CIRCULAR ECONOMY AS A SOLUTION FOR CONSTRUCTION DEMOLITION WASTE MANAGEMENT IN SRI LANKA

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Abstract: Construction industry Demolition Waste (DW) has become a worldwide problem. Unsuitable DW disposal methods, leads to various issues such as scarcity of land resources and pollution, ecological damages, and land depletion. Even though various waste management approaches are applied, the construction industry DW has been increasing day by day. Hence this paper focuses on investigating the currently used DW management concepts and the conditions that need to be present to implement CE concepts for DW management in Sri Lanka. This research aim was addressed using a literature review followed by in-depth semi-structured interviews with 13 experts using the qualitative research approach. Collected data were analysed using code-based content analysis. Findings revealed that disposing of DW is the main concept used in the construction industry in Sri Lanka for most of the materials. Moreover, it was found that three conditions should be satisfied to implement CE concept for DW management in the local context. These are having proper facilities for material separation, good quality of materials, and proper coordination between industries. Construction industry stakeholders can use the research findings in developing suggestions for satisfying the conditions to apply the CE approach and minimise the DW in Sri Lanka.

Keywords. *Circular Economy (CE); Construction Industry; Demolition Waste (DW); Sri Lanka.*

1. Introduction

The construction industry is one of the highest waste-producing industries in the world (Bilal et al., 2020). Construction and demolition (C&D) waste accounts for 30%-40% of all global solid waste generation (Pallewatta et al., 2023). It has a detrimental effect on the environment, costs, time, productivity, and social climate (Yeheyis et al., 2013). According to Wu et al. (2014), C&D waste is classified into three types based on its generation phase such as construction waste, renovation waste, and demolition waste (DW). In general, waste produced during demolition activities is greater than waste produced during the construction (Tissera et al., 2022). Considering its impact on the construction industry, this paper is mainly focused on DW management.

As highlighted by past studies there are several methods, concepts, tools, and applications to reduce waste (Castellet-Viciano et al., 2022; Liyanage et al., 2019; Marino & Pariso, 2016; Purchase et al., 2021). Among these, linear economy is still the primary approach used in waste management (Marino & Pariso, 2016; Purwanto & Prasetio, 2021). According to the linear economy concept, DW is considered a zero-value material, and most of them are disposed of in landfills (Purchase et al., 2021). This can lead to several issues such as shortage of land availability, water contamination, energy consumption, and harmful gas emissions (Ding et al., 2016). Hence, the Circular Economy (CE) has emerged as an innovative and transformative concept that offers potential solutions to the mounting challenges of the LE concept (Cecchin et al., 2021). CE is a broad area that consists of various concepts and principles (Çimen, 2021; Heshmati & Rashidghalam, 2021; Persson, 2015).

Considering the Sri Lankan construction industry, waste management is a critical factor because the generation of DW has exceeded the permit limits (Tissera et al., 2022). Further, Tissera et al. (2022) mentioned most of the construction waste has been dumped into lands without considering damages. Hence, effective waste management is an essential requirement to reduce the harmful consequences. Many researchers have investigated the management of construction waste both globally and in Sri Lanka (Jayakodi & Thayaparan, 2021; Liyanage et al., 2019). However, limited sources can be found in analysing current DW management approaches using the CE concepts. Further, previous research has not clearly explained why demolition contractors and construction industry stakeholders do not apply CE approaches to DW management. Therefore, this paper aims to investigate the currently used DW management concepts and understand the conditions that need to be present to implement CE concepts for DW management in Sri Lanka from demolition contractors' and other industry professionals' points of view.

This paper begins with an introduction followed by a literature review. Then, the research methodology, the research findings, and the discussion are presented. Finally, the findings are concluded with recommendations.

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2. Literature Review

A literature review on different types of construction industry DW, different types of construction waste management concepts in the construction industry, and usages of construction DW are presented in the following sub-sections.

