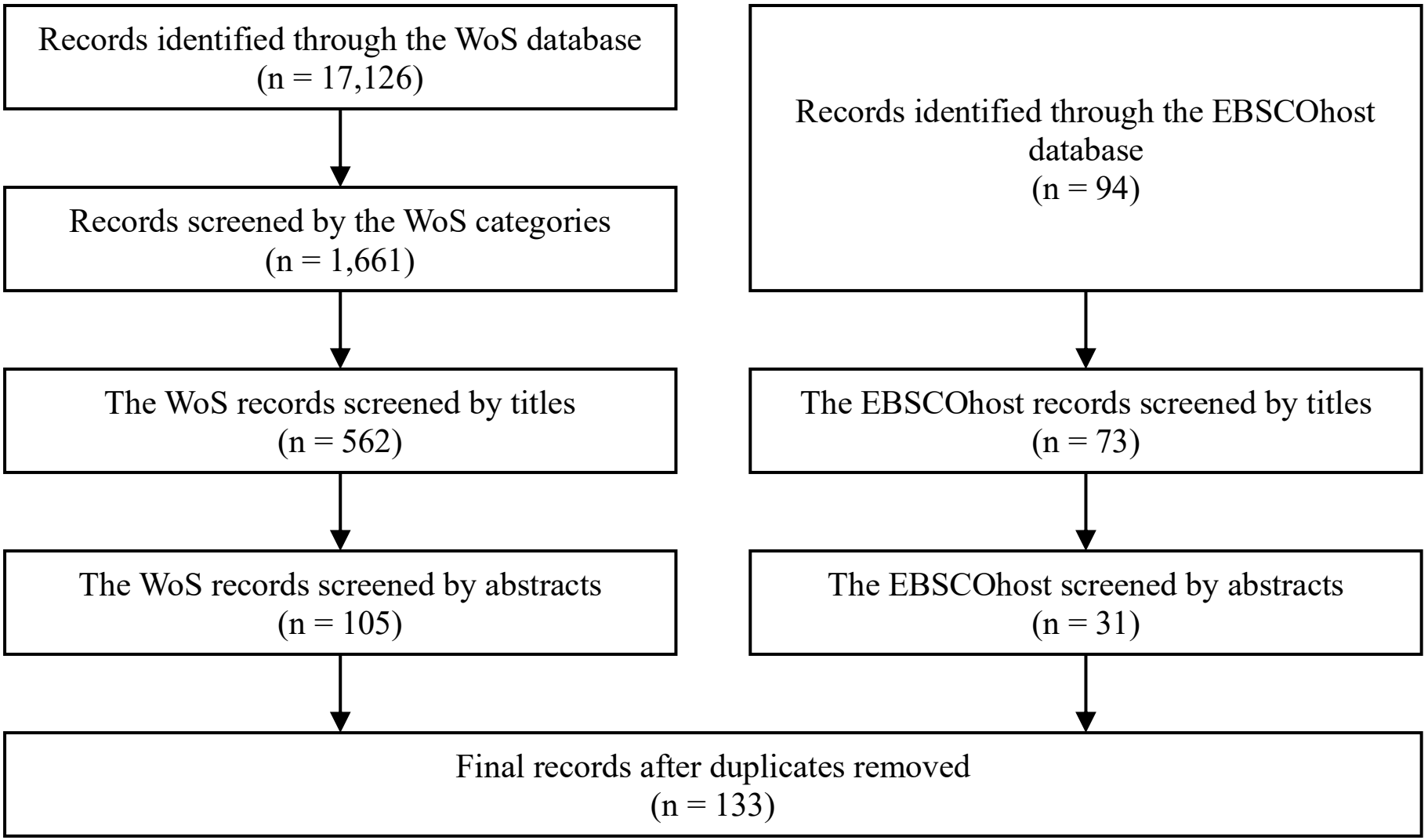

Fig. 1 Flowchart of literature search process.

