System Dynamics in Strategic Management: A Bibliometric Study

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Abstract System dynamics is one of the most prominent approaches to strategic management. It has been proved to be a useful methodology to overcome the limitation of the strategic learning process of decision-makers. This study aims to overview the theoretical and empirical development of system dynamics in strategic management field. Furthermore, it also provides further insights that might not fully evaluated in previous studies. This study uses bibliometric approach by using citation analysis and co-citation analysis to understand evolution trends, identifying patterns, and level of adoption of the research literature related to system dynamics in strategic management. For this purpose, literature published between 1984 and 2020 were retrieved from the Scopus bibliographical database. The main findings show which articles have the most significant influence on the field of research, how the research on the field of system dynamics application in strategic management evolved over time, and what is the future direction of research on that field.

Keyword: *system dynamics*, *strategic management*, *bibliometric analysis*, *citation analysis*, *co-citation analysis*

1. INTRODUCTION

As the time flows, science will continue to advance and develop with the work and creativity of scientists called research. System dynamics is one of scientific advancement that developed by Jay Wright Forrester in 1950s. System dynamics is an approach to model and simulate complex system of physical and social structure. By using system dynamics, we can experiment with models to design policies for selected problems. System dynamics approach have advantage as this method can be used in wide area of interest. In 1980, the study of system dynamics experiences significant methodological advances in the field of interactive simulation games. Throughout this period, system dynamics began to applied in strategic management area and primarily focused on improving the company's strategy formulation process [1]. Furthermore, starting from the 1990s, application of system dynamics in strategic management area become more frequent as 'System thinking' is starting to become a well-known term in management science, under the book 'The Fifth Discipline' by Peter Senge. This book contains an extraordinary review of strategic management problem using system dynamics approach and introduce the 'learning organization' term[1].

Cosenz & Noto [1] wrote the main reasons to make system dynamics began to be used in strategic management research. The framework of traditional strategic management approach is useful for encouraging decision-makers to design competitive strategies and measure the resulting outcomes. However, over the years, many authors have raised several critical issues related to traditional strategic management approach as that approach has the lack of perspective that can capture the dynamics complexity of managerial decision making.

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Frequently, traditional strategic management approaches fail to consider several relevant factors that can influence the planning and measurement of organizational performance. Therefore, it can be assumed that the traditional approach to strategic management limit the strategic learning process of decision-makers. To overcome those limitations, system dynamics modeling is finally used. Thus, system dynamics can support strategic management approaches and applications in a variety of ways. For example, it can be used to support the decision making process by simulating and testing the effects of alternative strategies on organization performance under certain conditions. Besides that, system dynamics can be combined with existing strategic management frameworks to provide a better understanding of phenomena that occur in complex and dynamics domains. Over the past 35 years, the number of articles that implement, operationalize, and re-conceptualize system dynamics in strategic management has increased as seen in Figure 1. Figure 1 reflect the richness of this subject in the field of research. Nevertheless, it is hard to find literature-based research that discusses about the use of system dynamics in strategic management. Cosenz & Noto [1] is the one that has done a literature review of system dynamics applications in strategic management. However, given the recent growth in literature on system dynamics application in strategic management, Cosenz & Noto [1] do not adequately cover the latest developments from the literature on the use of system dynamics in strategic management. Besides, Cosenz & Noto [1] study that use systematic review approach have drawback that cannot determine which articles that currently have the biggest influence on study area of system dynamics application in strategic management. Cosenz & Noto [1] study also have other drawback that cannot track the relationship between articles on study area of system dynamics application in strategic management so we don't know how an article on study area of system dynamics application in strategic management can influence other articles in the same area. This study aims to provide further insights that may not fully understood or evaluated in previous studies. Besides that, this study aims to analyze which articles currently have the biggest influence on study area of system dynamics application in strategic management and analyze how an article on study area of system dynamics application in strategic management can influence other articles in the same area.
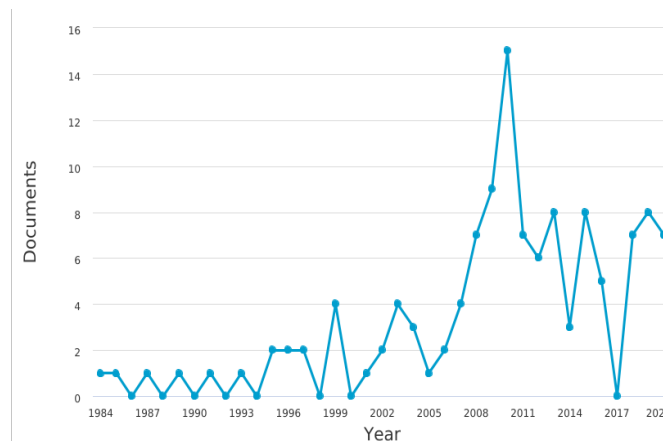

