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# DESIGN STRATEGIES TO MINIMIZE WASTE

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By

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DESIGN STRATEGIES TO MINIMIZE WASTE
(FOR A SUSTAINABLE FUTURE)

A THESIS APPROVED FOR THE

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## LIST OF SYMBOLS / ABBREVIATIONS

| | |
|---|---|
| EPA | Environmental Protection Agency. |
| WMS | Waste Management Strategies. |
| Sustainability | Balance between environment, equity, and economy. |
| Waste | Heterogeneous building materials from different types of construction activities. |
| WM | Waste Management. |
| Debris | Rubble, ruins, and litter from construction activities. |
| Demolition | Destroying or wrecking of any structure. |

## ABSTRACT

This research study is focused on obtaining waste minimization strategies that designers can apply to their projects. With a rapid increase in construction recently, the high production of waste produced is dumped in landfills after being used without segregating them with hazardous material or considering if the material can be re-used.

This paper considers how designers globally focus on environmentally responsible designs and the appropriate ways designers reduce material waste. This research will help understand what techniques designers can use in the name of environmentally sustainable design practices to practice waste minimization. The paper will consist of information about waste management strategies and the tools to assess the sustainable factors and explain the principles of using resources efficiently in the design stage; these factors are reviewed by describing how the designers can achieve these techniques in the design process. These factors are obtained with the help of survey responses and a literature review. Qualitative methods were used for the research. For analyzing the survey responses, descriptive analysis is chosen. This study is a step to create awareness for the designers to adopt and implement waste minimization strategies for a sustainable future.

**Keywords:** Waste minimization strategies, sustainable design, sustainable interior design, construction waste, design waste, circular economy, factors affecting material

# 1.INTRODUCTION

## 1.1 Background:

The construction market has increased significantly, in the industry, with around 1.6 trillion U.S. dollars in 2021, including private and public construction. It is expected to increase in the next few years (Statista, 2022), affecting the air quality from the chemicals which are caused due to furnishing and finishes in interiors and exteriors; it is affected due to the manufacturing or installation of materials and during material disposal. The effect of climate change and the health of occupants has led the United States government to introduce the Resource Conservation and Recovery Act (RCRA) in 1976 (Statista, 2023), which is regulated by the Environmental Protection Agency (EPA). EPA was introduced in 1970 to eliminate hazardous waste, protect the environment from chemicals in materials, and prevent hazardous waste from being dumped in landfills. In 1980 the government closed all the loopholes concerning waste management. In later years, considering the negative environmental impact, the United Nations released sustainable development goals to focus on the built environment and eliminating hazardous disposal (UN, 2015). By 2018 there were 600 million tons of construction and demolition (C&D) debris generated in the United States, which is twice the amount of

solid waste generated at the same time; approximately 455 million tons of C&D debris were directed to subsequent use, and about 145 million tons were disposed into landfills. This waste was caused due to the rise in construction, which was 342% from 1990 to 2018(U.S. Environmental Protection Agency Sustainable Management of Construction and Demolition Materials, 2018). However, the government took the initiative in 2018 for all new construction to contribute just 5.5% of all U.S construction waste which ended up with 76% of all the waste being recovered and recycled (U.S. Environmental Protection Agency Sustainable Management of Construction and Demolition Materials, 2018.

