

# 5S PRINCIPLES FOR SUSTAINABLE RESOURCE AND WASTE MANAGEMENT IN SRI LANKAN CONSTRUCTION PROJECTS

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## ABSTRACT

*The significant resource consumption and waste generation in the construction sector highlights the imperative for sustainable management of resources and waste, particularly in Sri Lanka. Over time, various techniques have emerged as potential solutions to address this challenge, with the 5S technique standing out as a widely discussed approach. This technique is focused on producing high-quality outputs with minimal wastage and high productivity, making it well-suited for sustainable resource and waste management. However, despite its potential, there is limited research exploring its application in this context within the construction domain, specifically in Sri Lanka. Therefore, this study aimed to investigate the applicability of 5S principles for sustainable resource and waste management in Sri Lankan construction projects. Initially, a comprehensive literature review was conducted on the 5S principles and the concept of sustainable resource and waste management, which led to the development of a conceptual framework for the application of 5S principles for sustainable resource and waste management. Following this, a pilot study using interviews was conducted to investigate the specific activities that could be implemented under the individual 5S principles for sustainable resource and waste management. Integrating these activities within construction projects could help mitigate the negative environmental impacts associated with resource consumption and waste generation in the industry.*

**Keywords:** 5S Principles; Construction; Resource Management; Sustainability; Sri Lanka; Waste Management.

## 1. INTRODUCTION

The construction sector, known for its high resource intensity, utilises around half of all natural materials extracted (Norouzi et al., 2021). This substantial extraction of natural materials, fuelled by the ever-growing construction demand, carries significant ecological impacts, including resource depletion, environmental contamination, biodiversity loss, increased greenhouse gas emissions, and adverse climate impacts (Bell, 2018; Oyedele et

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al., 2014). Furthermore, construction ranks among the leading industries in terms of waste generation, with research showing that construction-related waste accounts for approximately 30-40% of the total global solid waste, a percentage that continues to increase steadily (Purchase et al., 2022; Tennakoon et al., 2022). This high resource intensiveness and waste generation emphasises the need for sustainable resource and waste management within the construction industry.

Over time, various concepts have emerged as potential solutions to address the need for sustainable resource and waste management, with lean management standing out as a key approach (Tasdemir & Gazo, 2018). At its core, lean management focuses on creating customer value using fewer resources and minimising waste (Bhamu & Singh Sangwan, 2014; Tasdemir & Gazo, 2018). It consists of a range of techniques and principles, including Just-in-Time, Kaizen, 5S, Kanban, Six Sigma, value stream mapping (VSM) and total preventive maintenance (Tasdemir & Gazo, 2018). Among these techniques, the 5S technique has been commonly used to achieve different sustainability outcomes (Tasdemir & Gazo, 2018). With the principles of *seiri*, *seiton*, *seiso*, *seiketsu*, and *shitsuke*, the 5S technique aims to instil the values of organisation, neatness, cleanliness, standardisation, and discipline into the management of any activity (Gapp et al., 2008; Randhawa & Ahuja, 2017). This technique is focused on producing high-quality outputs with minimal wastage and high productivity (Randhawa & Ahuja, 2017), making it well-suited for sustainable resource and waste management.

Recent studies have shown that prevailing construction management practices in Sri Lanka prioritise traditional project management objectives, such as timely project completion, cost control, and adherence to quality standards, while giving minimal attention to sustainable resource and waste management (Victar & Waidyasekara, 2023). There are limited efforts targeted at managing resources and wastage, leading to notable inefficiencies in construction projects (Liyanage et al., 2019). Emerging initiatives, such as promoting sustainable material choices, improving construction and demolition waste management, and adopting green building standards, are beginning to gain traction but have not yet become mainstream topics (Victar & Waidyasekara, 2023). Considering the Sri Lankan context, research on the application of the 5S technique has also predominantly focused on the manufacturing and service sectors, with limited attention given to its implementation within the construction sector. For instance, in the manufacturing sector, Suraweera and Jayasena (2016) examined the factors influencing the long-term sustenance of 5S practices, using the Sri Lankan stationery industry as a case study. Similarly, Bandara et al. (2023) investigated how the 5S technique, as a quality assurance method, could enhance employee productivity in Sri Lanka's apparel sector. From a service sector perspective, Withanachchi et al. (2004) conducted a best-practice case study on a Sri Lankan public hospital, exploring how adopting the 5S technique improved the hospital's service delivery quality. It was also noted that these studies primarily regard 5S as a quality management technique rather than considering its applicability for effective waste and resource management. Although the application of lean construction techniques, which is closely related to 5S, has been the subject of previous studies in the Sri Lankan construction sector (Senanayake et al., 2024), they have not explored how the 5S principles, specifically, could be used for managing resources and wastage in construction projects. In these studies, 5S is merely identified as one of the various lean techniques available to reduce wastage, without delving into the practical application of the technique to achieve this goal.

