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ENHANCING CIRCULARITY IN STEEL STRUCTURES THROUGH DESIGN FOR DECOSNTRUCTION: INFORMATION NEEDS

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ABSTRACT

Design for Deconstruction (DfD) is identified as a key strategy for improving circularity in the construction industry. It mainly considers the integration of R principles into the building components and processes at the end of their life cycles. During the implementing the DfD for the building or infrastructure the material selection process plays a significant role. Having observed some of the building and infrastructure projects in Sri Lanka, the structure/frames represent a significant portion of the overall cost. However less attention had been paid on their end of lifecycle considerations (economic, social and environmental). As the first step, this study explores the potential of DfD steel structures in enhancing circularity. The research is based on a literature review examining on design phase deconstruction information requirement for enhancing circularity in construction products. The review identifies key factors influencing DfD, including durability, connection methods, structural characteristics, and ease of separation during deconstruction in general and the ability of material traceability, selective disassembly, and integration with digital technologies like Building Information Modelling for Deconstruction (BIMfD) in specific to steel structures. Large-scale deployment is nevertheless hampered by issues including certification requirements, market uncertainties, logistical limitations, and the absence of standardised reuse protocols, notwithstanding these benefits. In order to optimise the reuse potential of steel structures and facilitate the shift to a circular construction. The conceptual framework explains the integration between DfD principles, information requirements (product. process) and circularity dimensions for sustainable product delivery.

Keywords: *Circular Construction; Conceptual framework; Design for Deconstruction; Information Requirement; Steel.*

1. INTRODUCTION

Sustainability is an essential consideration in the current practice of every industry especially construction industry (Mhatre et al., 2021) due to its products and processes

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consume high volume of scarce resources and in general products are designed for long lifecycles. Circular construction is identified as one of effective solutions for improving sustainability within construction. It has been discussed with several practices, such as waste-to-energy supply chain (Pan et al., 2015) , eco-industrial park, waste-to-resource supply chain, cradle-to-cradle, industrial ecology regenerative design (Mahpour, 2018). Design for Deconstruction (DfD) has gained more global attention in recent past , for effective waste and resource management (Benachio et al., 2020). The concept of Design for Deconstruction (DfD) seeks to create construction assets such as buildings and infrastructure that can easily be reused or repurposed, utilizing recycled materials and elements, as well as reducing construction and demolition waste (Akanbi et al., 2019). Aligning with that, implementing DfD in construction industry can make a massive impact on sustainable practices, which is one of the important tasks to be achieved according to the past studies (Yates, 2013). Therefore, identifying practical techniques and suitable material applications for implementing DfD has become increasingly important. Literature explains several construction materials that are fit for DfD purposes. Among them steel is often pointed out as one of the most promising materials due to its recyclability, reusability, adaptability and ease of disassembly. Steel structures possess a number of attributes that are well suited to the circular economy principles of the built environment, and hence demonstrate a high degree of compatibility with DfD approaches.

Furthermore, some studies have comprehensively synthesised the applicability, advantages, implementation considerations and deconstruction potential of steel structures (Akanbi et al., 2019). However, no study was explained its design considerations (proactive information requirement) to make the steel as more DfD structure to enhance its circularity potentials. This led to a research gap in the development of a clear and integrated understanding on the role of steel in enabling DfD implementation. The study therefore aims to explore the potential of steel as a material for Design for Deconstruction by critically reviewing and consolidating the diverse perspectives available in existing literature. This study is carried out as part of a larger research initiative for MPhil study which is aimed at the development of a deconstruction information model for steel structures and therefore is a necessary preliminary investigation to understand the appropriateness and feasibility of implementation of steel in DfD practices.

2. RESEARCH METHODOLOGY

This paper derives from an extensive literature review that is part of an ongoing MPhil research project, which aimed at developing a Deconstruction Information Model (DIM) for Steel Structures by incorporating Design-for-Deconstruction (DfD) Data Features to Improve Circular Economy Decision-Making. Since the research is still at its preliminary phase, the examination relies solely on a review of existing literature that explained the current gap in understanding principles, and practices of DfD and its role in improving CE. Accordingly, the literature review has been utilized narrative review, where the past literature has interpreted in more descriptive way. In that case, literature evidence was sourced from journal articles, books, both published and unpublished bibliographies, conference proceedings, and various documents. In the literature review, essential terms such as circular economy, design for deconstruction, design for disassembly, Steel Construction, Steel Reuse, advantages, obstacles, and construction were examined (Sylvester et al., 2011).