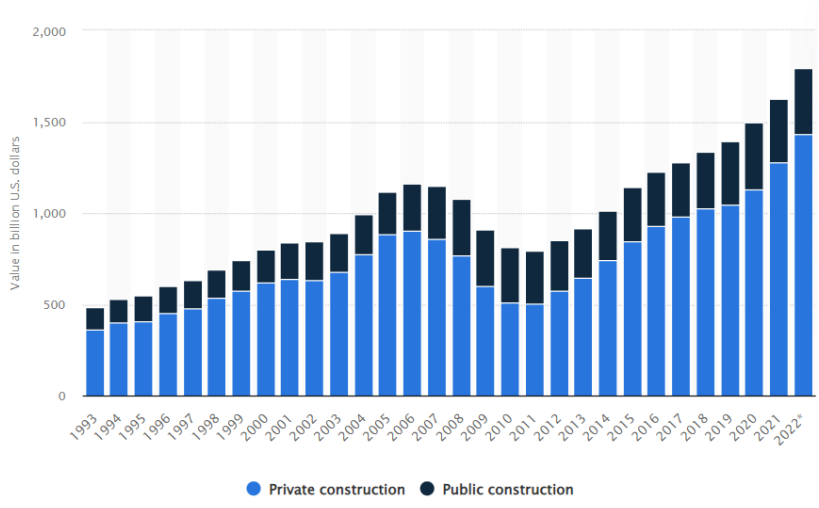


Image 1: Public and private construction spending in the United States from 1993-2020 (In Billion U.S dollars) (Source- Statista)

The consciousness of the environment and public health has led to the development of waste reduction strategies in design; according to Cargo (2013), During the initial days ‘the interior design profession was considered for designing appealing spaces; over 25 years, the design industry has seen a new phase of design strategies being implemented due to occupants’ health and increase waste contamination; with the increase in the environmental crisis; designers started to focus on implementing sustainable concepts and create environmentally responsible designs, the awareness on the interior environment has led to an introduction to sustainable design. The primary purpose of introducing sustainability was to control energy and waste in building construction; sustainability awareness emerged during the late 1960s, and the sustainability concepts’ progress was defined in 1999 (Cargo, 2013).

The concept of “sustainable design” is a broad framework that aims to support the well-being of the planet's ecosystem for future generations. “Sustainable interior design” is a process where the materials used in the interior space create a diminished negative impact on the occupant (Guerin & Kang, 2009). Under the sustainable umbrella falls the waste minimization Concept; the waste in interior design is the result of inefficient use of resources in the aforementioned interior space; 75% of the waste is produced from construction, such as bricks, tiles, clays, wood,

and drywall ends up in landfills, the material such as asphalt and concrete pay 95% of waste contributors To create a favorable ecological structure (EPA, 2018), “waste minimization” is defined as limiting the sources of hazardous waste and utilizing them by reusing them properly.

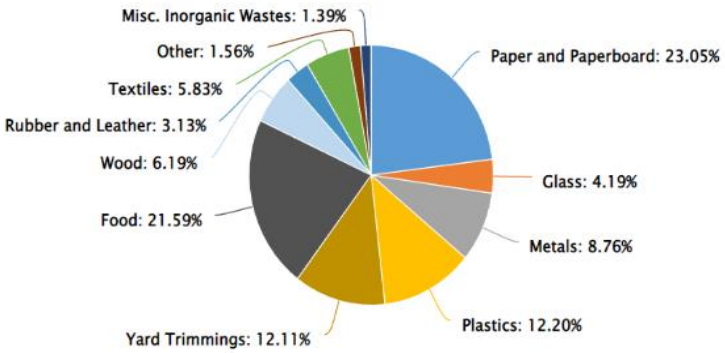


Image 2: Total municipal SW generated by materials in 2018 (EPA, 2018)

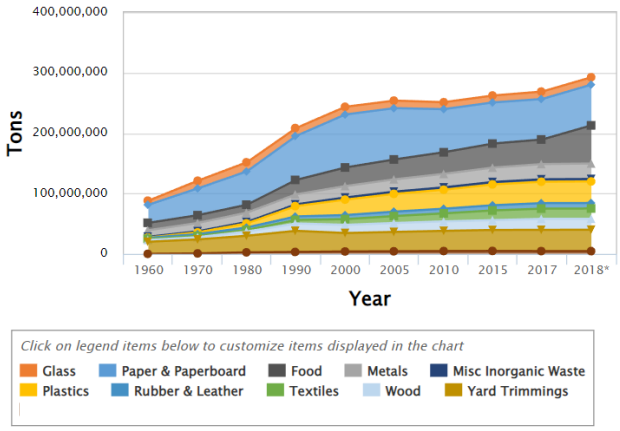


Image 3: Total municipal solid waste generated by materials from 1960 - 2018 (EPA, 2018)