2.1. DEMOLITION WASTE IN THE CONSTRUCTION INDUSTRY

Waste produced through building demolition projects is considered as DW (Poon et al., 2004; Wu et al., 2014). Generally, in building demolition projects, the total building structure is disposed of as DW which includes the substructure, superstructure, and external landscape (Poon et al., 2001; Wu et al., 2014). Mainly DW comprises a higher percentage of concrete, metal, mortar, brick, block, plastic, and timber and a lesser percentage of other mixed materials (Islam et al., 2019; Poon et al., 2004). According to Purchase et al. (2021), almost all the DW materials were dumped into landfills. Further Purchase et al. (2021), highlighted that more than 75% of waste generated by the construction industry has a residual value but it is not currently reused nor recycled. In addition, Wu et al. (2014) described that many reusable materials such as timber and steel can be recovered if it allows enough time for salvagers. Hence, proper management, control, and disposal of DW are very crucial tasks in every construction project to add value to those demolished materials (Sapuay, 2016).

Recently, the disposal of DW has created a huge risk to the environment and humans in Sri Lanka (Tissera et al., 2022). As a result, various construction waste management methods have been adopted to obtain a solution (Jayakodi & Thayaparan, 2021; Liyanage et al., 2019). In Sri Lanka, there are no clear regulations on the illegal dumping of DW that is produced from construction projects (Tissera et al., 2022). Therefore, an effective waste management method is a critical requirement.

2.2. CONSTRUCTION INDUSTRY WASTE MANAGEMENT PRACTICES

Nowadays, the high increment of wastage and its management is becoming a worldwide problem (Delay et al., 2007). Therefore, various types of waste management methods, tools, and concepts are used by different countries such as the linear economy concept, zero waste concept, circular economy (CE) concept, 3R concept, cradle-to-cradle approach, and IS concept (Elgizawy et al., 2016; Jayakodi & Thayaparan, 2021; Liyanage et al., 2019; Poon et al., 2004; Purchase et al., 2021; Yuan, 2013). The linear economy concept is the conventional system that has been practiced for a very long time in the construction industry waste management (Sharma et al., 2021). In the linear economy approach, raw materials are taken from natural resources use and then used and disposed (Marino & Pariso, 2016). It is identified that the disposal of the product at the end of its life cycle is the main reason for the depletion of natural resources (Jayakodi & Thayaparan, 2021). Moreover, Purchase et al. (2021) highlighted that the linear economy concept is not adequate to mitigate the environmental consequences caused by construction waste. As a result of that the Circular Economy (CE) concept has evolved as a solution to reduce environmental effects (Cecchin et al., 2021).

2.2.1 Circular economy concept

The CE concept is an economic model designed to maintain the value of resources and help prevent the end-of-life concept (Kirchherr et al., 2017). According to (Purchase et al., 2021), the CE concept comprises three main areas such as make, use, and return. Compared to the linear economy concept, CE promotes the efficient use of resources and a continuous flow of energy and materials (Jayakodi & Thayaparan, 2021). Further, Purchase et al. (2021) described that the CE concept helps to optimise the value of raw materials in construction as well as other industries. The CE concept helps to provide benefits in four key areas such as environment, economy, resource usage, and society (Heshmati & Rashidghalam, 2021).

Several authors have identified various concepts to achieve a CE (Jayakodi & Thayaparan, 2021; Persson, 2015; Purchase et al., 2021). Jayakodi and Thayaparan (2021) highlighted that the 3R (Reduce, Reuse, Recycle) concept is a main part of achieving the circular economy concept. However, , the new recycling hierarchy expands the 3R concept (Reduce, Reuse, Recycle) to the 5R concept (Refuse, Reduce, Reuse, Repurpose, Recycle) by adding another two steps to the existing 3R concept such as refuse and repurpose to increase the effectiveness (Aadal et al., 2013; Balwan et al., 2022). Out of these, the first two stages of the 5R concept are mainly focused on the preliminary stage of the project before waste is generated (Balwan et al., 2022). Since this study is focused on management of waste generated during demolition work, the last three steps of reuse, repurpose, and recycle can be considered as more appropriate concepts.

In addition, there are two other concepts in the circular economy concept such as cradle to cradle approach, and the industrial symbiosis concept (Persson, 2015). The cradle-to-cradle approach is a sustainable design concept that aims to create products, buildings, and systems that have a positive impact on the environment and society throughout their entire lifecycle (Toxopeus et al., 2015). According to Persson (2015), cradle-to-cradle approach is similar to reuse and recycling. Industrial symbiosis is the cross-sector approach that corporate between different sectors (Persson, 2015). Further, Persson (2015) mentioned that both approaches are eco-friendly and have high effectiveness. Moreover, it is highlighted that Industrial symbiosis is a comparatively beneficial concept as it creates various benefits not only for one sector but also for all the interrelated sectors (Castellet-Viciano et al., 2022).

