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A THEORETICAL ANALYSIS OF SYSTEM DYNAMICS METHODOLOGY ON INFRASTRUCTURE PROJECTS WITHIN THE ENERGY SECTOR

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Abstract The energy sector is critical to a country's economic and social development. Due to economic growth in South Africa, the state-owned firm has witnessed a demand for power supply over the last 20 years. To alleviate the existing supply restriction, it is now implementing capital expansion build programs. The completion of this project has been delayed. Over the last two decades, there has been a lot of system-based study such as considerable research that uses system dynamics (SD) as an analytical and modelling approach. However, merely limited critical reviews have been conducted to provide understanding of SD application in infrastructure projects. We summarize and analyse current research on SD models in infrastructure construction projects in the energy sector in this study, which is based on a thorough systematic literature review. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) approach was used to conduct a search and only 15 studies out of 130 were found to be relevant. According to the findings of the literature analysis, four main feedback structures from prior SD project dynamics models have been recognized as major trends. Design errors, rework and change management, performance and effectiveness, resource management, and project planning and control are some of the topics covered.

Keywords: Electricity, Infrastructure, Review, Systems, System dynamics model

1. Introduction

According to the International Energy Agency (IEA), 1.1 billion people do not have access to electricity majority of whom reside in rural regions [1]. Electricity is critical to long-term development and poverty reduction efforts; its availability has an impact on the lives of the poor and their ability to escape poverty. South Africa must strike a balance between seeking economic growth and ensuring that economic progress does not come at the expense of ecosystems.

Despite continuous and accelerated energy efficiency gains, many countries, including South Africa, are experiencing significantly higher energy consumption as a result of economic expansion and social needs [2]. In late 2009, the number of significant infrastructure projects in South Africa to address the energy crisis increased. The building of key projects like Medupi and Kusile is presently underway to update and expand the energy sector's infrastructure. Delays, quality issues, cost overruns, and system designs not integrated have plagued the Medupi and Kusile construction projects, all of which can be linked back to the project dynamics plan [3]. The utility has not done anything like this in more than 20 years, so these projects need to move quickly. During the previous build programme, the power utility relied on excellent technical abilities to ensure successful implementation.

The feasibility assessment for designing, constructing, commissioning, and handing over a physical structure leads to construction project management. Construction management can be viewed as a multi-layered system combining technology and management, consisting of numerous subsystems, containing different integrated, systematic, and complicated social

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activities involving enormous sums of money, extended periods of time, and several stakeholders [4]. As a result, effectively managing building projects is essential to satisfy schedule, cost, quality, environmental, and safety requirements is tough [5]. Failure to meet building goals is frequently linked to a number of issues that are rarely independent of one another [6].

Fast-paced technological advancements have resulted in unprecedented, dynamic customer demands, as well as ever-changing legal frameworks in the twenty-first century [7]. The electricity industry is not immune to these dynamics as it continuously evolves over time. [8] Argues that the nature of electrical industry projects can be framed as complex dynamic systems, because these projects are part of a system that includes several interdependent and dynamic components, as well as multiple feedback loops and non-linear interactions. These complexities could result in projects being delayed, quality problems, cost overruns, as well as a decline in organisational performance in the electricity industry, despite developments in construction equipment and management techniques. SD is a simulation-based modelling technique that excels at dealing with complexities and their consequences for decision-making [9].

SD modelling, which is based on systems thinking, aims to capture the systemic collection of elements and interactions that result in the observed problem behaviour. SD models can also be used to identify which components are important in the problem, as well as tools like causal loop diagrams and stock-flow diagrams that help organizations convey outcomes to stakeholders more effectively [10]. According to a recent survey conducted by the Massachusetts Institute of Technology (MIT), more than half of large technology development projects fail to reach their cost and schedule targets. SD approaches, according to [11], have been utilized extensively for complex projects over the last 35 years and have demonstrated a record of accomplishment of project management performance across the project lifecycle. Furthermore, some scholars have proposed potential solutions that could aid in improved project management of infrastructure projects in order to achieve the intended outcomes.

The SD model has been employed by a large number of construction management researchers during the last 20 years. However, there is a scarcity of systematic reviews of SD articles in this subject, preventing researchers from gaining a thorough and systematic grasp of research focuses and trends. Furthermore, some researchers erred in their application of SD. The use of SD in construction management lags behind other fields, such as economic development, rural and urban planning, environmental sciences, and the energy sector [12].The major goal of this research is to summarize a large body of work on electricity sector modelling in construction projects and to identify SD trends. The goal of this study includes (i) reviewing electricity sector modelling done with SD in construction projects (ii) identification on research gaps in literature.

2. Methods

The systematic review approach was used as the research methodology. A systematic literature review comprises a thorough examination of the literature on the subject at hand. The authors were able to access numerous approaches and outcomes within the area of system dynamics' contribution to power sector modelling inside infrastructure projects thanks to the rationale for adopting a systematic review as a methodology. This allowed the researchers to create a framework based on the triangulation of past research efforts. Furthermore, the rationale for systematic review is to investigate the subject, model theoretically the primary drivers, and support variables in order to develop a bias-free future research agenda. The review was conducted in three stages namely, planning the review, conducting the review and reporting the review.

