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ASSESSMENT OF MATERIAL WASTAGE AND MATERIAL RECONCILIATION PRACTICES IN SRI LANKAN ROAD CONSTRUCTION PROJECTS

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ABSTRACT

Road construction projects involve extensive use of materials such as asphalt, aggregates, and concrete, making them highly susceptible to material wastage and associated cost implications. Effective material reconciliation is therefore essential for monitoring material consumption, minimising wastage, and improving cost control. However, despite its importance, the application of structured material reconciliation practices in road construction projects in Sri Lanka remains limited and largely unstandardised. This study aims to identify wastage sensitive materials and examine the prevailing material reconciliation practices adopted in road construction projects in Sri Lanka. A quantitative research approach was adopted, where data were collected through a questionnaire survey administered among 54 road construction industry professionals using a heterogeneous purposive sampling technique. The collected data were analysed using descriptive statistical analysis with the support of IBM SPSS software, employing statistical parameters including mean and standard deviation. The findings revealed that asphalt is perceived as the most cost significant material in road construction projects. In contrast, aggregate and gravel were identified as the materials most susceptible to wastage due to factors such as transportation losses, handling issues, and storage challenges. The study further identified that material reconciliation in the Sri Lankan road construction sector is predominantly carried out through traditional manual practices. The adoption of advanced technological solutions and digital monitoring tools remains relatively limited. The study highlights the need for establishing standardised material reconciliation procedures and integrating digital technologies to enhance material monitoring, reduce wastage, and strengthen cost control in road construction projects.

Keywords: *Material Reconciliation; Material Waste; Road Construction Projects; Sri Lanka; Wastage Sensitive Materials.*

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1. INTRODUCTION

Road construction projects depend heavily on large volumes of few materials, making them highly susceptible to material wastage throughout the project lifecycle (Aftab et al., 2025). As a result, road projects generate substantial amounts of construction waste, making material wastage a critical challenge for the industry (Waty et al., 2018). This issue is particularly significant as excessive material waste contributes to cost overruns, resource inefficiencies, and adverse environmental impacts (Kothalawala et al., 2025). This necessitates the need for a proper mechanism to monitor the material wastage, since in road projects planned scopes, budgets, and meeting schedules are located in different geographic regions presenting significant challenges (Rachid et al., 2019). Material reconciliation is widely recognised as an effective mechanism for monitoring material consumption, identifying discrepancies between estimated and actual usage, and controlling wastage through proper documentation and accountability (Priyaruwan et al., 2020). Although material reconciliation and proper documentation are recognised as effective strategies to manage wastage, its actual application in road construction projects remains limited (Priyaruwan et al., 2020). Despite the importance, Sri Lanka lacks a structured framework to regulate construction waste in road projects which leads to uncoordinated and ineffective practices (Nishanthi & Ratnayake, 2025). The absence of proper material reconciliation system has been identified as the major reason for the excessive material wastage in construction sites in Sri Lanka (Kothalawala et al., 2025). According to Rameezdeen et al. (2004), ineffective waste measurement methods, insufficient record-keeping, and the inability to accurately capture waste generated through rework have hindered effective material control and reconciliation processes. Existing studies primarily focus on waste generation rates and disposal methods, with limited attention given to quantifying the associated cost implications specifically in road construction (Jayapadma et al., 2025). However, the absence of a standardised, structured approach to material reconciliation has led to frequent discrepancies between estimated and actual material usage in Sri Lanka (Rameezdeen et al., 2004). Consequently, a significant research gap exists regarding the implementation of material reconciliation in Sri Lankan road construction projects, particularly in identifying wastage-sensitive materials that require prioritised monitoring and establishing effective reconciliation approaches that can be integrated into the project lifecycle (Senarathna & Perera, 2021).Therefore this study aims to identify wastage sensitive materials and examine prevailing material reconciliation practices in road construction projects in Sri Lanka through below mention objectives. i.e. Critically review the significance of material reconciliation in road construction projects, with particular emphasis on wastage sensitive materials, and identify the current material reconciliation practices in the Sri Lankan road construction industry.

