International Journal of Academic Multidisciplinary Research (IJAMR)
ISSN: 2643-9670
Vol. 8 Issue 4 April - 2024, Pages: 207-216

System Dynamics Modelling for Municipal Solid Waste Management - A Literature Review

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Abstract: *This study aims to produce a study on municipal solid waste management through system dynamics modelling. The method used in this study is systematic literature review (SLR). The SLR is used to identify, evaluate, and interpret all relevant results related to particular research, particular topic, or particular phenomenon of concern. This study provides an overview of municipal solid waste management around the world with system dynamics modelling, The research shows that the system dynamics modelling for municipal solid waste management is quite limited; this is shown by the finding of 48 articles that relevant from 2014–2024. This study also classifies articles based on the causal loop diagram content, stock and flow diagram, as well as scenario used in the simulation study.*

Keywords—*causal loop diagram; literature review; municipal solid waste; system dynamics*

1. INTRODUCTION

Population growth and development and limited land resources in urban areas have created problems for decision makers in dealing with the ever-increasing rate of urban waste. Detailed and comprehensive accounting of waste generation, treatment and disposal forms the quantitative basis for the design and assessment of circular economy policy instruments (Maalouf & Mavropoulos, 2023).

Throughout the world, waste generation rates are increasing. In 2020, the world is estimated to produce 2.24 billion tons of solid waste, amounting to a footprint of 0.79 kilograms per person per day. With population growth and rapid urbanization, annual waste generation is expected to increase by 73% from 2020 levels to 3.88 billion tons in 2050 (Brief, 2022).

One of the challenges faced by many countries in the global waste problem, especially in low-income countries, is the issue of financing waste management systems. Moreover, for the operational costs of sustainable waste management. In high-income countries, operational costs including waste collection, transportation, processing and disposal generally cost more than $100 per ton. This is in sharp contrast to low-income countries which only provide 35 dollars per ton for operational costs for handling waste (Defitri, 2023).

The world government's efforts to reduce waste according to (Washington, 2018) are to support countries in making important financing, policy and planning decisions for solid waste management. Some of them are:

- Provide financing to countries that need it most, especially the fastest growing countries, to develop advanced waste management systems.
- Support major waste producing countries to reduce consumption of plastic and marine debris through comprehensive waste reduction and recycling programs.
- Reduce food waste through consumer education, organic management, and coordinated food waste management integration.

Before implementing various relevant efforts, of course the government and a decision maker need a simulation model, as a relevant tool for scenario analysis, which can help managers in making decisions and implementing city waste management policies. System dynamics (SD), a modeling approach that can describe the evolution of complex systems over time, because planning for solid waste management is concerned with multiple interconnected components, understanding the dynamic nature of their interactions becomes increasingly important (Guo, 2016).

This research aims to review existing knowledge about system dynamics for municipal waste management in a world context. This research uses Systematic Literature Review and bibliometric analysis. By exploring the theoretical and contextual developments of this research field. Through bibliometric analysis, an important research trend and its main contribution is the identification of journals in the Scopus database from 2014 to 2024.

The benefit of this study is to find out and map the results of system dynamics in municipal waste management conducted by previous researchers using bibliometric analysis,

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with this research we can find out whether the theme still has a chance to be developed in the future.

2. Research Methodology

This section outlines the procedures for conducting a systematic literature review (see Fig. 1).