Within this background, undertaking research with a particular focus on exploring the practical applications of the 5S principles, which are conducive to achieving sustainable resource and waste management goals, could be viewed as a forward step in driving sustainability initiatives in Sri Lankan construction projects. Therefore, this study aims to investigate the applicability of 5S principles for sustainable resource and waste management in Sri Lankan construction projects. In order to achieve this aim, two objectives were developed as follows:

1. Review the literature on 5S principles and the concept of sustainable resource and waste management to develop a conceptual framework on applying 5S principles for sustainable resource and waste management.
2. Examine the activities related to 5S principles in achieving sustainable resource and waste management in Sri Lankan construction projects.

## 2. METHODOLOGY

The study’s methodology included a comprehensive literature review to achieve the first objective. Subsequently, a pilot study was conducted via expert interviews to address the second objective. This design builds on prior studies that have integrated literature reviews and qualitative interviews to translate theoretical knowledge into practice (Bellamy et al., 2006; Brown et al., 2019). An overview of the research methodology is shown in Figure 1, followed by a detailed explanation of the individual stages.

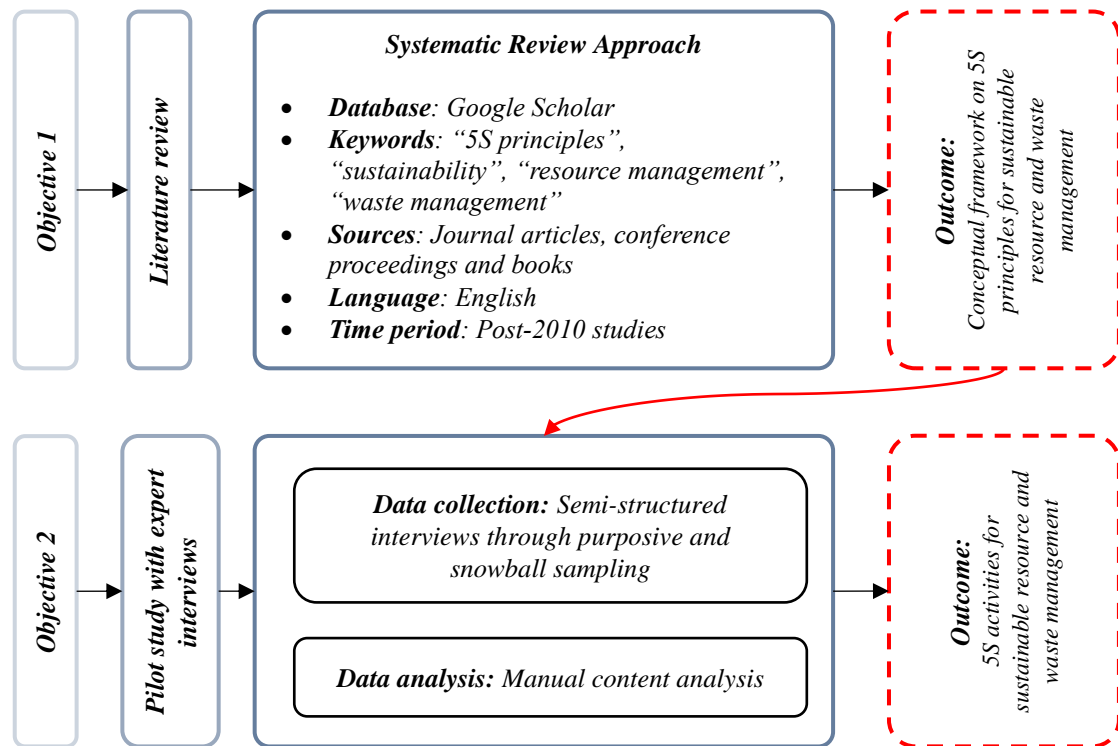


Figure 1: An overview of the research methodology

The literature review focused on exploring extant literature on the 5S principles and related activities, as well as the concepts of sustainable resource and waste management. A systematic approach was followed in undertaking the review. Google Scholar was selected as the primary database considering its comprehensive coverage on a wide range

of areas and ease of access while “5S principles”, “sustainability”, “resource management”, and “waste management” were used as keywords to locate relevant studies. The sources considered for the study were limited to journal articles, conference proceedings and books published in the English language. Moreover, emphasis was placed on post-2010 publications with the aim of gathering current insights on the topic. However, some earlier seminal studies were also included considering their significance to the study area. Based on the literature review, a conceptual framework was developed for applying the 5S principles for sustainable resource and waste management in construction projects.