Despite the increase in waste, one of the neglected sustainable developments in interior design is focusing on minimizing construction waste; this is due to the lack of importance given by the project team, which includes clients, architects, contractors, plumbing, and various people involved in multiple stages of construction. Waste management should be implemented as designers have control over construction waste regardless of whether they are pursuing any certification; they can work with contractors and other stakeholders to implement waste reduction strategies and promote sustainability throughout the process.

Table 1: Above table explains the design team's role and responsibilities and waste generation responsibilities. (Author, 2023)

| Who | What | Responsibilities towards wastage |
|---|---|---|
| Client | Owner with the power to on the property and responsible for financial decision-making. | - Last-minute changes by the clients lead to alteration and demolition, which leads to the wastage of materials.<br>- Due to a lack of |

| | | |
|---|---|---|
| | | communication with designers.<br>- Insufficient knowledge regarding services provided |
| Architect/designer | Architects/ designers take responsibility for fulfilling the owner's obligations and creating interior space layouts. | - Due to changes during the construction phase.<br>- Poor site layout<br>- Due to excessive material procurement<br>- Lack of communication with clients during the design stage. |
| Contractor | The contractor must ensure the site's workflow and health and safety risks. | - Improper way of managing vendors and traders.<br>- Managing materials |

| | | |
|---|---|---|
| | | usage.<br>- On-site operations |
| Stakeholder | Stakeholders' involvement in the project results in successful execution. | - Lack of knowledge on the project leads to changes and re-construction. |
| Project manager | The project manager collaborates with engineers, Architects, and other roles involved in the project. | - Failing to coordinate with other workers on the project team.<br>- Lack of planning the project according to the budget. |
| Labor | | - Re-work due to labor mistakes<br>- Improper cutting of materials |

This study highlights the strategies and techniques the interior design team can implement in the United States to prevent wastage during construction and eliminate the increase of landfills.

### 1.2 Interior designer's contribution to waste minimization

Interior designers are essential in waste minimization as they are involved throughout design planning until construction. Using traditional construction practices helps create a positive effect and good impact on the life cycle of the building. Moreover, it increases the quality of occupant life; in recent times, most of the materials used in interior spaces are unhealthy and are affecting the occupants; these types of buildings are known as "sick building syndrome." Material selection is essential as it is responsible for the air quality in interior space as well as it also plays an important role when the material is disposed into a landfill during demolishing; having sustainable materials helps achieve healthy indoor air quality and create a healthy environment by protecting, preserving, and restoring the global ecosystem. The increase in the usage of eco materials in interior space can be done quickly nowadays with available resources, which helps to improve indoor air quality (IAQ). The use of eco materials should be encouraged to lower the construction cost and reduce hazardous waste; products that contain a highly volatile organic compound (VOC) should often be avoided as they contain harmful

chemicals and are dangerous even after being disposed of. Below are the ways to choose non-toxic building materials.

Natural materials: Materials like raw lumber, clay plaster, and clay mortar, in general, are not processed; this is why they act as the best option for building construction.

Environmental claims: Some materials are considered green but toxic as they might contain harmful substances, so it is essential to evaluate building material content when provided by manufacturers. It is also important to check the label to see how much recycled material contains.

Re-using materials: Reusing materials is advisable as new materials contain chemicals that promote boosting the environment.

Interior designers should take the necessary steps while selecting materials to reduce health risks among the occupants in the built environment and lessen the dumping of hazardous waste in landfills; geographical location also plays a crucial role in selecting materials.