2. LITERATURE REVIEW

Given the scale of road construction work, a substantial amount of construction waste is generated during operations throughout the project lifecycle (Paranavithana et al., 2024). Road construction projects usually extend over wide geographical areas and are particularly susceptible to high threat due to unpredictable underground conditions (El-Sayegh & Mansour, 2015; Mishmish & El-Sayegh, 2018). Consequently, storage arrangements are often inadequate due to the limited availability of storage space in road projects (Aftab et al., 2025). However, uncertainties in road length and lack of specific material intensity data may lead to significant discrepancies in stock estimations which complicate resource allocation and increase risk of material waste (Grossegger et al., 2024). Ogbu and Adindu (2019) stated that road construction projects often lead to cost overruns, with the majority being due to material wastages. Accordingly, the impact of waste materials on projects encompasses cost, time, productivity, and sustainability (Nagapan et al., 2012). Hence, critical understanding of the underlying causes of material waste within the road construction industry is essential for improving efficiency, reducing environmental impact, and lowering project costs (Paranavithana et al., 2024).

2.1 WASTAGE SENSITIVE MATERIALS IN ROAD CONSTRUCTION

Focused studies on Aggregate Base Course (ABC) wastage in Sri Lankan Road projects indicate that material waste is primarily caused by inappropriate storage, improper utilisation, transportation damage, and inadequate documentation (Priyaruwan et al., 2020). Similarly, a study conducted in Qatar identified 26 generic causes of waste in infrastructure projects and through structural equation modelling, systematically categorised into five clusters i.e. (i) design, (ii) logistics, (iii) procurement, (iv) execution, and (v) others thereby highlighting the multifaceted ways of material wastage within the construction process (Aftab et al., 2025). Furthermore, poor material management practices, such as inaccurate procurement and suboptimal onsite storage practices, lead to excess inventory and increased material waste, emphasising the need for proper planning, supply, logistics, and transport (Yıldız et al., 2024). Thus, material management is important to minimise material waste in road construction (Priyaruwan et al., 2020).

Moreover, road construction projects face distinct material management challenges due to complex supply chains and the management of locally procured materials including large volumes of asphalt, aggregates, and reinforcement steel (Awaad et al., 2024). Material costs significantly influence the overall expenditure of a construction project while wastage reduces profit margins particularly in road construction where even minor reductions in material waste can result in substantial financial savings (Aftab et al., 2025). Aftab et al. (2025) further reported that key materials in road construction include subgrade, subbase, base, and asphaltic layers for pavements, along with concrete and steel for culvert and bridge structures.

Table 1: Wastage sensitive materials in road construction

Key material	Wastage Factors	Cost Significance	References
Aggregate	Loss during loading, transport, spillage and difficult recovery on site	Major cost component due to high consumption volumes and direct influence on overall pavement cost	[1], [2], [6], [8], [16], [17], [18], [19], [20], [21], [22]
Concrete	Over ordering and mixing errors, quick hardening limits reuse	High-cost burdens because unused or rejected quantities result in direct financial loss with limited recovery value	[3], [4], [5], [8], [9], [10], [11], [12], [15], [16], [18]

Key material	Wastage Factors	Cost Significance	References
Asphalt	Improper timing, placement, or compaction during surfacing operations	Highly cost significant as errors or inefficiencies often necessitate expensive rework or premature resurfacing throughout the pavement life cycle	[6], [7], [10], [13]
Sand	Lost due to wind, water displacement and spillage	Low priced yet extensive and repetitive usage requirements across multiple layers	[1], [13], [14], [21], [22]
Steel	Off-cuts, design changes, inaccurate bar bending schedules, theft and corrosion	High-cost significance duet to high value and wastage directly increases structural cost, limited reuse after cutting and bending	[2], [3], [10], [12], [21]
Gravel	Overestimation and unmanaged stockpiling cause waste	Moderate cost significance, mainly due to repurchasing needs and added transport cost	[13], [14]
Cement	Moisture exposure and poor storage lead to wastage	Moderate cost significance since any damaged cement becomes unusable, resulting in total material loss	[11], [12], [21]
Tarmac	Degrades if not promptly applied, process errors cause rework	Very High significance for sealing, surfacing degraded material requires full replacement	[11], [12], [22]
Granular Materials	Waste in site clearance, transport losses, and poor compaction	Moderate cost significance, as poor compaction affects pavement	[10], [13]

