System dynamics applications in performance measurement research

A systematic literature review

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Abstract

Purpose – This study investigates system dynamics (SD) applications in performance measurement (PM) research and practice. A bibliometric analysis was conducted to investigate the maturity of this research area and identify opportunities for development.

Design/methodology/approach – A systematic literature review (SLR) was conducted to provide a comprehensive and rigorous review of the existing literature. The search was conducted on 10 platforms identifying 97 publications, which were evaluated using bibliometric analysis.

Findings – The analysis revealed that applications of SD are most commonly used in the PM system design phase to model organisational performance. In addition, the bibliometric results showed a highly dispersed author set, with most studies using exploratory methods, suggesting that the research is in a relatively early stage of development. The results also showed that over 50 per cent of the causal models were not validated, emphasizing an important methodological gap in this research area.

Research limitations/implications – This SLR is limited to indexed publications on 10 platforms, the search strategy was relatively precise and only available papers in English language were used for the literature review.

Practical implications – PM systems supported by SD can help managers understand and improve organisational behaviours by addressing dynamic complexities and relationship between variables. This study evaluates the maturity of this research area including information about the current development of this area and opportunities to build on existing knowledge.

Originality/value – This study identifies how SD approaches are applied to PM and highlights areas that require further research consideration. This paper is the first of two publications to result from this study and focuses on evaluating the current state of this research area.

Keywords Performance measurement, System dynamics, Systematic literature review, Bibliometric analysis

Paper type Literature review

Erratum. It has come to the attention of the publisher that the article, Oladimeji, O.O., Keathley-Herring, H. and Cross, J.A. (2020), "System dynamics applications in performance measurement research: A systematic literature review" published in *International Journal of Productivity and Performance Management*, contained an error in the pagination for this article in Vol. 69 No. 7. The correct pagination for this article is pp. 1541-1578. These errors were introduced in the production process and have now been corrected in the online version. The publisher sincerely apologises for these errors and for any inconvenience caused.

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1. Introduction

Performance measurement (PM) systems have become known to be an important strategic management tool and an essential part of planning, organising and controlling processes in an organisation (Barnard, 1938; Neely *et al.*, 1995; Kaplan and Norton, 2001; Taticchi *et al.*, 2010). PM systems allow organisations to focus on improving overall effectiveness and efficiency by supporting their decision-making processes. In organizations, this tool also provides the frame of reference to understand the strategic development and goal-setting system of management. Due to the pervasive recognition and extensive use of PM across different fields, there tends to be varied definitions of what measurement is and how it is to be defined, especially when used in PM systems (Spitzer, 2007). This paper is focused on organizational PM systems, which provide formal and strategic frameworks used to support organisational processes for setting targets, allocating resources and other organisational operations. Organisational PM systems now include financial and non-financial measures that impact how managers make decisions and implement operations (de Waal, 2002).

The importance of organizational PM systems is based on the evolving engineering and business environment and can be categorised into a number of reasons, as described by Neely (1999). Some of the reasons include how the role of work is changing in national and international contexts and how it is supported by technological innovations to continuously improve, thereby, creating constant competitiveness to meet growing standards of performance. These reasons highlight the global environment of modern organizations and show how the increasing complexity can affect every aspect of a system. This is why PM systems hold the key for organisational success, by allowing organisations to drive strategy, actively and proactively manage organisational performance and improve on sustainable growth, when properly implemented (Spitzer, 2007). Although PM systems have evolved to include financial and non-financial measures, effectively improving strategic management, there is little empirical evidence that these advancements have led to measurable improvements in organisational performance (de Waal, 2002; de Waal and Kourtit, 2013).

Much of the available literature suggests the lack of success in implementing PM systems is still over 50 per cent, and there is still no consensus as to what accounts for these significant failure rates (McCunn, 1998; Bourne *et al.*, 2003; de Waal and Counet, 2009; Nudurupati *et al.*, 2011). Some of the reasons given have been inappropriate design, lack of management commitment, no clear strategy and inadequate resources (Bourne *et al.*, 2002; Neely, 2005; de Waal and Counet, 2009; Barnabè, 2011; de Waal and Kourtit, 2013). Most PM researchers agree that these problems have arisen due to the increasing complexity of organisational systems that cuts across all human activity (Boland and Fowler, 2000; Santos *et al.*, 2002; Bourne, 2005; Valmohammadi and Servati, 2011; Strohhecker, 2016). Some of the aspects of system complexity that current PM systems fail to effectively capture include time delays, cause and effect relationships and the dynamic nature of organisational system structures (Norreklit, 2000; Barnabè and Busco, 2012; Nielsen and Nielsen, 2015; Tsalis *et al.*, 2015; Bianchi, 2016; Cosenz, 2017). The time delay is important as it helps to identify leading and lagging indicators and their effects in a system. Also, visualizing the causal linkages in a system can help in recognizing the cause and effect relationships, and understanding the dynamic nature of these relationships can help in specifying the structure and behaviour of the PM system. These crucial functions are not present in traditional PM systems based on accounting managerial systems (Kaplan and Norton, 1996; Nielsen and Nielsen, 2015). Therefore, the demand for PM systems that adequately capture the complexity of organisational systems is on the rise. Also, a better understanding of strategic and organisational goals and their drivers is becoming an essential need for many organisations, which would increase the chances of success in implementing, using and updating PM systems.

System dynamics (SD) has been introduced to research and practice as one of the tools that can help improve on the limitations of PM systems as opposed to other operational research

techniques like data envelopment analysis and multiple criteria decision analysis (Santos *et al.*, 2018). SD is a technique that uses the concept of causal modelling and stocks and flows, to capture a dynamic and systemic view of the organisation's behaviour that existing PM systems do not provide. Furthermore, SD modelling also helps to improve understanding of organisational functions and behaviour (Goodman, 1997; Sterman, 2000; Forrester, 2007). Advancements in PM systems research directly contributes to organizational growth and development; therefore, it is important to understand and explore existing knowledge on how SD tools and principles have been applied to organisational PM. However, the existing literature lacks a systematic, comprehensive review that analyses and integrates current knowledge in the field. There have been several studies that have discussed the effectiveness of using SD to improve PM; for example, Cosenz (2014) used SD to design and apply PM in an academic institution. According to the case presented in paper of Cosenz (2014), using SD allowed them to identify key performance indicators and influence the decision-making processes for improvements in the university. In addition, they were able to assess the processes, products and people that allow for successful implementation of the PM systems and leverage on those areas for improvement. Another illustration is presented in Bianchi and Montemaggiore (2008), where SD is applied to the design, planning and control of the PM system, to enhance the public water utilities in a city. The results from their study show that SD significantly improved the processes, and managers were able to better understand the structure and behaviour of the water utility supported by the PM system. Other application areas include healthcare (Santos *et al.*, 2008; Best *et al.*, 2016), governance (Bianchi and Tomaselli, 2015; Sales *et al.*, 2016) and manufacturing (Ying, 2010; Seydhosseini and Soloukdar, 2011), which generally suggest that SD applications in PM enhance the effectiveness of the systems.

Traditional literature reviews are known to evaluate existing or current research studies, identify research gaps and help further advance the specific area of interest (Jesson *et al.*, 2011; Eriksson and Kovalainen, 2015). However, the systematic literature review (SLR) presents a comprehensive study of the research area and organises intellectual inquiries by using a rigorous, evidence-based review approach, with the aim to collect as many existing publications as possible related to the research question based on a search strategy and prespecified eligibility criteria (Higgins and Green, 2011; Kysh, 2013; Petticrew and Roberts, 2008). By evaluating the studies collected, researchers can extract, synthesise and analyse information to investigate relevant research questions. Therefore, the systematic review provides an advantage as it reduces bias and provides an improved understanding of the existing evidence in this research area. Furthermore, the systematic review is more credible, as the approach is well-defined and transparent. The bibliometric analysis, as it quantitatively analyses criteria for literature development, also provides an approach to assess the maturity of the research area. To evaluate the maturity, the framework developed by Keathley-Herring *et al.* (2016) was adapted for this study to guide the data extraction and analysis. The results of this analysis reveal information about the how this research field has developed over time and highlights opportunities for academic researchers and industry professionals interested in the research area to strategically advance the field.

There have been systematic reviews conducted in the areas of engineering and operations management in recent years to synthesise research with the aim of improving knowledge and understanding research trends, such as identifying the trends in the engineering management literature (Spurlock *et al.*, 2008), assessing the literature for practices of Kaizen events (Glover *et al.*, 2014) and assessing the maturity framework of a research area whose publications have made unique contributions to their disciplines using the systematic reviews (Keathley-Herring *et al.*, 2016) and whose publications have made unique contributions to their research areas. Also, there have been previous studies of SD application in organisational PM that has provided significant overviews of prior research and development on the advantage of combing these approaches (Bititci *et al.*, 2000; Sarkis,

2003; Akkermans and van Oorschot, 2005; Bititci *et al.*, 2012; Nielsen and Nielsen, 2012; Bianchi, 2016; Bititci *et al.*, 2018); however, the literature reviews were not the focus of these papers, and to the best of our knowledge, no previous paper has provided a SLR that is comprehensive and rigorous in examining, assessing and understanding the trends and maturity of the research area of PM and SD. A similar literature to this paper is the Cosenz and Noto (2016) publication where the paper adopted a systematic review to explore the use of SD in strategic management and discuss the developments in the field for increased learning, highlighting areas for future research. Cosenz and Noto (2016) applied the framework adapted from Tranfield *et al.* (2003), using a bibliometric analysis. This study of Cosenz and Noto (2016) differs from this paper as it did not specifically address the literature of SD applications in organisational PM or the maturity of the research area.

To address this gap, this paper conducts a systematic review across 10 platforms and assesses the collected publications using bibliometric analysis. There has been significant interest in the research area over the last 10 years (Bititci *et al.*, 2000; Bititci *et al.*, 2012; Bititci *et al.*, 2018), and this paper assesses several dimensions of the field and summarises the maturity of the area. Due to the scope of the review, this is the first of two planned papers that the publications identified by using the SLR to provide insights on trends and developments in this research area. While this paper focuses on the bibliometric results and maturity assessment, the second paper will focus on a thematic analysis as a follow-up study to synthesise key themes across publications (Oladimeji *et al.*, 2020).