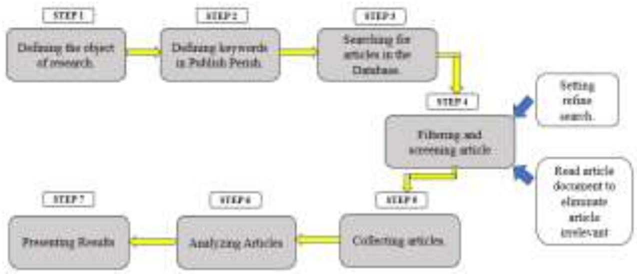

Fig. 1. *Research Methodology*

The first step involves clearly defining the research objectives of the scope of the study, the focus being to systematically review articles that explore the application of system dynamics in evaluating urban waste management in a world context. Moving on to Step 2, an attempt was made to refine the search criteria using Publish or Perish (PoP) software. This process also includes identifying appropriate keywords, especially articles, book chapters, conference papers that contain the terms "system dynamics", "municipal solid waste" in the title, abstract or keywords selected for the extraction process. The third step involved searching for articles in databases, and to ensure comprehensive coverage, the authors chose Scopus by Elsevier, as Scopus is considered one of the most extensive scientific databases, covering a wide range of journals across various disciplines that have an excellent reputation. In a search in the Publish or Perish (PoP) software database, the authors determine the research year from (2014-2024). This method has been used in previous research studies such as Oliveira et al. (2018), Herrera-Franco et al. (2020), and Mishra et al. (2021). The fourth step the author independently reviews the abstracts to assess the relevance of the extracted articles to the research objectives. The analysis was carried out only in the scope of "system dynamics" and "municipal solid waste" carried out, it was found that 70 articles were found and, in the filtering, and screening process they were reviewed with several elimination steps as follows: i. Document type setting limit to “article”, ii. Publication stage limit to “final”, iii. Read abstract to eliminate irrelevant articles. From the fourth step process, namely filtering and screening, 70 articles were eliminated to become 48 relevant articles in 22 different journals. In the fifth step, the researcher collected articles that had been filtered and screened, then in the sixth step the author carried out an analysis of the articles that had been collected using a qualitative approach to classify them based on the methodology used, namely "causal loop diagram", "stock & flow diagram and "run scenario analysis”. Then, finally, the seventh step, namely, presenting the results in the form of descriptive statistics which displays the number of articles per year and the number and name of publications published, and the number of documents published by the author's country. A qualitative approach was then applied to classify articles according to research type and methodology. Finally, scientometric analysis is used to demonstrate bibliometric clusters, including co-authorship and co-occurrence (keyword) analysis.

3. Results

The number of articles published per year is shown in Fig. 2, where in 2014, 2015 there are two articles published, in 2016 and 2017 there are four articles, in 2018, 2019 there are sixteen articles published, in 2020 there were four articles published, in 2021 there are sixteen articles published, in 2022 thirteen articles are published and in 2023 there are fifteen articles published and then in 2024 there is only one article published because at the time of writing this article the author was doing it at the beginning of 2024. Relevant articles are published in 22 different journals (see Fig. 3).

Based on the search results, the 48 selected articles were written by authors from various engineering disciplines with different national backgrounds and spread throughout the world. Fig. 4 shows that there are 31 countries of origin for publications regarding "system dynamics", "municipal solid waste" where China is the country with the number of publications with 14 articles, second followed by Japan, the United Kingdom and the United States with 5 articles, followed by the third number is the country Brazil and Spain.

Classification of each article based on the type of research and methods is an important step in the literature review process. The classification can be seen in Table 1, showing the classification of articles that are extracted and have a history of being cited by othes. Table 1 categorizes them according to the type of research and methodology used.

Next, this study uses scientometric analysis, specifically co-authorship and co-occurrence, as a tool for science mapping. VOSviewer software (van Eck & Waltman, 2010) was used to perform this analysis. Co-authorship as a proxy for research collaboration deserves attention, this reflects a shift in the policy-to-science paradigm. There has been a formal transition from funding individual investigators to supporting collaborative groups. The rationale behind this change is the belief that when many experts collaborate on a particular problem, there is a greater likelihood of achieving effectiveness, innovation, and productivity.

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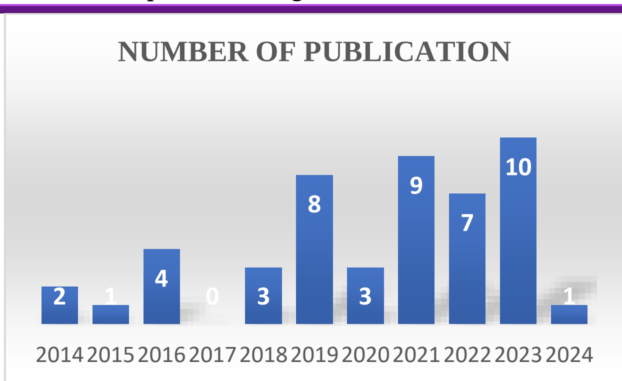