[1] (Patil & Pataskar, 2013); [2] (Busari et al., 2019); [3] (Mazhar et al., 2023); [4] (Fanijo et al., 2023); [5] (Ray et al., 2021); [6] (Havanagi et al., 2012); [7] (Rahman et al., 2020); [8] (Waty et al., 2018); [9] (Ahmed et al., 2025); [10] (Grossegger et al., 2024); [11] (Swinburne et al., 2010); [12] (Aftab et al., 2025); [13] (Rajendran & Gambatese, 2007); [14] (Krausmann et al., 2017); [15] (Ouslimane et al., 2025); [16] (Yuriz et al., 2020); [17] (Thakur et al., 2022); [18] (Assadi, 2022); [19] (Priyaruwan et al., 2020); [20] (Perera & Shandraseharan, 2023); [21] (Munkombwe & Chibomba, 2025); [22] (Paranavithana et al., 2024)

As evidenced by Table 1, concrete and aggregate emerge as the most extensively investigated materials in the existing literature, reflecting their widespread investigation across most of the reviewed studies. Consequently, these materials can be identified as the most wastage sensitive, yet careful consumption is adequate due to its high-cost significance. Additionally, sand, gravel, cement, tarmac, steel, and granular materials were found to be moderately susceptible to wastage, underscoring the substantial research emphasis placed on these materials due to their extensive utilisation in road construction and their significant implications for project cost, quality, and sustainability.

2.2 MATERIAL RECONCILIATION AND ITS BENEFITS

Material reconciliation is a key technique in material waste management which aims to eliminate discrepancies between the amount of material procured and the quantity specified in Bills of Quantities (BOQ) (Ajayi et al., 2017). Senarathna and Perera (2021) further state that preparation of material reconciliation report compares the difference between store records and actual material requirement. Thus, the wastage can be considered as proportionate to the actual work done (Mishra & Aithal, 2022). Effective material reconciliation ensures accurate tracking of usage, minimises waste, and enhances cost control, aligning with sustainable construction practices (Ahmad et al., 2025). Road construction projects are regarded as high risk because of the constant cost escalation, which is mainly due to the wastage of materials (Kothalawala et al., 2025). It is imperative for contractors to have a precise understanding of the materials required for each activity to compare against the actual material consumption (Manewa et al., 2007). In addition, comprehensive documentation and record keeping managed by quantity surveyors, are primarily essential to ensure accuracy and transparency in the process of material reconciliation (Ekanayake et al., 2025).

The precise determination of road layer service time and careful tracking of material movements, especially in the context of demolition activities when on site recycling is often unrecorded and essential to reduce discrepancies between estimated and reported waste generation (Grossegger et al., 2024). Similarly, Priyaruwan et al. (2020) revealed implementing effective material management practices lead to secure resources, control departmental expenditures, ensure reliable supplies, and maintain accurate records, including material reconciliation. Periodic updating of the material reconciliation reports is a key determinant of cost control through the detection of excesses or shortages (Ogbu & Adindu, 2019). Moreover, material reconciliation is preferred over work studies as it overcomes challenges such as inaccurate waste measurement during construction (Rameezdeen et al., 2004). Accordingly, the absence of proper material reconciliation system has been identified as a major contributor to material wastage in Sri Lankan road construction projects highlighting the need to adopt into appropriate waste minimisation approaches (Priyaruwan et al., 2020).

2.3 CURRENT MATERIAL RECONCILIATION PRACTICES AND TECHNIQUES IN SRI LANKA

Effective project delivery requires actions such as accurate material estimation, effective scheduling, regular monitoring, risk management, inventory management, and the adoption of technology enabled tracking and monitoring systems (Gunawardana & Bandaranayake, 2024). Material reconciliation was conducted by examining the difference between the store records and actual requirement of the material according to the items in the BOQ (Perera & Amarathunga, 2018; Rameezdeen et al., 2004). Material reconciliation reports are prepared to achieve timely and cost targets (Waduwawala et al., 2019). The Table 2 presents the current material reconciliation practices, tools used and the supporting management approaches within the Sri Lankan construction industry.