Even though various CE concepts can be used for DW management, these are not effectively implemented in the Sri Lankan context yet. Therefore, the next sections focus on analysing the conditions that are needed for implementing CE concept for DW management in the Sri Lankan context.

3. Research Methodology

Since this study focuses on understanding the conditions that need to apply CE concepts for DW management in Sri Lanka from demolition contractors' and other industry professionals' points of view, a qualitative approach was selected. It is needed to collect data from a predetermined group of selected experts regarding the building demolition sector. Therefore, an interview survey was applied as the research strategy. Accordingly, semi-structured interviews were used as the data collection method as it is one of the most important sources to collect qualitative data. In semi-structured interviews, some prepared questions as well as extra questions can be asked and it allows the collection of more data from the respondents (Nayak & Singh, 2021).

After selecting the data collection technique as semi-structured interviews, it is needed to identify how the expert interviewees are selected. Choosing experts based on particular criteria will increase the quality of the material, minimise bias, and streamline the research process (Esomonu et al., 2020). The purposive sampling technique is chosen to collect data for this study. When selecting experts for the study, experience, and knowledge related to building demolition in the construction sector were considered. Therefore, in this study, over 10+ years of experience in demolition contractors, technical officers, and project managers were selected to collect data. Accordingly, 13 semi-structured interviews were conducted with industry experts. The profile of interviewees is given in Table 1.

Table 1, Profile of the Interviewees

Respondents	Designation	Experience
DC-01	Demolition Contractor 01	15+ years
DC-02	Demolition Contractor 02	10+ years
DC-03	Demolition Contractor 03	15+ years
DC-04	Demolition Contractor 04	10+ years
DC-05	Demolition Contractor 05	10+ years
TO-01	Technical Officer 01	15+ years
TO-02	Technical Officer 02	15+ years
TO-03	Technical Officer 03	10+ years
TO-04	Technical Officer 04	10+ years
PM-01	Project Manager 01	15+ years
PM-02	Project Manager 02	15+ years
PM-03	Project Manager 03	15+ years
PM-04	Project Manager 04	15+ years

Among the different data analysis techniques that can be used to analyse qualitative data, content analysis can be identified as the most frequently used and understandable techniques (Lester et al., 2020). Further, the authors highlighted that in order to find patterns, themes, and relationships within textual material, content analysis is the most suitable data analysis method (Dey et al., 2014; Lester et al., 2020). Therefore, code-based content analysis was selected as the data analysis method for this study. Data collected from the interviews through interviews were digitally recorded with consent, transcribed and analysed using manual content analysis. The key findings derived through data analysis are presented below.

4. Research findings and discussion

Two interview guidelines were structured to gather necessary information from the demolition contractors and the other industry professionals. The initial sections focus on gathering information regarding mostly produced material types and selecting them for the analysis. Then focus on gathering opinions of the interviewees for currently used demolition waste management methods in Sri Lanka and conditions needed for implementing CE approaches to DW management. The key findings are presented below.

4.1. DEMOLITION WASTE MATERIAL TYPES

Since various types of DW materials were produced in the construction projects, it is necessary to select the most produced DW materials in the Sri Lankan context to carry out the analysis. Hence, the opinions of the interviewees were collected regarding mostly produced DW materials in the Sri Lankan projects. Interview findings are illustrated in Table 2.

Table 2, Mostly produced demolition waste material types

Respondents	Demolition Waste Material Types					
	Concrete	Timber	Metal	Brick	Glass	Plastic
DC-01	✓	✓	✓	✓		
DC-02	✓	✓	✓	✓		
DC-03	✓	✓	✓			
DC-04	✓	✓	✓	✓		
DC-05	✓	✓	✓			
TO-01	✓	✓	✓	✓		
TO-02	✓	✓	✓			
TO-03	✓	✓	✓	✓		
TO-04	✓	✓	✓			
PM-01	✓	✓	✓	✓		
PM-02	✓	✓	✓	✓		
PM-03	✓	✓	✓	✓		
PM-04	✓	✓	✓	✓		

According to the interviewees, concrete, timber, and metal are the most produced DW materials in Sri Lankan projects. Further, nine out of thirteen interviewees mentioned bricks as mostly produced demolition waste material, but other interviewees mentioned it has a low percentage because bricks were crushed in the demolition process. In addition, it is clearly highlighted that glass and plastic have comparatively low percentages of demolition waste. Further, PM-01 highlighted that "even though plastic has the ability to be recycled, there is not much-demolished plastic produced in construction projects". Hence, the focus was limited to concrete, timber, steel, and bricks in investigating the demolition waste management methods used in Sri Lanka and the conditions needed for implementing CE approaches to DW management.