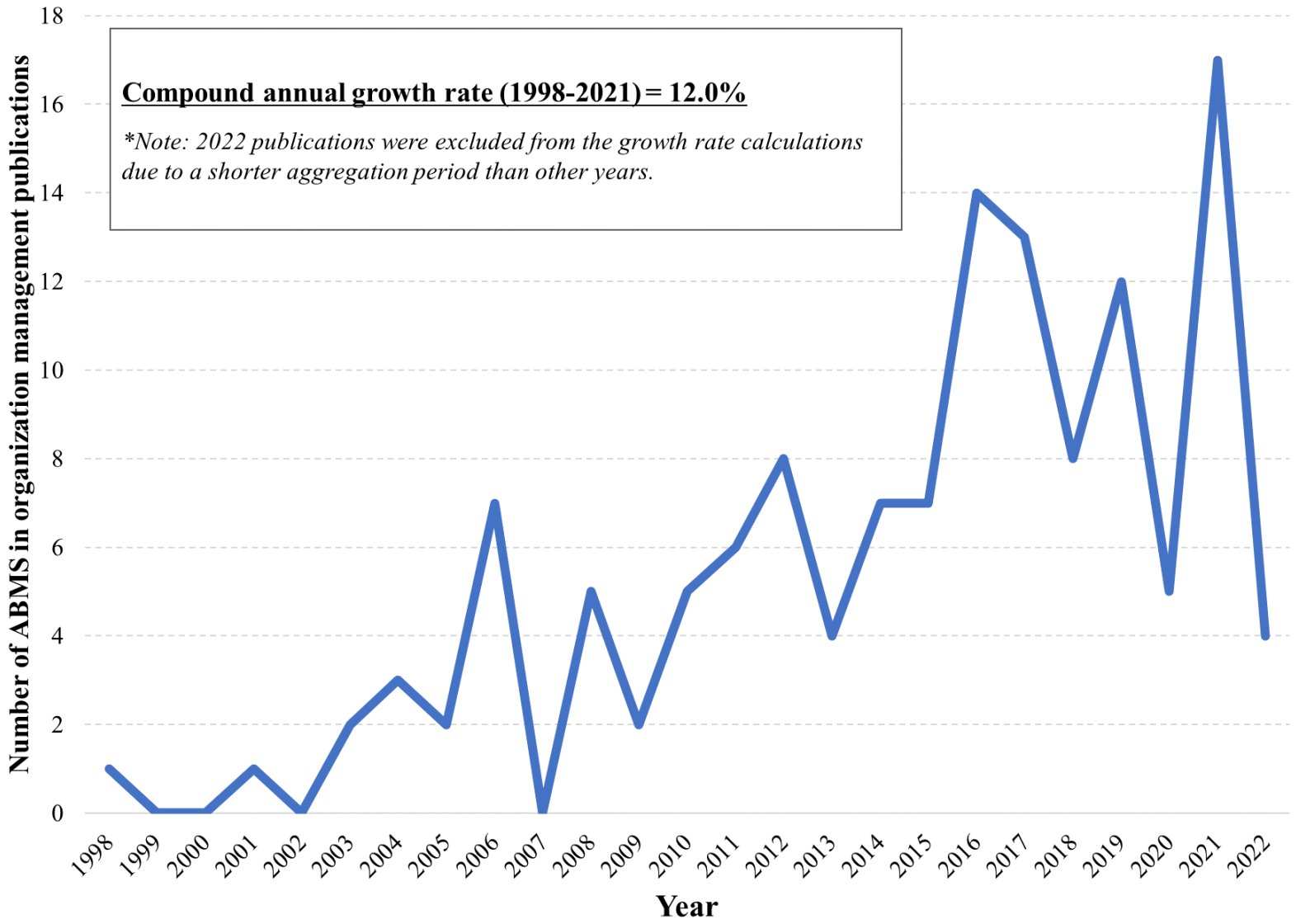

Fig. 2 Publications of ABMS applications in organization management per year.