Fig. 2. *Number of articles*

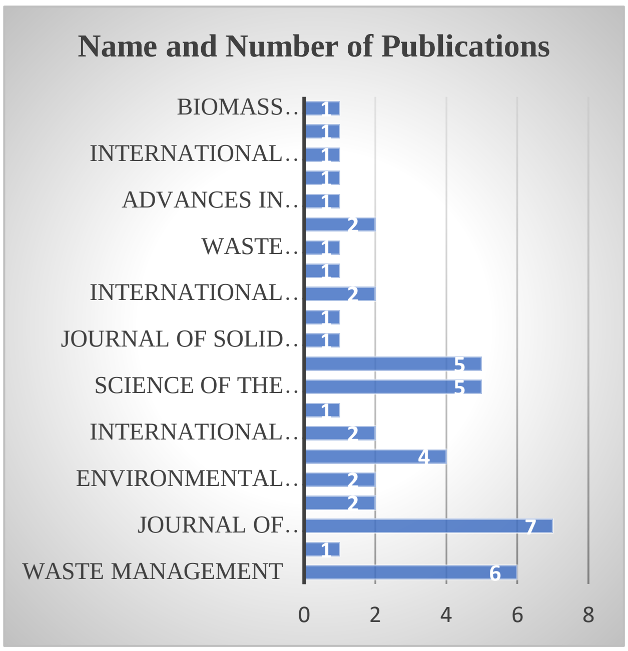

Fig. 3. *Journals*

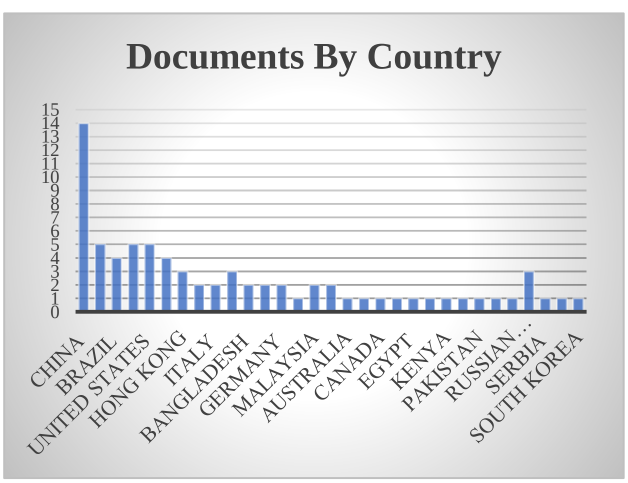

Fig. 4. *Countries of researchers*

Table 1: Classification of articles

No	Articles	Causal Loop Diagram	Stock & Flow Diagram	Simu-lation	Citation
1	(Simonetto, 2014)	✓	✓	✓	5
2	(Vivekananda & Nema, 2014)	✓	✓	✓	17
3	(Al-Khatib et al., 2015)	✓	✓	✓	12
4	(Al-Khatib, 2016)	✓	✓	✓	22
5	(Sukholthaman, 2016)	✓	✓	✓	133
6	(Vélez & Mora, 2016)	✓	✓	✓	7
7	(Guo, 2016)	×	✓	✓	23
8	(Estay-Ossandon, 2018a)	×	✓	✓	37
9	(Nola, 2018)	×	✓	✓	36
10	(Estay-Ossandon, 2018b)	×	✓	✓	47
11	(Ge, 2019)	✓	×	×	3
12	(Qu, 2019)	✓	✓	✓	16
13	(Babalola, 2019)				12
14	(Lee et al., 2019)	✓	✓	✓	37
15	(Phonphoton, 2019)	✓	✓	✓	33
16	(Lewis, 2019)	×	×	✓	4
17	(Xu,2019)	✓	✓	✓	6
18	(Tseng et al., 2019)	✓	✓	✓	21
19	(Popli, 2020)	✓	✓	✓	4
20	(Xiao et al., 2020)	✓	✓	✓	110
21	(Pinha, 2020)	✓	✓	✓	34
22	(W. Wang & You, 2021)	✓	✓	✓	53

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No	Articles	Causal Loop Diagram	Stock & Flow Diagram	Simu-lation	Citation
23	(Dianati, 2021)	✓	✓	✓	16
24	(Xiao, 2021)	×	✓	✓	30
25	(Taffuri, 2021)	✓	✓	✓	10
26	(Chen, 2021)	×	✓	✓	19
27	(Chica-Morales, 2021)	×	✓	✓	2
28	(Meng, 2021)	✓	✓	✓	2
29	(Rafew, 2021)	✓	✓	✓	28
30	(Lu, 2021)	×	✓	✓	14
31	(Hosseinalizadeh, 2022)	✓	✓	✓	9
32	(Jovičić, 2022)	×	✓	✓	4
33	(Alam, 2022)	✓	✓	✓	21
34	(H. Liu, 2022)	✓	✓	✓	2
35	(Yang, 2022)	✓	✓	✓	0
36	(C. Wang, 2022)	✓	✓	✓	1
37	(Xiao, 2022)	×	✓	✓	16
38	(Chu, 2023)	✓	✓	✓	6
39	(Z. Liu, 2023)	×	✓	✓	0
40	(Gombojav, 2023)	×	✓	✓	1
41	(Oliveira, 2023)	×	✓	✓	0
42	(Siran,2023)	✓	✓	✓	0
43	(Muhammad, 2023)	×	✓	✓	0
44	(Rafew, 2023)	✓	✓	✓	2
45	(Al-Shihabi, 2023)	✓	✓	✓	2
46	(Martinez-Valencia, 2023)	✓	✓	✓	0
47	(Eslami, 2023)	×	✓	✓	2
48	(Li, 2024)	✓	✓	✓	0

Therefore, large amounts of public research investment are directed at organized research units that bring together various types of expertise from various subject areas or scientific disciplines. Fig. 5 visually depicts a co-authorship network, where nodes represent authors, and connections are created when authors share authorship of an article. This network visualization provides insight into the collaborative relationships between authors in the research domain. Fig. 5 shows that there are 7 authors with more than 1 published article, namely Al-Khatib with 2 published articles, Eslami with 2 published articles, Estay-Osandon with 2 published articles, Galvote with 2 published articles, Ravew with 4 published articles, Wang with 3 published articles and Xiao with 3 published articles.