3. DESIGN FOR DECONSTRUCTION

Tleuken et al., (2022) stated that Design for Deconstruction (DfD) is the concept that considers the final demolition stage during initial design and planning. And also, it focuses on increasing the value that has been input into the building material or structural element even after the building's end-of-use. Kanters (2018) identified DfD is a method where a design team designs a building that facilitates not only adaptation and renovation, but also the reuse of building materials and components. As mentioned previously, deconstruction process can be predicted at the design stage of a construction process (Akanbi et al., 2019). Therefore, this concept can outbreak with number of advantages economically, environmentally and socially (Akinade et al., 2020). For an example, if the buildings are initially designed for deconstruction, it will significantly improve the environmental effect due to the possible recovery of almost 95% savings of the embodied energy of the construction materials and up to 50% of the total building's life cycle energy (Tleuken et al., 2022). Moreover, it also massively improves the waste management issues.

DfD has its own set of principles which is supposed to follow when the practices of it implemented (Rios et al., 2015) it includes reducing the number of materials and components used; Choosing materials that are possible for reusing and recycling; Using visible and reachable building elements connections; Using simple (yet strong) and connections that are easy to deconstruct, (e.g. dry connections, dissolvable chemical or reversible welding connections); and practicing utilization of building modules that are robust, substitutable and convenient for transportation (Akinade et al., 2020). Supportively, Rios et al., (2015) also provided a similar definition with addressing the key principles as above mentioned.

Tleuken et al., (2022), identify some benefits of DfD in the industrial market such as, reducing the time required for building demolition and labour involved in demolition works. DfD could bring some economic incentives. Meanwhile, uncertainty about the quality of the reused material; low demand due to users' negative perception; financial profitability of demolition practices rather than disassembly; earthquake risks when using bolting connections; high risks of reinforced concrete corrosion can identify as basic shortcomings (Tleuken et al., 2022).

3.1 IMPLEMENTATION OF DFD IN THE CONSTRUCTION INDUSTRY

DfD is still in its early stage of implementation globally (Akinade et al., 2017). Nevertheless, researchers have examined various aspects of DfD from different perspectives (Akanbi et al., 2019). According to Kanters (2018), general construction principles that support the design for deconstruction are, (a) the overall building design, (b) materials and connections, (c) the construction and deconstruction phases, and (d) communication, competence, and knowledge. Moreover, in the same study, the author mentioned about major categories to be considered when implementing DfD in the construction industry. They are as; (a) general design and construction principles, (b) Specific materials' potential for DfD, (c) DfD throughout the design process, (d) Tools for DfD, (e) Existing building stock potential and (f) Barriers and drivers for DfD.

3.2 FACTORS TO BE CONSIDERED IN SELECTING MATERIALS FOR DFD

Material selection has a major consideration on the DfD implementations (Ranasinghe et al., 2025; Zoghi et al., 2022). Tzourmakliotou (2021) has reviewed the number of past literature and identified following list of factors to be considered specifically for the material selection for DfD implementation for building construction which is summarised in Table 1.

Table 1: Material related factors involved in the DfD

No	Material Related Factors
1	Use of durable reusable materials
2	Use as connections nut/bolt that can be easily removed instead of nails and gluing
3	Use prefabricated, modular assemblies
4	Avoid composite materials during design specification
5	Minimize number of connectors and limit the different types
6	Minimize number and types of building components
7	Avoid toxic and hazardous materials
8	Use of recyclable materials
9	Avoid materials with secondary finishes, such as coating which compromise reuse potential
10	Select easily separable materials with reuse potential
11	Use lightweight materials

Source - (Tzourmaklioutou, 2021)

The aim of DfD for buildings/infrastructure is to find solutions for the problems of reusing and recycling building materials when their useful lives are coming to an end (Tzourmakliotou, 2021). As previously mentioned, DfD envisions a closed cycle of resource use and reuse as opposed to the conventional linear material flow, which starts with the extraction of raw materials and ends with the disposal of garbage in landfills (Akinade et al., 2020). DfD strategy uses fewer virgin materials and produce less waste during construction, renovation, and demolition; it also wants to build structures that are "material banks" of future building materials and prolong building lives in situ (Mahpour, 2018). For the design team to achieve a high degree of DfD, choosing the appropriate materials, connections, and components is arguably the most significant task to be completed (Akbarnezhad, 2014). Before determining whether a material is durable enough to be reused in its current form or, if it cannot be reused, whether it can be readily recycled, consideration should be given to issues like whether the specific material or its component is suitable for reuse, recycling, and disposal procedures (Crowther, 1999).

