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# MANAGING COMPLEXITY AND STAKEHOLDER DYNAMICS IN LARGE-SCALE INFRASTRUCTURE PROJECT

**M.D. Saeed** [1] **H.Y. Khudhair** [2]

*1. Faculty of Business and Law, British University in Dubai, Dubai, UAE*
*mohamed.emirati@gmail.com*
*2. Azman Hashim International Business School, University Technology Malaysia, Johor Bahru, Johor, Malaysia*
*harith.albayati@yahoo.com*

**Abstract-** The report showcases instances where system dynamics techniques were employed in publications. The report includes a synthesis of selected articles and used methodology. Although the system dynamics model is used in its research topic, "Concrete Waste Management by Life Cycle Assessment". In addition, an analysis and causal loop diagram were created to examine the outcomes. Scientific discoveries indicate the link between concrete waste management and ecological effects. Rising waste quantities translate into heightened adverse effects on the ecosystem. However, the causes and uses of trees show the relationship of variables, indicating the concrete waste effectiveness among ecological impact. Studying the chosen publications highlights the crucial role of system dynamics in comprehending the complexity of waste management in construction, and our investigation confirms the same. By modeling waste generation, disposal processes, recycling, and related costs, system dynamics offers a holistic perspective that allows for informed decision-making for sustainable waste management practices. Through our report, we aim to contribute to the ongoing initiatives since reducing harmful environmental consequences is vital for creating an eco-friendlier construction industry landscape. As depicted through specific publications, system dynamics modeling is a successful strategy for analyzing complex waste-related issues and their environmental consequences. Utilizing this methodology for investigating the issue of "Waste Management by Life Cycle Assessment of Concrete", we can uncover improved alternatives for diminishing concrete waste in landfills. Concurrently considering cost factors, this strategy will lessen the detrimental impacts of concrete waste on the surroundings.

**Keywords:** Managing Complexity, Stakeholder, Infrastructure Projects, Project Management.

## 1. INTRODUCTION

The construction field considers the primary cause of solid waste generation worldwide [1]. In addition, it is usually stated that a high quantity of construction and demolition waste is generated yearly because of the several construction activities worldwide [2]. Furthermore, the solution to reduce the generated or accumulated waste in landfills is considered one of the leading challenges. Most of the construction waste dispose of the landfills, which causes severe environmental impacts. Although, some statistics in China show that 29% is the generation of solid waste in a year, and 40% accounts for construction activities [3]. On the other hand, Fédération International du Recyclize (F.I.R.) indicated that one tonne of recycled aggregates could save around 0.6 $m^3$ of landfill space. For instance, one tonne of waste disposal in the landfill requires almost 0.6 $m^3$ of landfill space. Furthermore, there are many options and ways to reduce construction waste and find better solutions. For example, system dynamics has been used in many studies and different fields. Moreover, the construction field considers a vast industry with many obstacles and barriers, which require modeling and simulation that could lead to advantages and better solutions.

Managing the waste generated from construction and demolition activities poses significant challenges due to the sheer volume of waste and its potential environmental impact. Traditional garbage disposal techniques, such as landfilling, have demonstrated their inability to provide sustainable solutions [4]. Researchers and professionals have been exploring diverse modeling and simulation approaches in response to these obstacles. System dynamics is one methodology that has gained popularity in waste management investigations. Holistic knowledge of system dynamics facilitates in-depth analysis rendering it an essential tool. Dynamic relationships between diverse components within a complicated system can be scrutinized for efficient garbage management. Experts hope to create effective waste management strategies that prioritize sustainability by employing system dynamics techniques. The selected articles have demonstrated the effectiveness of using system dynamics in various waste management scenarios. These include waste reduction at the construction stage, waste disposal charging fees, and construction and demolition waste management policies [5].

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Concrete waste's environmental consequences warrant careful consideration, and the application of system dynamics in waste management might be instrumental in tackling this problem. The study seeks optimal methods for reducing concrete waste generation by creating a system dynamics model considering life cycle assessment. In addition, financial constraints can aid in promoting recycling and mitigating its environmental consequences. The report will develop a causal loop diagram highlighting the complex relationships between concrete waste management systems. The analysis of this diagram will shed light on the potential leverage points for sustainable waste management practices. An appreciation of how various factors interrelate enables policymakers to devise more practical waste management strategies to lessen the ecological impact of concrete waste and encourage an eco-friendlier construction sector.

## 2. SYNTHESIS

The report summarizes selected articles focused on waste management in the construction field using system dynamics models. The articles strive to discover novel approaches in mitigating building debris and its environmental consequences and determining landfill disposal charges. The utility of system dynamics models in addressing waste management challenges has been established. The report focuses on conducting research within the "Concrete Waste Management by Life Cycle Assessment" framework, utilizing system dynamics methodologies to identify optimal approaches for decreasing concrete waste generation and mitigating its detrimental environmental consequences.

### 2.1. System Dynamics Purposes in The Research Publications

The purpose of system dynamics in the research publications is on the same topic: waste management in construction fields, such as reducing generated waste and its impact on the environment, and a charging fee for generated waste. Moreover, the publications consider finding better and more suitable solutions for the management of construction and demolition waste. As known, the construction field is complex and extensive and consists of many variables. In addition, the high number of activities in the construction field led to a need for more clarity, obstacles and barriers in some areas. Furthermore, the dynamic system model used in research publications in this report has shown some advantages in managing construction waste in several areas, such as financial perspective, the process of waste disposal, and waste management options. Even though sustainability metrics have improved, including a system dynamics model has led to decreased landfilled waste, leading to ecological advantages and a longer-term sustainable trajectory [6]. The first article is "A system dynamics-based environmental performance simulation of construction waste reduction management in China." Because of the high quantity of construction waste generated from construction activities and its influence on the environment, the first article's purpose is to develop a system dynamic model for construction waste management reduction at the construction stage, which helps to simulate the environmental advantages and benefits based on construction waste management reduction, the study proposed for the city of Shenzhen in China [7]. Moreover, the simulation program used in the article is Vensim. Overall, the simulation will help achieve future sustainability and development in construction waste management. Furthermore, the disposal of construction waste in landfills impacts the environment because of the accumulation of the waste, which counts in a million tonnes. The simulation of system dynamics has shown some advantages, such as reducing the total waste generation by 27.05%.