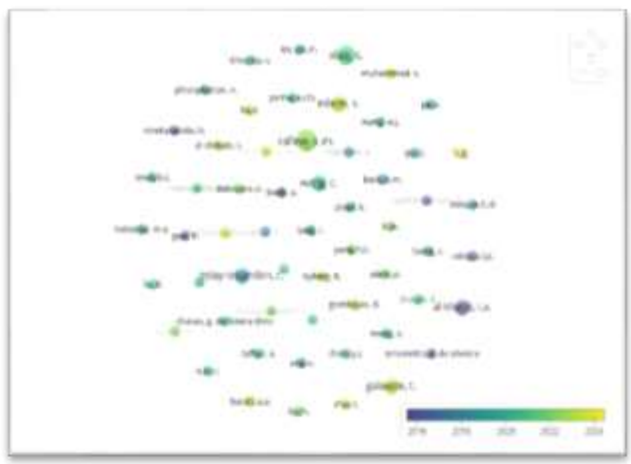

Fig. 5. *Co-authorship network*

Keyword occurrence analysis aims to map co-occurring keywords and organize them into different research groups. The aim is to explain the internal structure and composition of the research domain, providing insight into the boundaries of the research field as indicated by (Hu et al., 2019). Mapping these co-occurring keywords can provide a comprehensive understanding of the knowledge structure within a research theme and potentially identify future research opportunities. Fig. 6 illustrates the keyword co-occurrence network, with the most keywords being “system dynamics”, “municipal solid waste”. This visualization allows identification of main themes and relationships between keywords in the research domain. For each of the 32 keywords, the total link strength of co-occurrence with other keywords will be calculated. The keyword with the greatest total link power will be selected. Fig. 6 shows a network consisting of nodes and edges. Nodes are represented by circles, each circle representing frequently occurring keywords, taken from the title and abstract of the article. The size of the circle indicates the number of publications associated with the term, both in the title and abstract of the article. The larger the circle size means the greater the number of articles that are relevant to that keyword. The largest circle shows the keywords that appear most frequently are "model" and "system".

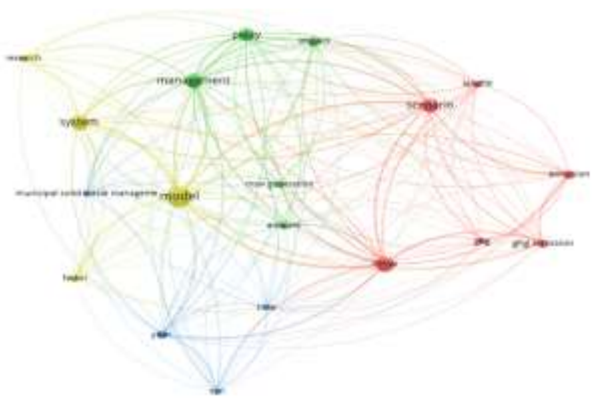

Fig. 6. *Co-occurence network*

Meanwhile, edges show the relationship between pairs of nodes and the strength of the relationship is represented by distance. The closer the distance between one node and another node, the higher the relationship between these nodes. Each keyword is close to each other, indicating that frequently appearing keywords tend to be in positions close to each other in the visualization. Based on the proximity of these keywords, clusters/groups can be built. Clustering here is used to get insight or an overview of bibliometric grouping. Fig. 6 shows that There are 4 clusters with 19 items. Cluster 1 consists of (emission, GHG, GHG emission, landfill, MSW, scenario), Cluster 2 consists of (amount, impact, management, MSW generation, policy), Cluster 3 consists of (municipal solid waste management, time, ton, year) and finally cluster 4 consisting of (factor, model, research, system).

4. Summary

This research reviews articles from the Scopus database regarding system dynamics regarding municipal waste management. Through this review, 50 articles published in 22 different journals were discussed. This research classifies system dynamics articles based on the availability of Causal Loop Diagrams, Stock and Flow Diagrams, Run scenarios. This research also shows co-authorship networks and keyword co-occurrence. The results of bibliometric analysis show that research on system dynamics for municipal solid waste has an upward trend from year to year so it is very possible to be developed and implemented in all cities in the world. The limitation in writing this article is that it only comes from the Scopus database, this also means that the results will be more complex and different if combined with other databases such as Google Scholar, Web of Science, Pubmed, Semantic Scholar, Crossreff and others.

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