The purpose of this study, therefore, is to review the existing knowledge on the applications of SD tools and principles to organisational PM, using a SLR and bibliometric analysis. By exploring the theoretical and contextual developments of this research area through a bibliometric analysis, important research trends and the key contributions are identified. It also demonstrates the research gaps and opportunities for future research. The study investigates the development of the research area by analysing several dimensions, such as authorship characteristics and methodologies used, to assess the development of these dimensions in the research area and suggests strategies for improvement. The following section provides a description of the research methodology that explains the SLR stages including the scoping study, search strategy and exclusion criteria. In Section 3, the results of the bibliometric analysis are discussed, which are then further explored using the maturity assessment framework in Section 4. Section 5 discusses the managerial implications from the findings and analysis. Finally, Section 6 summarises the paper, provides the study limitations and gives directions for future research.

2. Research methodology

A SLR adapted from Tranfield *et al.* (2003) and Higgins and Green (2011) was used to provide a rigorous and extensive search of the research area. To achieve the goals of this study, the scope of the SLR was defined as research that applied SD to organisational PM, where organisational PM was defined as a strategic management tool directed towards an organisation's vision and strategy. Also, SD was defined as any modelling technique that used a causal loop diagram or stock and flow diagram, or even applied these concepts at an abstract level. First, the following research questions were defined to guide this study:

(1) How has the literature regarding SD applications in organisational PM systems evolved over time?

(2) What is the current state of this research area?

(3) What are the key areas of future work that should be addressed to develop the maturity i.e. authorship (co-authorship networks), research design, publication characteristics, content characteristics and impact characteristics of this research area?

The remaining steps of the approach, which include the scoping study, development of search strategies and application of the exclusion criteria (Moher *et al.*, 2009, 2015), will be discussed in the following sections.

2.1 Scoping study

A general search of relevant studies in the research area was conducted to identify an initial paper set that captures the scope and purpose of this study. The scoping study was conducted on 10 platforms as follows: (Compendex (Ei Village 2), Emerald Journals, IEEE Xplore, Web of Science, EBSCO, JSTOR, ProQuest, ScienceDirect, Scopus and SpringerLink). The initial scoping review identified 10 papers, which were publications selected from the last two decades, based on a simple search using the search terms "system dynamics" and "performance measurement". The publications included the following: Vaneman and Trianfis (2001), Grizzle and Pettijohn (2002), Santos *et al.* (2002), Akkermans and van Oorschot (2005), Su *et al.* (2007, 2010), Capelo and Dias (2009a), Cosenz and Bianchi (2013), Gunarsih *et al.* (2016), Hu *et al.* (2017). These articles in general focused on designing or implementing PM systems using SD modelling tools and approaches to improve organisational learning and performance outcomes. The scoping study suggested that many papers used the BSC as a guiding PM framework and that there were various levels in the organisation where SD was applied (e.g. business units, department/functional levels and organisational levels.). Also, other exploratory approaches were observed, such as hybrid models that consisted of data envelopment analysis (DEA), analytic hierarchy process (AHP) and statistical analyses. Therefore, the search strategy was designed to capture publications that study the use of SD as a primary focus of the paper and are mainly concerned with the organisational level of performance.

2.2 Search strategy

The publications identified during the scoping study were analysed to provide input into developing the search strategy including evaluating aspects such as terminologies used, author disciplines and locations, publication sources and key references. These results were used to define relevant search terms and strategies such as what portion of the paper was to be searched (i.e. title and abstract versus full text). The set of platforms to be searched were identified by consulting with library and industrial and systems engineering experts regarding appropriate platforms for the research area. The platforms were also selected based on the availability of full text articles, the topics and the disciplines included. Ultimately, the initial 10 databases were maintained (i.e. EBSCO, Emerald Journals, Compendex (Ei Village 2), IEEE Xplore, JSTOR, ProQuest, ScienceDirect, Scopus, SpringerLink and Web of Science). An initial set of search terms was defined consisting of any potentially relevant terminology identified during the scoping study or during consultations with the subject area experts. This initial set of search terms was extensively tested using an iterative process to determine which terms were most useful in capturing relevant publications. The search protocol was then defined to utilise equivalent search phrases across all the platforms to ensure consistency in the search approach. A title and abstract search was selected to identify papers that had SD and PM as a primary focus. Furthermore, search tools such as proximity operators, truncations and wildcards were tested while refining the search.

The capture rate for the search was evaluated to ensure that the search strategy was effective and was properly scoped. The capture rate for each platform was calculated as the percentage of scoping set articles that were in the particular platform (as determined by searching for the article by name in that platform), which were also retrieved from that platform by using the search phrase (Higgins and Green, 2011). For example, out of the ten

scoping set papers, Compendex had only five available on its platform (as verified by searching for the papers by title), which include publications from the following: Vaneman and Trianfis (2001), Akkermans and van Oorschot (2005), Su *et al.* (2007, 2010), Hu *et al.* (2017). Out of the five available papers, only four were captured, which results in an 80 per cent capture rate. The capture rate for each of the platforms selected ranged from 80 per cent to 100 per cent, and each paper in the scoping set was captured on at least one platform, resulting in a total capture rate across all platforms of 100 per cent and indicating an acceptable rate for identifying publications (Oladimeji *et al.*, 2017). The purpose of the scoping study and calculation of the capture rate was twofold. First, it was to verify that the search protocol was adequate to capture relevant papers included in the platforms (i.e. that the minimum capture rate for each of the platforms was sufficient). Second, it was to verify that the platforms selected provide adequate coverage of the research area, given the adopted search protocol (i.e. that each scoping set article was retrieved from at least one platform).

Once the search strategy and search terms were finalized, the platforms were queried with the following phrase: "((performance NEAR/3 (measurement OR management)) OR (balanced scorecard)) AND ('system dynamics' OR 'systems modelling' OR 'business dynamics')." Depending on the unique algorithms associated with each database, the searches were specialised with search terms or characters, to ensure accuracy in how the terms were applied. The features of the search – the Boolean operators, proximity operators, truncation and wildcards – varied across the different databases, and in order to be as comprehensive as possible, the search phrases were designed to achieve a balance between sensitivity and precision, by leveraging the proximity operator (Higgins and Green, 2011). This approach ensured that variations of relevant terms were applied including "performance measurement", "performance management", "balanced scorecard", "system dynamics", "modelling", and "business dynamics". No limiters were applied (e.g. date, document type, domain, etc.) to ensure that the search was comprehensive and would capture a wide variety of publications. The full text available limiter was not used, and any publication whose full text was not immediately available was searched for on Google Scholar and a university library system although some publications were found to be inaccessible, and therefore were excluded from the study. There was no restriction on publication types; so, practice-focused publications by industry professionals were also identified in the search. However, due to the timing of the search, the results only cover articles published up to September 2017.

2.3 Exclusion criteria

Once the search strategy was finalized, the search was executed on the 10 platforms, and the total number of publications identified using the search protocol for each, referred to as the "raw" (initial) results, is summarized in Table I. No limiters were used to ensure that the search was comprehensive across various disciplines and publication types. The platforms were reviewed in a sequential order based on ascending number of raw results. The citations were downloaded for review, and all duplicates were removed. The remaining results were then evaluated by reviewing the titles and abstracts capturing all papers that contained the concepts of SD and PM. Once the initial review was complete, the selected publications were reviewed in detail, and a set of exclusion criteria were used to select relevant publications for the final paper set. The results after all exclusion criteria have been applied is the "final" result, as summarised in Table I. To improve the rigour of the search, exclusion criteria were developed and tested by the team of three researchers, using group evaluations of randomly selected publications and inter-rate agreement exercises. A preliminary analysis was conducted by Oladimeji *et al.*, (2017) on four of the 10 platforms including Compendex (Ei Village 2), Emerald Journals, IEEE Xplore and Web of Science to initially explore the development of the research area and to further develop the exclusion criteria. The exclusion criteria included removing any paper that was not written in English and that did not apply

SD to PM at a strategic/organisational level, and the integration of SD and PM was required to be a primary focus of the paper.

To illustrate, Web of Science was examined first as it had the lowest number of raw results ($N = 189$). First, the citations were downloaded and the titles and abstracts were evaluated. Any potentially relevant publication was downloaded for further review. In cases where the full text was not immediately available, the citation was searched for using the alternative search platforms. This process resulted in the selection of publications, which were then reviewed in detail by reading the full text. During this evaluation, the exclusion criteria were applied, and after this second review, twenty papers were selected for inclusion in this study. The second platform to be evaluated was to be Emerald Journals, as it had the next smallest number of raw results ($N = 322$). The citations were downloaded and compared to the previous results, removing 88 publications that had already been identified on the Web of Science and therefore were excluded from the study as duplicates. The second review (i.e. reading of the full text and application of the exclusion criteria) resulted in 11 additional publications being selected for inclusion in the study. This process of selecting papers and then identifying and removing duplicates was repeated until all platforms had been evaluated. Table I shows both the raw and final (post exclusion) results of the study.

The PRISMA standard of reporting shows how the papers were identified, screened and selected for this systematic review, and it is summarised in Figure 1. The records were initially screened by reviewing the initial titles and abstracts to determine the papers which fit the scope of the review process ($N = 2,153$). If the abstract suggested potential relevance, a full text reading of the publication was done to ensure the final paper set met the objectives of the study. This full text reading gave a final paper set of 97 publications after removing duplicates.

The final paper set consisted of 97 publications, which were selected for inclusion in this study. The publications in the final paper set are summarized in the appendix according to the platform from which they were selected including citation information (i.e. publication year, author information and title) (see Table AI).