The second article, "A system dynamics model for determining the waste disposal charging fee in construction," identifies that disposal costs can be minimized and the lifespan of landfill can be prolonged by knowing which waste management option is practical [8]. For example, collect, sort, reduce, reuse, recycle, and disposal. In addition, it was found that the waste disposal construction fee (WDCF) is sufficient to decrease the construction and demolition waste in China (Yuan & Wang, 2014). Moreover, WDCF has been applied recently in China for the purpose of municipal solid waste. On the other hand, the model described in the article is in line with the principle of system dynamics that was oriented in the 1960s by Jay Forrester to deal with large system scales with high complexity.

The third article is "A Dynamic Model for Construction and Demolition (C&D) Waste Management in Spain: Driving Policies Based on Economic Incentives and Tax Penalties," aimed at reducing the construction and demolition waste, which is achieved through a simulated model designed by using system dynamics as a methodology. Furthermore, two policies were assessed by potential impact: incentives and tax penalties. In addition, the assessment helps to evaluate the influence of government behavior regarding the recycling method of construction and demolition waste of aggregates. Spanish law mandates that non-hazardous construction and demolition waste must decrease to 70% by 2020. The stakeholders' current behavior towards waste management creates difficulties in achieving the objective [9].

### 2.2. Aims and Objectives of Used Publications

The targeted publications aim to achieve specific objectives for managing construction waste, including reducing waste production and mitigating its ecological footprint. The first article employs system dynamics modeling to evaluate and enhance future development and sustainability in construction waste management. The second article aims to determine the waste disposal charging fee in construction and identify practical waste management options. The third piece of writing seeks to advance sustainable construction by examining economic motivations and financial repercussions affecting construction and demolition waste management in Spain.

### 2.3. Report on Methodology

The first article's methodology is based on a system dynamic model. The article proposes a system dynamic management model for construction waste reduction. In addition, four components are involved with construction waste reduction management: measures of source reduction, behaviors reduction, regulations and policies of the government, and finally, the ecological benefits. Although source reduction relates to minimizing the generated waste, which refers to this model to management performance on-site and low-waste technologies. While behavior reduction is related to on-site sorting, which is determined by objectives such as affected by attitudes and behavioral mechanisms. On the other hand, the environmental performance of construction waste management is measured by the benefits of land, air, and water. Figure 1 illustrates the construction waste management process, highlighting the multiple phases and steps involved. The diagram provides a visual representation of construction waste management and its possible routes. The beginning stage of the process involves generating waste materials due to construction-related activities. The nature and structure of the waste determine its categories. Sorting follows as the subsequent action in the process, where waste is divided into groups determined by whether it can be reused, recycled, or thrown away.

The waste can journey through different pathways after the sorting stage. Source reduction is a crucial aspect of waste management, focusing on reducing the amount of waste generated in the first place. The overall waste burden can be decreased by adopting measures to minimize waste during construction activities [10]. One significant challenge in construction waste management is illegal dumping which can result in environmental hazards and increased waste accumulation. The diagram illustrates how waste production relates to the amount of illegal dumping, unveiling potential outcomes of poor waste management methods.

The diagram also highlights the two primary waste destinations: landfill and recycling. The part of the waste that undergoes recycling processing is termed the amount of landfill waste, with this category encompassing materials transformed into new products. Conversely, it can also refer to materials repurposed in alternative manners. Efficient recycling practices can reduce waste disposal volumes, protecting valuable landfill areas and lowering environmental footprints. Recycled waste can be transformed into usable materials, minimizing the need for fresh raw resources and lowering waste production. Implementing recycling and reusing initiatives can minimize the adverse ecological effects of building waste. To sum up, Figure 1 gives an overall view of the construction waste management process, which emphasizes the significance of lowering sources, correctly classifying, recycling, and reusing to implement sustainable waste management procedures, as these methods help minimize the load on landfills and the environment [11].

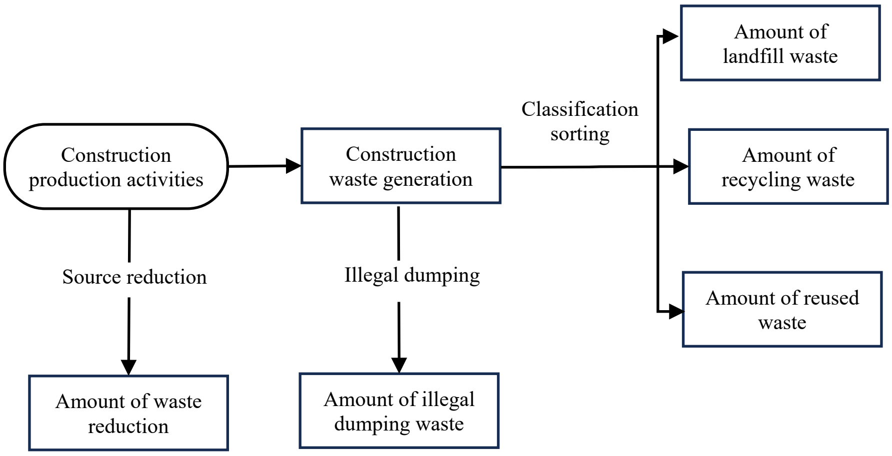

Figure 1. The process of construction waste management, which consists of waste generation (et al. Ding 2016)

Figure 1 illustrates the causal loop diagram of construction waste management reduction. In addition, five casual loops are identified and analyzed, and among five casual loops, four (R1, R2, R3, and R4) are positive, while the remaining loop, B1, is negative. The amount of waste wither recycling, sorting, dumping, and landfill connected with incentive, cost, and environmental impact. The diagram shows how different elements contribute to waste management efficiency and environmental performance. Understanding the diagram is recognizing the beginning waste as indicated by the "Total amount of waste generated". Several variables will influence subsequent developments.

The "Amount of recycling waste (R2)" loop indicates that an increase in recycling efforts leads to a reduction in waste that ends up in landfills "Amount of waste landfill" and reduces the need for new construction materials "Construction materials saved via reuse". The diagram emphasizes the importance of cost in managing waste. The recycling incentive loop highlighted by the "Cost of waste landfill" demonstrates that greater expenses associated with dumping serve as an impetus for waste reduction strategies, resulting in less trash ending up in landfills "Amount of waste reduction".