Figure 1.Number of published articles on study area of system dynamics application in strategic management by year (1984-2020)

In the end, the outcomes from this study is to determine the current trend of study on area of system dynamics application in strategic management and get insight how study on area of system dynamics application in strategic management has evolving over time. In the end, we could predict what kind of research that will be done in the future for this study area so we can plan the future research on area of system dynamics application in strategic management To examine the current trend and structure of research on system dynamics application in strategic

management, this study conducts the relatively new methods called citation analysis and co- citation analysis. Citation analysis and co-citation analysis are used by Fahimnia, et al. [2], Maditati, et al. [3], and Mishra, et al. [4] to get the current trend and analyze future direction of research for respective area of interest. According to Mishra, et al. [4], citation analysis is a quantitative technique that provides information about the level of influence of research articles in a particular field, while co-citation analysis tracks the relationship between each articles and their research fields. Citation analysis allows researchers to understand when major articles in a field are published and how their popularity has grown over time, and whether an article is still influences current research. Co-citation analysis can determine the main research groups or cluster in a research field and explain how they have developed over time. In this study, researchers used CitNetExplorer software to conduct bibliometric analysis by assessing the network among frequently cited articles. CitNetExplorer is a software tool developed to analyze and visualize direct citation networks [5].

2. LITERATURE REVIEW

2.1 SystemDynamics

System dynamics was invented by Jay W. Forrester from Massachusetts Institute of Technology (MIT) in 1950s. According to Wang & Peng [6], system dynamics approach is based on feedback control theory and the use of computer simulation technology to do a quantitative research in complex socio- economic fields. Farsi, et al. [7] said that the system dynamics method reflects the complex interactive behavior of all system components by considering the consequences of each action and decision through the whole system. The purpose of system dynamics study is to understand how each component in a system influence each other and find the best decision and policies to improve system performance [8]. Wang & Peng [6] point that the application of system dynamics divided into 3 phase: preliminary analysis, specified analysis, and comprehensive analysis as shown at Figure 2. Preliminary analysis including the process to state the problem, determine system boundary, and determine cause and effect relationship for each components of system. Specified analysis including the process to build system structure, build quantitative model based on system structure, and simulate the quantitative model to find out the system behavior. Comprehensive analysis including activity to compare the result of each scenario from simulation step before and evaluate that result to make decision or policies to improve the system.
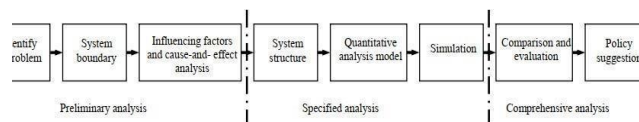

Figure 2. System dynamics modelling process

2.2 Strategic Management

According to Gupta, et al. [9], strategic management is the process of analyzing internal and external environments to plan, implement, observing, and revise organization strategies to improve organization performance. Gupta, et al. [9], point that strategic management takes place in three stages: strategy formulation, strategy implementation, and strategy evaluation as seen on Figure 3. Strategy formulation consist of process to develop organization vision and mission, identify external condition (opportunity & threat), determine internal condition (strength & weakness), establish long term objective of organization based on the result of previous process, and generate strategies, evaluate each of strategies generated before, then choose the best and feasible strategy to be implemented. Strategy implementation is the process to transform the strategy to become actions that should be carried out by organization members and use organization resource. Strategy evaluation is the process to measure the effect of strategies implementation to organization using performance measurement. In strategy evaluation, corrective action is also taken to improve the organization performance.
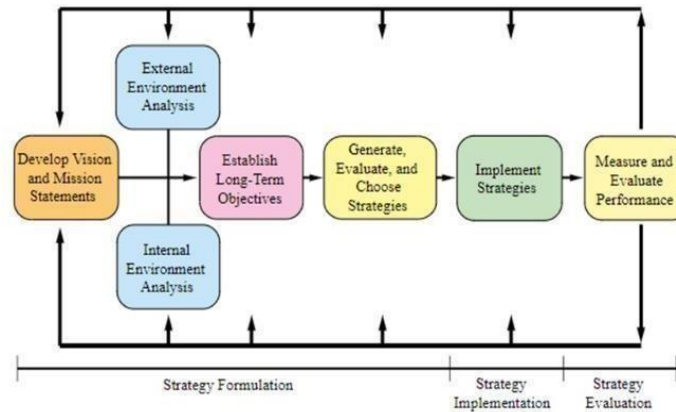
Figure 3.Strategic management process

Strategic management process is a dynamics and continuous. Changes to one of the components in strategic management process can require changes to one or all other components. Therefore, the activities of strategy formulation, implementation, and evaluation must be carried out continuously, not only at the end of the year or every semester [10]. Because the continuity of strategic management process, system dynamics approach suitable to be used in strategic management.