2.4 Data extraction

An Excel spreadsheet was used to document, organise, manage and analyse information from each of the publications in the final paper set. The Excel spreadsheet contained a framework consisting of criteria across several dimensions of research area maturity, such as author names/affiliations, publication title, year of publication, industry, citations, context and keywords. The characteristics chosen were based on criteria and metrics that show the development of the research area and provided useful insights on these trends

Platforms	Raw results	Duplicates removed	Excluded publications	Final results
Web of Science	189	N/A	169	20
Emerald Journals	322	88	225	9
SpringerLink	1,832	139	1,682	11
IEEE Xplore	2,541	358	2,179	4
ScienceDirect	2,599	329	2,268	2
Compendex (Ei Village 2	4,629	649	3,958	22
Scopus	5,358	879	4,462	17
JSTOR	5,804	613	4,468	3
EBSCO	5,830	1,003	4,824	3
ProQuest	8,376	1,041	7,329	6

Table I.
Table showing raw results, duplicates, results removed due to other exclusion criteria and final results from the platforms

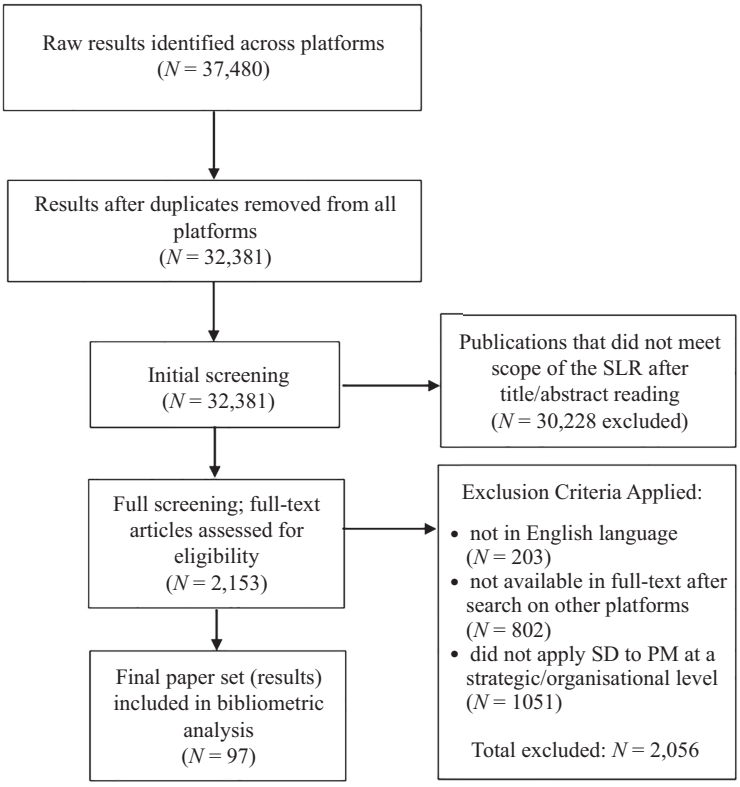

Figure 1.
Flow of information for a systematic review of organizational PM and SD

(Keathley-Herring *et al.*, 2016). Specifically, it included evaluating dimensions such as publication and author characteristics, the impact of these characteristics on the research area, the extent to which SD has been applied in PM phases and the types of research methods used in this research area, based on information extracted from the final paper set. The relevant information and data were extracted from each the publications in the final paper set and stored in the database. The analysis was then conducted by evaluating each criterion, and the results are discussed in the following section.

3. Results

The aim of the analysis was to describe the relevant characteristics of the research area to evaluate the development of this research area. Evaluation of the collected publications shows that the first publication is from 1997, which is expected, as previous literature reviews on PM, individually, have suggested the mid to late 1990s as the development of the research area (Bititci *et al.*, 2000; Bititci *et al.*, 2012; Bititci *et al.*, 2018). However, the earliest paper that comprehensively applied SD in PM is from the year 2002 by Santos *et al.* (2002). In the paper, the authors created a casual model and stock and flow model of the PM system and ran simulations to test scenarios showing how SD could be used for improving PM systems. The results of that study demonstrated that SD added value to PM systems by facilitating communication, increasing commitment and understanding and influencing decision making. The following sections discuss the results of the criteria used in this analysis,

including the discussion based on the maturity assessment framework (Keathley-Herring *et al.*, 2016).

3.1 Publication trends

As shown in Figure 2, the results from the final paper set suggest an increase in the number of publications from the years 1997–2016 in this research area. This trend provides evidence of sustained and growing interest in the research area. The search was completed in September 2017, resulting in the relatively lower value for the final year. Because the data for this year are incomplete, the year 2017 cannot be evaluated as part of the trend; however, the preliminary 2017 results are still included in Figure 2 to show the activity in the field as of September 2017.

The Compendex platform had the most relevant publications, as seen in Table I ($N = 22$), based on methodology used. Also, most publications were from peer-reviewed academic journals (54 per cent), followed closely by peer-reviewed academic conference papers (37 per cent). This indicates that the majority of the publications are peer reviewed and research-focused. However, practice-focused publications accounted for comprised 2 per cent of the final paper set, suggesting some, albeit limited, dissemination of the research results to industry professionals.

As seen in Table II, the most common publication source was *Systems Research and Behavioral Science*, with h-index of 39 (4 papers) followed by *The International Journal of Productivity and Performance Management*, with h-index of 48 (3 papers) at the time this research was being written. The other top journals also had a system dynamics,

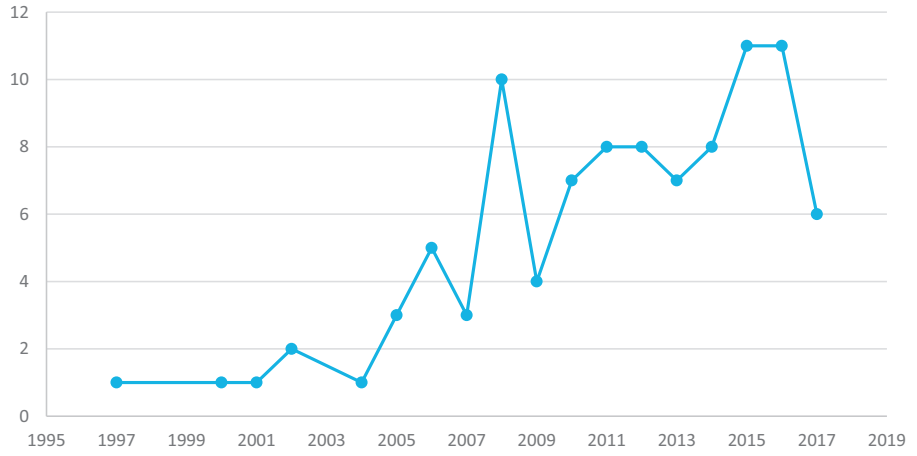

Figure 2.
Publications per year ($N = 97$)

Journal	Number of papers
Systems Research and Behavioral Science	4
International Journal of Productivity and Performance Management	3
International Journal of Public Administration	2
Journal of Management Control	2
Management Decision	2
System Dynamics Review	2
The Journal of the Operational Research Society	2

Table II.
Table showing most common journals by number of papers

engineering or management focus. The total number of journals identified for this review was 57, and those ($N = 40$) not identified in Table II only appeared once in the final paper set.

In general, the results of the publication trends suggest an active and growing field. However, the fragmented nature of the publication sources, as evidenced by the large number of journals ($N = 40$) containing only a single publication on the topic, suggests that this research area is less mature and lacks any sources that are dedicated to this topic. Future developments should include an expanded focus on communicating research results to industry professionals, so they can actively adopt the studied techniques and the use of publication outlets within the system dynamics, engineering and management fields.

3.2 Performance measurement phases

As discussed previously, the four phases of the PM system development process are design, implementation, use and review (Bourne *et al.*, 2000). In the design phase, SD is used for planning, formulating, modelling and proposing conceptual approaches that enhance PM systems. The design phase is the most commonly studied in this research area, as seen in Figure 3 below. By modelling the PM system (i.e. metrics and relationships), stakeholders can better understand the structures and behaviours of PM systems (Tsalis *et al.*, 2015). In the implementation phase, SD is used to model the execution and deployment of the PM system including modeling behaviours that lead to successful adoption. Implementation does not necessarily lead to use of PM systems; therefore, SD is used to communicate, review and ensure that stakeholders understand the PM system that is to be executed and monitor the success of the implementation process (Barnabè and Busco, 2012). Although it is less common, the results of this study also identified examples where SD is applied in the use and review phases (Santos *et al.*, 2002, 2008). In the use phase, SD is primarily used for policy evaluation and assessing different scenarios. That is, PM processes are investigated to assess whether there have been improvements, and "what-if" analyses are considered to analyse different scenarios. The review phase focuses on auditing PM systems to ensure that they are strategically aligned and functioning well.

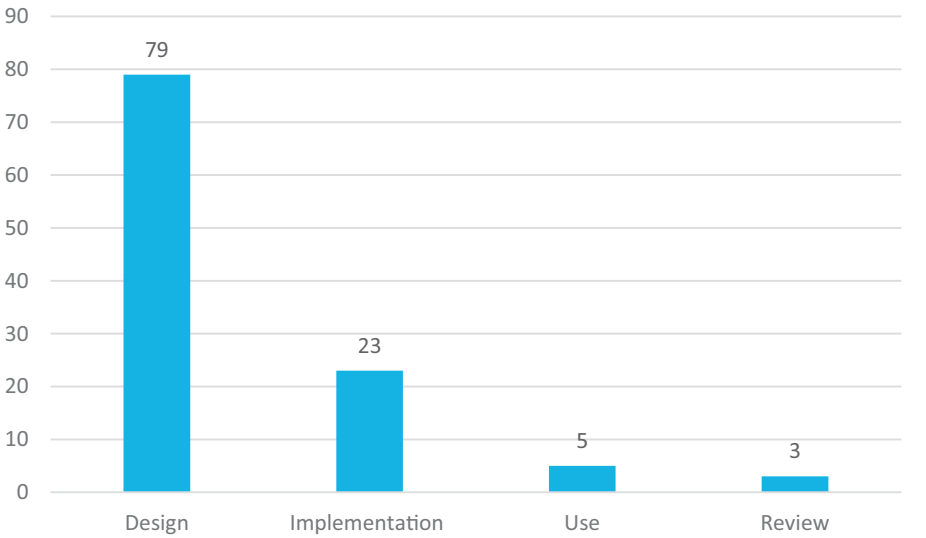

Figure 3.
PM phases explored in the literature

Although most publications focused on one phase of the PM system development process, some discuss two or more of the phases. A significant percentage of the existing research is mainly focused on the design phases, which highlights an important gap in using SD to improve the way that people interact with the PM system rather than just improving the function of the PM system itself. The other phases need to be explored for future research to be able to validate and improve upon the PM systems. Application of SD can potentially help with the dynamic nature of the implementation phase, provide important insights to support decision-making during the use phase and can assist in auditing the results during the review phase.

3.3 Extent of SD application

The reported extent to which SD was applied to organisational PM was also investigated. In the final paper set, 14 (14 per cent) papers only applied the general principles from SD without reporting the application any specific modelling tools (i.e. causal loop diagramming, stock and flow, etc.). Figure 4 summarizes the results of the remaining 83 papers across categories describing the level of SD modelling applied. The results capture all the categories that were used in each publication; thus, each publication could be associated with more than one category. Of all the 97 papers in the final paper set, 72 per cent used a causal model, while only 19 per cent tested scenarios.