The planning stage began by identifying the essential ideas that connected to the research objective in order to improve the analysis of the evaluated material. The criteria included a broad overview of the subject matter and a restriction on evaluated papers to those written in English, ensuring that the articles were relevant to the subject matter. A keyword search of online databases was undertaken to collect relevant material that aligned with the goal and direction of this research. This review looks at the available literature on SD models in the electrical sector. The purpose is to concentrate on the role of system dynamics in electrical sector modelling. Individual articles in the SD and electrical sectors were thoroughly analysed

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with the design objective in mind to determine the emphasis, distinctiveness, and relevance. Filters based on the PRISMA technique were constructed, according to [13], in order to determine how the articles correspond with the standpoint of this research. Table 1 shows the activities that were examined at each level of our quantitative study.

According to [14], the PRISMA technique divides the article removal procedure into four stages: (1) identification; (2) selection; (3) eligibility; and (4) inclusion. Keywords and complementary terms were employed in all databases searched during the Identification step, and all articles recognized were extracted for the second stage (Selection). In the second stage, the following filters were used: The article's type, peer-reviewed status, and English language are all factors to consider. Titles and abstracts were read in the third step (Eligibility), and papers with content directly linked to the topic and within the areas of SD modelling, construction, infrastructure projects, and the electrical industry were selected, with all others being discarded. 15 publications were selected for study during the fourth stage (Inclusion).

2.1 Selection And Criteria Inclusion Of The Analysed Studies

An evaluation criteria is presented in Table 1. A systematic review principle proposed by [13], was used. The second stage which is conducting the review started by searching literature using online databases such as Elsevier Scopus, Google scholar, Springer Link, Science Direct, and Emerald Insight. Keyword search was undertaken using online databases pertaining to the following themes to collect relevant material that aligned with the goal and direction of this research:

1) Modelling the dynamics of infrastructure projects
2) System dynamics modelling in construction/infrastructure projects within the electricity industry

Besides searching on the online databases, relevant journal articles about construction project and on-time delivery of infrastructure projects that were published, were also collected. These journals included the International Journal of Project Management, the Journal of Construction Engineering and Management, the Journal of Management in Engineering, the Journal of Civil Engineering and Management, and the Journal of Construction Management and Economics. This review only includes studies published within the last twenty years (2001-2021). The criteria as tabulated in Table 1, it comprises a general evaluation of the research subject, as well as limiting reviewed papers to those written in English, ensuring that the reviewed articles are relevant to the research area.

2.1.1 Inclusion criteria

To be included in our systematic review, first, a practical screening of the titles and abstracts was conducted following the next inclusion criteria. A study had to meet the following criteria to be included:

1. The study must be an article published in a peer review journal in the English language within the last twenty years (2001-2021).Thus, other publication forms (conference proceedings, books, newspaper articles, unpublished works) were not included
2. Mentioning in a categorical manner of system dynamics model in infrastructure model within electricity industry (methodology, approach, analysis)

For our systematic review, we conducted an initial search using the search string, which yielded 130 articles. The researcher conducted a preliminary assessment based on reading the abstracts of all selected papers in order to concentrate on the most pertinent literature (see Table 1, which details the criteria for evaluation).

2.2 Studies selection

In the selection stage, the identified articles were subjected to a double screening. A first sorting of the articles' titles and abstracts allowed us to include 130 potentially relevant studies. Each of these 130 articles were reviewed and assessed according to the inclusion criteria. The second screening went beyond the title and abstract into the full text of the papers. 117 studies did not fulfil the inclusion criteria. Therefore, after the two-step practical screening, the literature review on finally involves 15 potentially relevant studies that met all the inclusion criteria as highlighted in Figure 1. All the papers that fulfilled the practical and methodological inclusion criteria were analysed [15].

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Table 1. Details of the Criteria for Evaluation

ID	Type of decision	Criteria for Evaluation
EX1	Exclusion	Literature found informally (conference papers, book reviews, masters and doctoral theses etc.)
EX2	Exclusion	Papers that have been duplicated
EX3	Exclusion	Papers published in a language other than English
IN2	Inclusion	Relevance in the context of the research
IN3	Inclusion	Journal articles
IN4	Inclusion	Mentioning in a categorical manner of system dynamics modelling and electricity (methodology, approach, model, and analysis)
IN6	Inclusion	Mentioning in a categorical manner of modelling the dynamics of infrastructure projects (methodology, approach, model, and analysis)