The literature review was followed by a pilot study targeted at investigating the activities that could be implemented under the individual 5S principles for sustainable resource and waste management, specifically in Sri Lankan construction projects. Expert interviews were chosen for the pilot study due to limited local expertise in the study areas. Following the classification of interviews by Saunders et al. (2019), semi-structured interviews were selected since they facilitated the collection of specific data, while also exploring additional insights that arose during data collection. Moreover, the use of semi-structured interviews was also suitable, because the pilot study was guided by pre-determined themes/key questions developed based on the outcomes of the literature review. Considering limitations with expertise available in the study area, a combination of purposive and snowball sampling techniques was used to connect with experienced interviewees. Accordingly, interviews were conducted with seven experts who are well-qualified and experienced in the domains of environmental sustainability and 5S principles in relation to the construction industry. The profile of the interviewees is shown in Table 1.

*Table 1: Profile of interviewees for the pilot study*

<b>Name</b>	<b>Designation</b>	<b>Experience</b>
<b>E1</b>	Project Manager	22
<b>E2</b>	Environmental Manager	18
<b>E3</b>	Planning Manager	16
<b>E4</b>	Planning Engineer	20
<b>E5</b>	Construction Manager	21
<b>E6</b>	Environmental Officer	15
<b>E7</b>	Planning Engineer	18

The interview guideline comprised of two sections: Section 1 targeted the demographic information of the interviewees while Section 2 looked at the 5S activities for sustainable resource and waste management. Interview questions were developed guided by the conceptual framework and the findings of the literature review. Each interview lasted between 30-60 minutes, recorded with the consent of the interviewees, and transcribed verbatim before the analysis. Considering the qualitative nature of the data collected and the relatively manageable volume of data, manual content analysis was selected as the most appropriate data analysis method for the study. Herein, a directed content analysis approach was followed with the analysis being directed by the literature review findings. Findings from the literature review and the pilot study are elaborated in detail under Sections 3 and 4 of the paper.

### 3. 5S PRINCIPLES AND SUSTAINABLE RESOURCE AND WASTE MANAGEMENT

The literature review was focused on exploring the 5S principles as well as the key areas of sustainable resource and waste management. The outcomes of the literature review led to the development of a conceptual framework for applying the 5S principles for sustainable resource and waste management.

#### 3.1 THE 5S PRINCIPLES

The 5S principles were introduced in Japan in the early 1980s by Takashi Osada as a technique for establishing and maintaining a quality environment within an organisation (Jiménez et al., 2015). These principles highlight the basic requirements for producing high-quality products and services with little to no wastage, while sustaining high productivity levels. The name 5S comes from the first five letters of the Japanese terms *seiri*, *seiton*, *seiso*, *seiketsu* and *shitsuke*, which, when translated to English, means organisation, neatness, cleanliness, standardisation, and discipline, respectively (Randhawa & Ahuja, 2017). According to Gapp et al. (2008), the 5S principles reflect the Japanese way of thinking of “doing the right things in everyday life in the right way.” These five principles are elaborated in detail in the following sections:

- *Organisation (Seiri)*: This is the first “S” and focuses on distinguishing between necessary and unnecessary goods/items, to eliminate the latter (Jiménez et al., 2015; Randhawa & Ahuja, 2017). *Seiri* calls for effective workplace utilisation and suggests that goods/items should be categorised based on their relevance and frequency of use with the objective of creating an efficient workplace (Randhawa & Ahuja, 2017). This ultimately leads to fewer hazards and less clutter that could interfere productivity (Michalska & Szewieczek, 2007). The benefits of adopting this principle include savings in the use of space, minimising searching times, making damage detection easy and creating a safe and comfortable workplace (Sorooshian et al., 2012).
- *Neatness (Seiton)*: Neatness focuses on workplace efficiency and is generally analysed by the time taken for getting and putting things back (Randhawa & Ahuja, 2017). It places emphasis on creating efficient and effective methods to arrange goods/items, facilitating easy accessibility, use, and storage. Further, it highlights the significance of a well-defined workplace layout to enable seamless and safe operations (Low & Ang, 2003). In simple terms, this principle emphasises that “there must be a place for everything, and everything must be in its place” (Michalska & Szewieczek, 2007, p. 212). The benefits of maintaining neatness within the workplace include lowering mistakes, speeding up processes, and fostering better employee morale and creativity (Sorooshian et al., 2012).
- *Cleanliness (Seiso)*: Cleanliness refers to the upkeep of a neat and clean workplace, a responsibility of everyone involved (Randhawa & Ahuja, 2017). This includes three primary activities: cleaning the workplace, maintaining its appearance, and implementing preventive measures to sustain cleanliness. A commitment to effective housekeeping practices inherently addresses safety issues, while assigning responsibility for regular maintenance and providing required resources aids in minimising hazards linked to inefficient operations (Low & Ang, 2003). Maintaining a clean workplace offers numerous benefits, including improving output quality,