The findings reveal that a strong majority of the 83 publications used the causal model in the SD applications and also translated the causal model into a stock and flow diagram and/or a simulation model. The causal models were often applied to strategy maps, stock and flow models were used for designing dynamic PM systems based on these maps and simulations were used to represent the current system behavior, for strategic decision making. However, only about 20 per cent of the papers used the developed simulation models to test alternate scenarios. Furthermore, less than 40 per cent of the models in the "ran simulations" and "tested scenarios" categories were actually verified. As it was only possible to evaluate the extent of SD application that was actually reported in the papers, it is certainly possible that some of the authors applied SD in other ways not reported in their papers; still, it is telling that relatively few papers in the final paper set went beyond reporting the results of tested scenarios. Overall, these results suggest the need for future research that goes beyond developing initial models to represent the current state of the PM system, to include studies which focus on use of the model to investigate performance improvement alternatives and validation of the model over time.

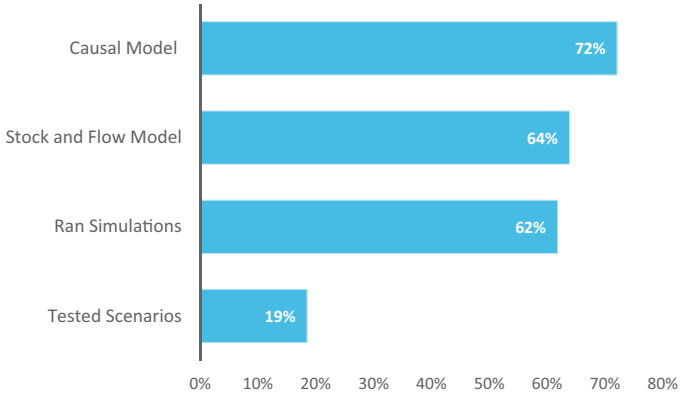

Figure 4.
Extent of reported application of system dynamics

3.4 Methodologies used

The methods analysis investigated the techniques used for data collection and analysis from the final paper set. As no restriction was placed on publication type in the search, there were both academic research papers (e.g. peer-reviewed journal and conference papers; dissertations) and practice-focused publications (e.g. trade magazine articles focused on industry professionals) in the final paper set, although the majority of articles (92 per cent) were academic in nature. Given these differences, these two types of papers were analysed separately. For the academic papers, as a formal research methodology was used, both the data collection and data analysis techniques were examined (see Figure 5). For the practice-focused works, as the methodologies were less-structured, only a broad categorization of the overall approach was used (see Figure 6). About 60 per cent of publications (both academic and practice-focused) used one or more of the data collection and analysis methods in their work.

As shown in Figure 5, examination of the techniques used in academic papers reveals that the use of secondary data is the most commonly used data collection method, followed by case studies and organisational documents. This suggests that most of the work being conducted

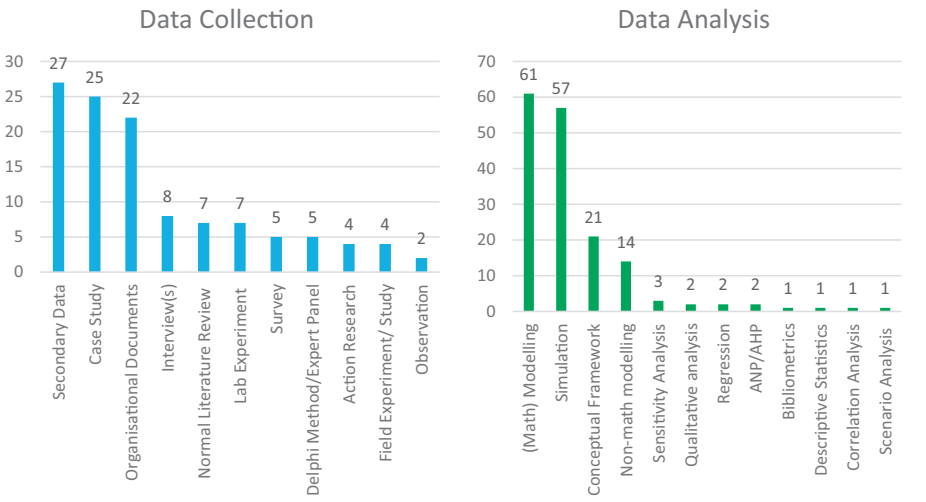

Figure 5.
Data collection ($N = 116$) and data analysis ($N = 166$) methods used in academic papers

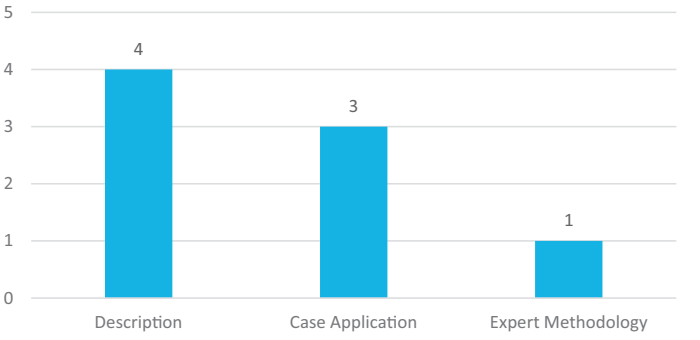

Figure 6.
Methods ($N = 7$) used in practice-focused publications

is exploratory and focused on examining the feasibility or usefulness of applying SD to PM systems. The data analysis methods most often applied are math modelling and simulation techniques.

For practice-focused works, as shown in Figure 6, description represents the method most used. The practice-focused papers were found to have three primary purposes. First, description publications focused on communicating information about a technique or approach. For example, some papers in this set focused on describing what SD is and how it might be useful in this area. Case applications were general discussions about how SD has been applied in the past. Unlike academic case studies, these papers did not follow an explicit approach or state any research questions or objectives. Finally, expert methodologies included publications where subject area experts communicated best practices.

In terms of academic publications, the data collection and analysis methods are as expected for this research area and suggest that most of the work is exploratory. This suggests that future research should focus on collecting more data through primary sources like case studies to provide direct corroboration of the existing evidence as this will help improve the integrity of the research. Testing of data through, for example, scenario analysis should also be investigated. Furthermore, the use of more advanced methods like action research, large-scale studies, statistical studies, etc. should be introduced. In practice-focused works, the techniques are approaches used by industry professionals for communicating emerging and established best practices; as indicated previously, they represent neither a data collection nor an analysis technique but rather constitute an overall approach. The practice-focused methods mostly consist of descriptions, and the results suggest that additional explorations of case applications and expert methodologies are important to improve the maturity of the area. Finally, the results suggest that more collaborations among these two groups will also help to advance this research area.

An examination of the academic papers in the final paper set over time revealed that many papers published before 2008 were primarily conceptual and mostly focused on exploratory research, while the most recent academic papers are more empirical and focused on descriptive research. This suggests growth in the research maturity that opens up opportunities for more explanatory studies, which still seem to be largely lacking.

3.5 Industries

The analysis of the industries examines the organisational contexts on which the publications were focused. Overall, eleven publications in the final paper set did not specify an industry, used a hypothetical organisation or focused only on theoretical frameworks. From those 86 publications that did specify an industry, 17 papers mentioned aspects that were not studied in any other paper such as corporate social responsibility, military, waste management and zoo management. Figure 7 shows the industries with two or more mentions in the final paper set.

The results show that the concept of organizational PM and SD is mostly frequently studied in academic settings, such as school systems and universities and businesses, such as start-ups and corporations, with the focus on improving strategic performance management. However, the range of unique industries is quite broad, including examples in governance and the police. The collaboration of academic and business industries is also another interesting aspect, as this suggests that there are instances of theoretical frameworks being developed into practical applications. The remaining 28 industries (not shown in Figure 7) had only one mention in a single publication. Overall, while the results suggest that SD is being applied to PM in a broad range of organisational contexts, there is a clear need for replication studies in those industries that currently are represented by only one or a few publications. In addition, there is a need for multi-industry studies (Kunc, 2008; Bianchi, 2016).

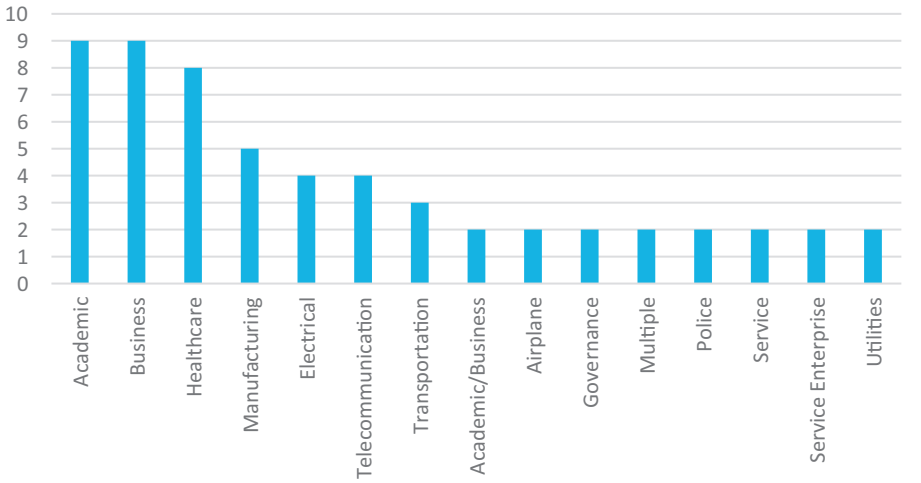

Figure 7.
Most common industries ($N = 58$)

3.6 Impact of publications

The impact of the publications in the final paper set can be assessed using the average citations per year. The data on total citations of the papers were obtained from Google Scholar during May 2018. The average citations per year were then calculated based on the total number of citations divided by the number of years since they were published. Figure 8 shows the average number of citations per year only for the most highly cited publications.

This information indicated the most commonly cited publication is the Boland and Fowler publication, which has an average of 20.28 citations per year (2000). The article is titled "A systems perspective of performance management in public sector organisations" and was published in the International Journal of Public Sector Management. As of May 2018, it had 365 citations from Google Scholar. The authors proposed a dynamic performance management framework that is expected to provide a better understanding of the system and help organisations focus on strategic policies and in how they can be attained. The most common themes in these highly cited publications relate to designing conceptual frameworks to improve decision-making through strategic management by exploring the dynamic complexity of the organisational structures through developing a SD model of the PM system (Bianchi *et al.*, 2015). A greater focus on dissemination of advancements in this research area, such as publishing results in sources with good h-index ranking or impact factor or presenting recent information of research at conferences and seminars, would help to improve the visibility of the work, allowing for more cohesive development of this research area and more effective transfer of best practices to industry.