Designers should adopt environmental design by taking the initiative to minimize waste through reuse, recycling, and reducing materials and promote using recycled and reclaimed products.

## 1.3 Problem Statement

In most cases, interior designers consider implementing waste management strategies in their design; however, only a few designers are implementing it in their projects; fewer designers are restricted due to barriers such as a lack of knowledge regarding waste management, lack of exposure during their education related to the design field, lack of client interest, and cost constraints and many more. (Ashour, 2022). In the United States alone, 170,000 commercial buildings have been under construction, and 44,000 structures have been torn down as sustainable failure buildings (U.S. Environmental Protection Agency Green Building Workgroup, 2004). With the increase in building construction, it is necessary to accelerate designers' practice toward sustainability and to manage vast amounts of waste produced from these multiple constructions. Most existing research studies highlight waste produced during construction waste (Ekanayake & Ofori, 2004; Nagapan Rahman, 2014; Magalhães, Danilevicz, and Saurin, 2017). Still, limited studies are focusing on explaining the importance and strategies that can be used to minimize waste; more investigation is necessary to address the waste issue; these previous studies have stressed more on the output that is caused by the wastage; in reality, most of the wastage can be stopped during the design stage instead of implemented during the construction

stage can help in achieving designing out of waste which plays a vital role in waste management (Ajayi et al., 2018 a, Magalhães, Danilevicz and Saurin, 2017)

**1.4** Significance of Study:

This study's purpose is to create awareness of available strategies for waste minimization in interior design and the importance of waste management; the overall study will act as a guide for the designers to achieve potential ways of achieving waste minimization in interior design; The survey findings can act as a reference point for future designers to refer to the causes and how to overcome those barriers and create a better design for future projects.

**1.5 Research questions:**

1. Strategies to minimize waste in design practice?
2. What are the barriers faced by design to achieve waste minimization?
3. Which project phase contributes to the most material waste?

**1.6 Research Purpose:**

This study creates awareness of environmentally responsible designs and the appropriate ways designers can reduce waste.
This research aims.

i. To explain the most appropriate ways interior designers can use the available strategies to minimize waste.

ii. To focus on challenges designers face during project implementation.

iii. To determine the tools to assess sustainable factors.

iv. To focus on the strategies that can be implemented during the design phase to minimize waste during construction.

v. This study generalizes waste minimization strategies used in the whole country with the help of survey findings.

The overall study aims to create awareness of a broad understanding of the sustainable practice to promote waste minimization strategies and preserve resources through the design stage.

## 1.7 Literature gap

In existing studies knowledge gap exists in addressing how designers can reduce waste and how it will affect their practice; moreover, the other research study focused on various kinds of sustainable interior design strategies, and there are minimal papers focusing solely on waste

minimization strategies in interior design which are of 15 years old. In addition, many studies have shown waste minimization in the construction stage and sources and causes of waste during construction; still, there need to be more studies focusing on waste during the design stage and how the waste can be controlled.

# 2. LITERATURE REVIEW

## 2.1. Introduction:

This section represents the studies addressing how to overcome the obstacle concerning waste minimization and creating a path for sustainable approach design practice. Various opportunities can be used for the sustainable design approach, and one of them is implementing strategies to minimize waste in design. This chapter gives an understanding of sustainability strategies and what role designers have in sustainability. Further illustrates the relation between sustainability and waste minimization by explaining the strategies to minimize waste in interior design practice.

## 2.2. What is sustainability?

Sustainability is known for being capable of maintaining ecological balance. In recent years the term “sustainability” has gained much popularity. The whole reason for implementing sustainable concepts is to balance environmental and social issues (Kang,2004).