4. ANALYSIS OF STRUCTURAL MATERIALS FOR DFD POTENTIALS

Material selection plays a vital role in the successful implementation of Design for Deconstruction (DfD). Kanters (2018) explained that choosing materials that are easily dismantled, reused, or recycled is one of the most important parts of designing for deconstruction. Table 2 presents a summary of literature during last two decades that have identified the structural materials that have high potentials for DfD.

Table 2: Potential materials for DfD

Materials / Authors	Steel	Timber	Concrete	Masonry	Prefabricated Structures	(Roofing materials, Architectural elements)
A1	✓	✓	✓	✓		✓
A2	✓	✓		✓		✓
A3	✓	✓		✓		
A4	✓	✓			✓	
A5	✓	✓	✓	✓		
A6	✓					
A7	✓	✓	✓		✓	
A8	✓	✓	✓			
A9	✓					
A11	✓					
A12	✓	✓			✓	
A13	✓	✓	✓	✓		
A14	✓	✓				
A15	✓	✓				
A16		✓				
A17	✓	✓	✓			
A18	✓	✓			✓	
A19	✓	✓			✓	
A20		✓				

A1-(Guy & Shell, 2002), A2-(Chini & Bruening, 2003), A3-(Crowther, 1999), A4-(Webster & Costello, 2006), A5-(Addis, 2012), A6- (Durmisevic, 2006), A7-(Gorgolewski, 2008), A8-(Guy & Ciarimboli, 2005), A9-(Tingley & Davison, 2011), A10-(Tingley, 2013), A11- (Rios et al., 2015), A12-(Kibert, 2016), A13-(Kanters, 2018), A14-(Akanbi et al., 2019), A15- (Tleuken et al., 2022), A16-(Passarelli et al., 2025), A17-(Daly, 2023), A18-(Ostapska et al., 2024), A19-(Pristerà et al., 2024), A20- (Patrizi et al., 2026).

The durability, connection techniques, and structural behaviour of the materials used have a significant impact on the viability of deconstruction at the end of a building's life (Kanters, 2018). These characteristics make some materials more reusable by nature, while others present challenges with deterioration, separation, or recycling. Moreover, Kanters (2018) emphasizes that materials like steel, masonry, and wood can facilitate reuse within a circular construction framework. Among these, steel and wood are regarded as closed-loop cycle materials since they have the potential to be repeatedly processed and reused (Ostapska et al., 2024). On the other hand, because of restrictions on recycling and reuse, materials like roof tiles, thermosetting plastic insulation, plasterboard, foundations, and masonry components are typically not categorized as closed-loop materials (Guy & Shell, 2002).

In a similar vein, Tingley (2013) investigated the viability of deconstruction for materials such as steel, concrete, masonry, and wood. Accordingly, timber structures' uniform sizes and straightforward construction techniques make them ideal for deconstruction. Deconstruction potential is also greatly influenced by the type of jointing system, with mechanical connectors like bolts or metal plate connectors facilitating simpler disassembly (Hopkinson et al., 2018). Masonry components, such as bricks and blocks, are frequently reusable, but the kind of mortar used is important because lime mortar is easier to separate and clean than cement mortar (Addis, 2012). In contrast, because of the strong bonding produced by cement-based joints, reinforced concrete structures are more challenging to disassemble. Because steel is highly recyclable and steel connections are versatile, steel structures are widely recycled even though they are not directly reused (Tingley & Davison, 2011).

Hybrid structural systems have also been studied recently. The potential of timber-concrete composite (TCC) floors for DfD applications is explained by Holly et al. (2023). The study shows that using deconstructable connectors can make it easier to disassemble and reassemble TCC components while preserving structural integrity. TCC flooring that incorporates DfD principles can increase carbon storage capacity and encourage material reuse (Chini & Bruening, 2003). However, in order to overcome technical and financial obstacles, such systems must be designed, built, and disassembled using a multidisciplinary approach (Rose et al., 2018). In order to facilitate broader adoption, the study recommends that future research concentrate on commercializing deconstructable connectors and lowering additional costs (Smeets et al., 2019).