minimising equipment failures and creating a safe and pleasant working environment (Sorooshian et al., 2012).

- *Standardisation (Seiketsu)*: Standardisation refers to ongoing and repetitive upkeep of organisation, neatness, and cleanliness, which are synonymous with seiri, seiton, and seiso, within the workplace (Randhawa & Ahuja, 2017). This involves the development of standard operating procedures to establish improved workplace practices, which allows for control and consistency (Michalska & Szewieczek, 2007; Randhawa & Ahuja, 2017). Standardisation offers benefits such as lowering maintenance and overhead expenses while boosting process efficiency (Sorooshian et al., 2012).
- *Discipline (Shitsuke)*: Discipline refers to ingraining the ability to perform tasks the way they are supposed to be done, thereby fostering the development of positive workplace habits (Randhawa & Ahuja, 2017). This aligns with the principle of Kaizen – the Japanese equivalent for repeated improvement. Herein, organisations must consistently analyse their existing practices in order to improve them and ensure their ongoing applicability (Low & Ang, 2003). This principle calls for a proactive change in behaviour among employees at all levels within an organisation (Randhawa & Ahuja, 2017), which, in turn, yields benefits such as enhancing labour productivity, improving output quality, and reducing workplace accidents (Sorooshian et al., 2012).

The literature review also revealed a set of typical activities that could be carried out under each of the 5S principles, as summarised in Table 2.

Table 2: Typical activities carried out under the 5S principles

5S Principles	Definition	Activities
<b>Organisation (Seiri)</b>	Distinguishing between necessary and unnecessary good/items to eliminate the latter	Store unwanted items collected in the workspace Give items a tag (red tagging) Identify and dispose of items that have not been used
<b>Neatness (Seiton)</b>	Creating efficient and effective methods to arrange goods/items facilitating easy accessibility, use and storage	Organise the workspace so that everything has a place Tag and label items with a colour code system Use neat and well-arranged notice boards to identify items Install guidance maps throughout the workspace
<b>Cleanliness (Seiso)</b>	Upkeeping a neat and clean workplace	Implement periodical cleaning Assign a map for cleaning staff and their respective areas Prevent equipment from being exposed to dust and dirt while cleaning Use cleaning checklists and supervision
<b>Standardisation (Seiketsu)</b>	Ongoing and repetitive upkeep of organisation, neatness and cleanliness	Visualisation of slogans in the workplace Use standard colour coding systems Use standardised checklists

5S Principles	Definition	Activities
		Implement supervision to encourage improvement in 5S
<b>Discipline (Shitsuke)</b>	Consistently analysing existing practices to improve and ensure ongoing applicability	Foster improvement of self-discipline and positive attitudes Introduce training programs Develop a checklist as a reminder to sustain all habits Continuous monitoring to identify and refine areas for improvement

### 3.2 KEY AREAS OF SUSTAINABLE RESOURCE AND WASTE MANAGEMENT

The aim of this study is to investigate the applicability of 5S principles for sustainable resource and waste management in construction projects. To achieve this, it is important to identify the key areas that warrant attention in the pursuit of sustainable resource and waste management. Environmental rating systems serve as a valuable starting point for identifying these specific areas of focus. Following a thorough analysis of different environmental rating systems, six key areas related to sustainable resource and waste management were identified, as shown in Figure 2.