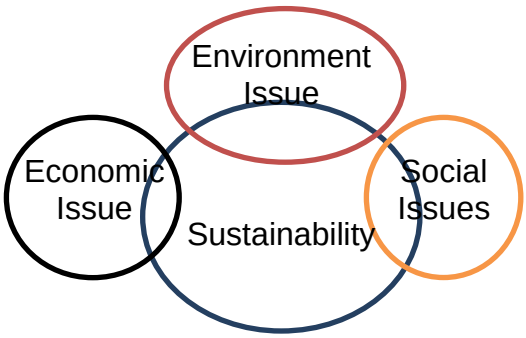

Image 4: The image explains the involvement of sustainability in balancing economic, environmental, and social issues. (Author, 2023)

The post-industrial revolution has led the world towards rapid industrialization, which involved producing heavy and cheap building techniques, leading to the destruction of the environment. During the post-industrial revolution, the construction scale grew as most people migrated to cities (image 5).

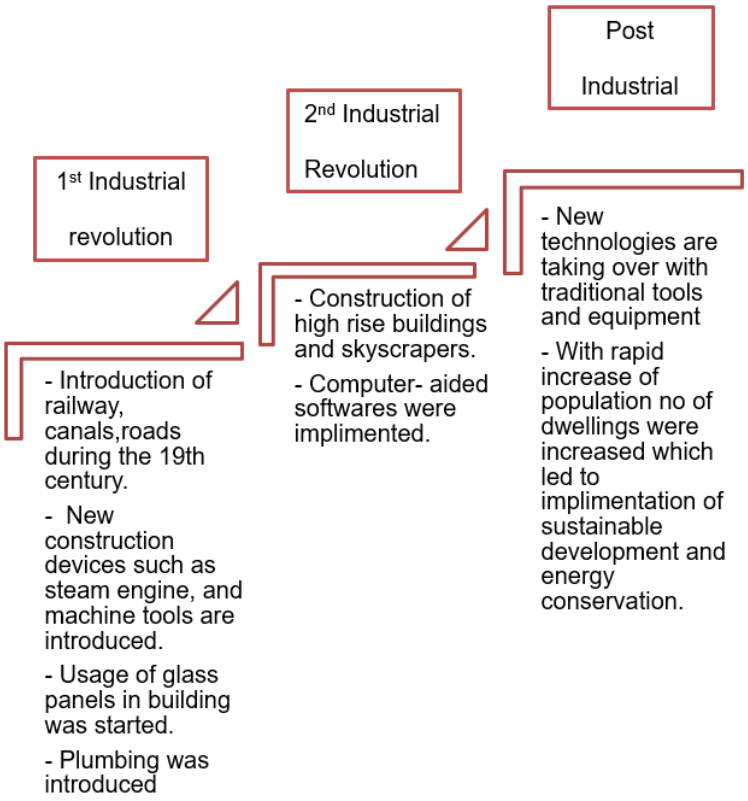


Image 5: The image explains how the industrial revolution changed the construction industry.

Over the years, several initiatives have been taken to implement sustainable concepts concerning environmental issues. Thomas (2015) implies that sustainability refers to the action of human activities to satisfy human needs while not exhausting the vast resources available. Image 5 illustrates the roadmap of initiatives taken between the 19$^{th}$ and 20$^{th}$ centuries to meet sustainable and green building goals. Understanding the growing environmental concerns, the government initiated an agency during the 1970s known as EPA (Environmental protection agency). The agency needed better ground to set the standards during the initial stages. In later years, it began to make a significant impact on controlling the environment by designing acts, eliminating the products affecting the environment, and avoiding hazardous waste. Throughout,80’s it has strengthened laws and governed air & water quality to control toxic substances; from the ’90; organizations and technologies were introduced, such as WELL. BREEAM, USGBC, etc., to create environmental awareness in the design industry.