4.2. CURRENTLY USED WASTE MANAGEMENT CONCEPTS FOR EACH MATERIAL TYPE

Findings in relation to the waste management concepts currently used in managing concrete, timber, steel, and brick DW are discussed in the below sections.

4.2.1 Concrete waste

All the interviewees stated that disposal is the main concept that is currently used for concrete waste management in the Sri Lankan construction industry. DC-01, a demolition contractor, highlighted that "While I am demolishing a building, landowners contacted me and asked to fill their lands using the demolished waste. So, I disposed of the concrete rather than separately collecting it and reusing". Further, all the other demolition contractors agreed that most of the concrete waste is not recovered and disposed of to fill lands. In addition, PM-04 mentioned that "There are no proper regulations in Sri Lanka to restrict the unwanted disposal methods, therefore most of the time concrete waste was dumped into lands unnecessarily". Further, all the project managers agreed that concrete waste has been dumped into lands unnecessarily in the Sri Lankan context.

Furthermore, all the project managers and some demolition contractors highlighted that concrete demolition waste has been used for road construction as a subbase or filing material and temporary works. However, PM-1 and PM-3 mentioned that there is no proper mechanism to coordinate between road construction stakeholders and building owners, so demolished concrete waste usage is less in Sri Lanka. Moreover, TO-2 and PM-2 mentioned that there are concrete recycling centers in Sri Lanka. Further, they highlighted that in a few projects concrete waste was sent to recycling centers for manufacturing concrete blocks and recycled aggregates. According to TO-2, one of the only few such places that collected demolished concrete is located in the southern province and is handled by the municipal council. There is a concrete waste

separation machine that has the capability of separating the aggregate, soil, and other solid particles in this recycling center. However, the collection center is under the operation of the municipal council and the concrete block preparation process is stopped due to government political issues.

Hence from the findings, it was clearly highlighted that disposing of concrete is the main concept that is currently used in the Sri Lankan construction. Only a few of the projects are using demolition waste as temporary material. Further, it is highlighted that even though having the capability of reusing or recycling in the Sri Lankan context, concrete waste is not reused or recycled and disposed of to fill the lands due to several issues.

4.2.2 Timber waste

According to the findings all the demolition contractors mentioned that timber members, windows, and doors are recovered, and sold to the building owners. Further, DC-2 mentioned that "some of the older wood had been purchased by shop owners to do decorations, wood crafting, and some other purposes". However, both technical officers and project managers argued that since the quality of the demolished timber is low in the demolished buildings, the building owners do not use demolished timber in their houses. For example, PM-3 stated that "The quality of the demolished timber is low compared to new materials. If it was reused, then it is needed to have precautions for decaying and damages. Most of the time used for temporary purposes". Further, most of the interviewees mentioned that in Sri Lankan projects demolished timber was burned at sites without using them due to this.

Furthermore, three demolition contractors out of five interviewees and all the project managers mentioned that timber be used as temporary items such as fences, storerooms, and formwork. For example, PM-4 highlighted that "Timber can be used for temporary works such as constructing storerooms, temporary fences, and support structures". Further, PM-1 mentioned that "In construction, demolished timber members are used as formwork". In addition, PM-4 mentioned that "Demolished timber can be used for landscaping purposes and making temporary decks". Moreover, DC-04 mentioned, "I sold timber members for trucks that came to collect unwanted materials. They will collect those materials and use them for burning and some other purposes". In addition, PM-3 mentioned that "There is a possibility of using timber as firewood for other industries". In addition, PM-04 mentioned that "Timber waste has been collected by the old products collecting trucks which have gone in the roads". They collect timber and sell it for burning purposes. Furthermore, all the project managers mentioned that if it is possible to provide non-usable timber for the cooking sector or other industries that can be used timber as firewood will be beneficial. This is an example of using the IS concept for demolished timber waste.