Also, the information needs for reusable concrete components within DfD frameworks were investigated by Uotila et al. (2024). Accordingly, concrete components have a major impact on emissions during construction, but they also present a significant opportunity for CO2 reduction through reuse. The researchers created a thorough list of data requirements pertaining to the characteristics and potential for reuse of concrete components through expert workshops (Xia et al., 2022). These findings provide valuable guidance for designers and construction professionals during the early stages of projects and support the broader implementation of DfD principles in concrete construction (Daly, 2023). As the literature has increasingly recognised steel as a prominent material for DfD, and preliminary observations confirm its cost significance, this paper further investigates the design stage information requirement to enable the deconstruction of steel structures at the end of their physical or economic life.

5. STEEL FOR DESIGN FOR DECONSTRUCTION

Steel structure deconstruction is an innovative shift within the construction industry (Yeung et al., 2017). Which is also centered on selective disassembly techniques to preserve significant structural steel members intact for reuse, rather than re-melting or downcycling (Price, 2025). Contrary to the conventional demolition process, deconstruction aims at longer material lifecycles, less landfill wastes, and making significant reductions in embodied greenhouse gas (GHG) emissions (Andisheh, 2024). This paradigm is consistent with the principles of circular economy and sustainability, particularly if DfD methods are used in the early phases of the design process (Berglund-Brown & Ochsendorf, 2025). Empirical research has indicated that even in structures originally not designed for disassembly, steel components can be recovered satisfactorily and reused in new construction activities if adequate documentation, procurement planning, and fabrication procedures are adopted (Gorgolewski et al., 2008). Such research has shifted the academic discussion from feasibility assessment to optimization and upscaling of steel reuse systems.

5.1 CIRCULAR CONSTRUCTION POTENTIALS OF STEEL

The current literature explains the fact that steel has a great potential for supporting circular construction practices thanks to its recyclability, reusability, adaptability and high material recovery value (Hradil et al., 2024). The environmental benefits of reusing and recycling steel have been clearly established, particularly its capacity to reduce greenhouse gas emissions, save embodied energy, and support the construction sector's carbon neutrality targets (Berglund-Brown & Ochsendorf, 2025).

Furthermore, the literature identifies the successful implementation of steel deconstruction being influenced not only by the material properties of steel but also by supportive design, technological and market-based approaches (Dunant, 2018). Design for disassembly principles, such as modularity, standardisation and use of dismountable connections, allow for efficient dismantling and material recovery (Tleuken et al., 2022). Simultaneously, digital technologies such as BIMfD (Building Information Modelling for Deconstruction), enhance the traceability, documentation of materials, and deconstructability assessment, allowing for improved decision-making throughout the building lifecycle (Jayasinghe & Waldmann, 2020).

Moreover, prior research highlights a range of economic and industrial applications linked to steel deconstruction, including the establishment of certification systems, circular supply chains, and digital platforms for trading reclaimed steel components (Basta et al., 2020; Davis et al., 2024). The literature reviewed therefore shows that steel deconstruction is an integrated strategy that combines environmental sustainability, (Rios et al., 2015) technological innovation and circular material management in the built environment (Gorgolewski, 2006). Table 3 summarises the advantages and applications of steel DfD reported by various authors.

Table 3: Advantages and applications of steel DfD

Category	Advantages / Applications of Steel Deconstruction and DfD	References
Environmental Benefits	Steel recycling and reuse through deconstruction significantly reduce greenhouse gas (GHG) emissions and environmental impacts compared to conventional recycling and landfilling methods.	(Yellishetty et al., 2011), (Berglund-Brown & Ochsendorf, 2025), (Ranasinghe et al., 2025), (Zoghi et al., 2022)
Embodied Energy Conservation	Reuse preserves the embodied energy and material value associated with rolling, fabrication, and machining processes, achieving greater carbon and energy savings than recycling.	(Dunant, 2018), (Davis et al., 2024)
Contribution to carbon neutrality	Steel deconstruction supports carbon neutrality goals in the construction industry by minimizing embodied carbon emissions and maximizing material recovery.	(Dunant, 2018), (Yellishetty et al., 2011)