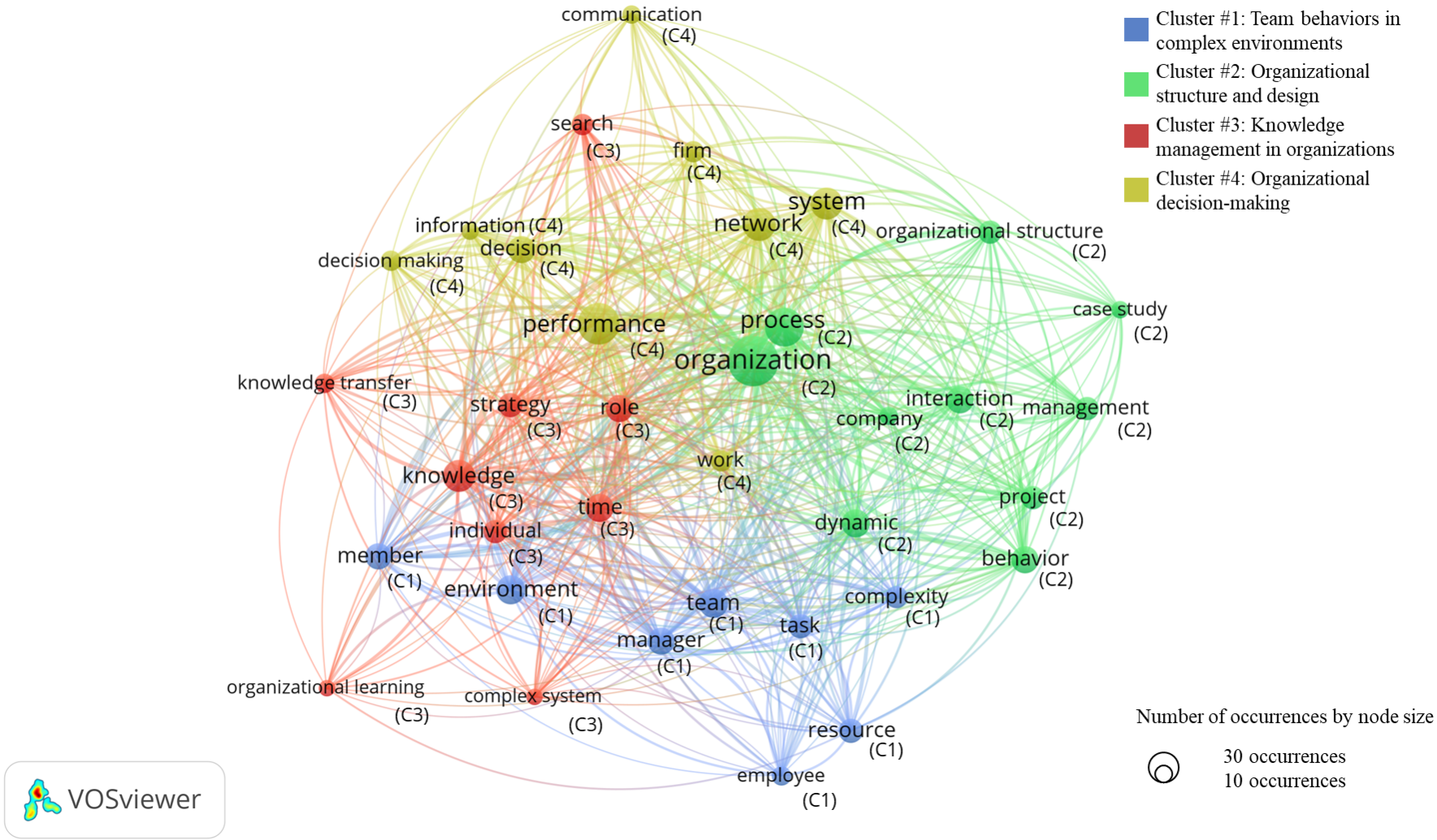

Fig. 3 Static map of the network visualization.
(*Note: Number in parentheses indicates cluster numbers. The letter size for each term corresponds to the number of occurrences*)