2.3 Bibliometric Analysis

Bibliometric analysis is the relatively new method used in research. Bibliometric analysis developed due to advancement of computerized data processing. Bibliometric analysis is a quantitative analysis of bibliographic records from published articles. According to Ellegaard & Wallin [11], This type of analysis is based on the identification of a collection of literature, i.e. publications in a particular subject area. Statistical tools are used as part of the bibliometric analysis work tool. Such techniques include impact indicators, citation and co-citation analysis, as well as bibliometric mapping. Bibliometric analysis became an appealing method to be used in research because the large increase in the number of publications.

2.3.1 Citation Analysis

Citation analysis is a quantitative technique that provides information about the level of influence of research articles in a particular field [4]. Citation analysis allows researchers to understand how their popularity has grown over time when an article in a field are published and whether an article is still influences current research. In citation analysis, the number of citation frequency of an article is evaluated to show their significance in their respective field of research [4]. From explanation above we could say that frequently cited articles have a relatively more important role in the investigated area of research. It can also be said that the citation analysis assumes that influential scientists and important works are quoted more frequently than others [12]. This analysis can also be used to identify key research streams [13].

2.3.2 Co-Citation Analysis

Co-citation analysis tracks the relationship and relationship between authors and their research fields [4]. Co-citation analysis can be illustrated in Figure 4. Figure 4 shown that there are articles A, B, X, Y, and Z. Article X cites articles A and B together, as well as articles Y and Z. This can be inferred that articles A and B are cited or quoted together. In this analysis, the number of scientific articles cited in a set of two specific documents is cited and the researcher interprets it as a measure of the similarity of the content of the two documents [14]. Outcome from co-citation analysis is citation mapping. The citation mapping technique illustrates how articles are cited and co-cited over time, which allows this study to map the flow of research and analyze the sources and direction of future research [15].
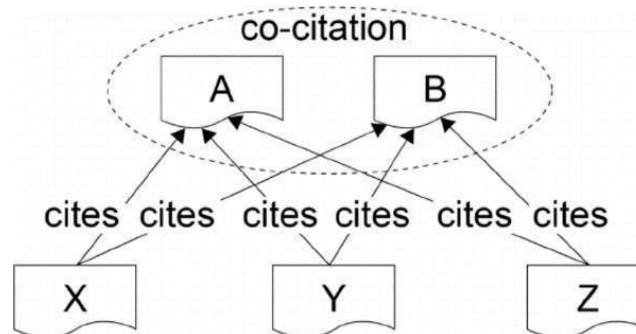
Figure 4. Co-citation analysis illustration (Fujiwara & Yamamoto [15])

3. METHODOLOGY

3.1 Data Collection Stage

Several steps were taken in the effort to collect data. First, researchers conducted a search for articles that apply system dynamics in strategic management using a combination of keywords: (a) system dynamics = "system dynamics" AND (b) strategic management = ("strategic management" OR "strategy") in Scopus, one of the most prominent academic research databases. The search is limited to documents published in the period 1984- 2020. 1984 was chosen because it is the first year of research on the use of system dynamics in strategic management. The selection results will then be refined based on the language (English) and type of document (articles and conference papers). To ensure that each article selected uses the terminology, the researcher will manually review the article title, abstract, and keyword. Articles whose titles, abstracts, and keywords are not specified in the terminology will not be used. Articles which does not focus on using system dynamics as support tools in strategy management will also be removed.

3.2 Citation Analysis Stage

The selected articles from data collection stage will processed using citation analysis with CitNetExplorer. CitNetExplorer is a data analysis tool used to do citation analysis by analyzing direct citation of a published article. This analysis is useful for evaluating article performance [3]. Citation analysis uses citations as the main variable. This analysis was carried out to evaluate citation frequency of an article and the number of citations showing their significance in the field of research [4].