3.7 Authorship characteristics

This section evaluates the authorship characteristics of the final paper set including most common authors, authors per year, author geography, author affiliation and co-authorship analysis. There were 184 unique authors (including co-authors), and about 15 per cent of the authors had more than one publication in the final paper set. Bianchi has the most publications with ten papers in the final set. Figure 9 below shows the authors with more than one publication. This could suggest that most authors may not view this field as their primary area of research, hence just publishing in this area once or twice and indicating a lack of "experts" in this area.

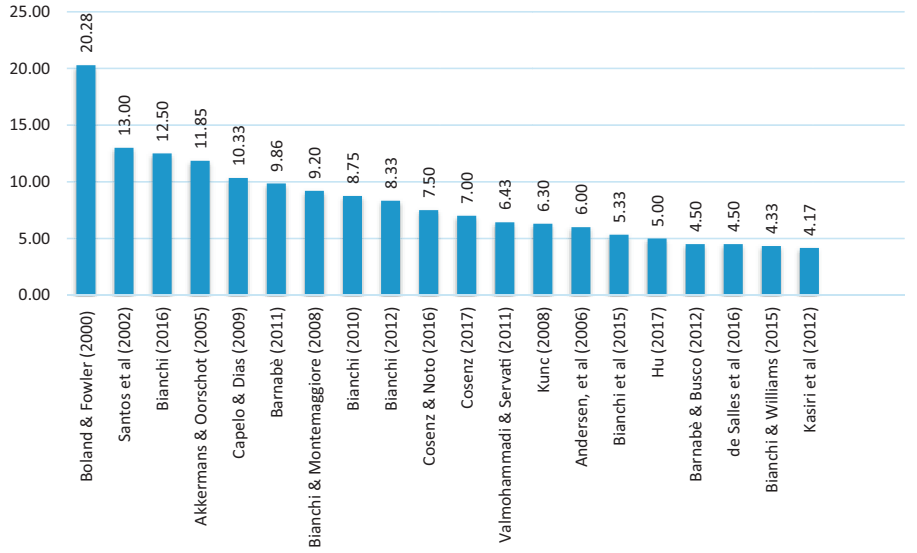

Figure 8.
Average citations per year for most highly cited publications ($N = 20$)

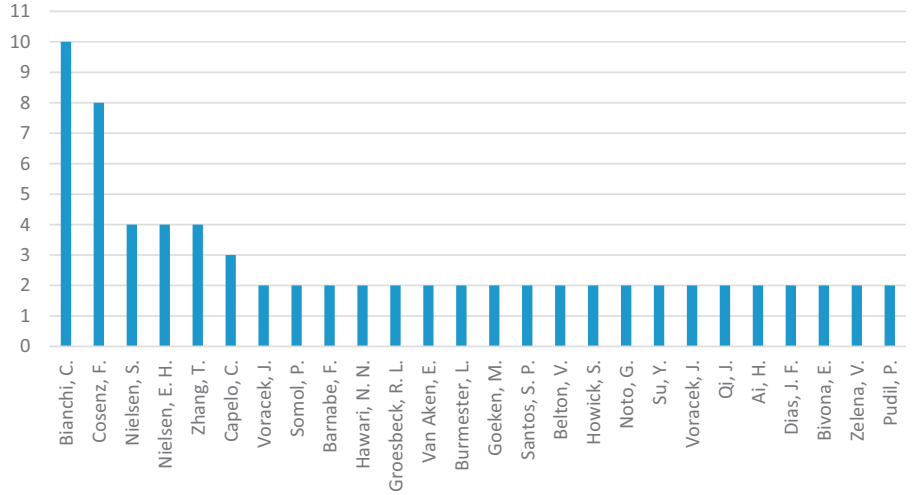

Figure 9.
Most common authors

The emergence of new authors per year is summarized in Figure 10, which shows an increasing trend from year 1997–2016 indicating the number of new authors per year is significant. As discussed previously, the data for 2017 are incomplete as the search ended in September 2017, and therefore, authors who published in 2017 ($N = 12$) cannot be evaluated as part of the trend. The significant number of new authors provides the research area with an increasing wealth of knowledge, as well as different perspectives of applying SD to organisational PM. This can also help emerging researchers and industry professionals to be aware of the existing contributions and build on the relevant works in the research area. This also indicates good prospects for the research area as increasing interest suggests increasing

development of SD applications in PM research. In terms of future developments, there is a need for more balance between established authors and new authors entering the field, including the need for more collaborations between new and established authors.

The next analysis looked at the geographic location of the authors based on their institutional affiliation. As shown in Figure 11, the authors that have contributed to the research area are primarily from China, followed by the United States and Canada. Only four publications had institutional affiliation from just one country, indicating a strong body of multinational research collaborations. Overall, the results suggest that the research is international, although, as noted, China has a good number of author/co-authors emerging in the field. Also, most of the research is from institutions in Asia, North America and Europe, with relatively few authors from South America or the Middle East and none from Africa or

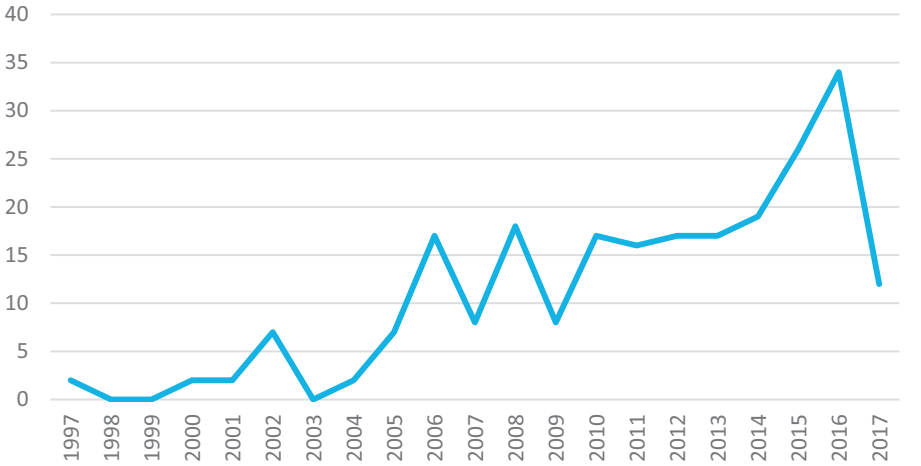

Figure 10.
New authors per year

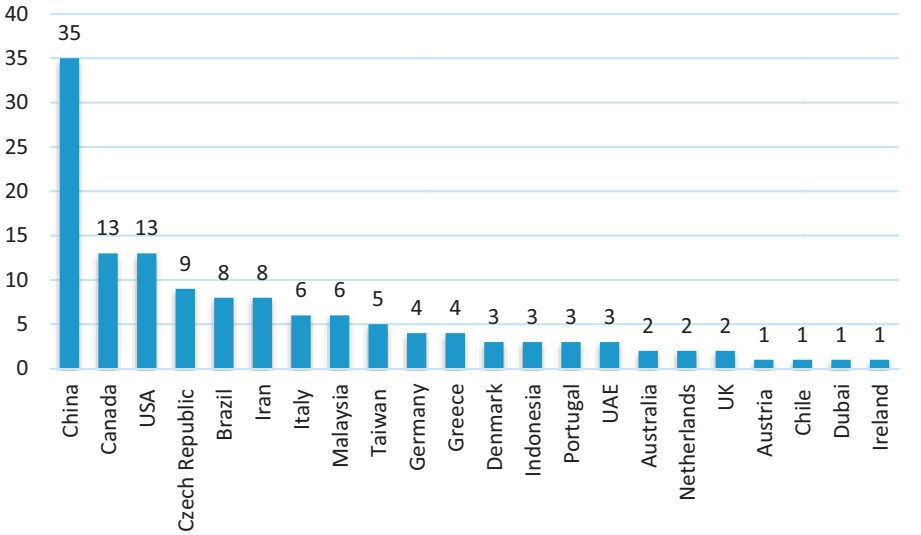

Figure 11.
Author geography (based on institutional affiliation)

Central America. Future research should focus on collaborations among scholars from different regions, particularly the under-represented regions noted above, to broaden the perspectives underlying research in this area. One way this might be achieved is through international academic conferences or workshops focused on the subject.

Table III shows author affiliation by discipline, for those disciplines with three or more occurrences in the final paper set. While the research cuts across diverse disciplines, there is an indication that most of the authors are from the management or industrial and systems engineering disciplines (both with 23 total publications).

This suggests a strong interest from the two disciplines in applying SD to PM to continuously improve organisational performance and managing processes. About 35 per cent of the papers had multidisciplinary authorship from industrial engineering, management and economics. This suggests increasing opportunities for researchers across these disciplines to work in interdisciplinary research across academic setting and organisations. Future work should also seek to engage under-reported disciplines to broaden the perspectives and contributions.

3.8 Co-authorship analysis

Co-authorship is evaluated using network analysis to help understand interactions and interrelationships among prominent authors in this research area. An initial, exploratory network analysis, which was used on four platforms (Compendex (Ei Village 2), Emerald Journals, IEEE Xplore, and Web of Science) was conducted to gain preliminary insights into key authors and relationships (Oladimeji *et al.*, 2018). The analysis was conducted with the final paper set to recognise prominent authors and their contributions to the research area.

The network analysis was conducted using the NodeXL software tool developed by Codeplex, which is embedded in Microsoft Excel. NodeXL uses mathematical and statistical algorithms to compute the metrics and features of the network. The Fruchterman–Reingold algorithm was initially applied, and the resulting network was adjusted for clarity to ensure that all author names were readable, as seen below in Figure 12. (specifically, in Figure 12, all authors with a betweenness centrality of 2.0 or less have been omitted in order to generate a legible figure). The co-authorship network in Figure 12 shows authors as nodes or vertices, represented by the dots and their collaborations on publications as edges, which are represented by lines. The size of the nodes represents the number of publications by an author, and the thickness of the edges indicates the number of co-authored papers between two authors.