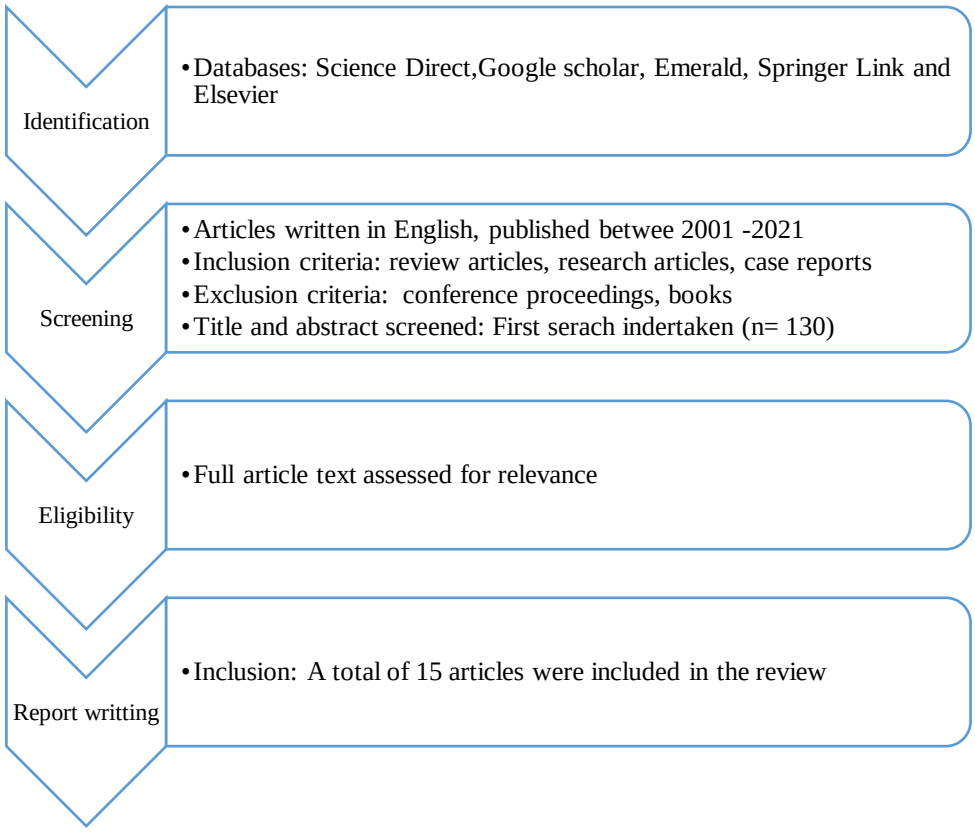

Fig. 1 Systematic review flow diagram

3. Results and discussion

According to the findings of the literature research, there is a growing corpus of knowledge on the subject on the applications of SD in the energy sector. In design management, SD modelling has been used. Several scholars have used SD modelling to do research on construction project management, as shown in Table 3 below. SD is a strong tool for understanding situations including dynamic complexity and policy opposition. SD is a dynamic field in and of itself.

We may now participate in the modelling process thanks to recent improvements in interactive modelling, feedback structure representation tools, and simulation software [16]. The most important literature on SD in the context of infrastructure projects is presented. Professor J. W. Forrester of MIT was the first to establish the SD modelling

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and simulation method through computer simulation. The earliest description of the use of SD in project understanding was in 1964, but it wasn't until the 1980s when project-specific applications began to be published. Many more examples of the usage of SD in project management have been recorded since 1990.

[17] states that SD was first used in project management. They declared that each project component is considered independent, which caused the model to be disconnected from the actual project. The first models were created to investigate the dynamics of R&D projects. The terms "perceived progress" and "actual progress" were established, emphasizing that managerial decisions are based on impressions of the project's state, which may differ significantly from reality. Each of the identified papers were thoroughly examined to identify its main research topic. In combination with the key words identified through the co-occurrence network as highlighted in Figure 2, eight research topics involving different internal and external complexities are identified, including sustainability, project planning and control, performance and effectiveness, design error, rework and change management, strategic management, resource management and risk analysis.

Based on the ranking from Literature in terms of most researched topic, only four feedback structures from the eight are found to be relevant for this study. Four significant feedback structures from prior models of project dynamics in infrastructure construction projects are mentioned below based on the review's findings. Table 2 displays the research topics and their trends in SD from the selected articles from 2001 to 2021.