Another significant factor in waste management is "illegal dumping waste." As these variables increase, it results in adverse environmental impacts and increased costs "Cost of illegal dumping". In contrast, waste management strategies that work effectively contribute to better environmental performance, and reducing waste through initiatives like waste reduction helps mitigate illegal dumping [12]. The diagram additionally illustrates how behavior affects garbage disposal. The Reduction behavior loop signifies that promoting waste reduction behaviors among stakeholders can decrease the total cost of source reduction management "Total cost of source reduction management". Highlights of the intricate connections between variables that impact construction waste reduction. Bringing attention to the value of reusing items and decreasing waste highlights the significance of protecting natural resources. Moreover, increasing environmental performance is vital for lasting growth. The article underscores the significance of cost, inspiration, and behaviors in forming waste management strategies and their consequences for environmental durability.

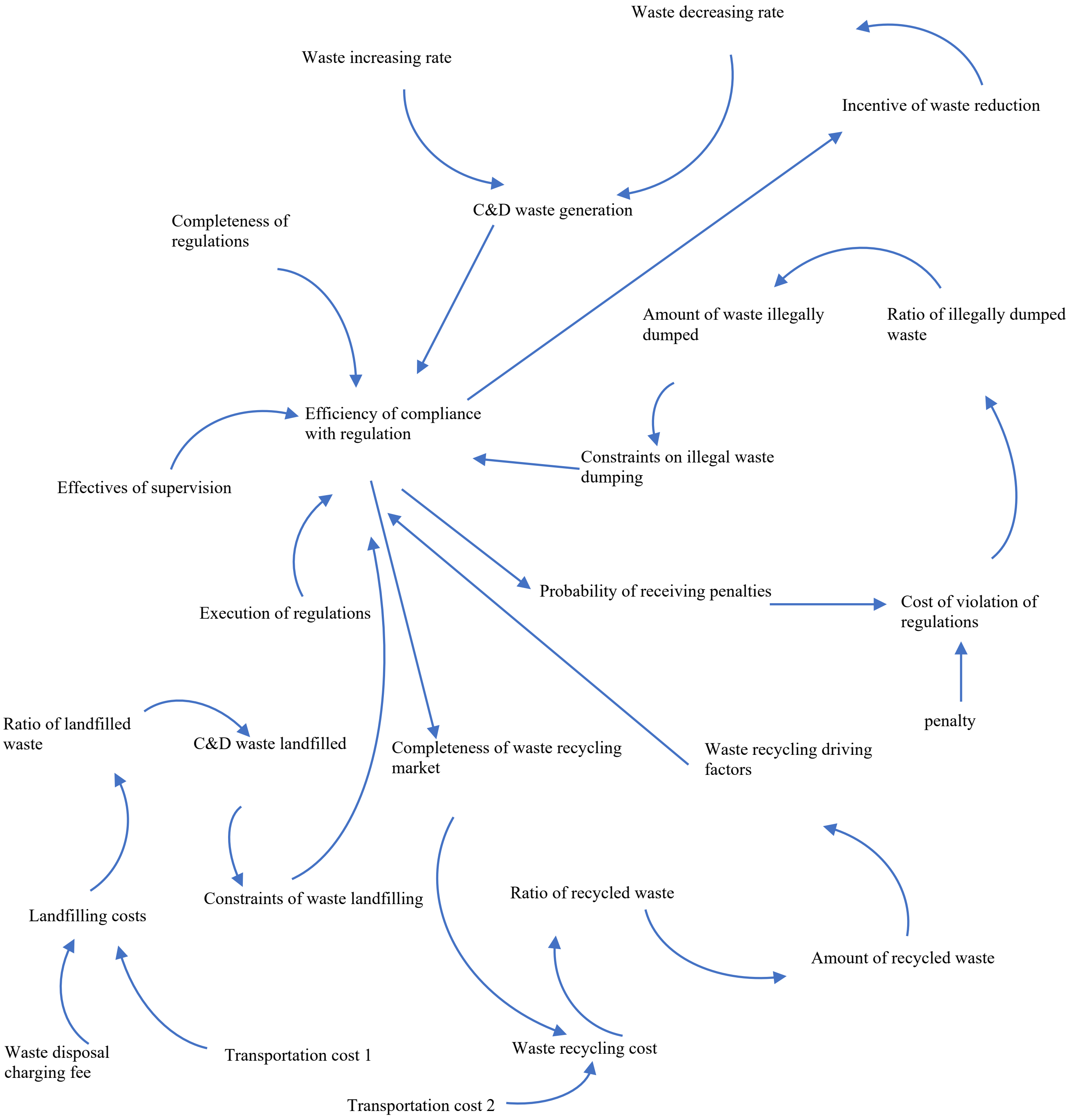

Figure 2. Illustrates The causal loop diagram of WDCF (Yuan and Wang 2014)

The second article's methodology is based on the system dynamic model. Figure 2 identifies the causal loop diagram of WDCF that is affected by numerous variables related to the waste management process. For example, the waste generation of construction and demolition process, reuse and recycling waste, disposal of the waste to landfills, and finally, dumping the waste, which is illegal (Yuan and Wang, 2014). The diagram depicts the intricate interactions and cyclical processes that affect the fee for charging and its consequence on waste creation, recycling, landfilling, and unlawful dumping. The component "C&D waste production" is central to the diagram, highlighting the aggregate quantity of construction and demolition waste produced. From here on, multiple variables enter the picture.

The loop illustrating the "completeness of regulations" suggests that clear and detailed guidelines can result in better waste handling. With less rubbish creation, these regulations can bring about a cleaner atmosphere. The diagram also underscores the rewards and consequences effect on waste management techniques. The "Incentive of waste reduction" cycle demonstrates that offering motivations for lessening waste creation diminishes waste age. Nevertheless, the "Probability of receiving penalties" loop reveals that this fear can prevent unlawful garbage disposal and ensure conformity with waste management standards [13]. The two loops, the proportion of waste that ends up in landfills versus the proportion that is recycled, shows how charging fees for waste disposal impacts. Increased charges can motivate individuals to recycle, reducing the quantity of garbage sent to dumps.