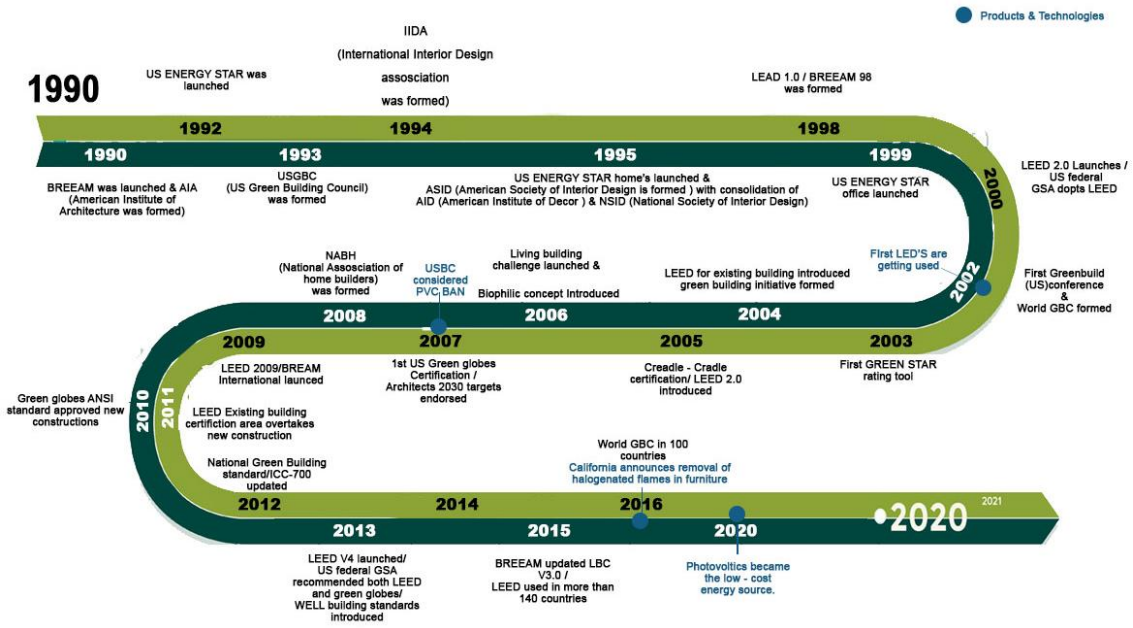


Image 6: explains the roadmap of sustainable development and the green building movement over the years (Source: Greenbuilding.com, Author, 2023).

### 2.2.1 SUSTAINABLE INTERIOR DESIGN PRACTICE

According to ASID (American Society for Interior Designing), an interior designer's responsibility is to reverse the negative impact that is caused due to climate change can be healed by taking responsibility for reducing resource consumption, eliminating chemical emissions, and creating awareness of a circular economy.

To create interior furnishing, material & finishes, a certain number of natural resources are extracted, which involves the process from extracting to disposal, as shown in image 6.