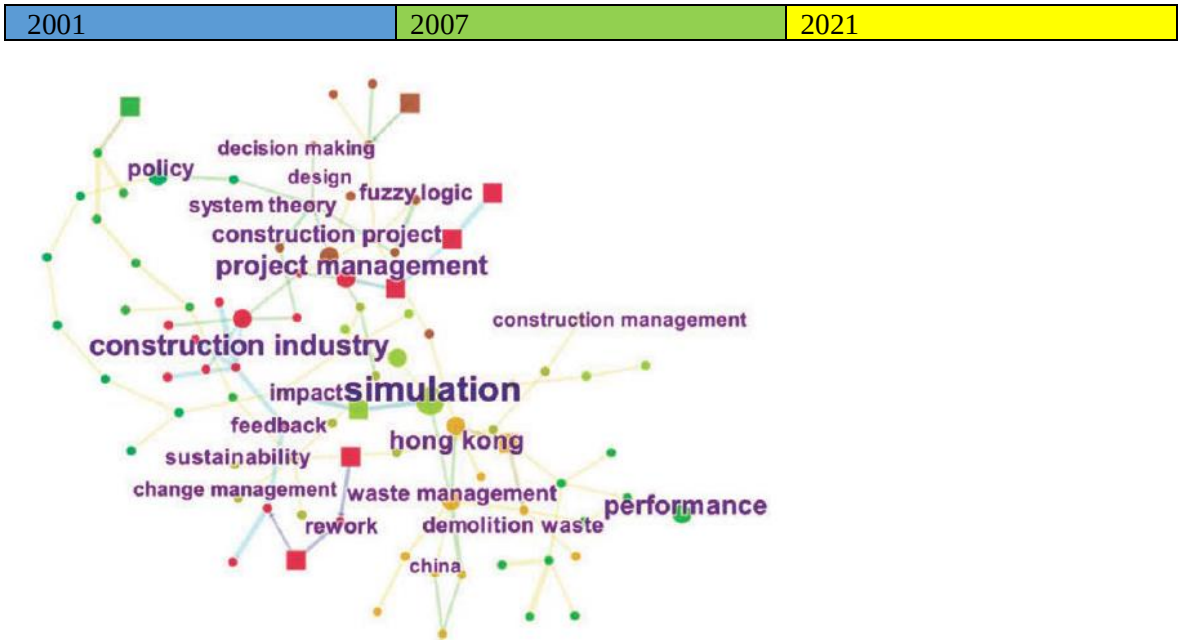

Fig. 2 Keyword co-occurrence network analysis

Table 2. Research topics and their trends

Research topic	2001-2006	2007-2012	2013-2021	Total
Design error, rework, and change management	1	2	3	6
Resource Management	1	1	1	3
Planning and Control	1	1	2	4
Performance and effectiveness	0	1	1	2

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3.1. Design Error, Rework, And Change Management

The error and change cause a rework cycle is frequently the most important reason for the complexity of construction projects [18]. Furthermore, mistakes made throughout the design process inevitably result in rework [19].As a result, design fault, rework, and change are all intertwined. According to [20] using system dynamic approach developed an SD model to depict how construction changes and rework can affect the project management system.

Planned activities with a focus on dynamics arising from active interventions, and uncertainties with unattended dynamics components outside the control of project management, are the two fundamental sources of dynamics that infringe on a project system. This was also the first study to look at project management with SD in a quantitative way. Furthermore, the necessity of detecting project dynamics was stressed in this study.

[15] created a dynamic change management system to expedite the completion of construction projects. The model simulation indicates that managerial decisions on change or rework should be based on a thorough evaluation of the trade-offs involved. [21] said that quality and change management for large-scale concurrent design and construction projects were priorities. [18] developed a dynamic planning and control technique for quality and change management by combining multiple current methodologies around a basic SD model. [22] model the expansion of the electricity system using SD methodology. This article presents an interdisciplinary approach to long-term computer modelling of large-scale power systems, as well as the simulation of the system's economic, technical, and environmental elements. The key findings could be useful in strategic planning for businesses as well as investment appraisals for power plant projects using the Real Option approach. As a result, the most effective rework prevention measures are unknown.

[23] Outlined a forensic management strategy based on SD. Their SD model may be used to figure out how and why rework happens. [23] demonstrated a system for managing change. They combined the SD model with a fuzzy logic-based change prediction model to mimic the interactive cycle of concurrent design and construction caused by unexpected changes and their consequences.They showed that SD may be used in conjunction with other research approaches.

[24] developed an SD model to characterize the influence of severe weather on megaproject construction for more precise construction planning to avoid project delays, cost overruns, and increased rework. [25] stated that design errors, which result in rework and/or design revisions, are the biggest cause of schedule delays and cost overruns in design and construction projects. They go on to say that, despite the fact that design faults are common, most design and construction businesses do not track the number of errors they make, and hence have minimal awareness of the mechanisms that sabotage project performance. According to the findings, despite project managers' best attempts to recover schedules, design errors can cause considerable delays in the project schedule. Furthermore, deadline pressure has been demonstrated to have a negative impact on a variety of construction operations that are unrelated to design errors. They created an SD model to capture the dynamics of design faults and rigorously assess their detrimental impact to correct the errors.

[26] created a model that includes the rework cycle and a workforce component to show how project dynamics affect the number of the workforce required at any given time. In some form, almost all dynamic project models have a rework cycle [27] . As a result, comprehending project delays and interruptions requires an understanding of the rework cycle [28]. From 2012 to 2018, additional quantitative and sensitivity analyses were conducted for design error, rework, and change management by using SD models. Articles related to construction change and rework is ranked as the most researched topic as per table 2, looking at the dynamics at play and complexity of infrastructure projects.

3.2. Performance And Effectiveness

[29] claims that an organization's performance is driven not only by its complex structure, which consists of multiple interconnected components, but also by its official and informal policies.

SD modelling aids in the optimization of management plan revisions and policy formulation to improve project performance in

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the actual world. SD has been employed in a lot of research to investigate organizational performance. [27] applied SD modelling to integrate engineering procedures and local influencing factors in order to boost construction company performance. Performance and effectiveness is ranked last, it's the least researched topic according to table 2 although there is interest in the topic as there is a gradual increase in number of articles published. Based on these studies, both the effects of internal and external complexities of project performance can be streamlined by using System dynamics modelling.

3.3. Resource Management

Since 1994, scholars have been interested in resource management, demonstrating that SD is ideal for resource management. There are two types of resources used in construction: material and non-material resources. [30] in Pakistan, an SD model for the electricity generation sector was developed. It was about Pakistan's electrical supply, resources, and pollution dynamics. This study, which employs SD methodology, assesses current policy in light of environmental issues and available, but limited, resources. The authors conclude that maintaining the current strategy appears to effectively attract investments from independent power producers, but not without potentially negative effects for the environment and the economy. This model's flaw was that it was relying too heavily on one variable to drive the model.