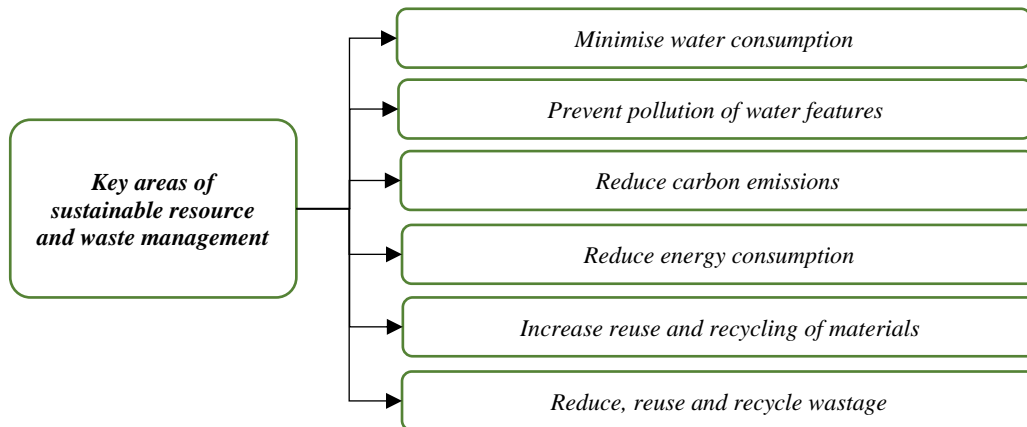


Figure 2: Key areas of sustainable resource and waste management

The identification of these areas was informed by the CEEQUAL (Civil Engineering Environmental Quality Assessment and Award, also known as BREEAM Infrastructure) rating system, considering its robustness, global application, and suitability for projects of different scales. Moreover, CEEQUAL highlights the focus areas for sustainable resource and waste management at a construction site, which aligns closely with the project-level focus of the current study. The current study explored how the 5S principles can be applied to these six key areas of sustainable resource and waste management.

### 3.3 CONCEPTUAL FRAMEWORK

The literature review led to the development of the conceptual framework, shown in Figure 3, for applying the 5S principles for sustainable resource and waste management. The framework highlights the key areas of sustainable resource and waste management: minimising water consumption, preventing pollution of water features, reducing carbon emissions, reducing energy consumption, increasing reusing and recycling of materials,



and reducing, reusing, and recycling wastage. It also outlines the 5S principles: organisation (seiri), orderliness (seiton), cleanliness (seiso), standardisation (seiketsu), and discipline (shitsuke). The aim of this framework is to integrate these two concepts to explore how the 5S principles can be applied to sustainable resource and waste management. This framework formed the basis for conducting the pilot study, which investigated the activities that could be implemented under the individual 5S principles for sustainable resource and waste management in Sri Lankan construction projects.