The results from the network analysis indicate that there were 184 authors and co-authors in this network, with 261 interactions between the authors represented by the unique edges. The analysis uses an undirected graph, that is, all edges represent a two-way relationship. Edges with duplicates from the result suggest that the same author and co-authors interacted multiple times (there were a total of eight duplicate edges in the final paper set). Overall, these metrics show both the unique and total interactions among the authors. The self-loops

Discipline	Authors
Management	12
Economic and management	11
Health	10
Industrial engineering	10
Industrial and systems engineering	8
Information technology	3
System engineering	3

Table III.
Author affiliation by discipline

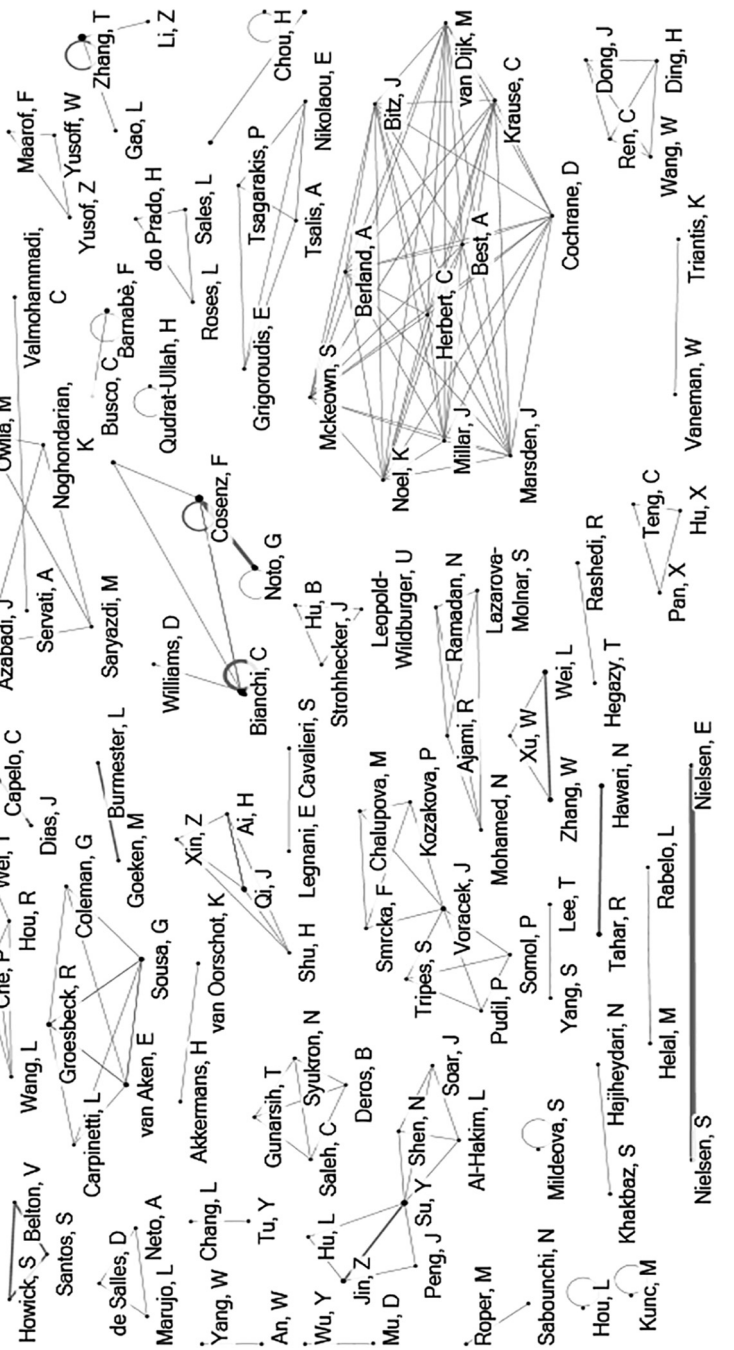

Figure 12.
Co-authorship network with betweenness centrality greater than two

indicate publications where there was only one author, which occurred in this network 16 times. Publications ($N = 6$) from the final paper set that had a single author were authored by Bianchi and Montemaggiore (2008); Bianchi and Tomaselli (2015); Bianchi (2016) and Cosenz (2014, 2017); Cosenz and Noto (2015), who have emerged as prolific authors in the PM and SD literature. Also, these two authors have several collaborative works with other authors, which enhances their impact in this research area (see Figures 9 and 12).

Graph density is calculated using the ratio of the total edges multiplied by two, divided by the number of possible connections (Otte and Rousseau, 2002). Research suggests that a graph density of at least 60 per cent shows a dense graph and a prominent level of interaction in a network (Scott, 1988, 2017). This is important because a high level of interaction increases the expertise in the research area. The graph density of the current network is approximately 1.5 per cent, indicating a sparse graph structure and thus, a low level of interaction among authors in the network. These results also agree with the initial analysis, using only four platforms (Oladimeji *et al.*, 2018). For this network, therefore, the low graph density indicates limited collaborations and suggests a relatively low level of overall expertise in the research area. Efforts can be made to increase collaboration and interactions through academic conferences or workshops in the research field.

The centrality measures in a network analysis are indicative of the influence and significance of the authors in the network. For this analysis, the betweenness centrality and closeness rankings are explored to investigate these measures. The betweenness centrality is used to understand the authors who collaborate more frequently with other authors in the network and is calculated by the shortest communication paths between the authors. In this network, Bianchi had the highest betweenness centrality, with a score of 52.5. This is due to the fact that this author had the largest number of journal papers and books published and had a large number of collaborations with the other authors in the network. This result is particularly interesting because an initial analysis using only four platforms (Oladimeji *et al.*, 2018) found Su *et al.*(2007, 2010, 2014) as the author with the highest betweenness centrality as he had the widest publications (conference paper, journal papers and book chapter). The results suggest that Bianchi may be the current leading expert in the field and that researchers and industry professionals can use Bianchi's works as a resource to gain an overview of developments in this research area. Bianchi's work also highlights potential areas where the field needs to be further developed; for example, including qualitative modelling to enhance dynamic performance management is an area identified in one of Bianchi's studies (Bianchi and Tomaselli, 2015).

Closeness centrality shows how closely connected the authors are to each other, that is, it shows the minimum path distance between the authors. The minimum closeness centrality is 0 and the maximum closeness centrality is 1 (100 per cent). For the closeness centrality, the lower the score, the better (Wasserman and Faust, 1994; Carrington *et al.*, 2005), as authors with a lower centrality tend to publish regularly with authors with the most influence in the network. This can also increase the information exposure and thus knowledge in the research area (Haythornthwaite, 1996). The analysis shows that the minimum path distance between the authors is about 0.435 (43.5 per cent); thus, authors have an average level of interaction with the most important authors in the network.

4. Discussion based on maturity assessment framework

Finally, the results from the bibliometric analysis were used to assess the current maturity of the research field, by adapting the levels of maturity models from Wettstein and Kueng (2002); Van Aken *et al.* (2005); Pöppelbuß and Röglinger (2011); Bititci *et al.* (2015) and Keathley-Herring *et al.* (2016) that consisted of the following: low (emerging), moderate (developing) and high (maturing) areas. A low level (represented by the inner pentagon in

Figure 13) indicates the research area is exploratory, with few advanced methods, few experts and many conceptual frameworks, where models are developed as a diagnostic tool. A moderate level (represented by the middle pentagon) suggests more descriptive work, more advanced methods, more emergence of experts and models used for analysis of the management processes and as an operational tool. A high level (represented by the outer pentagon) indicates well-developed infrastructure, much interaction between disciplines, research groups, where advanced methods are applied in practice, that is, research is used in supporting decision-making processes at every level in the organisation. As shown in the radar graph (Figure 13), the following criteria were used to assess the maturity of the research area: publication characteristics, content characteristics, author characteristics, research design characteristics and impact.

As seen in Figure 13, the research area appears to currently have a low level of maturity in all dimensions except the content characteristics. The analysis of the first maturity dimension, publication characteristics, was investigated using the publication outlets, trends and type. The publication outlets from this field are mostly from research-focused management and engineering sources that include academic journals and conference papers. In addition, the publication trends show increasing interest in the research area. This suggests this area is generating increasing interest in terms of research, which indicates some initial development of the field. In addition, the publications are represented in diverse outlets, but less than 20 per cent of the papers have been published more than once from the same outlet. This shows there is not a central hub for this research, which is somewhat expected given that this is a sub-area, that is, there are dedicated journals for PM and journals for SD, but no sources specifically focused on SD in PM. Also, the publication type is mainly academic, with relatively few practice-focused publications to disseminate the research findings to industry professionals. Thus, it appears that this research area is still emerging in terms of publication trends. To improve the maturity of the research area, publishing more often in business journals or in practice-focused magazines could help to advance this research area.

The content characteristics explored through the topics and scope of the research area suggest that authors agree on fundamental aspects such as terminology, definitions, constructs and keywords though the focus of the publications is still relatively narrow. This investigation shows that most SD models are developed for the design phase of PM, that is, more dynamic PM frameworks are being designed. Also, analysis of the publications reveals that most of the work is conceptual and not yet tested in practice although there are some studies that are starting to branch out in studying other phases like the implementation phase

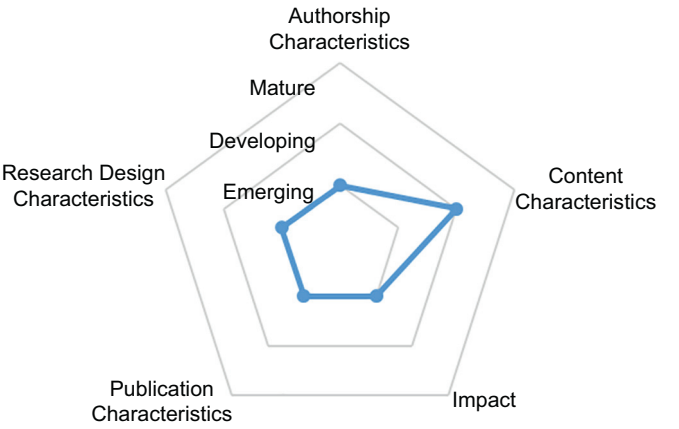

Figure 13.
Maturity assessment

as well as in applying frameworks in limited case studies. This indicates that there is consistency in the topics represented, but the evidence in practice is limited – the case studies are scoped down to make them feasible, meaning that the studies do not yet represent reality but a sterilised version, suggesting a developing area of research. The development of models for other phases can help in the refinement of theories in the research area by exploring practical applications in implementation.

The analysis of the authorship characteristics investigated the author quantity, diversity and collaborations. There are strong indications from the SLR results that there need to be more collaborations in this research area. The authorship characteristics including the sparse co-authorship network show that of the 184 unique authors, only about 15 per cent have published more than once. Also, only a few authors regularly publish together, even with many new authors emerging every year. Furthermore, authors also need to collaborate with industry professionals to increase actionable knowledge in the research area. The diversity of the research area is also mostly concentrated in industrial and systems engineering and management although more interaction with other disciplines and industry professionals will improve the maturity of the research area. Perspectives from other disciplines like business can help enhance the studies in practice. Overall, the analysis of the authorship characteristics suggests an emerging area of maturity, as co-authorship shows a thinly dispersed network.