[31] developed an SD model for design and build construction projects that incorporates important subsystems (such as different stages or human resources contribution to projects) and their interactions. [32] proposed a dynamic model-based approach for managing construction resources (labour and materials). The model simulation of the resource level targeting procedure revealed that resource coverage and project performance have a time-cost trade-off. Without mentioning outsourcing, policy implications for the main variables stated as the target material level, target workforce level, material acquisition rate, and workforce-based engineering rate were also explored. Excessive resource idling and low material resource coverage, according to the model, might have an influence on project objectives, causing delays in the project schedule and cost overruns. As a result, the SD model is primarily used to systematically manage material resources in order to ensure project delivery on time and within budget in early studies, and he established an SD model for construction resource management to solve these difficulties.

To evaluate investments in integrated information management in the construction industry, causal loop diagramming was used by [33] to depict the qualitative SD model for the study of the dynamics of construction enterprise resource planning systems, and to identify the major variables that influence the successful evaluation of construction enterprise resource planning in the construction industry using SD principles. Resource management is ranked as the third most reached articles as highlighted in table 2, although there is a gradual interest in the topic.

3.4. Project Planning And Control

A form of SD-based issue that has lately arisen is planning and control. [34] Introduced the system's dynamic planning and control approach to assist project management's strategic and operational components. Vensim developed a project management solution that combined the standard CPM approach with SD modelling. A strategic core of SD, a tactical layer of agent-based modelling, and an operational layer of network-based tools, optimisation approaches, discrete-event simulation, and statistics are among the tool's features.

[18] SD's strength is strategic project management, not operational project management, according to him. By combining many existing approaches around a basic SD model for quality and change management, they built dynamic planning and control methodology. [35] modelled the engineering process using SD methodology and ran simulations to see how project management decisions affected the outcome, efforts to improve constructability and design sharing and reduced the impact of cost overruns and project completion delays. Project planning and control, mainly relating to cost/schedule control, is the second most popular topic. The number of papers have been stable over the two 5-year periods. These studies often use System Dynamics Modelling to explore complicated relationships between internal activities and their feedback in solving problems as shown in table

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2. According to the findings, it is advisable to focus on improvement efforts early in the project.

As previously mentioned, Table 3 summarizes the collection of studies that were reviewed. To summarize, systematic review in a certain subject is widely regarded as a critical approach for researchers to enrich the method's present body of knowledge and to inspire them to conduct future study [36]. [37] did a content study of SD-related literature in the energy industry, emphasizing SD's role in electricity modelling. This review helped to organize the material into categories based on important study areas. Models for policy analysis, generation capacity growth, financial instruments, demand side management, and micro-worlds were among them.

The two most modelled subjects, according to the study, are policy evaluation and power capacity expansion. [38] conducted an energy-related SD model literature review. The study's major goal was to summarize a significant body of literature as well as the most recent SD developments in the energy sector, including renewable energy. [36] read articles about social network analysis in the context of building project management. These reviews gave academics a multi-dimensional understanding of a method that may be used in a certain discipline, as well as some potential study avenues for the method's use in future studies.

[39] performed a critical analysis of SD modelling in construction management research. The findings show that SD modelling is critical in streamlining various complicated casual relationships at the activity, project, and industry levels across the eight topics, as well as its significant potential in uncovering the impact of complicated contextual conditions on project planning and control, effectiveness, and efficiency.

[12] performed a critical analysis of an SD analytical approach for construction project management study. The findings demonstrate that construction management researchers have been paying more attention to SD in recent years. However, none of the systematic reviews looked at SD modelling in the context of infrastructure projects in the energy industry.

According to the database, the earliest description of the use of SD in understanding projects was published in 1964, although the first project-specific applications were not recorded until the 1980s. Many more examples of the usage of SD in project management have been recorded since 1990 [17]. The findings of the literature review led to a number of conclusions. The first is that the number of articles published on SD modelling in infrastructure projects in the electrical industry has increased in recent years.

Four significant feedback structures from earlier SD models of project dynamics and distinctive characteristics of construction projects have been recognized as major trends, according to the findings of the current review. Design errors, rework, and change management are among them, as are performance and effectiveness, resource management, and project planning and control.

These studies have attempted to address a number of dynamics issues that arise in complicated construction projects to some extent. Despite these efforts, little or no study has been done to understand the dynamics at play in guaranteeing on-time delivery of infrastructure projects in the energy sector, as well as to reduce the costs associated with project delays.

Certain variables, such as scope change, design engineer competency, and multitasking, are not addressed on the presented models to ensure on-time delivery of infrastructure projects, according to the literature studied. Further research is needed to evaluate the impact of modifications in each of these factors individually and collectively on the model's overall project performance. The focus should be on how these modifications effect the overall projected completion time and project job quality.