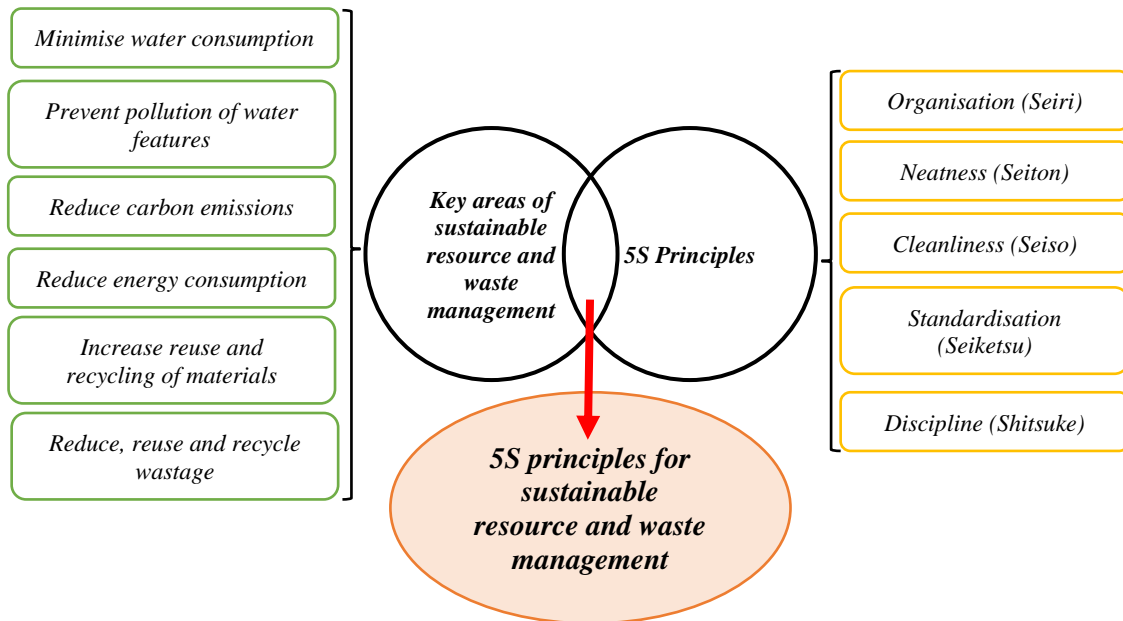


Figure 3: 5S principles for sustainable resource and waste management

#### 4. 5S ACTIVITIES FOR SUSTAINABLE RESOURCE AND WASTE MANAGEMENT

The purpose of conducting the pilot study was to identify the activities that could be implemented under the individual 5S principles for sustainable resource and waste management in Sri Lankan construction projects. During the expert interviews, the typical activities that could be carried out under the 5S principles, identified from the literature review (refer to Table 2), were presented as a guide for the interviewees to suggest activities that could be implemented to achieve sustainable resource and waste management in construction projects.

All interviewees recognised the importance of minimising water consumption and preventing pollution of water features during the construction stage of a project. E2 pointed out that while more attention is typically given to managing water resources during the operational phase, less emphasis is placed on this during construction. The interviewees identified several 5S activities that could be employed to manage water resources and reduce wastage. Initially, the focus should be on reducing water consumption, followed by repurposing or recycling used water for other applications. Interviewee E7 emphasised, “Our priority should be to reduce water usage where possible; then we can think about how we can collect and reuse the water that we have already used for other applications”. The importance of raising awareness in this area was also highlighted.



Regarding carbon emissions, the interviewees observed that this area has received limited attention in most construction projects. They suggested that a reduction in carbon emissions can be achieved by standardising the use of plant and equipment powered by alternative energy sources (e.g., electric vehicles) and ensuring regular maintenance for efficient operation. Additionally, repurposing waste materials and considering carbon emissions in material selection were identified as strategies to reduce carbon emissions from construction projects. In contrast, more attention has been given to reducing energy consumption in construction projects due to high energy costs. The interviewees mentioned using energy-efficient plant and equipment, low-cost renewable energy sources like solar, and strategic allocation of energy-demanding systems as methods to reduce energy consumption. Interviewee E5 noted, “*We are trying to use solar energy more on our sites; especially our outdoor lighting systems, they are powered by solar energy, it cuts our costs and minimises our environmental footprint as well*”. Regular maintenance, monitoring energy consumption, balancing energy demands during peak hours, and raising awareness about responsible energy consumption practices were also recognised as potential activities to reduce energy consumption.

Finally, the interviewees highlighted the increasing focus on reducing, reusing, and recycling materials and waste in construction projects. Storage was identified as a major concern, as improper storage leads to high material wastage. The need for neat and organised material storage was emphasised, and the potential for adopting techniques like Just-In-Time material delivery to eliminate the need for long-term storage was acknowledged. Moreover, the interviewees stressed the importance of standardising the use of reusable and recyclable materials and categorising and segregating waste materials to facilitate alternative uses.

A detailed summary of the findings from the pilot study regarding the 5S activities for sustainable resource and waste management are presented in Table 3.

Table 3: 5S activities for sustainable resource and waste management

5S Principle	Activities to achieve sustainable resource and waste management
<b><i>Minimise water consumption</i></b>	
Organisation (Seiri)	<ul style="list-style-type: none"> <li>• Selection of low water-consuming taps and taps with aerators</li> </ul>
Neatness (Seiton)	<ul style="list-style-type: none"> <li>• Monitor and cut off water taps when not in use</li> <li>• Eliminate unnecessary usage with cups and binding threads</li> <li>• Follow appropriate sequencing of activities</li> </ul>
Cleanliness (Seiso)	<ul style="list-style-type: none"> <li>• Use sand filtration for vegetation</li> <li>• Implement continuous cleaning schemes</li> </ul>
Standardisation (Seiketsu)	<ul style="list-style-type: none"> <li>• Use storm water and recycled wastewater for toilet flushing</li> <li>• Use storm water and recycled wastewater for gardening</li> </ul>
Discipline (Shitsuke)	<ul style="list-style-type: none"> <li>• Conduct toolbox meetings</li> <li>• Undertake proper education</li> <li>• Conduct awareness programs</li> <li>• Create a degradation chart for maintaining water resources</li> </ul>
<b><i>Prevent pollution of water features</i></b>	
Organisation (Seiri)	<ul style="list-style-type: none"> <li>• Systematic disposal of wastewater</li> </ul>
Neatness (Seiton)	<ul style="list-style-type: none"> <li>• Use sedimentation tanks</li> </ul>