Category	Advantages / Applications of Steel Deconstruction and DfD	References
Circular economy integration	Steel structures support circular economy principles through recyclability, reusability, adaptability, and material value retention.	(Gorgolewski, 2006), (Basta et al., 2020)
Design application under DfD	DfD promotes modular construction, standardized components, and bolted/dismountable connections that facilitate easier dismantling and reuse.	(Bartsch, 2025)
Digital application	BIM for Deconstruction (BIMfD) enables material tracking, salvage value assessment, traceability, and deconstructability evaluation for optimized recovery solutions.	(Jayasinghe & Waldmann, 2020)
Quality assurance applications	Steel reuse requires documentation, provenance tracing, inspection, and non-destructive testing to ensure structural performance and safety compliance.	(Kanyilmaz et al., 2023),
Economic benefits	Reused steel can become cost-competitive under favourable conditions such as shorter transportation distances and limited testing requirements.	(Dunant, 2018), (Basta et al., 2020)
Market and supply chain applications	Development of digital marketplaces, certification systems, and circular supply chains can normalize steel reuse practices within the construction industry.	(Kanyilmaz et al., 2023), (Dunant, 2018)
Industry transformation	Steel deconstruction supports the transformation of the construction industry towards sustainable and circular material economies.	(Bartsch, 2025)

5.2 DEMAND OF REUSING STEEL IN CONSTRUCTION

The reuse of structural steel presents a distinct opportunity to minimize embodied carbon in buildings, as direct reuse bypasses the energy and heavy emission processes of remelting and re-rolling scrap (DBM Vircon, 2024). Current studies highlight that reuse often results in greater life-cycle environmental advantages compared to recycling, as long as reuse recovery rates and transportation and processing impacts are effectively handled (Bartsch, 2025).

The demand for recycled steel is influenced by three interconnected factors (Hart et al., 2019). Initially, regulations and corporate decarbonization goals enhance the motivation to obtain materials with lower embodied carbon. Research modelling the circularity of steel indicates that policy; procurement regulations, reuse objectives are crucial for generating consistent demand (Davis et al., 2024). Secondly, cost indicators, when the expenses of demolition, deconstruction, and refurbishing are on par with new production or when new steel prices increase, reuse gains commercial appeal, yet studies indicate this is significantly influenced by context and is sensitive to logistics and labour expenses (Temmerman et al., 2012). Client preferences and sustainable procurement in construction are generating a specialized demand for verified reused materials, encouraging supply-chain investment and intermediary entities that can facilitate the exchange of reclaimed inventory (Tingley et al., 2017).

5.3 PRACTICALITIES AND BARRIERS TO IMPLEMENTATION

Research and project case studies highlight various persistent practical obstacles that hinder extensive reuse of steel. Some of the major barriers can identify as inventory and alignment, salvaged pieces from demolition vary in size, quality, and state, complicating their alignment with designers' standard specifications without considerable refabrication or innovative design adjustments (Bartsch, 2025). Deconstruction compared to demolition methods influences yields: meticulous deconstruction enhances reusable yield but raises time and labour expenses (Yeung et al., 2017).

According to Bartsch (2025), standards, certification, and structural traceability present significant challenges. The absence of standardized guidelines for certifying the suitability of reclaimed components (bolt configurations, remaining section capacity, connection details, fatigue lifespan) creates liability issues for engineers and insurers. Recent evaluations urge the establishment of standardized assessment protocols and material passports to record history, grading, and testing to close trust gaps (Akbarnezhad, 2014).

Additionally, in the perspective of economical practicalities, several life-cycle assessments (LCAs) and business-case studies indicate that the environmental advantages of reuse may be diminished if transport distances are extensive, if significant reconditioning is necessary (such as sandblasting, re-coating, non-destructive testing), or if extra embodied emissions result from changed structural details. Therefore, local supply chains, disassembly-focused reversible design, and prefabrication methods enhance practicality (Bartsch, 2025).

Past studies also indicate that reuse of steel is still low across countries and markets. The survey and case-study research by (Tingley et al., 2017) measured the low historical rates of reuse while also identifying technical and institutional factors that enhanced reuse in particular projects. Recent studies support the use of digital tools such as; material passports, searchable reclaimed inventories and procurement incentives to consolidate demand and lower transaction expenses. Summary of identified barriers and challenges to implement DfD for steel structures has provided in Table 4.