3.3 Co-citation Analysis Stage

Besides citation analysis, this study also uses co-citation analysis. Co-citation analysis is carried out to investigate the relationship between authors, topics, journals, or keywords, thus explaining how they relate to each other [4]. CitNetExplorer, the software used in citation analysis is also used for co-citation analysis, but for the different purpose. In co-citation analysis, CitNetExplorer used to visualizes the relationship/ citation link between research articles. Øyna & Alon [13] explains that two articles are called co-citation if both appear in the reference list of the third article. The resulting visualization, called a citation map, can be used as a basis for classifying the best articles in the chosen research area. The number of citations determines proximity in a map, which means that two articles are assumed to investigate similar topics if they are located close to each other on the map. This co-citation mapping provides insight into the evolution that is occurring in a field of research.

3.4 Discussion and Conclusion Stage

This stage is the final part of the research which includes interpretation and concluding the results of the previous analysis. From the results of the analysis, it can be identified which articles have the most significant influence on the field of research and how the relationship between these articles.

4. RESULT AND DISCUSSION

4.1 Data Collected

493 document collected as the result for document search that apply a combination of keywords "system dynamics", "strategic management" and "strategy" for articles and conference papers published in the period 1984-2020, based on the English language that included in business, management, and accounting field. From 493 documents, only 147 selected by reviewing the uses of system dynamics terminology and strategic or strategic management in document title, abstract, and keywords manually. 147

selected document downloaded and reviewed manually to determine whether the documents using system dynamics as support tools in strategy management or not. From 147 documents, only 123 documents meet the specified conditions. A total of 123 documents are processed using citation and co-citation analysis with CitNetExplorer software.

4.2   Citation Analysis
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The result from citation analysis is the list of articles with highest citation frequencies from 123 documents shown onTable 1. As seen on table 1, the highest cited publication is Lyneis, etal.[16] published in 2001. The publication in beginning period of system dynamics application in strategic management research by Morecroft [17] in 1985 only ranked number 4 in the list of publications with the highest citation frequencies

Table 1. Top 10 most cited publication based on citation analysis

Author (year)	Citation
Lyneis, et al. (2001)	145
Rodrigues & Bowers (1996)	141
Demirkan, et al. (2010)	82
Morecroft (1985)	80
Gary, et al. (2008)	62
Wang, et al. (2015)	57
Poles (2013)	55
Barnabè (2011)	55
Lyneis (1999)	50
Choi, et al. (2010)	49

4.3   Co-Citation Analysis

The result from co-citation analysis is visualization of citation network shown in Figure 5. CitNetExplorer usually includes selected publications from the network, and bydefault includes only 30 of the most frequently cited publications [5]. Figure 5 shows the

30 most quoted publications. In the visualization, each circle represents a publication, labeled with the first author's last name. CitNetExplorer uses curved lines to show citation relationships. In addition, the circle's vertical position is determined bythe time when the publication was published. Publication in the horizontal direction is determined by the proximity of the publication. Publications located at the highest point or do not have precedent in the citation network are considered basic knowledge. Thus, it can be seen that the publication located at the highest point in the network are Lyneis, et al. [16], Morecroft [17], Morecroft, et al. [18], Kumar & Vrat [19], Risch, et al. [20], Rodrigues & Bowers [21], Hafeez & Abdelmeguid [22], and Warren [23]. Those articles will further act as a source of basic knowledge for

the field of system dynamics in strategic management. Besides that, closely related publications in the citation network are identified and divided into clusters or groups. There are two clusters for research in area of system dynamics application in strategic management, marked in green and blue. In this case, the green cluster will be called region I, and the blue cluster is called region II.

4.4   Discussion

Citation analysis result show us that top 2 most cited publications from 123 documents collected have the similar number of citation frequencies with more than 140 citations. Those citation frequencies have large different with citation frequencies of others publication in the list shown at Table 1. So, the top 2 most cited publications illustrate the current research trend of system dynamics application in strategic management. Although, publication in beginning period of system dynamics application in strategic management research by Morecroft [17] still classified as a publication that has high citation frequency, publications about system dynamics application in strategic management are slightly

evolved from the beginning period of system dynamics application in strategic management. Publications by the Lyneis, et al. [16] and Rodrigues & Bowers [22] discuss about system dynamics application in strategic management for projects. Instead of discuss system dynamics application in strategic management for company or organization in general which discussed in publications from the beginning period of system dynamics application in strategic management, Lyneis, et al. [16] and Rodrigues & Bowers [22] discuss about system dynamics application on specified area of strategic management.