Furthermore, the diagram illustrates how landfilling expenses and transportation fees affect waste administration choices. Rising landfill expenditures can inspire resource conservation, and transportation costs can influence the feasibility of waste treatment and disposal techniques. Moreover, the loops illustrate how a well-functioning recycling system can positively impact recycling figures. These loops feature "Consequence of effective waste management" and “Important elements in recycling”. Figure 2 illustrates the intricate mechanics underlying the waste disposal charging fee. This fee affects waste creation, recycling, landfilling, and illegal dumping in various way. Effective rules are vital in shaping how waste is handled, with incentives, penalties, and market forces all playing a critical function. Sustainable waste reduction and recycling results demand a close examination of these components.

Figure 3 illustrates the four feedback loops, which start from loop one, which includes the related process of C&D waste landfilled. Loop two, which relates to C&D waste generation. Loop 3 considers the quantity of recycled waste, and Loop four considers the quantity of illegal dumping waste. Each loop highlights a distinct component of the waste management system and demonstrates how interconnected elements affect outcomes. The first loop delves into the significance of C&D waste landfills and investigates elements influencing disposal rates. The illustration shows how the "Constraints of waste landfilling" directly affect the "C&D Waste Landfilled Rate." In addition, the "Reward of waste reduction" helps reduce the total rate of C&D waste production and reduces the quantity of waste sent to landfills. Loop 2 delves into "C&D waste generation" and its influencing factors. The decrease in waste production has a noticeable influence on the generation rate of C&D waste. By minimizing waste output, it can significantly lower the total rate. Strict adherence to waste management rules and guidelines can lead to lower waste output, ultimately enabling compliance with legal requirements [14]. The third loop tackles the " Amount of recycled waste " and investigates the factors behind efficient waste recycling. The recycling process is affected by the market's completeness and the efficiency of compliance with regulations. The incentive for waste reduction fosters a higher recycling rate by encouraging more recycling practices. The fourth loop focuses on " illegally dumped waste" and explores reasons for unlawful waste management. Factors such as the prohibition on illicit garbage disposal and adherence to rules impact the likelihood of facing fines for illegal dumping. The expense of failing to comply with regulations adds to the larger picture of illegal waste disposal, alongside the volume of waste disposed of improperly.

The third article's methodology is based on the system dynamic model, which is used to enhance the process of construction and demolition waste disposal methods. Furthermore, the figure below illustrates the construction and demolition waste generation model. In addition, the process is affected by the disposal of untreated waste, which goes to disposal sites. On the other hand, recycling goals and objectives are involved in the process of the model, but the actual goal and the effectiveness of stakeholders need some help [15]. Although, the increase in recycled construction and demolition waste, such as storage or treated, will be contingent on the inflow of recycled waste and the outflow of aggregate materials, as illustrated in the figure 3. Furthermore, the inflow construction and demolition waste volume will depend on the percentage of the material that can convert into aggregates, as illustrated by. Figure 3 portrays the quantity of construction and demolition (C&D) waste generated during various waste management and recycling phases. The diagram offers an inside look at C&D waste generation, treatment, and reusing stages and the discrepancy between planned recycling goals and attained outcomes. The diagram initially highlights the creation of untreated C&D waste from civil engineering, signifying the initial waste generated during construction and building projects, which can be sizable. Subsequent stages involve considering the generation of untreated C&D waste employed in the building. Evident paths split in two after this point. Properly disposing of untreated C&D waste involves routing it to designated areas like landfills via the first path. Significant environmental repercussions can occur, leading to resource depletion. In contrast, the alternative approach entails processing and reusing C&D materials.