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Table 3. SD related to construction projects model summary

Published	Authors	Title	Purpose	Conclusion
2001	[30]	Understanding the dynamics of electricity supply, resources and pollution: Pakistan's case	An assessment of the existing resource policy	The current energy policy is unsustainable in terms of attracting investments.
2002	[31]	System dynamics modelling of design and build construction projects	Design and build construction projects modelled in order to optimize time and cost performance.	In design and build construction projects, a system dynamics model is constructed that integrates significant subsystems (such as different phases or human resources input to projects) and their interactions.
2002	[20]	Using SD to better understand change and rework in engineering project management systems	The requirement for an awareness of how certain dynamics can obstruct a project management system's performance.	Love constructed an SD model to describe how construction changes and rework can affect the project management system. This was also the first study to take a quantitative look at project management.
2003	[29]	System Dynamics Approach to Exploring Performance Enhancement in a Construction Organization	Performance enhancement in a construction organisation	A model is created to investigate policies that can improve a construction firm's performance.
2005	[40]	Modelling the Dynamics of an Infrastructure Project	Modelling the dynamics of an infrastructure project	To capture the dynamism of construction projects in the construction phase, a dynamic simulation model is built. As dynamic hypotheses, eight essential feedback structures from earlier project dynamics models and the specific characteristics of building projects are identified. They cover labour structures, equipment, material, labour-equipment interaction, schedule, rework, safety, and quality.
2005	[32]	A model-based dynamic approach for construction resource	He notes that excess resource idling can result in cost overruns, while low resource coverage or long lead time in resource acquisition can delay the project schedule.	For building resource management, he created a system dynamics model. In addition, policy implications for the main variables of goal material level, target workforce level, material acquisition rate, and workforce based engineering rate were explored without any mention of outsourcing.

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Table 4. SD related to construction projects model summary (Cont')

Published	Authors	Title	Purpose	Conclusion
2007	[41]	A Systematic Approach to Modelling Change Processes in Construction Projects	Modelling changes in construction projects	An SD model with an integrated fuzzy logic-based change prediction model. He demonstrated how SD could be used in conjunction with other research approaches.
2007	[22]	An interdisciplinary approach to long-term modelling for power system expansion	Interdisciplinary modelling approach of large-scale power systems over a long-term horizon	The value of simulation models that may be used interactively.
2012	[24]	A conceptual system dynamic model to describe the impacts of critical weather conditions in megaproject construction	Modelling the impacts of critical weather conditions in megaproject construction.	An SD model was created to characterize the effects of key weather conditions in megaproject development, allowing for more precise construction planning to avoid project delays, cost overruns, and increased rework.
2013	[25]	A system dynamics model for assessing the impacts of design errors in construction projects	They pointed out that design errors, which result in rework and/or design revisions, are the biggest cause of schedule delays and cost overruns in design and construction projects.	They created an SD model to capture the dynamics of design errors and assess their negative consequences in a methodical way.
2013	[26]	System dynamics applications with impact	A typical SD model for project dynamics	The workforce component of the model has the rework cycle at its heart, indicating how the project dynamics at play would result in variations in the size of the workforce required at any given time.
2014	[42]	Applying SD for nuclear power plant design	Analysed an SD model for outsourcing engineering services in a large and complex project organisational structure	SD model for outsourcing design services in a project.
2016	[43]	Analysis of policy options for projects in the electricity industry in Sub-Saharan Africa: A System dynamics approach	An SD approach to managing project risks	The model is an expansion of (27), incorporating political risk, project management competence, unforeseen technical challenges, and an insurance index to generate scenarios that can be utilized to reduce project delays and increase project quality.

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Table 5. SD related to construction projects model summary (Continue)

Published	Authors	Title	Purpose	Conclusion
2019	[39]	System dynamics modelling for construction management research: Critical review and future trends	Critical review on system dynamics for construction projects and future trends	This systematic review indicates that SDM has been increasingly advocated by researchers over the past two decades to explore nonlinear and dynamic complexity issues involved in Construction Management
2021	[12]	System dynamics analytical modelling approach for construction project management research: A critical review and future directions	A critical review and future directions	The results show that SD has received increasing attention from construction management researchers over the past five years.

4. Conclusions

This paper provides a thorough review of studies on the contribution of SD modeling to the power industry. It addressed the current state of the field as well as gaps in the literature about models designed to improve project on-time delivery in the electrical industry. The power industry is confronted with numerous issues on a global scale. It's impossible to summarize all characteristics of electricity-based SD models, including their diverse objectives, time spans, and aims, depending on the region taken into account. According to the findings of the analysis, scholars have progressively advocated using SD modeling to investigate non-linear and dynamic complexity over the last two decades. It's a crucial method for simplifying complex causal relationships at the project and industry levels.

Furthermore, it has the potential to expose the impact of contextually complex variables on project planning and control, effectiveness and performance, strategic management, and long-term sustainability. The research on electricity SD models is quite similar all over the world, highlighting the need of optimizing power plant design, output, and consumption. A survey of the literature revelead that SD modeling has made a significant contribution to the electrical sector in this research. However, additional effort is needed to fully realize the benefits of SD modeling in the electricity industry. The findings of the study provide a comprehensive knowledge of SD modeling used in Infrastructure projects, as well as insights into prospects and relevant resources for future SD modeling applications in Infrastructure research. The construction of a theoretical framework model based on the gaps revelead in this study will be the focus of future research.