Moreover, interviewees mentioned that some demolished timber collecting centers in Sri Lanka collect timber from private projects. However, PM-05 mentioned that "even though there are some timber collection places around Sri Lanka, not much of demolition timber was reused or recycled". Further, all the interviewees mentioned that in the Sri Lankan context, there is no proper mechanism or infrastructure facilities for timber waste recycling. Further, none of the interviewees mentioned the recycling of wood waste in the Sri Lankan context.

Hence, from the findings, it is clearly highlighted that even though some wooden members are used by the building owners, most of the demolished wood waste was burned and not reused or recycled in the Sri Lankan context.

4.2.3 Steel waste

All the demolition contractors mentioned that they recovered the reinforcements from the concrete and used or sold them. DC-2 highlighted that "If the reinforcement is usable and has a good quality, I recovered those materials. The building demolition price will be adjusted according to the value of those materials". Hence, reusing materials is a "win-win" situation for both clients as well as for the demolition contractors. Further, DC-1 and DC-4 highlighted that reinforcement has high durability compared to other demolished materials, so the clients are keen to reuse those materials. In addition, DC-3 mentioned that "Comparatively price of new reinforcement bars is getting high due to the economic condition of the country, so the builders are looking to minimise the cost incurred for their projects and they utilise the existing reinforcement as much as they can". Therefore, it is profitable to use existing reinforcements. Moreover, all the project managers agree with the demolition contractors' idea that most of the clients in Sri Lanka reuse existing metals. In addition, PM-1 mentioned that "In government projects, the government collects the reinforcement and stores them at a site. After that evaluate the materials, then sell them using an auction". Further, PM-3 explained that "Due to material scarcity of the country most of the clients use existing steel reinforcement for their constructions". Therefore, it is highlighted that the reusing concept is currently practiced in the Sri Lankan context.

However, most of the interviewees mentioned the quality of the reinforcement, and they clearly mentioned that demolition reinforcements can be used only for non-structural purposes. For example, DC-1 mentioned that "Since the material has less bearing capacity, most of the time demolished steel used for concreting basement slabs, temporary buildings, and toilet slabs". Moreover, all the project managers agree with the idea that only demolished waste is used for temporary works. Furthermore, all the industry professionals highlighted that most of the demolished steel waste was purchased by iron shop owners to melt and manufacture iron products. For example, DC-2 mentioned "I recovered all the metal waste and sold them to iron shop owners. When demolition work was ongoing, they called and told me to recover those reinforcements and other metals. After that, they send those metals to India for manufacturing purposes". Further,

most of the interviewees highlighted that there are some companies in Sri Lanka that recycle reinforcement and manufacture "L iron" and other steel products. Moreover, it was highlighted that scrap metal is recycled by the manufacturers and prepared products.

4.2.4 Brick waste

According to the findings, all the interviewees mentioned that disposing of bricks for filling purposes is the main practice currently used in Sri Lankan construction projects. All the demolition contractors mentioned that bricks are very difficult to separately collected without crushing when demolishing. For example, DC-1 mentioned, "When demolishing the buildings, it is difficult to collect bricks without crushing and most of the bricks are damaged and only used for filling purposes". Further, all the interviewees agreed with the idea that most of the brick waste has been dumped into lands without reuse.

In addition, the interviewees mentioned if it is possible to recover bricks without crushing then can be used for temporary works. For example, PM1 highlighted that "In some of the projects I worked on, demolishing bricks are used for constructing septic tanks and some other temporary works which are not high load bearing works". Further, three interviewees (DC-4, PM-3, and PM-4) mentioned that bricks are used as an alternative to aggregates in some construction projects. Moreover, PM1 and PM2 mentioned that some of the sellers have obtained crushed bricks and reproduced bricks. However, there is no proper coordination between the demolition contractors and those sellers. As a result, most of the brick waste has been sent to fill the lands.

Hence from the findings, it was clearly highlighted that even though the capability of reusing or recycling in the Sri Lankan context, demolished brick waste is not reused or recycled and disposed of to fill the lands.