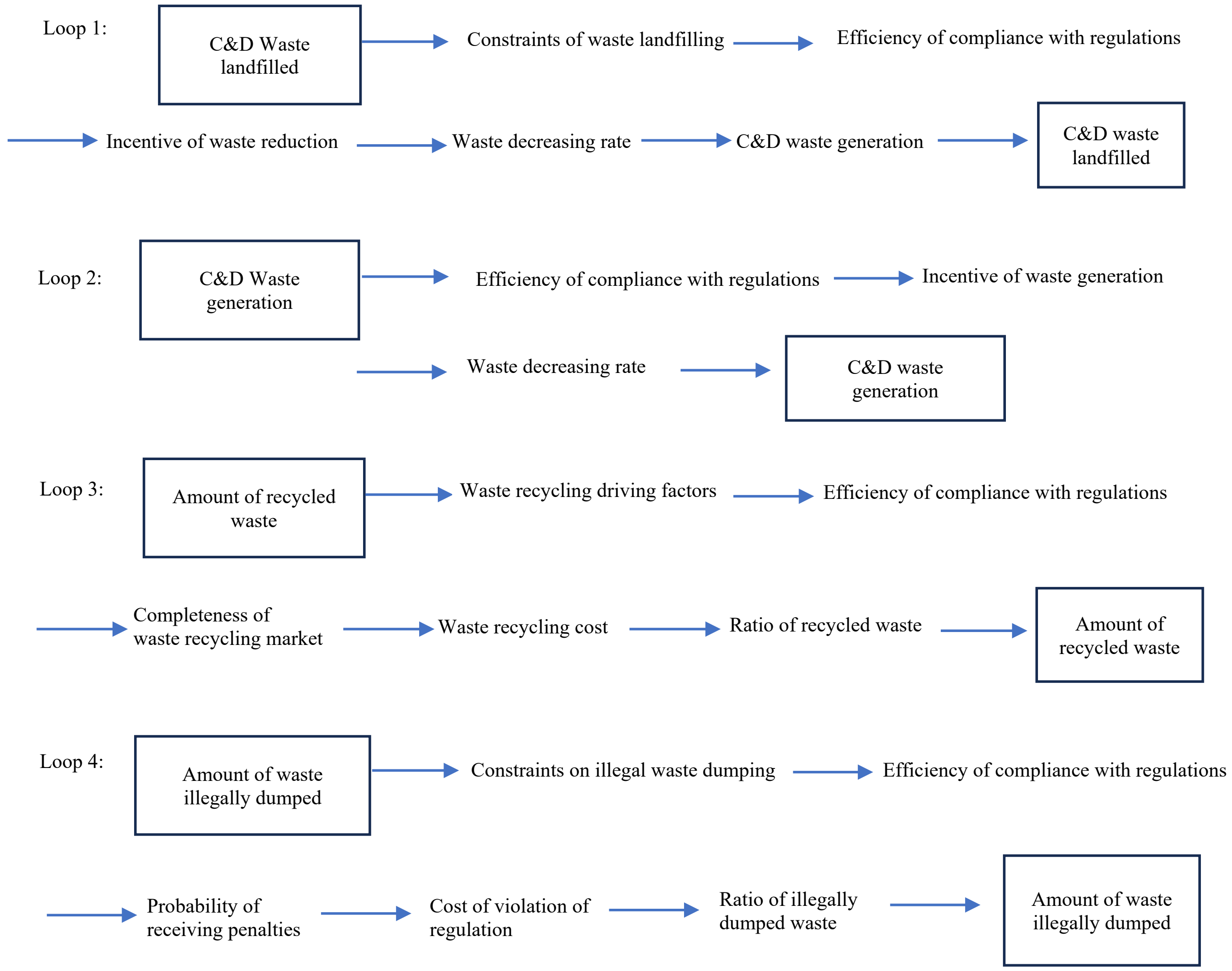

Figure 3. Illustrates the four feedback loops (Yuan and Wang 2014)

The "Storage of treated C&D waste" highlights the temporary holding of waste before its recycling or reuse. The recycled C&D waste component denotes the portion of waste undergoing recycling treatment. In contrast, the "percentage of recycled materials" variable signifies the proportion of materials successfully recycled. The recycling procedure relies heavily on the customer's desire for recycled goods, which shows how much clients want to utilize recovered materials instead of fresh ones. Rising demand for recycled products can inspire recycling initiatives and minimize the requirement for fresh resource extraction [16]. The diagram underscores the "recycling goal." The "actual recycling" circle underscores how short the actual recycling outcome fell short of the intended mark. The variance between the two highlights the productivity of existing recycling schemes and flags areas where waste management approaches must be refined. To summarize, Figure 4 offers a detailed look at the quantity of inflow of C&D waste and its management. Stressing the value of proper recycling underscores the urgent requirement for increased resource utilization. Closing the gap necessitates elevating genuine accomplishments, ensuring the eco-friendliness of construction and demolition waste management.

### 2.4. Using System Dynamics in Own Research

System dynamics can be applied to own research topic, concrete waste management, using life cycle assessment and cost. The scale of concrete waste produced in construction and demolition is monumental. However, concrete waste has become a worldwide problem that accumulates in landfill and has an ecological impact. Furthermore, numerous alternatives exist for discovering improved solutions. One method of avoiding concrete waste in landfills is to reuse it, which benefits the environment. Conversely, the cost of sending concrete waste to landfills can be hefty. Nonetheless, transforming it into usable products can radically minimize its load in these facilities, thereby advancing environmental stewardship and intergenerational sustainability. Raw material extraction using aggregates necessitates considerable energy and resources, despite being pricey. Recycling concrete waste can minimize the quantity of garbage deposited in landfills, thus benefiting the environment and saving money. System dynamics analyses can showcase these consequences [17]. Moreover, the system dynamic model can include and analyze all the research problem components of concrete waste management.

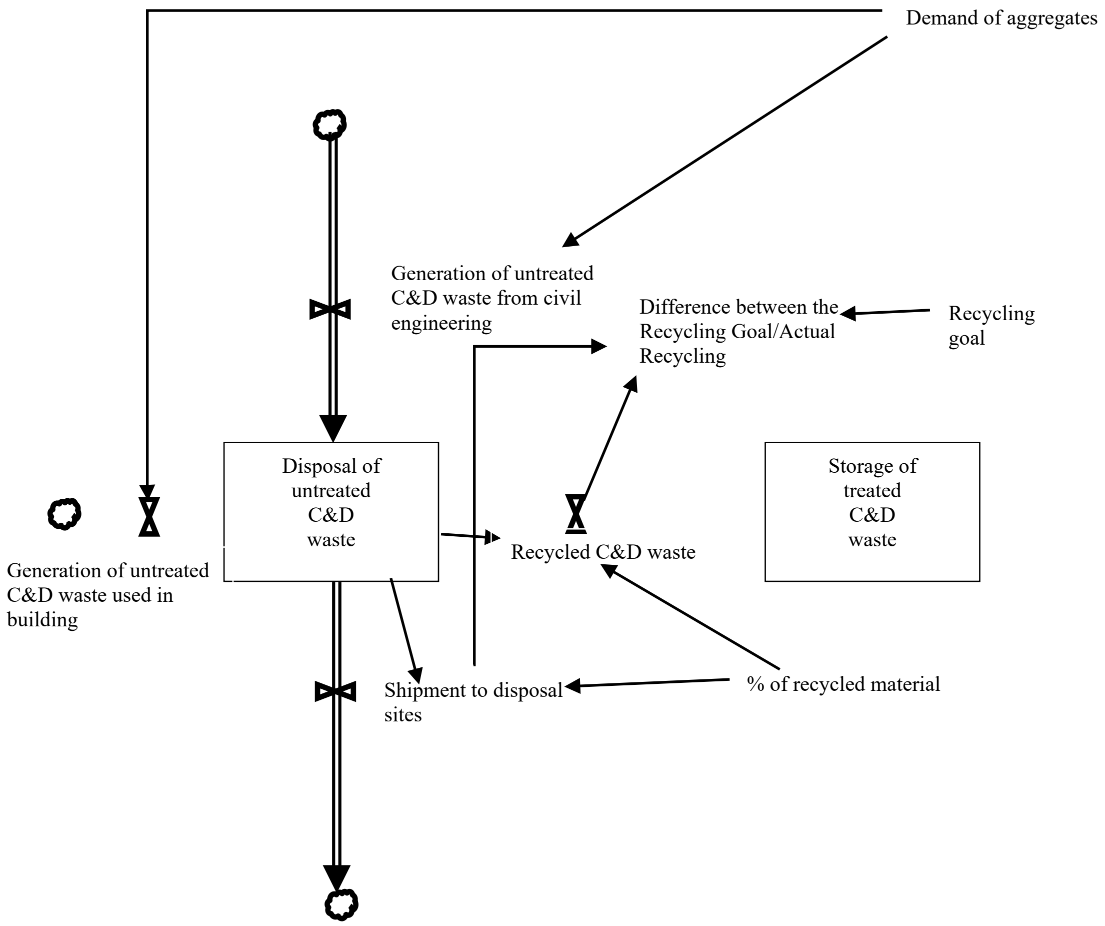

Figure 4. The volume of inflow construction and demolition waste (Calvo, Candamio and Corti 2014)