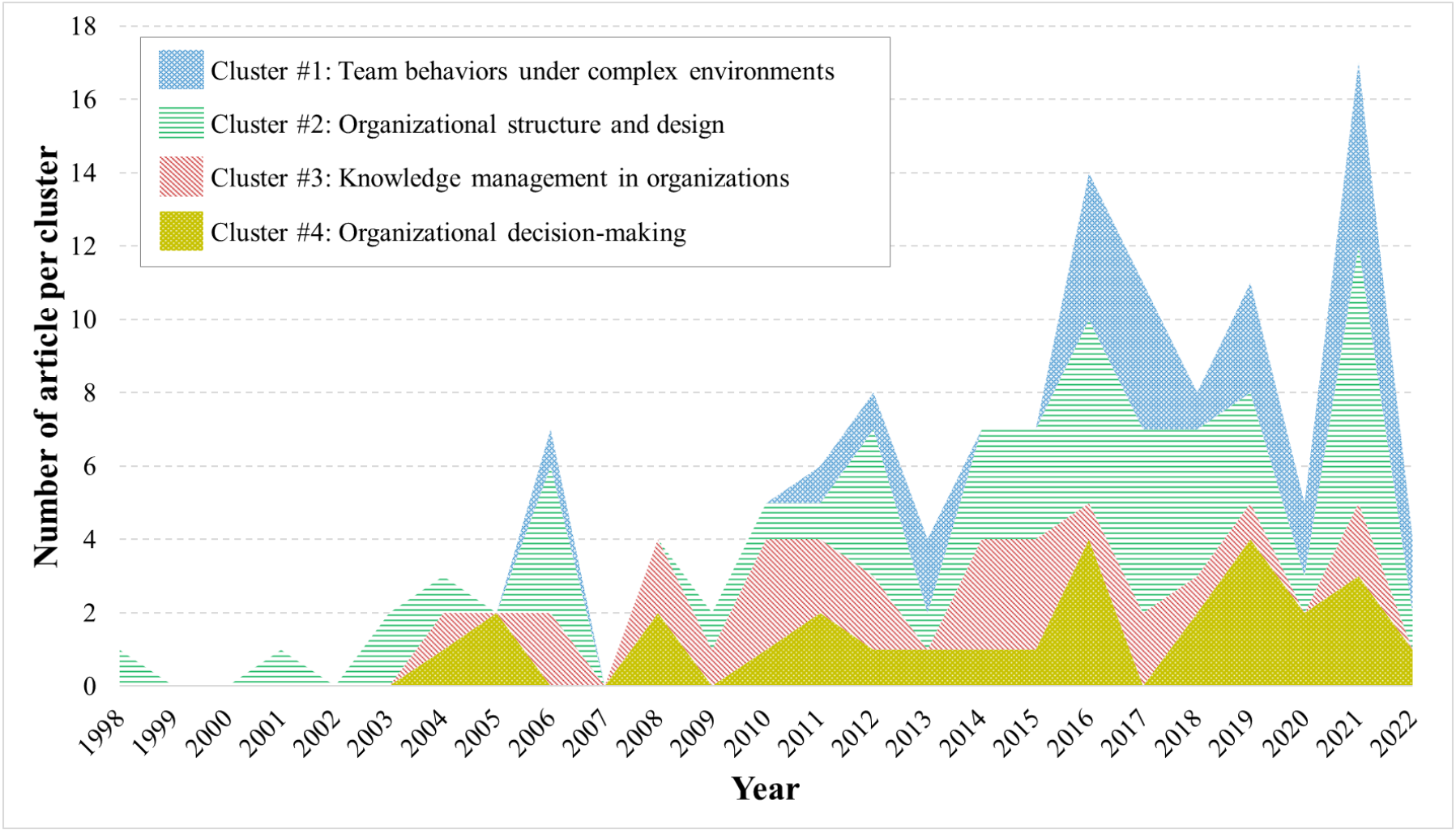

Fig. 4 Applications of ABMS in organization management article counts per cluster by year.