The research design characteristics were investigated through the research methods used in the final paper set; this analysis shows secondary data, case studies and organisational documents are the most used data collection methods, rather than methods that are generally considered to be more advanced such as action research or experimental methods (lab and field). Also, the fact that mathematical modelling and simulation are the most common data analysis methods was expected, given the focus of the research area on SD; however, more scenario analysis and mixed methods analysis are needed to further develop the research area. Although there is a prevalence of case studies, it still appears that many conceptual models are being developed, with low adoption in industry. Furthermore, a significant percentage of the models from the publications have yet to be validated. This reinforces the previous finding that the research area is still mainly exploratory and yet to be developed for practice (Van Aken *et al.*, 2005; Tsey *et al.*, 2016). This can be improved by academic researchers and industry professionals collaborating to enhance the actionable knowledge and skills of the field, such as through professional development courses and transfer of the research to more industries. Thus, overall, the research field appears to have low maturity in terms of research design.

Exploration of the impact characteristics through the total citations and citations per year shows that about one-fifth of the publications have a strong impact on the research area. The most impactful publications explored sustainable organisational performance using a dynamic balanced scorecard (BSC) and enhancing strategies through SD modelling. In addition, when combined with the evidence that the number of papers per author shows less than 30 per cent of authors published more than once and due to the relatively small number of publications, the research area also seems to have low maturity in this assessment dimension (Penfield *et al.*, 2014).

Overall, the analysis shows that the research area, although emerging, currently has a low level of maturity. This means that current evidence should be interpreted cautiously as much work remains to validate and generalize the findings to create best practices for using SD as a practical tool to improve PM. The development and maturity of this field will help more academic researchers and industry professionals to incorporate SD as a tool that can revolutionise PM, like the dynamic BSC. In the implementation phase, SD can be used to model organizational behaviour related to adoption to test scenarios for improving implementation success. In the use and review phases, an SD-supported PM system can be used to improve data-driven decision-making and the shared understanding of organizational behaviour and performance drivers among managers.

5. Managerial implications

A number of studies from the final paper set suggest that applying SD tools and approaches to PM systems is recognised as an appropriate method for enhancing organisational performance and decision-making processes (Bititci *et al.*, 2000; Cosenz and Noto, 2015; Bianchi, 2016). This is because SD can help improve on the deficiencies of PM, as it can model cause and effect relationships and dynamic behaviours over time (Forrester, 1969; Sterman, 2000). From the results of this SLR, it appears that many academic researchers recognise the aforementioned opportunities, but only a few industry professionals are actually adopting SD models in their PM systems. Despite evidence highlighting the benefits of SD in PM, more effort is needed to understand the behaviour and structure of PM systems, for better execution of frameworks. Thus, future work should focus on engaging both academic researchers and industry professionals to strengthen the existing approaches to increase the usability of SD-supported PM systems in practice. Also, industry professionals can help identify the most effective strategies for applying SD to PM in practice and facilitate information exchange, which will help improve the quality and rigour of the execution.

Furthermore, as operating environments continue to have increased complexity, the need to prioritise the validation of models becomes increasingly important and requires a collaborative effort between academic researchers and industry professionals. For example, the academic researchers and industry professionals can be involved in field experiments that can advance current shortcomings and limitations of the knowledge area. In this review, the bibliometric analysis on industries suggests that SD can be applied to PM systems in different subject areas, which makes it an adaptable approach for improving performance in many types of organizations. It can also be adapted to the different phases of PM for continuous improvement. This review revealed that SD can help managers understand and improve complex systems by addressing dynamic complexities and relationship between variables, thereby, giving interested researchers and practitioners the opportunity to build on existing knowledge.

This review provides guidance necessary for professionals interested in adopting a SD-supported PM system by describing the trends and developments in the research area. A better understanding of the advancements and challenges reported in the literature can ensure that professionals are well-informed on the current usability of this approach. In spite of the limited SD application levels (see Figure 4) currently reported in the literature, the approach can be considered as viable when management or other stakeholders are examining methods to enhance PM systems. Reports from literature suggests that applying SD to PM adds value to the framework and improves knowledge of organizational behaviour and performance drivers (Santos *et al.*, 2002, 2018). In addition, adoption of this research area as practice can improve the economic and financial aspects of organisations, as it can increase the efficiency and quality of management decisions, such that strategic goals are better attained. Also, adoption could improve job satisfaction and commitment of organisational personnel, as they have more clarity regarding their roles in the organisation and how they impact performance results. Furthermore, adoption can help personnel learn to use systems thinking, which also helps them to more effectively align their behaviour with the strategic goals of the organisation (de Waal and Kourtit, 2013).

6. Conclusions

This paper presents the results of a SLR and bibliometric analysis of SD applications in organisational PM. The findings increase understanding of the current uses of SD in organisational PM, identifies the research gaps and suggests strategies for improving the maturity of the field. The results show a generally increasing interest in this area of research, which is highlighted by the increasing number of publications and authors and the impact of

the publications. However, there is also significant room for improving the maturity of the research area. The key findings of the SLR and maturity assessment include the following:

(1) The most popular analysis techniques being applied are modelling and simulation, which suggest that most of the publications look to understand the behaviour of the complex systems, to provide insightful assessments of the systems and to give the possibility of predictions.

(2) The SD applications mostly make use of causal models, and very few tested the models or applied the models to scenarios. Validating models and scenario analysis can help improve the expertise in the research areas as more models become validated and implemented.

(3) All the phases of the PM system development process have been examined to some degree when SD is applied to organisational PM; however, the design phase has received the most attention by far. Thus, other phases should be further explored because as PM systems progress, the need for the consequent phases are being revealed, and therefore, due to small developments in these areas, they may present challenges to the management process. Also, the other phases help to highlight important information needed for updating PM systems.

(4) The academic community is leading the development of SD in PM with relatively few practice-focused publications to communicate best practices with industry professionals. Stronger collaborations between these two groups would advance the maturity and effectiveness of this approach.

(5) The authors with the highest average citations per year presented a discussion on a systems perspective of performance in public sector organisations (Boland and Fowler, 2000). The most impactful papers explore PM from a system perspective by providing a framework applying SD tools and approaches aimed at improving performance.

(6) Author affiliations are spread over a number of disciplines, with the highest affiliation to industrial and systems engineering and management. There also seems to be an interdisciplinary approach, such that knowledge is integrated from two or more disciplines and skills are transferable between disciplines.

(7) Publications are primarily from China, followed by the United States and Canada. Regions that were not represented in the results can participate with other regions who are constantly publishing to improve the research in this field

(8) Analysis of the authorship characteristics shows that Bianchi (2016) is the most common author, and from the network analysis, he is also the author with the highest betweenness centrality, that is, Bianchi clearly has significant influence on how information in the research area is shared.

(9) The network analysis further suggests that authors need to collaborate more frequently, as the network for the research area is sparse. In addition to this, more interactions between authors can help in the development of the research area and also improve the network configurations.

With respect to the study limitations, this SLR is limited to the publications indexed on the 10 platforms used in the analysis. Also, only publications in English language with available text were used. In cases where the full text was not available, additional platforms such as Google Scholar were used to search for the paper. Furthermore, this study focused on

publications that dealt with organisational performance measurement only, and there may be relevant applications in other PM areas that could be considered. There is variability in the quality of papers in the final paper set, as some studies required a blinded peer-review process and others did not. In addition, the SLR only considered the bibliometric analysis in evaluating values from data extracted.

From the maturity assessment framework, there is an indication that the research area is not well developed. To advance this field, researchers need to focus on stronger collaborations to improve the content and theoretical concepts in the research field. Also, the use of different methodological approaches will improve the diversity of the research. Finally, building more accurate models and focusing on model validation are important steps towards making this a viable approach for use in practice. In addition, as the existing literature mainly focuses on the design phase, other individual PM phases (implementation, use, review) can be further explored to investigate how SD can be applied, and models can be developed to comprehend the dynamic nature of the processes.

This study provides important insights into the developmental maturity of this research area through bibliometric analysis. To extend this analysis, a thematic analysis of the literature will be conducted to more fully understand the themes in the research area; this will provide a meta synthesis of the results and integrate findings that will help identify trends in the research area with an emphasis on the concepts used.

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(The Appendix follows overleaf.)

Appendix

Year	Author	Publication title
2011	Lee, T.L and Yang, S.	Using balanced scorecard and system dynamics in exploring the performance of Taiwan's pharmaceutical industry
2009	Qudrat-Ullah, H.	Beyond the balanced scorecard: towards the dynamic balanced scorecard
2007	Teng, C.X., Pan, X.D. and Hu, W.X.	A dynamic performance evaluation method based on SD—BSC
2012	Voracek, J., Tripes, S., Pudil, P. and Somol, P.	Symbiosis of management and leadership in nonprofit sports club
2014	Yusof, Z., Yusoff, W.F.W. and Maarof, F.	Causality analysis in business performance measurement system using system dynamics methodology
2012	Zhang, T.	An overview of dynamic balanced scorecard
2011	Zhang, T.	Study on the performance management system of service-oriented manufacturing enterprises
2008	Zhang, T. and Gao, L.	Study on the application of dynamic balanced scorecard in the service industry
2008	Zhang, T.and Li, Z.	A case study based on the dynamic balanced scorecard in manufacturing industry
*2008	Santos, S.P., Belton, V. and Howick, S.	Enhanced performance measurement using OR: a case study
*2011	Barnabè, F.	A "system dynamics-based balanced scorecard" to support strategic decision making: Insights from a case study
*2012	Barnabè, F. and Busco, C.	The causal relationships between performance drivers and outcomes: reinforcing balanced scorecards' implementation through system dynamics models
*2016	Best, A., Berland, A., Herbert, C., Bitz, J., van Dijk, M.W., Krause, C., Cochrane, D., Noel, K., Marsden, J., McKeown, S. and Millar, J.	Using systems thinking to support clinical system transformation
2008	Newsome, I.M.	Using system dynamics to model the impact of policing activity on performance
*2015	Bianchi, C. and Williams, D.W.	Applying system dynamics modeling to foster a cause-and-effect perspective in dealing with behavioral distortions associated with a city's performance measurement programs
2015	Chou, H.H.	Multiple-technique approach for improving a performance measurement and management system: action research in a mining company
*2016	De Salles, D.C., Neto, A.C.G. and Marujo, L.G.	Using fuzzy logic to implement decision policies in system dynamics models
2015	Khakbaz, S.B. and Hajiheydari, N.	Proposing a basic methodology for developing balanced scorecard by system dynamics approach
2008	Kunc, M.	Using systems thinking to enhance strategy maps
2008	Nielsen, S. and Nielsen, E.H.	System dynamics modelling for a balanced scorecard: Computing the influence of skills, customers, and work in process on the return on capital employed
*2012	Kasiri, N., Sharda, R. and Hardgrave, B.	A balanced scorecard for item-level RFID in the retail sector: a Delphi study