Table 2: Current material reconciliation practices in construction projects in Sri Lanka

Category	Element	References
Material Reconciliation Practices	Comparison of Theoretical vs. Actual Quantities	[1], [2], [3], [10], [11], [16], [17], [18], [20]
	Physical Stocktaking and Audits	[2], [12], [18]
	Detailed Documentation	[2], [3], [21]
	Reconciliation Reports	[3], [10], [11], [15], [19]
Supporting Management Approaches	Lean construction practices	[3], [13], [14]
	Circular Economy principles	[5], [6], [7], [9]
Supporting Tools and Technologies	Spreadsheets and Basic Databases	[8]
	Construction ERP Systems	[4], [12], [21]
	Building Information Modeling (BIM)	[3], [12]

[1] (Rameezdeen et al., 2004); [2] (Priyaruwan et al., 2020); [3] (Kothalawala et al., 2025); [4] (Hewavitharana et al., 2025); [5] (Victar & Waidyasekara, 2024); [6] (Bimsara et al., 2024); [7] (Wanaguru et al., 2022); [8] (Pararajasingam et al., 2024); [9] (Victar & Waidyasekara, 2025); [10] (Manewa et al., 2007); [11] (Seneviratne et al., 2015); [12] (Jayapadma et al., 2025); [13] (Pandithawatta et al., 2019); [14] (Senevirathne & Wimalasena, 2025); [15] (Waduwawala et al., 2019); [16] (Abeyrathne et al., 2022); [17] (Paranavithana et al., 2024); [18] (Karunasena et al., 2023); [19] (Swaranjali, 2017); [20] (Perera & Amarathunga, 2018); [21] (Gowthaman et al., 2025)

According to Table 2, the comparison of theoretical and actual material quantities is the most widely adopted material reconciliation practice in construction projects. Traditional manual and paper-based methods continue to dominate material reconciliation activities in the Sri Lankan road construction sector (Priyaruwan et al., 2020). In addition to these direct practices, lean construction approaches such as the 5S concept support material reconciliation by improving material organisation, monitoring, and control (Senevirathne & Wimalasena, 2025; Thilakarathna & De Silva, 2014). Similarly, Circular Economy principles contribute to reconciliation objectives through waste reduction and resource efficiency (Victar & Waidyasekara, 2024). Furthermore, technologies such as spreadsheets, databases, ERP systems, and BIM facilitate material reconciliation by improving data management, stock control, and reporting capabilities. Therefore, while management approaches and technologies support effective material reconciliation, they are distinct from the reconciliation practices themselves.

2.4 DRAWBACKS IN CURRENT MATERIAL RECONCILIATION PRACTICES

Notable limitations can be identified in existing material reconciliation practices which leads to ineffective material management (Eze et al., 2020). Thus, material reconciliation practices remain inconsistent, informal, and inadequately documented within developing construction sectors such as Sri Lanka (Pararajasingam et al., 2024). However, further drawbacks such as lack of standardisation, inadequate knowledge of staff, improper recording and return of materials can be observed in current material reconciliation practices in Sri Lanka (Priyaruwan et al., 2020). Material management systems are conducted manually, with stock accumulation or depletion determined by input output balances although quantifying flows and stocks remain challenging due to data uncertainties and limited availability (Rameezdeen et al., 2004). Traditional methods are often encountered with incomplete documents and delays in documentation (Pathiranage & Halwatura, 2010). The absence of records on criminal wastage, and the difficulty of capturing waste from rectification work, though its tedious nature often restricts quantification to the most used materials in Sri Lankan projects (Rameezdeen et al., 2004). Moreover, inefficient material monitoring and lack of real time tracking systems have been reported as a significant issue in Sri Lankan construction industry (Ekanayaka & Eranga, 2025).