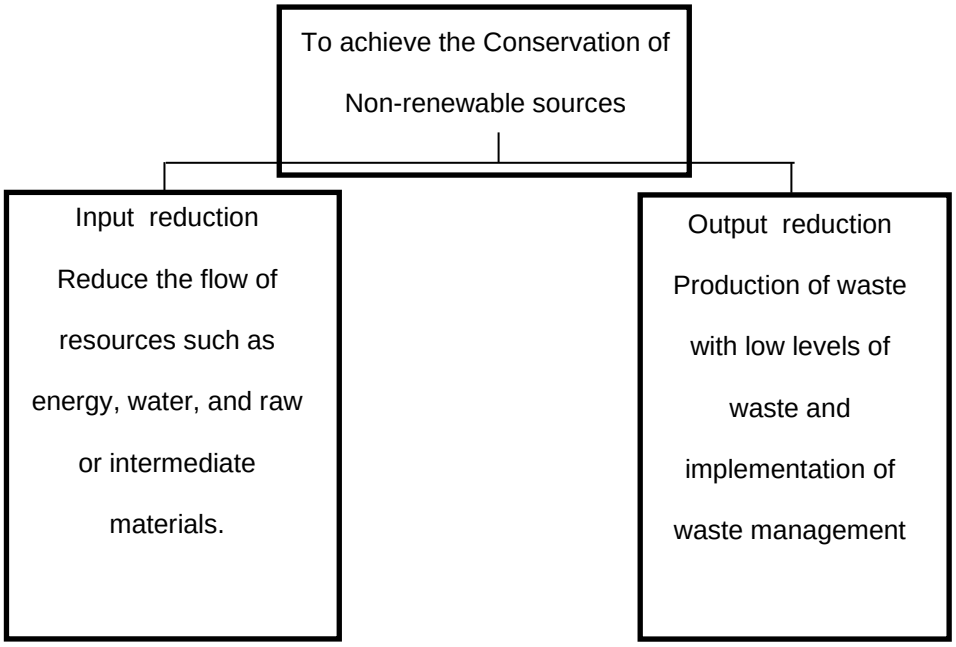


Image 6: Explains the conservation of non–renewable resources through input and output reactions (Kang, Gurn, 2009).

To achieve environmentally sustainable design, the designer should view the environmental issue as a design criterion in the interior design process; this will help control construction waste, reduce the hazardous waste in landfills, and improve environmental benefits.

### 2.2.2. STRATEGIES FOR SUSTAINABLE DESIGN

Many of the best designers have faced challenges when implementing sustainability. A survey designed in 2010 by USGBC explains that understanding people, projects, and accurate information could positively impact the built environment (Pyke, McMahon, & Dietsch, 2010). Wanamaker (2018) explains the three domains' importance of the interconnected notions formed so that the other principles are reflected by involving one principal design (image 7).

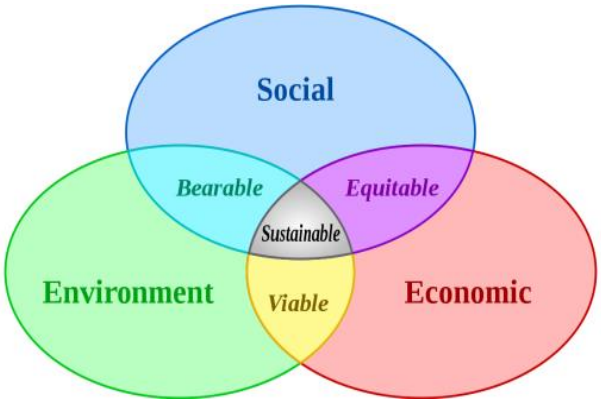


Image 7: Explains the social, economic, and environmental interconnection (Wanamaker, 2018).

i) Factors causing environmental issues: Many issues affect the environment, including pollution and degradation of natural resources such as water, soil, air,

and noise pollution. Global warming has become a significant challenge and a barrier to sustainable development. Greenhouse gas emissions, fossil fuel emissions, and depletion of resources and raw materials are also critical concerns. Additionally, the effects of illegal dumping in local communities must be addressed.

ii) Factors causing economic Issues: The expenses related to materials, energy, water, labor, equipment, waste transportation, and disposal costs are all critical considerations. The prices of filling valuable land with construction and demolition waste and the expenses related to reuse and recycling should also be considered.

iii) Factors causing social factors: The collection, sorting, and disposal of construction and demolition waste (C&DW) can have short- and long-term impacts on health and safety. It is also essential to consider the attitudes of project stakeholders towards C&DW management, as well as the shifting public perception and awareness of C&DW issues. Incentives can play a critical role in preventing illegal dumping of C&DW. Additionally, the

aesthetic impacts of recycling plants and stockpiled materials should be considered.

With the help of the above principles of interconnected notions, table 2 explains a few steps that can be taken toward environmental design strategies for designers to monitor or support their design solutions in the form of material selection, health criteria, waste management, resource management, and design components.