## 3. ANALYSIS

This section covers the creation of a causal loop diagram for my research topic, featuring all pertinent elements. In contrast, a thorough review of the diagram will uncover its complex causal patterns. In addition, the development of a causal loop diagram is created by using Vensim software. The causal loop diagram is crucial in comprehending the concrete waste management framework's intricate relationships and reciprocal influences [18]. The starting point for crafting a causal loop diagram is recognizing important components of concrete waste management. Each variable is related to others due to their causal connection, creating multiple loop effects. The analysis of the sophisticated causal loop diagram uncovers essential details. The diagram illustrates the influence of expense on trash disposal choices. Expanding waste management fees motivates more concerted recycling efforts, creating a favorable feedback loop that decreases trash disposal and increases recycling. In contrast, the expense of illegal garbage disposal has detrimental effects, resulting in undesirable environmental repercussions and higher charges. The causal loop diagram highlights the value of behavior in waste control. By fostering waste reduction behaviors among important stakeholders, total costs associated with sustainability initiatives decline, ultimately resulting in improved environmental performance.

The Vensim software's application in crafting the causal loop diagram guarantees its precision and dependability. This software enables incorporation of numerous factors and displays their connections visually strikingly and easily graspable [19]. Analyzing the causal loop diagram sheds light on the complexities of managing concrete waste. The diagram unveils the intricate connections between several factors affecting waste creation, recycling, and environmental performance. By understanding these interactions, policymakers and stakeholders can develop effective, sustainable concrete waste management strategies and contribute to a more environmentally friendly construction industry.

### 3.1. Causal Loop Diagram (CLD)

Figure 5 illustrates a detailed casual loop framework portraying the framework of a system dynamics model for cement waste administration. The image portrays the dynamic interactions between the factors affecting concrete waste production, disposal methods, and recycling practices. Visualization of these processes enables the model to offer informative insights into waste management techniques and their ecological effects. The causal loop diagram consists of various interconnected variables. The very essence of this metric is the " Quantity of concrete waste" generated during construction and demolition processes.

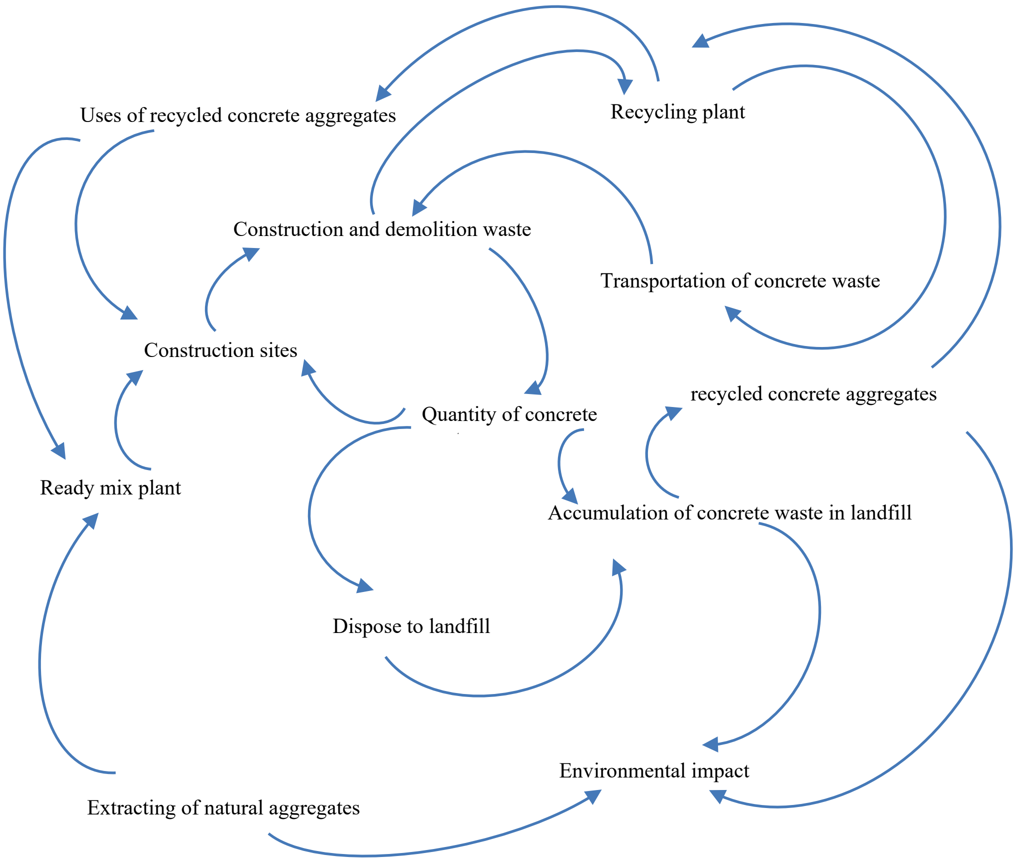

Figure 5. Structure of system dynamics model of concrete waste management Authors' own

From here, numerous possibilities arise, with each route ending at distinct conclusions regarding waste management. The connection between the deposition of concrete in landfills and its ensuing environmental consequences is one of the primary feedback loops highlighted in the diagram [20]. The rising quantity of concrete trash thrown out worsens the impact on the ecosystem. This feedback loop crystallizes the imperative of reducing concrete waste disposal to alleviate detrimental ecological effects. The "Recycling Plant" is a vital factor contributing significantly to waste handling. When concrete waste is directed to recycling plants, it is converted into recycled concrete aggregates, which can be reused in various construction applications. Using recycled concrete aggregates reduces the demand for extracting, conserves natural resources, and provides positive feedback on construction sites.