3. RESEARCH METHODOLOGY

Quantitative research approach was adopted in this study since it statistically analyses the data. Initially, a literature review was conducted to identify the wastage sensitive materials and material reconciliation practices from existing studies. Questionnaire survey offers data which can be interpreted and analysed (Cohen et al., 2017). Therefore, the perspective of material reconciliation practices was collected from industry practitioners. The heterogeneous purposive sampling technique was used for quantitative approaches to select a representative sample from the population as it assisted in selecting a sample that is relevant to a range of experiences, perspectives, and characteristics (Tongco, 2007). The questionnaire survey was administered to approximately 80 construction industry professionals to collect data, as it is sufficient to get a moderate response rate of 60-70%. The questionnaire consisted of three main sections. The first section is used to collect demographic information of the respondents, and second and third sections are used to gather insights of wastage sensitive materials and material reconciliation practices in road construction projects in local context. In addition, questionnaire surveys were circulated via email, LinkedIn and WhatsApp to encourage participation of industry practitioners. IBM SPSS software was employed as the primary analytical tool to facilitate the statistical evaluation of the survey data utilising descriptive statistical analysis. The analysis was further elaborated through the application of key statistical parameters including Mean, Standard Deviation, and Variance, derived from ratings of the respondents (Yin et al., 2022).

4. RESEARCH FINDINGS

This section presents the result and findings obtained from the questionnaire survey conducted among industry professionals with reference to wastage sensitive materials and prevailing material reconciliation practices.

4.1 RESPONDENT'S DEMOGRAPHIC INFORMATION

Most respondents represented main contracting organisations. However, participants from consultancy firms, subcontractor organisations, and government institutions were further included to ensure comprehensive coverage of all relevant stakeholder groups within the construction industry. The professional roles of the selected respondents are further illustrated in Figure 2. Quantity Surveyors constituted most of the respondents, whilst the remaining participants comprised Project Managers, Site Engineers, Material and Storekeepers, Technical Officers, Contract Administrators, and Deputy Project Managers.

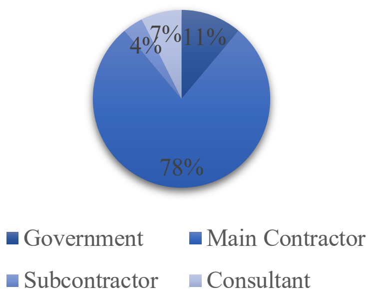

Figure1: Type of organisation

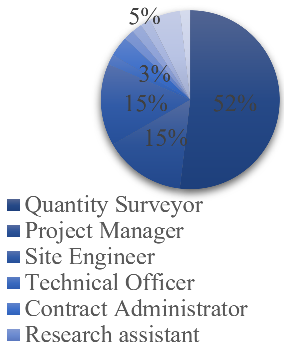

Figure 2: Respondent's role

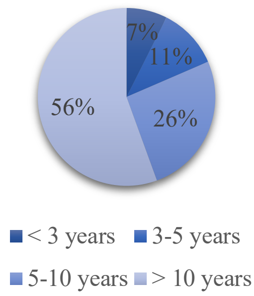

Figure 3: Years of experience

The distribution of respondents according to their level of industry experience is presented in Figure 3. In terms of industry experience, the largest proportion of respondents possessed more than ten years of professional experience, followed by those with experience ranging between five and ten years affirming that most survey participants had substantial industry exposure. Moreover, based on the demographic study of the analysis, the average years of experience and minimum qualifications reflected an adequate amount of experience and expertise, which subsequently guarantees the ability of the respondents to properly understand and answer the questionnaire.

4.2 Assessment of Wastage Sensitivity and Cost Significance of Materials in Road Construction Projects

4.2.1 Cost Significant Materials in Road Construction Projects

The respondents were provided with a 5-point Likert scale to assess the level of cost significance of each identified material. The materials subject to evaluation were derived from the literature synthesis.

Table 3: Statistical parameters of cost significant materials from descriptive analysis

Key material	Mean	Std. Deviation
Asphalt	4.5000	0.86330
Aggregate	4.1296	1.02876
Concrete	3.9815	1.07266
Granular Materials	3.7593	1.04494
Cement	3.7407	1.06727
Gravel	3.7222	1.20403
Steel	3.6667	1.19748
Tarmac	3.5000	1.29949
Sand	3.3889	1.10602

The standard deviation values range between 0.863 and 1.299, indicating a moderate level of variability in perceptions of respondents regarding the cost significance of materials used in road construction projects. Subsequently, cost significance of each material was ranked according to the calculated mean value. The result revealed that asphalt recorded the highest mean score, indicating the highest cost significance among listed materials marking higher than 4.20 Mean value.