Co-citation analysis result shows us that publications about system dynamics application in strategic management can be divided into 2 clusters. Besides that, we know that there are 8 publications considered as source of basic knowledge for the field of system dynamics in strategic management. The first cluster has 2 publications as source of basic knowledge, whereas the second cluster has 6 publications as source of basic knowledge. Morecroft [17] and Warren [23] are the sources of basic knowledge for cluster 1. Lyneis, et al. [16], Morecroft, et al. [18], Kumar&Vrat [19],
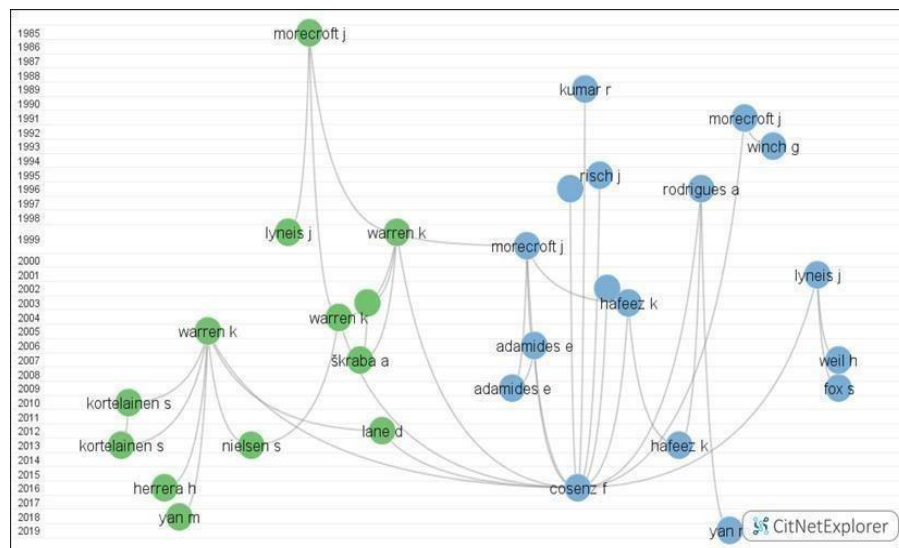

Figure 5. Citation Network

Risch, et al. [20], Rodrigues & Bowers [21], Hafeez & Abdelmeguid [22] are the sources of basic knowledge for cluster 2. Morecroft [17] discuss about application of system dynamics for building mental model of decision making structure in strategic management. Where, Warren [23] discuss about using system dynamics to do resource allocation strategy in strategic management. Those 2 publications discuss about system dynamics application in strategic management for company or organization in general. Besides that, those 2 publications only build general model of strategic management instead of detailed model. Lyneis, et al. [16] and Rodrigues & Bowers [21] discuss about system dynamics application in strategic management for projects. Hafeez & Abdelmeguid [22] discuss about system dynamics application in human resource and knowledge management, part of strategic management. Morecroft, et al. [18], Kumar&Vrat [19], and Risch, et al. [20] discuss about system dynamics application in strategic management for company but make detailed operation models to choose the best strategies instead of general

models. From explanation above, we can determine that cluster 1 publications theme is about system dynamics application in strategic management for company or organization in general whereas, cluster 2 publications theme is about system dynamics application for specified area or detailed model in strategic management area.

From citation analysis dan co-citation analysis result we can get insight that publication about system dynamics application in strategic management can be divided into publication that discuss about general application of system dynamics in strategic management and publication that discuss about system dynamics application in detailed and specified area of strategic management. The second group that discuss about detailed and specified area of strategic management is relatively new and differ from the first group that represent publications in the beginning period of system dynamics application in strategic management. So, we can say that research area of system dynamics application in strategic management are slightlyevolved. Although, publication that discuss about

general application of system dynamics in strategic management still popular, publication that discuss about system dynamics application in detailed and specified area of strategic management is the current trend of research in that field and could be used as future direction for research about system dynamics application in strategic management.

5. CONCLUSSION

This study to get deep understanding of theoretical and empirical development of system dynamics application in strategic management field use bibliometric approach: citation and co- citation analysis. From the citation analysis we get list of articles that has highest number of citation frequencies. From co-citation analysis we find that research about system dynamics application in strategic management divided into research that discuss about general application of system dynamics in strategic management that represent the beginning period of system dynamics application in strategic management and publication that discuss about system dynamics application in detailed and specified area of strategic management that represent the current trend of research in that area. From that analysis we also know that current trend of research about system dynamics application in strategic management are slightly evolved if we compare it with research from the beginning period of system dynamics application in strategic management.

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