Furthermore, the illustration highlights the significance of transportation in managing concrete waste. The transportation of concrete waste poses environmental concerns due to associated emissions and energy usage. Enhancing transportation procedures can help mitigate the environmental effects of concrete waste management. The favorable cycle involving "Ready-mix plant" highlights the probable advantages of applying reused materials, particularly applicable to "Uses of recycled concrete aggregates." The loop highlights the advantage of utilizing recycled concrete aggregate in ready-mix plants, which helps reduce the demand for primary materials. The complexities of concrete waste management are encapsulated within the causal loop diagram of the system dynamics model, highlighting the demand for reasonable management approaches. The waste management process has substantial environmental ramifications, emphasizing the significance of suitable administration strategies [21]. By identifying the feedback loops and correlations between various variables, the model provides a foundation for developing effective strategies to minimize concrete waste generation, increase recycling rates, and reduce the environmental impact of construction and demolition activities. Through uninterrupted refinement and practical knowledge assimilation, this methodology for system dynamics modeling can act as an indispensable instrument for decision-makers. Policymakers, building organizations, and other parties can profit from its utilization in advancing durable concrete squander administration methods.

### 3.2. Examination of The Developed CLD

Investigation of the constructed causal loop diagram (CLD) for concrete waste management uncovered essential findings. These discoveries illuminated the intricate connections between diverse factors and their environmental consequences. The display of constructive and destructive feedback loops within the CLD underscores their pivotal function in evaluating the success of waste management initiatives and their ecological effects. Among the more notable destructive feedback loops illustrated in the diagram is the correlation between the "Quantity of concrete waste" and its "Accumulation in landfill." With increased quantities of concrete waste, the amount stored in landfills also rises [22]. This chain of events ultimately harms the ecosystem, with increased landfill pressure resulting in pollution and potential soil and groundwater contamination. This unfavorable feedback underscores the pressing requirement to implement waste minimization and recycling strategies. We may considerably lessen our ecological footprint by lowering the quantity of concrete waste in garbage dumps.

In contrast, the diagram depicts a variety of beneficial cycles that facilitate greener garbage handling methods. In particular, the Recycling Plant factor takes center stage in reinforcing beneficial cycles. At recycling plants, concrete waste is transformed into "Recycled concrete aggregates," fit for inclusion in upcoming construction undertakings. Lowering extraction rates has a favorable impact on both resources and the environment. Incorporating green materials into building processes via recycled concrete aggregates in "Ready-mix plants" strengthens the sustainability loop.

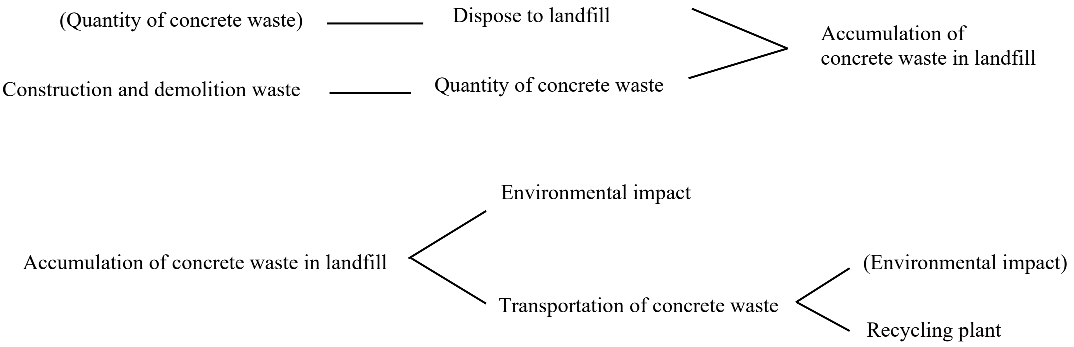

Figure 6. Examination of the developed CLD Authors' own

The "Transportation of concrete waste" parameter highlights a critical aspect of concrete waste handling. During the transfer of waste from building locations to recycling facilities or dumpsites, a negative ecological effect occurs due to pollutants and energy usage. We can significantly diminish the collective environmental consequences by streamlining transportation and positioning recycling facilities for maximum convenience [23]. The investigation of the constructed CLD demonstrates a clear link between the piling up of concrete trash in landfills and the environmental consequences. Concrete waste overflowing in landfills leads to increased negative environmental consequences from hazardous leachate contamination, methane gas production, and the finite capacity for further waste disposal. Efficient waste management requires a focus on recycling and waste reduction to offset the harmful repercussions [24]. The analysis in Figure 6 connects variables via a "Causes tree." For instance, the buildup of concrete debris in dumpsters is recognized as a factor in the adverse ecological implications, underscoring the requirement for tackling garbage piling up in landfills to enhance overarching waste management sustainability. Figure 8's "Uses tree" identifies three fundamental goals: disposing of concrete waste in landfills, transporting it, and the recycling procedure. These objectives share a common connection to the environmental implications of managing concrete waste, as demonstrated by their relationship to the Environmental effect [25].

In conclusion, examining the developed causal loop diagram provides valuable insights into the complexity of concrete waste management and its impact on the environment. The interaction between constructive and destructive feedback loops underscores the significance. Sustainable waste management techniques are imperative to lessen garbage accumulation in dumps, boost recycling initiatives, improve transportation strategies, and lower the ecological consequences of structure and demolition exercises [26]. The CLD is vital for lawmakers, granting them imperative details and views. Policymakers can exploit it to formulate effectual strategies. Waste management professionals and stakeholders can benefit from it to advance environmental safety initiatives [27].

## 4. DISCUSSION AND RESULTS

Investigating the causal loop diagram for concrete waste management yielded meaningful discoveries. These findings illuminated the intricate connections and patterns within the waste management framework as the conversation centered on the consequences of the discoveries. These discoveries possess immense potential for guiding practical waste administration plans. These plans must prioritize a lower ecological footprint to attain more sustainability. The causal loop diagram illustrates crucial elements of concrete waste administration [28]. Direct observation reveals that the volume of concrete waste directly impacts its ultimate collection in dump sites. As landfills expand, the destructive ecological consequences multiply, comprising tainted soil, underground water, elevated greenhouse gas emissions, and wasted assets, which highlights the pressing requirement to execute waste decrement and recycling techniques to avoid concrete waste ending up in landfills and advocate for a circular economic system strategy [29]. One of the circuits exhibiting positive reinforcement is the role played by recycling plants, which recycle concrete waste into reusable materials. Reusing these aggregates can lessen the call for virgin materials and defend the natural world. The following loop illustrates how recycling may be crucial in environmentally friendly concrete waste management [30].