<b>5S Principle</b>	<b>Activities to achieve sustainable resource and waste management</b>
Cleanliness (Seiso)	<ul style="list-style-type: none"> <li>• Isolate contaminated water before being released to water channels</li> <li>• Filter storm water through siltation</li> <li>• Purify contaminated water before being sent out</li> <li>• Ensure contaminated water is not mixed with potable water</li> </ul>
Standardisation (Seiketsu)	<ul style="list-style-type: none"> <li>• Analyse water contamination</li> </ul>
Discipline (Shitsuke)	<ul style="list-style-type: none"> <li>• Use silt traps</li> <li>• Install wastewater treatment plants</li> <li>• Conduct awareness programs</li> </ul>
<b>Reduce carbon emissions</b>	
Organisation (Seiri)	<ul style="list-style-type: none"> <li>• Use electrical vehicles rather than those using fossil fuels</li> <li>• Separate debris without setting fire to them</li> </ul>
Neatness (Seiton)	<ul style="list-style-type: none"> <li>• Undertake timely maintenance of plant and equipment</li> <li>• Maintain adequate material and power for activities (avoid over capacity)</li> </ul>
Cleanliness (Seiso)	<ul style="list-style-type: none"> <li>• Conduct regular maintenance of plant and equipment</li> </ul>
Standardisation (Seiketsu)	<ul style="list-style-type: none"> <li>• Use energy efficient plant and equipment</li> <li>• Proper identification and installation of suitable ventilation and lighting systems</li> <li>• Base material selection decisions on carbon emissions, energy consumption, and impact on eco-system</li> <li>• Undertake preventive maintenance of plant and equipment</li> </ul>
Discipline (Shitsuke)	<ul style="list-style-type: none"> <li>• Create checklists for frequent monitoring</li> </ul>
<b>Reduce energy consumption</b>	
Organisation (Seiri)	<ul style="list-style-type: none"> <li>• Use energy efficiency plant and equipment</li> <li>• Proper identification and installation of suitable ventilation and lighting systems</li> <li>• Use solar energy systems</li> </ul>
Neatness (Seiton)	<ul style="list-style-type: none"> <li>• Proper placing of lighting and ventilation arrangements</li> </ul>
Cleanliness (Seiso)	<ul style="list-style-type: none"> <li>• Undertake preventive maintenance of plant and equipment</li> </ul>
Standardisation (Seiketsu)	<ul style="list-style-type: none"> <li>• Manage peak requirements with respect to grid peak hours</li> <li>• Allocate a daily consumption per person</li> <li>• Regular monitoring of energy consumption</li> <li>• Create work procedures to maximise efficiency of plant and equipment</li> </ul>
Discipline (Shitsuke)	<ul style="list-style-type: none"> <li>• Undertake awareness programs to minimise unnecessary energy usage</li> </ul>
<b>Increase reuse and recycling of materials</b>	
Organisation (Seiri)	<ul style="list-style-type: none"> <li>• Stack/Store materials based on their properties</li> <li>• Use appropriate storage facilities</li> </ul>
Neatness (Seiton)	<ul style="list-style-type: none"> <li>• Orderly storage of materials</li> <li>• Collect materials as per the categorisation</li> </ul>
Cleanliness (Seiso)	<ul style="list-style-type: none"> <li>• Careful usage and proper workstation cleaning and management</li> <li>• Regular housekeeping</li> </ul>

5S Principle	Activities to achieve sustainable resource and waste management
Standardisation (Seiketsu)	<ul style="list-style-type: none"> <li>Select reusable and recyclable materials</li> <li>Select storage method as per material type</li> </ul>
Discipline (Shitsuke)	<ul style="list-style-type: none"> <li>Ensure proper planning and monitoring to reduce material usage, rework and wastage</li> </ul>
<b>Reduce, reuse, and recycle wastage</b>	
Organisation (Seiri)	<ul style="list-style-type: none"> <li>Categorise root cause for waste generation and take appropriate mitigation measures</li> <li>Select reusable and recyclable waste and store for future usage</li> </ul>
Neatness (Seiton)	<ul style="list-style-type: none"> <li>Segregate waste based on recovery potential</li> </ul>
Cleanliness (Seiso)	<ul style="list-style-type: none"> <li>Implement continuous cleaning to remove any non-recoverable waste</li> </ul>
Standardisation (Seiketsu)	<ul style="list-style-type: none"> <li>Categorise waste for future use</li> </ul>
Discipline (Shitsuke)	<ul style="list-style-type: none"> <li>Ensure proper planning and monitoring to reduce material usage, rework and wastage</li> <li>Adopt Just-in-Time principles</li> </ul>