REFERENCES

[1] International Energy Agency, “Key World Energy Statistics 2020,” 2020.
[2] Department of Mineral Resource and Energy, “Integrated Resource Plan,” 2019.
[3] J. Brown, S. George, and J. Dillard, “Integrated reporting,” *Eskom*, 2020. https://www.eskom.co.za/IR2016/Pages/default.aspx
[4] J. Wang and H. Yuan, “System Dynamics Approach for Investigating the Risk Effects on Schedule Delay in Infrastructure Projects,” *Journal of Management in Engineering*, vol. 33, no. 1, p. 04016029, Jan. 2017, doi: 10.1061/(asce)me.1943-5479.0000472.
[5] P. X. W. Zou, G. Zhang, and J. Wang, “Understanding the key risks in construction projects in China,” *International Journal of Project Management*, vol. 25, no. 6, pp. 601–614, Oct. 2007, doi: 10.1016/j.ijproman.2007.03.001.
[6] F. Nasirzadeh and P. Nojedehi, “Dynamic modeling of labor productivity in construction projects,” *International Journal of Project Management*, vol. 31, no. 6, pp. 903–911, 2013, doi: 10.1016/j.ijproman.2012.11.003.

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

[7] F. A. Adero and W. O. Odiyo, "Leadership Theories and the Desired Competencies of the 21st Century Organization Leader," *International Journal of Business Management, Entrepreneurship and Innovation*, vol. 2, no. 3, pp. 16–35, Sep. 2020, doi: 10.35942/jbmed.v2i3.115.

[8] J. D. Sterman, "The energy transition and the economy: A system dynamics Approach," Massachusetts insitute of technology, 1981.

[9] A. Gholizad, L. Ahmadi, E. Hassannayebi, M. Memarpour, and M. Shakibayifar, "A System Dynamics Model for the Analysis of the Deregulation in Electricity Market," *International Journal of System Dynamics Applications*, vol. 6, no. 2, pp. 1–30, Jan. 2017, doi: 10.4018/ijsda.2017040101.

[10] S. P. Shepherd, "A review of system dynamics models applied in transportation," *Transportmetrica B*, vol. 2, no. 2. Taylor and Francis Ltd., pp. 83–105, May 04, 2014. doi: 10.1080/21680566.2014.916236.

[11] K. Cooper, G. Lee, and J. Sterman, "Managing the Dynamics of Projects and Changes at Fluor," 2009.

[12] X. Xu and P. X. W. Zou, "System dynamics analytical modeling approach for construction project management research: A critical review and future directions," *Frontiers of Engineering Management*, vol. 8, no. 1, pp. 17–31, Mar. 2021, doi: 10.1007/s42524-019-0091-7.

[13] A. Padilla-Rivera, M. G. Paredes, and L. P. Güereca, "A systematic review of the sustainability assessment of bioenergy: The case of gaseous biofuels," *Biomass and Bioenergy*, vol. 125. Elsevier Ltd, pp. 79–94, Jun. 01, 2019. doi: 10.1016/j.biombioe.2019.03.014.

[14] A. G. Araújo, A. M. Pereira Carneiro, and R. P. Palha, "Sustainable construction management: A systematic review of the literature with meta-analysis," *Journal of Cleaner Production*, vol. 256. Elsevier Ltd, May 20, 2020. doi: 10.1016/j.jclepro.2020.120350.

[15] M. Park and F. Pena-Mora, "Dynamic change management for construction: Introducing the change cycle into model-based project management," *Syst Dyn Rev*, vol. 19, no. 3, pp. 213–242, Sep. 2003, doi: 10.1002/sdr.273.

[16] J. Sterman, "Business Dynamics, System Thinking and Modeling for a Complex World Climate Interactive and the C-ROADS Simulation View project Dynamic Models for Population (Routine) Screening: Understanding Long Term Trends in Policy Decisions of Clinical Practice Guid," 2002.

[17] A. Rodrigues and J. Bowers, "The role of system dynamics in project management," 1996.

[18] S. Lee, F. Peña-Mora, and M. Park, "Dynamic planning and control methodology for strategic and operational construction project management," *Autom Constr*, vol. 15, no. 1, pp. 84–97, Jan. 2006, doi: 10.1016/j.autcon.2005.02.008.

[19] P. E. D. Love, P. Mandal, and H. Li, "Determining the causal structure of rework influences in construction," *Construction Management and Economics*, vol. 17, no. 4, pp. 505–517, 1999, doi: 10.1080/014461999371420.

[20] P. E. D. Love, G. D. Holt, L. Y. Shen, H. Li, and Z. Irani, "Using systems dynamics to better understand change and rework in construction project management systems," *International Journal of Project Management*, vol. 20, no. 6, pp. 425–436, Aug. 2002, doi: 10.1016/S0263-7863(01)00039-4.

[21] S. Lee and F. Pena-Mora, "System dynamics approach for error and change management in concurrent design and construction," in *Proceedings of the 2005 Winter Simulation Conference*, 2005.

[22] A. Dimitrovski, A. Ford, and K. Tomsovic, "An interdisciplinary approach to long-term modelling for power system expansion," 2007.