The diagram illustrates the critical part transportation takes in controlling concrete waste. Environmental degradation caused by transportation, primarily due to emissions and energy consumption, demands proactive measures that involve optimizing transportation strategies while ensuring recycling facilities are nearby construction sites. Managing concrete waste can be less environmentally harmful when transportation distances are shorter. Investigating the constructed causal loop diagram shed light on the connection between gathering concrete waste in dumpsters and its ecological implications [31]. The importance of Artificial Intelligence and Data Mining techniques in predicting diabetes within the United Arab Emirates healthcare sector. The findings emphasize the significance of age, gender, and genetics in diabetes prediction [32]. It can be inferred that an incremental increase in the number of attributes utilized for building the classifiers has a positive impact on the accuracy and Kappa statistic values [33]. The accumulation of concrete waste worsens environmental issues, warranting measures to cut disposal and promote recycling and reusing techniques. This discovery underscores the importance of adequate waste management techniques to mitigate the strain on dumpsites and preserve the natural world. The "Causes tree" analysis underscores the links between factors and their environmental implications. As an illustration, the investigation finds that the buildup of concrete debris in dumpsters is primarily responsible for the detrimental ecological effects. Strategic waste reduction and sustainable waste disposal practices are essential to lessen the adverse impact on the environment [34].

The "Uses tree" identifies three primary objectives for concrete waste management: building up trash in dumps, shipping waste, and treatment plant operations. Each of these objectives directly or indirectly relates to the environmental impact. This finding underscores the interconnected nature of concrete waste management as holistic waste management strategies is needed to address this challenge [35]. The analysis indicates that adopting a more sustainable strategy for concrete waste management is feasible, which entails reducing waste creation, boosting recycling initiatives, and optimizing delivery and disposal procedures. Decreasing concrete waste sent to landfills helps conserve resources, mitigate environmental damage, and advance a circular economy. Encouraging recycling and reusing materials is essential to this effort [36]. which comprise knowledge generated from projects in the form of lessons learned, updated project management standards, and individual learning that becomes organizational learning [37].

The discussion and findings emphasize the necessity of an extensive and long-term strategy to deal with concrete waste. The causal loop diagram offers illuminating perspectives on the intricate relationships and mechanisms within the waste management framework. Using this model, policymakers, waste management specialists, and other stakeholders can devise successful strategies that promote sustainability and minimize the adverse environmental effects of concrete waste management. By adopting waste reduction, recycling, and environmentally responsible disposal methods, we can safeguard natural resources and ensure a greener future for the construction sector.

## 5. CONCLUSIONS

In essence, the analysis of relevant literature offered worthwhile insights, and creating a causal loop diagram for concrete waste management helped illuminate the intricacies of waste management in the construction sector. The publications demonstrated how system dynamics models could be used to explore the relationships between various variables, and their impact was shown on waste generation, recycling, and environmental outcomes. The publications featured causal loop diagrams that exposed the intricate relationships between variables, posing difficulties in analyzing these advanced systems. Despite initial reservations, using system dynamics models uncovered valuable insights into exploring these connections and grasping the dynamic interplay of waste management.

Furthermore, the findings highlighted the crucial nature of addressing concrete waste management, which has substantial environmental consequences. The efficacy of transportation procedures was discovered to be directly linked to the environmental implications of waste administration. The deposition of concrete waste and the extraction of aggregate had an additional influence, highlighting the significance of implementing eco-friendly techniques to minimize waste production, foster recycling, and perfect waste removal procedures. The findings of these studies underscore the urgent requirement for holistic and linked waste management tactics in the building industry. Crafting a causal loop diagram has yielded illuminating insights in this essential field. System dynamics modeling integration allows researchers to comprehend waste management systems' intricate dynamics thoroughly. Environmental enhancement sites can be located through this technique, and stakeholders might find it beneficial. Investigation into the usage of system dynamics models revealed their potential for application beyond waste management, specifically in the construction sector. Model innovations may offer viable solutions for complex problems in multiple sectors, enhancing critical thinking practices. The reviewed works exhibited the potency of system dynamics modeling, as showcased by the examined literature and the created causal loop diagram. The intricate connections and feedforward mechanisms depicted in the diagrams offer enlightening information. Decision-makers and specialists in the field can utilize these insights to devise more ecologically friendly garbage administration plans and lessen the adverse environmental effects of construction initiatives. Proceeding with continued study and practical implementation of system dynamics models may aid in creating a more durable and ecologically conscious construction sector.

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## BIOGRAPHIES

Name: **Mohamed**
Middle Name: **Darwish**
Surname: **Saeed**
Birthday: 17.10.1991
Birthplace: Dubai, UAE
Bachelor: Civil Engineering Technology, Faculty of Engineering Technology and Science, Higher Colleges of Technology, Dubai, UAE, 2014
Master: Engineering Management, Faculty of Engineering, University of Wollongong in Dubai, Dubai, UAE, 2016
Doctorate: Ph.D., Project Management, Faculty of Engineering and IT, British University in Dubai, Dubai, UAE, 2019
The Last Scientific Position: The Last Scientific Manager of Pavement and Materials Quality, Roads and Transport Authority, Dubai, UAE, Since 2023
Research Interests: Sustainability and Life Cycle Assessment of Construction Materials and Recycled Materials in Road and Building Projects, Waste Management and Project Management
Scientific Publications: 2 Papers

Name: **Harith**
Middle Name: **Yas**
Surname: **Khudhair**
Birthday: 19.10.1986
Birthplace: Dubai, UAE
Bachelor: Management, Faculty of Management, Ajman University, Fujirah, UAE, 2008
Master: Master of Technology Management, Faculty of Business, Staffordshire university, Kuala Lumpur, Malaysia, 2012
Doctorate: Ph.D., Management, Faculty of Management, University of Technology Malaysia, Johor Bahru, Malaysia, 2021
The Last Scientific Position: Lecturer, Department of Management, Faculty of Business, University of Technology Malaysia, Kuala Lumpur, Malaysia, Since 2021
Research Interests: Manufacturing, Business Administration, Marketing, Management, Innovation, Quality Management, Customer Satisfaction, Service Quality
Scientific Publications: 22 Papers