Table 4: Practicalities and barriers to implementation of DfD in steel

Category	Identified Barriers / Challenges in Steel Reuse and Deconstruction	References
Inventory and Component Compatibility	Salvaged steel components vary in size, quality, and condition, making it difficult to align them with standard design specifications without additional refabrication or design modifications.	(Bartsch, 2025)
Time and Labour Requirements	Careful deconstruction methods improve reusable material yield; however, they increase time consumption and labour costs compared to conventional demolition practices.	(Yeung et al., 2017)
Standards and Certification Issues	The absence of standardized certification guidelines for reclaimed steel components creates uncertainty regarding structural suitability, safety, and liability among engineers and insurers.	(Dunant, 2018), (Bartsch, 2025)

Category	Identified Barriers / Challenges in Steel Reuse and Deconstruction	References
Lack of Structural Traceability	Limited availability of material history, grading records, and testing documentation reduces confidence in the reuse of reclaimed steel components.	(Akbarnezhad et al., 2014)
Need for Material Passports and Assessment Protocols	Existing studies emphasize the importance of standardized assessment protocols and material passports to improve trust, traceability, and quality assurance in reclaimed steel reuse.	(Bartsch, 2025), (Akbarnezhad et al., 2014)
Transportation and Reconditioning Costs	Environmental and economic benefits of reuse can decrease when transport distances are high or when extensive reconditioning processes such as sandblasting, recoating, and testing are required.	(Bartsch, 2025)
Supply chain limitations	Lack of localized supply chains and inadequate disassembly-oriented design practices reduce the practical feasibility of steel reuse.	(Bartsch, 2025)
Low market adoption	Historical reuse rates of steel remain low across many countries and construction markets despite the recognized benefits of reuse practices.	(Dunant, 2018), (Tingley et al., 2017)
Technical and institutional constraints	Technical limitations and institutional barriers continue to hinder the wider adoption of reclaimed steel reuse practices.	(Dunant, 2018), (Tingley et al., 2017)
Limited digital integration	Insufficient use of digital tools such as material passports, searchable reclaimed inventories, and procurement incentive systems limits efficient material recovery and market coordination.	(Bartsch, 2025), (Tingley et al., 2017)

5.4 DECONSTRUCTION INFORMATION REQUIREMENT FOR STEEL TOWARDS ENHANCING CIRCULARITY

Figure 1 shows the conceptual framework for DfD information requirement for CE while Figure 2 shows the theoretical framework that explains the link between DfD principles, information requirements for sustainable deconstruction and how this contributes in circularity (circularity dimensions). However, this is high end framework and component level information is required to develop a more accurate material passport. The process model mainly consists with three sections. DFD principles need to be considered at the design stage and then key information requirement for DFD. Having designed the product by using appropriate deconstruction information the product will achieve circularity dimensions at the end of its effective lifecycle. This framework needs further development in components level and also needs its usability in Sri Lankan context which are yet to undertake during the MPhil.

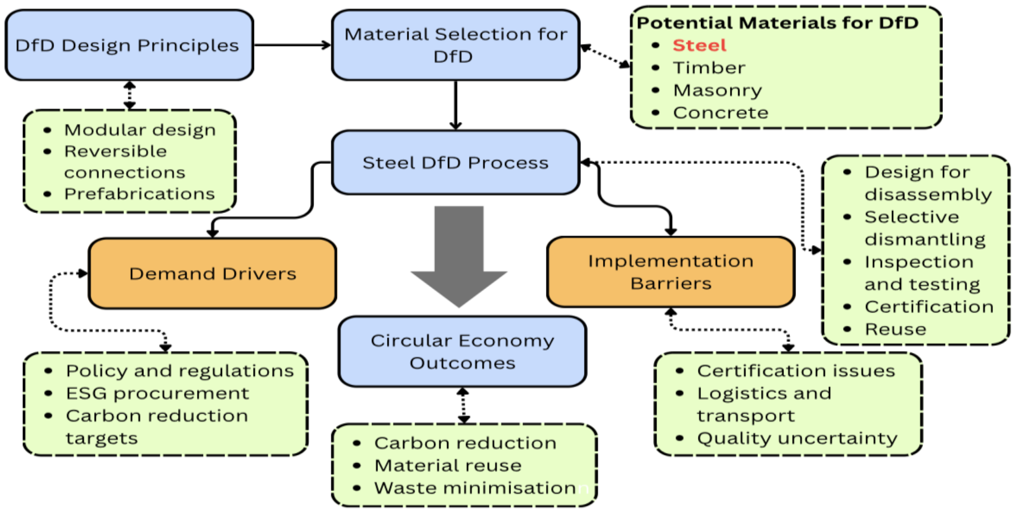

Figure 1: Conceptual framework for DfD information requirement for circular construction