## 5. DISCUSSION

In exploring the application of 5S principles for sustainable resource and waste management, the first two areas of focus were on minimising water consumption and preventing the pollution of water features. The findings revealed that while these areas are highly regarded during a building’s operational phase, they receive less attention during construction. This is consistent with the observations of Waidyasekara et al. (2016), who noted that water use efficiency is often given a low priority during construction. The study also highlighted the importance of reducing water use and implementing techniques for repurposing or recycling used water, aligning with the aforementioned authors’ recognition of less water-intensive construction technologies as effective conservation methods. However, it is important to note that some of the activities suggested, such as using filtration systems, sedimentation tanks, and on-site treatment plants, can incur higher costs, potentially making them economically unviable.

The study further revealed that the 5S technique could be used to reduce carbon emissions, an area rarely considered in Sri Lankan construction projects. This corresponds with the work of Ng et al. (2015) who noted that lean techniques like 5S could drive waste reduction and resource efficiency, thereby mitigating environmental impacts, which include the reduction of carbon emissions. Emphasis was placed on the use of alternative energy sources, efficient waste management, and prioritising low-carbon materials. However, here too, further assessment would be needed to assess the viability of some of these measures. For instance, whether it is economically viable to replace fossil fuel-powered vehicles with electric vehicles considering the comparatively higher cost of electricity or whether low carbon emission materials are readily available in the market and can be easily sourced are areas to be considered before undertaking any transition.

Regarding the reduction of energy consumption, the study found that the activities recommended are similar to those for reducing carbon emissions, justified by the significant contribution of energy consumption to carbon emissions. Tasdemir and Gazo (2018) corroborated these findings, recognising that standardised and neat work practices,

as advocated by the 5S principles, can lead to reduced energy consumption. The authors have also emphasised the importance of continuous improvement, recognised in the current study through the necessity of undertaking awareness programs as an area of significance.

Aligned with previous research by Morales-Plaza et al. (2020) and Senanayake et al. (2024), the current study recognised that the 5S principles could be used to effectively minimise wastage while simultaneously driving alternative uses for waste materials. As noted in the current study and supported by Morales-Plaza et al. (2020), adopting 5S principles introduces greater orderliness to the construction process, which minimises waste generation in the first place while also ensuring that any generated waste is managed and reused efficiently. The findings also suggested the need for standardising the use of reused or recycled materials, a fact supported by Tennakoon et al. (2024). Importantly, with storage being recognised as a major source of waste, the potential for adopting techniques like Just-In-Time material delivery was recognised. However, the feasibility of such techniques must be further explored, especially considering the wide and sometimes international sourcing of materials.

## **6. CONCLUSIONS**

Recent studies have revealed a lack of emphasis on sustainable resource and waste management in construction projects, particularly in Sri Lanka. Therefore, exploring the practical applications of the 5S principles, which are conducive to achieving sustainable resource and waste management goals, was recognised as an imminent research need since it could, in turn, drive sustainability initiatives in Sri Lankan construction projects. Consequently, this study aimed to investigate the applicability of 5S principles for sustainable resource and waste management in Sri Lankan construction projects. Initially, literature on the 5S principles and the concept of sustainable resource and waste management were reviewed in detail, which led to the development of a conceptual framework for the application of 5S principles for sustainable resource and waste management. Subsequently, an expert interview-based pilot study was conducted building on the conceptual framework to investigate the activities that could be implemented under the individual 5S principles for sustainable resource and waste management, specifically in Sri Lankan construction projects. The interviews revealed fifty-eight activities, categorised into six key areas of sustainable resource and waste management, as defined based on the CEEQUAL rating system.

As a next step in this study, the researchers aim to conduct a Delphi study to prioritise the identified 5S activities for sustainable resource and waste management and develop a practical framework that can be implemented in construction projects to achieve sustainable resource and waste management targets. While this study's qualitative approach does not necessitate statistical generalisation, it acknowledges the limitation in the broad applicability of study findings, paving the way for future quantitative studies with a wider range of participants from the construction industry. However, it is important to note that conducting such quantitative studies may pose challenges in the current Sri Lankan construction landscape due to limited expertise in the study areas.

## 7. REFERENCES

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