[23] P. E. D. Love, D. J. Edwards, and Z. Irani, "Forensic project management: An exploratory examination of the causal behavior of design-induced rework," *IEEE Trans Eng Manag*, vol. 55, no. 2, pp. 234–247, 2008, doi: 10.1109/TEM.2008.919677.

[24] Boateng, Chen, and Ogunlana, "A conceptual system dynamic model to describe the impacts of critical weather conditions in megaproject construction," *Journal of Construction Project Management and Innovation*, vol. 2, no. 1, pp. 208–224, 2012.

[25] S. Han, P. Love, and F. Peña-Mora, "A

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

system dynamics model for assessing the impacts of design errors in construction projects," *Math Comput Model*, vol. 57, no. 9–10, pp. 2044–2053, May 2013, doi: 10.1016/j.mcm.2011.06.039.

[26] G. P. Richardson, "Concept models in group model building," *Syst Dyn Rev*, vol. 29, no. 1, pp. 42–55, Jan. 2013, doi: 10.1002/sdr.1487.

[27] K. Reichelt and J. Lyneis, "The Dynamics of Project Performance: Benchmarking the Drivers of Cost and Schedule Overrun The Nature of Project Problems," *European Management Journal*, vol. 17, no. 2, pp. 135–150, 1999.

[28] Lyneis, J. M, and D. N. Ford, "System dynamics applied to project management: a survey, assessment, and directions for future research," *Syst Dyn Rev*, vol. 23, no. 3, pp. 157–189, 2007, doi: 10.1002/sdr.

[29] S. O. Ogunlana, H. Li, and F. A. Sukhera, "System Dynamics Approach to Exploring Performance Enhancement in a Construction Organization," *Construction Management and Economics*, 2003, doi: 10.1061/ASCE0733-93642003129:5528.

[30] H. Qudrat-Ullah and P. I. Davidsen, "Understanding the dynamics of electricity supply, resources and pollution: Pakistan's case," 2001.

[31] S. Chritamara, O. S.O, and N. L. Bach, "System dynamics modeling of design and build construction projects," *Construction innovation*, pp. 269–295, 2002.

[32] M. Park, "Model-based dynamic resource management for construction projects," *Autom Constr*, vol. 14, no. 5, pp. 585–598, Oct. 2005, doi: 10.1016/j.autcon.2004.11.001.

[33] I. Hristov and A. Chirico, "The Limits of the Balanced Scorecard," *Open J Soc Sci*, vol. 04, no. 11, pp. 53–58, 2016, doi: 10.4236/jss.2016.411004.

[34] J. Anto, "An empirical study of Enterprise Resource Planning systems in construction industry," *International Research Journal of Engineering and Technology*, 2016.

[35] N. Minami, L. Soto, and D. Rhodes, "Dynamic lean management of the naval construction process," *EMJ - Engineering Management Journal*, vol. 22, no. 2, pp. 36–43, Jun. 2010, doi: 10.1080/10429247.2010.11431862.

[36] X. Zheng, Y. Le, A. P. C. Chan, Y. Hu, and Y. Li, "Review of the application of social network analysis (SNA) in construction project management research," *International Journal of Project Management*, vol. 34, no. 7, pp. 1214–1225, Oct. 2016, doi: 10.1016/j.ijproman.2016.06.005.

[37] S. Ahmad, R. Mat Tahar, F. Muhammad-Sukki, A. B. Munir, and R. Abdul Rahim, "Application of system dynamics approach in electricity sector modelling: A review," *Renewable and Sustainable Energy Reviews*, vol. 56. Elsevier Ltd, pp. 29–37, Apr. 01, 2016. doi: 10.1016/j.rser.2015.11.034.

[38] A. Leopold, "Energy related system dynamic models: a literature review," *Cent Eur J Oper Res*, vol. 24, no. 1, pp. 231–261, Mar. 2016, doi: 10.1007/s10100-015-0417-4.

[39] M. Liu, Y. Le, Y. Hu, B. Xia, M. Skitmore, and X. Gao, "System dynamics modeling for construction management research: Critical review and future trends," *Journal of Civil Engineering and Management*, vol. 25, no. 8, pp. 730–741, 2019, doi: 10.3846/jcem.2019.10518.

[40] L. D. Nguyen and S. O. Ogunlana, "Modeling the dynamics of an infrastructure project," *Computer-Aided Civil and Infrastructure Engineering*, vol. 20, no. 4, pp. 265–279, 2005, doi: 10.1111/j.1467-8667.2005.00392.

[41] I. A. Motawa, C. J. Anumba, S. Lee, and F. Peña-Mora, "An integrated system for change management in construction," *Autom Constr*, vol. 16, no. 3, pp. 368–377, May 2007, doi: 10.1016/j.autcon.2006.07.005.

[42] S. Lisse, "Applying system dynamics for outsourcing services in design-build projects," *Journal of Project, Program & Portfolio Management*, vol. 4, no. 2, p. 20, 2014, doi: 10.5130/pppm.v4i2.3196.

[43] N. O. Ogano and L. Pretorius, "Analysis of policy options for projects in the electricity sector in sub- Saharan Africa: A system dynamics approach," *South African Journal of Industrial Engineering*, vol. 28, no. 1, pp. 20–35, 2016, doi: 10.7166/28-1-1607.