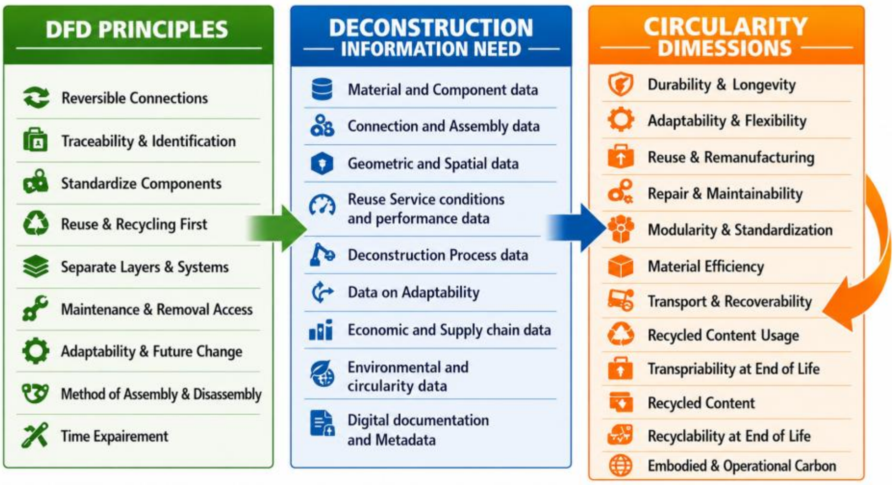

Figure 2: Theoretical framework for DfD information requirement for circular construction

6. DISCUSSION

The study explains deconstruction information needs of steel structure towards achieving a circular construction. Steel structure is used in the preliminary framework development as it covers most of the DfD principles such as recyclability, reusability, structural adaptability and compatibility with reversible connections, thus contributing to circular economy goals as illustrate in figure 2. Steel reuse is improved by integrating DfD with technologies such as digital traceability, material passports, and Building Information Modelling for Deconstruction (BIMfD). This emphasises that for steel DfD deployment to be successful, digital systems, standardised documentation, and integrated supply chains are essential. However, there are obstacles, such as the need for certification, the uneven quality of recycled parts, the absence of standard procedures, the expense of transportation, and the lack of market trust. The economic feasibility of salvaged steel applications is further reduced by the lack of regional supply chains and insufficient market infrastructure. According to this study, earlier studies on steel for DfD have been dispersed among a number of viewpoints, including economic and environmental ones. By consolidating these viewpoints, the study provides a comprehensive understanding of the applicability of steel structures in DfD, serving as a critical foundation for future research in deconstruction-oriented design and circular construction practices.

7. CONCLUSIONS

This research explored the capability of steel frameworks for Design for Deconstruction (DfD) and their role in circular construction. The results show that steel ranks among the best materials for DfD because of its strength, ability to be reused, recyclability, flexibility, and suitability for reversible connection systems. Alongside its ecological and financial advantages, steel reuse can greatly enhance carbon reduction and resource efficiency in the constructed environment. The review results emphasizes that effective steel deconstruction relies on both material characteristics and efficient information management, digital traceability, along with the incorporation of DfD principles in the design phase. As regulatory pressure intensifies, procurement driven by ESG principles and decarbonization goals is generating demand for reused steel; however, obstacles like certification demands, traceability problems, logistical limitations, and market unpredictability persist in obstructing extensive acceptance. Consequently, the research suggests a conceptual framework connecting DfD principles, deconstruction data needs, and circular economy results. Moreover, this study is limited to the review of steel structures. Therefore, the findings may not fully represent the technical, regulatory, and market conditions associated with other construction materials or different geographical contexts. This paper lays the groundwork for creating a Deconstruction Information Model (DIM) for steel structures and facilitate upcoming studies on component-specific information needs and digital resources to improve steel reuse and circularity in the construction industry.

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