4.2.2 Wastage Sensitive Materials in Road Construction Projects

Several road construction materials were provided to respondents to evaluate considering the possibility of wastage of given materials using 5-point Likert scale. The scale ranged from 1 (Very low possibility) to 5 (Very high possibility) reflecting the perceived degree of wastage possibility attributed to each material. The collected data were subjected to descriptive statistical analysis.

Table 4: Statistical parameters of wastage sensitive materials from descriptive analysis

Key material	Mean	Std. Deviation
Aggregate	3.7407	1.26170
Gravel	3.6852	1.24118
Granular Materials	3.3889	1.21960
Sand	3.1296	1.25962
Concrete	2.9074	1.24792
Cement	2.8704	1.16629
Asphalt	2.8333	1.16149
Steel	2.8333	1.20924
Tarmac	2.6111	1.13962

As per the given table, aggregate recorded the highest perceived possibility of wastage marking 3.74 Mean, followed by gravel reflecting 3.68 Mean value. In contrast tarmac recorded the lowest possibility of wastage marking 2.61 Mean value. The standard deviation ranging from 1.13 to 1.26 reflects the moderate variability in perceptions of respondents regarding the wastage potentiality of the determined materials considering the practical complexities in construction projects. The identified materials were systematically ranked considering the Mean value to facilitate a comprehensive interpretation of the result.

4.3 Material Reconciliation Practices in Road Construction Projects

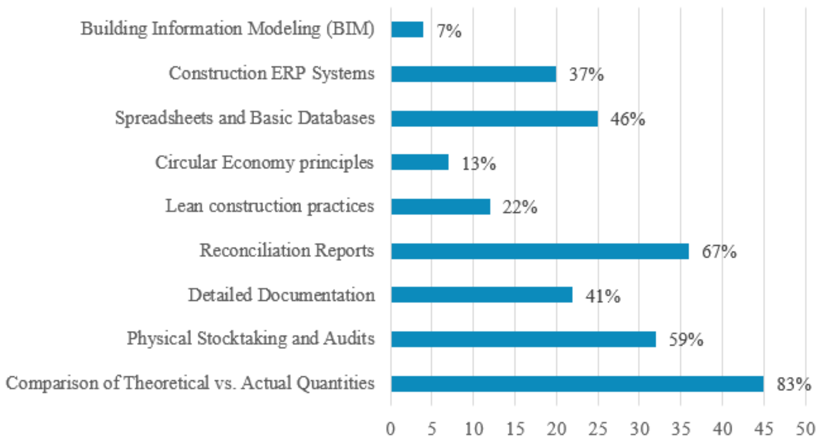

Figure 4: Current material reconciliation practices identified

The findings revealed that the comparison of theoretical quantities against actual quantities utilised was the most widely practised material reconciliation method, as reported by 83% of the survey respondents. Accordingly, 67% of respondents have stated that preparation of reconciliation reports is widely applied in road construction projects followed by 59% of respondents have mentioned that physical stocktaking and audits are widely used. Moreover, spreadsheet-based material reconciliation and use of databases have been identified as moderately used in road construction projects as mentioned by 46% of respondents while construction ERP system was used in few road construction projects as mentioned by 37% of respondents. Practices such as lean construction practices (22%), and circular economy principles (13%), are less frequently used in road construction projects. Notably, Building Information Modelling (BIM) recorded the lowest adoption rate of merely 7%, suggesting that this technology remains largely unsuitable and inapplicable within the current material reconciliation practices of road construction projects in Sri Lanka.