Based on the findings, it appears that while sending demolished materials to landfill still appears to be the dominant option reusing, recycling, and IS concepts are also applied to demolition metal waste management in the Sri Lankan context to some extent. It is a plus point for the country as well as for the environment. However, it is needed to improve the linkage and coordination between the suppliers and the contractors. Also, there are some conditions that need to be satisfied to reuse demolition waste.

4.3. CONDITIONS FOR IMPLEMENTING REUSE, RECYCLE, AND IS CONCEPT

According to the findings, most of the demolition waste has been dumped into lands without reuse. Even though some steel material is reused most of the other materials are disposed of without reuse. According to the interviewees, there are some conditions that are needed for implementing CE concepts for DW management.

Condition 1: Facilities for separating waste materials

One of the main conditions is the separation of material waste. According to demolition contractors, they did not have facilities for the separation of the concrete materials. It is mentioned that in Sri Lanka JCBs or excavators are used for demolishing the buildings and difficult to separate materials using those machines. Further, DC-2 mentioned that "To use concrete waste, it is needed to separate the material particles. I did not have facilities for separation of concrete waste, so I dumped them into necessary land". In addition, DC-1 mentioned, "It is difficult to collect bricks without crushing due to lack of facilities availability". Further, interviewees mentioned that if there is a proper way of separating the materials, those materials can be reused for the projects.

Condition 2: Quality of the demolished materials

Adequate quality required to use demolished waste for structural works is another condition that is considered before reusing. PM-1 stated, "If the demolished concrete is used for structural works, the building can be damaged and fall because of the low quality". In addition, PM-2 mentioned that "Most of the time, demolished timber was decayed and not adequate enough to use for the actual purpose". Moreover, DC-1 mentioned that "Most of the time demolished steel used for concreting basement slabs, temporary buildings, and toilet slabs due to less bearing capacity". All the interviewees agreed that clients are searching for good quality materials for their buildings and they are concerned about durability. Therefore, it is clear that adequate quality is an important factor in reusing demolition waste for new projects.

Condition 3: Proper coordination between sectors and stakeholders

Another condition for implementing CE concepts is that proper coordination is required between the sectors. TO-2 mentioned that "Even though there are some recycling centers in Sri Lanka, not much of concrete waste has been recycled in the Sri Lankan context because of the lack of coordination between industries". In addition, PM-05 mentioned that "even though there are some timber collection places around Sri Lanka, not much of demolition timber was reused or recycled due to lack of coordination and awareness". Moreover, interviewees explain that it is required to have proper coordination between steel recycling centers and contractors to use the demolition waste materials without wastage. Furthermore, it is highlighted that most of the DW has been dumped into lands without using due to lack of coordination and it is needed to have a proper mechanism to overcome this issue.

Hence, it is needed to have a proper mechanism for material separation, good quality materials, and proper coordination between industries to implement the CE concepts for DW management. If these three conditions can be fulfilled, then it is possible to reduce the wastage in Sri Lanka as well as in the world.

5. Conclusions and recommendations

Overall, this paper is mainly focused on understanding the waste management concepts used and the conditions needed to apply CE concepts for DW management in Sri Lanka. Data was collected using 13 respondents and analysed the currently used waste management concepts and conditions for implementing CE concepts. It was revealed that disposing was the main concept that is currently used in the Sri Lankan context in managing concrete, timber, and bricks. Reuse, recycling, and IS concepts are used only to a limited extent, particularly in managing concrete, timber and steel waste. Hence, the CE concepts are not much used in the Sri Lankan context due to several challenges. Furthermore, it was highlighted that three conditions such as a proper mechanism for material separation, good quality materials, and proper coordination between industries are needed to implement the reusing, recycling, and IS concepts. If these three conditions are fulfilled, then CE concepts can be used for demolition waste management, and it will help to minimise the dumping of DW in Sri Lanka. Therefore, it is clear that to minimise the waste problem, all the stakeholders need to be involved actively. Further, the government needs to provide the necessary facilities for demolished contractors. In addition, it is needed to have proper quality standards for using materials in construction projects to minimise the waste problem. Further, this study is limited to analysing the conditions for implementing the CE concepts and does not consider the other challenges and suggestions for mitigating the issues. Therefore, researchers can analyse the solutions that can be used to mitigate the conditions for DW management in future research.

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