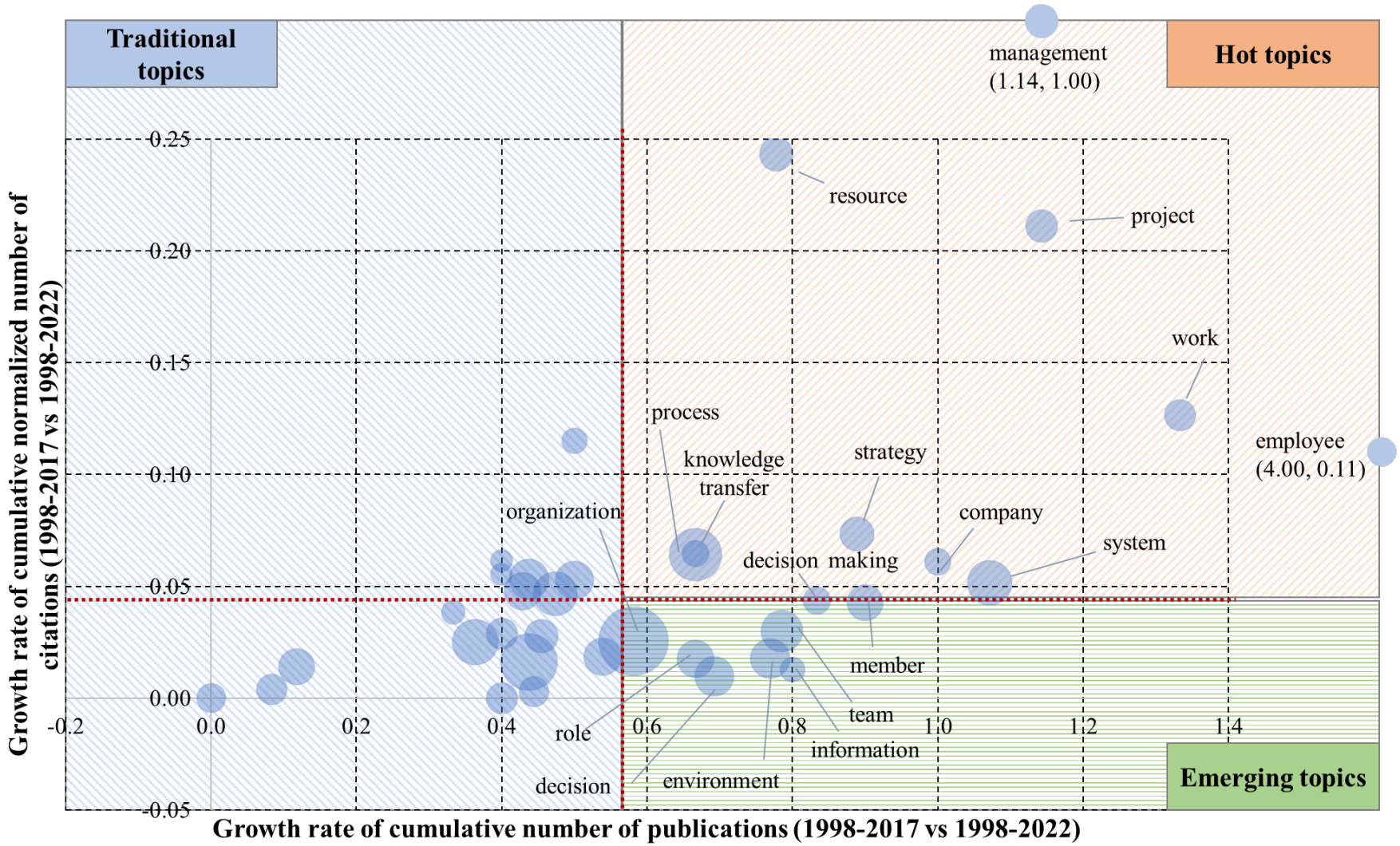

Fig. 5 Trend analysis of 36 key terms identified from 133 articles
(*Note: The positions of "management" and "employee" circles are shifted due to the space of the paper. Exact coordinates are given in parentheses.*)