4.4 INPUT DOCUMENTS USED IN MATERIAL RECONCILIATION

The respondents were requested to mention the input documents that predominantly utilised to conduct material reconciliation in road construction projects through an open-ended question. The responses received were systematically compiled and presented in a frequency table to facilitate a more accurate and structured analysis of the collected data. The empirical findings demonstrate a pronounced reliance on procurement and site records including material issue note, goods received note, and stock records emerging as primary input documents. As illustrated in the radar chart these documents represents the highest frequency of usage as input documents to conduct material reconciliation indicating that prevailing industry practices remain heavily rely on manual paper-based approaches.

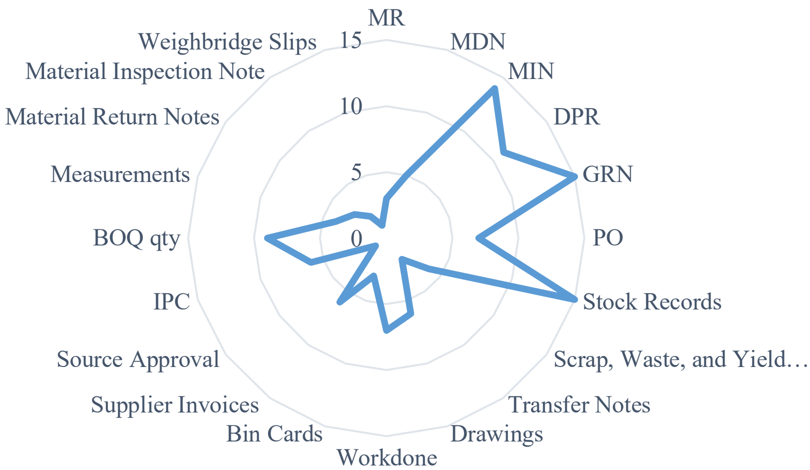

Figure 5: Input documents used in road construction projects

5. DISCUSSION

The findings present wastage sensitive materials and the current material reconciliation practices within road construction projects in Sri Lanka. Thus, the analysis revealed that asphalt emerged as the most cost significant material, and it presents a mean value that exceeds threshold value and shows the presence of strong impact of asphalt on the total costs of the projects (Rajendran & Gambatese, 2007). The significance of the other materials like aggregate and ready-mix concrete was further found to be relatively high. Aggregate and gravel were identified as the materials most susceptible to wastage, a finding attributable to the considerable losses incurred during transportation, spillage during handling, and the inability to recover such materials once lost on site (Priyaruwan et al., 2020). These results correlate with previous studies that have found aggregates as high waste prone materials in road construction works due to the substantial quantities involved in road construction projects (Waty et al., 2018). Furthermore, the findings suggest that material reconciliation is predominantly conducted through traditional methods such as comparison of theoretical quantities with actual quantities, preparation of reconciliation reports, and physical stocktaking (Kothalawala et al., 2025). However, the adoption of advanced practices, including ERP systems, lean construction techniques, and circular economy practices remains relatively limited. This implies that material reconciliation processes are largely manual and decentralised highlighting the necessity for enhanced standardisation and greater integration of digital technologies to improve material monitoring and waste control.

6. CONCLUSIONS

This study investigated road construction materials and prevailing material reconciliation practices within the context of road construction projects in Sri Lanka. Based on the descriptive statistical analysis asphalt was established as the most cost significant material whereas the aggregate and gravel demonstrated the highest possibility of wastage due to losses incurred during handling, transportation and storage. The findings further revealed that material reconciliation practices within the Sri Lankan road construction industry are majorly based on the traditional manual method including theoretical and actual quantity comparisons, reconciliation reporting and physical verification of stock. Even though these techniques offer a simple approach to tracking the material utilisation, the implementation of advanced technological solutions, including ERP systems, and other digital monitoring tools, remains considerably limited within the industry. Thus, the research underscores critical importance of establishing standardised material reconciliation procedures and advocating for the integration of modern digital technologies to enhance material tracking, minimise wastage, and strengthen cost control mechanisms in road construction projects in Sri Lanka. This study is limited to the context of road construction projects in Sri Lanka. Therefore, the applicability of the findings is constrained within similar project environments. Future studies can be extended the scope to other infrastructure sectors and explore advanced approaches of conducting material reconciliation in global construction sector and adoptability and suitability of the identified approaches to further enhance material management practices within the construction industry.

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