Table AI.
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(*continued*)

Year	Author	Publication title
*2012	Nielsen, S. and Nielsen, E. H.	Discussing feedback system thinking in relation to scenario evaluation in a balanced scorecard setup
*2016	Sales, L.D.S.B., Roses, L. K. and Prado, H.A.D.	Application of dynamic balanced scorecard in the brazilian army information technology governance
2014	Wei, L., Zhang, W.X. and Xu, W.Z.	The performance evaluation of enterprise informatization research based on dynamic balanced scorecard
2015	Hawari, N.N. and Tahar, R.M.	A dynamic model of balanced scorecard to enhance strategic university planning process
2005	Sousa, G.W., Cesar Ribeiro Carpinetti, L., Groesbeck, R.L. and van Aken, E.	Conceptual design of performance measurement and management systems using a structured engineering approach
*2015	Tsalis, A.T., Nikolaou, E. I., Grigoroudis, E. and Tsagarakis, P.K.	A dynamic sustainability BSC methodology as a navigator for exploring the dynamics and complexity of corporate sustainability strategy
2008	Sabounchi, N.S. and Roper, M.A.	Process performance measurement based on a dynamic approach
2008b	Burmester, L. and Goeken, M.	Multidimensional representation of system dynamics simulation models
2011	Yang, W.M. and An, W.J.	A new framework for evaluation index system of regional science and technology
2010	Parisi, C.	Using qualitative system dynamics to enhance the performance measurement of sustainability
2016	Rashedi, R. and Hegazy, T.	Examining budget policies for new and existing facilities: a system dynamics approach
*2017	Cosenz, F.	Supporting start-up business model design through system dynamics modelling
2005	Mildeova, S.	The principles of system dynamics towards balanced scorecard implementation
2007	Tu, Y.M. and Chang, L C.	Dynamic interactive framework to link business intelligence with strategy
2011	Wu, Y. and Mu, D.	Study of system dynamics model of green supply chain based on balanced scorecard
2013	Wei, L. and Xi Zhang, W.	Research of corporate erp performance evaluation model based on system dynamics
2017	*Hu, B., Leopold-Wildburger, U. and Strohhecker, J.	Strategy map concepts in a balanced scorecard cockpit improve performance
2009b	Capelo, C. and Dias, J.F.	A feedback learning and mental models perspective on strategic decision making
2012	*Bianchi, C.	Enhancing performance management and sustainable organizational growth through system-dynamics modelling
2013	Navarra, D. and Bianchi, C.	Territorial governance, e-government and sustainable development policy: a system dynamics approach
2015	*Cosenz, F. and Noto, L.	Combining system dynamics modelling and management control systems to support strategic learning processes in SMEs: a dynamic performance management approach
2016	*Bianchi, C.	Dynamic performance management
2016	*Strohhecker, J.	Factors influencing strategy implementation decisions: an evaluation of a balanced scorecard cockpit, intelligence, and knowledge

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Table AI.

Year	Author	Publication title
2002	*Santos, S.P., Belton, V. and Howick, S.	Adding value to performance measurement by using system dynamics and multicriteria analysis
2011	*Valmohammadi, C. and Servati, A.	Performance measurement system implementation using Balanced Scorecard and statistical methods
2016	Wu, Y.J. and Liu, Z.X.	Study on performance evaluation of product warranty service system based on balanced score card and system dynamics
2016	*Cosenz, F. and Noto, G.	Applying system dynamics modelling to strategic management: a literature review
2017	Bivona, E. and Cosenz, F.	Framing caesarean section reduction policies through a dynamic performance management approach: a maternity pathway case-based analysis
2017	Costanza, F.	Social media marketing and value co-creation: a dynamic performance management perspective
2015	Hawari, N.N. and Tahar, R.M.	Microworlds of the Dynamic Balanced Scorecard for University (DBSC-UNI)
2006	Ren, C., Chai, Y. and Liu, Y.	Dynamic performance management system
2014	*Su, Y., Soar, J., Shen, N. and Al-Hakim, L.	Adapted lean thinking for healthcare services: an empirical study in the traditional chinese hospital
2014	Cosenz, F. and Noto, G.	A dynamic simulation approach to frame drivers and implications of corruption practices on firm performance
2014	Chalupova, M., Voracek, J., Smrcka, F. and Kozakova, P.	Dynamic modelling of ZOO management: from challenge to opportunity
2008	*Bianchi, C. and Montemaggiore, G.B.	Enhancing strategy design and planning in public utilities through "dynamic" balanced scorecards: insights from a project in a city water company
2008a	Burmester, L. and Goeken, M.	Combining system dynamics and multidimensional modelling – a metamodel based approach
2010	*Su, Y., Peng, J. and Jin, Z.	Quantitative models for service quality strategy implementation
2010	Legnani, E. and Cavalieri, S.	Exploring the causal relationships of KPIs in after sales service systems
2009	Qi, J., Li, L. and Ai, H.	A system dynamics approach to competitive strategy in mobile telecommunication industry
2009a	*Capelo, C. and Dias, J.F.	A system dynamics-based simulation experiment for testing mental model and performance effects of using the balanced scorecard
2010	*Bianchi, C., Bivona, E., Cognata, A., Ferrara, P., Landi, T. and Ricci, P.	Applying system dynamics to foster organizational change, accountability and performance in the public sector: a case-based italian perspective
2010	*Bianchi, C.	Improving performance and fostering accountability in the public sector through system dynamics modelling: from an "external" to an "internal" perspective
2006	Ren, C., Dong, J., Ding, H.and Wang, W.	Linking strategic objectives to operations: towards a more effective supply chain decision-making
2006	Qi, J., Ai, H.J., Shu, H. and Xin, Z.	System dynamics report of telecom industry in China

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Year	Author	Publication title
2004	Helal, M. and Rabelo, L.	An enterprise simulation approach to the development of a dynamic balanced scorecard
2002	Groesbeck, R.L., Sousa, G.W.L., and van Aken, E.	Using systems dynamics modeling to explore interrelationships in a performance measurement scorecard
2001	*Vaneman, W. K. and Trianfis, K.	Planning for technology implementation an SD DEA approach
2010	Ying, Y.	Modeling and simulation of operational decisions in manufacturing enterprises based on SD and BSC
2011	*Seydhosseini, S. and Soloukdar, A.	Recognition dynamic model of world class manufacturing in iranian automotive industry
2012	Capelo, C., Lopes, A. I. and Mata, A.	Teaching the balanced scorecard through simulation
2013	Nielsen, S. and Nielsen, E. H.	Transcribing the balanced scorecard into system dynamics: From idea to design
2010	Che, P., Wang, L., Hou, R. and Wei, T.	System dynamics modeling for telecom operation enterprises' service performance
2015	Ramadan, N., Ajami, R., Mohamed, N. and Lazarova-Molnar, S	Modeling and simulation for enterprise decision-making: successful projects and approaches
2005	*Akkermans, H.A. and Van Oorschot, K.E.	Relevance assumed: a case study of balanced scorecard development using system dynamics
2007	*Su, Y., Hu, L. and Jin, Z.	System dynamics modeling for strategy implementation of service innovation
2014	Bianchi, C. and Rivenbark, W.C.	Performance management in local government: the application of system dynamics to promote data use
2013	*Cosenz, F. and Bianchi, C.	Designing performance management systems in academic institutions: a dynamic performance management view
2016	*Gunarsih, T., Saleh, C., NurSyukron, D.W. and Deros, B.M.	A hybrid balanced scorecard and system dynamics for measuring public sector performance
2012	Hou, L.	The system dynamics analysis of the enterprise ERP project
2011	Saryazdi, M.D., Noghondarian, K., Owlia, M.S., and Azabadi, J.H.	System dynamics modeling for efqm excellence model: case study of a regional electricity company in Iran
2014	*Cosenz, F.	A dynamic viewpoint to design performance management systems in academic institutions: theory and practice
2015	*Bianchi, C.and Tomaselli, S.	A dynamic performance management approach to support local strategic planning
2015	*Bianchi, C., Cosenz, F. and Marinković, M.	Designing dynamic performance management systems to foster SME competitiveness according to a sustainable development perspective: empirical evidences from a case-study
2006	*Andersen, D.F., Bryson, J.M., Richardson, G.P., Ackermann, F., Eden, C. and Finn, C.B.	Integrating modes of systems thinking into strategic planning education and practice: the thinking persons' institute approach
2015	*Nielsen, S. and Nielsen, E.H.	The balanced scorecard and the strategic learning process: a system dynamics modeling approach.

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Table AI.

Year	Author	Publication title
2016	Kalnins, J.R. and Jarohnovich, N.	Dynamic model of enterpreneurial university: case of Ventspils University College development vision
2017	Anjomshoae, A., Hassan, A., Kunz, N., Wong, K.Y. and de Leeuw, S. (2017)	Toward a dynamic balanced scorecard model for humanitarian relief organizations' performance management
2017	Noto, G.	Combining system dynamics and performance management to support sustainable Urban transportation planning
2016	Banaś, D., Michnik, J. and Targiel, K.S.	System modeling and control of organization business processes by use of balanced scorecard and system dynamics
2013	Dolakova, V., Voracek, J. and Zelena, V.	Corporate Language Culture as Promising Performance Driver
2013	Shojaei, M., Ghochani, S. M. and Mottaghi, M.	Combining dynamic system and balanced score card (BSC) in performance evaluation (case study: Mahan plane company)
2014	Zelena, V.	Multimodal Management
2013	Sedlakova, J., Voracek, J., Pudil, P. and Somol, P.	Dynamic modelling of governance in non-profit organizations: case of community social services
2000	*Boland, T. and Fowler, A.	A systems perspective of performance management in public sector organisations
1997	Davis, A. and O'Donnell, J.	Modelling complex problems system dynamics and performance measurement
2006	Gonzalez, L.	Performance measurement using systems dynamics in an SME

Table AI.

Note(s): Publications marked * were cited in the paper

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