Table 2: Literature Summary Table: summary of sustainable strategies

| Design solution | Author |
|---|---|
| i) Material selection | |
| Evaluate manufacturers that supply sustainable materials. | Ruuska, Häkkinen, 2014.<br>Sabnis, Pranesh, 2017. |
| Product impact on the environment | Health product declaration, 2017 |
| Sustainable certification | Stelmack., Foster, Hindman, 2014,<br>Bacon, L, 2011 |
| Product lifecycle assessment | Kang, 2009 |

| | |
|---|---|
| | Ceschin, Gaziulusoy, 2016 |
| i) Health criteria | |
| | |
| Chemical exposure control | Sabnis, Pranesh, 2017.<br>Stelmack., Foster, Hindman, 2014 |
| Biodegradable products | Tucker,2014 |
| ii) Waste minimization | |
| Design adaptability | Kang, 2009<br>Ruuska, Häkkinen, 2014. |
| Durability | Fadaei, Iulo, Yoshida,2015<br>LEED, 2017 |
| Reduce packaging | Stelmack., Foster, Hindman, 2014 |
| Recyclable materials | Tucker, (2014).<br>Yu (2015) |
| Adaptive reuse | Celadyn, 2019 |
| Efficient construction methods | Ruuska, Häkkinen, 2014<br>Stelmack., Foster, Hindman, 2014 |

## 2.3. WASTE IN INTERIOR DESIGN

### 2.3.1. Interior design process

The design has a more significant influence on the construction as project considerations are finalized way ahead. Managing waste on-site is the most recognized practice, but the waste during the design is usually neglected; due to this, 33% of waste on-site is generated (Ajayi & Oyedele, 2018a; Li et al., 2015; Wang et al., 2015). However, identifying waste management strategies to eliminate waste during the design process will help to improve project performance.

Table 3: Explains interior design process from design to construction stage (Author, 2023)

| | | |
|---|---|---|
| | Brief | - Client briefing<br>- Client interests<br>- Project requirements<br>- Budget |
| | Design development | - Concept<br>- Research<br>- Sketching<br>- Visual boards |

| | | |
|---|---|---|
| Design/<br>Pre-construction stage<br>↓ | | - Preliminary drawings<br>- 2D drawing.<br>- 3D models<br>- Estimates draft.<br>- Site visits |
| | Planning | - Construction drawings<br>- Schedules<br>- Permits<br>- Site visits<br>- Budget check |
| Construction stage<br>↓ | Construction | - Site visits<br>- On-site markings<br>- Material procurement<br>- Construction<br>- Project handover |
| → Wastage to landfill | | |

2.3.2. Causes of waste in interior design practice

The above table mentions that the interior design process involves various stages. Working professionals are responsible for a particular role

and can generate waste at any stage. Waste caused at each stage of interior design is summarized as follows:

I. Wastage during the design stage: During the design stage, waste can be caused by inaccurate design changes. The significant effect can be due to the flaws in the contract paper, such as the lack of

    a) Scope of Work
    b) Drawings
    c) Consultants and Contractors
    d) Design Fees
    e) Cancellations
    f) Reimbursable Costs
    g) Payment Terms
    h) Insurance

II. Material procurement & Handling: This stage's waste can be due to excessive or under-ordering. Ordering material by mistake can also lead to waste as it will not be helpful to the project. The designers involved during this stage should look up material requirements and order the materials according to the requirement; sometimes, even after designers oversee the order, there might be an issue from the

suppliers. Once the materials have arrived on the site, the on-site manager should ensure the loading and unloading of the material, as they may be damaged during the process. The material should be stored properly as it can wear and tear due to extreme weather conditions.

III. On-site: During this phase, waste can also be caused due to the failure of the material or can also be due to labor. When the materials are under-ordered and need a necessary replacement, the designer should make sure to use proper replacement, or it may lead to wastage. Ensuring adequate material control and a waste management plan can lead to waste control on the site.

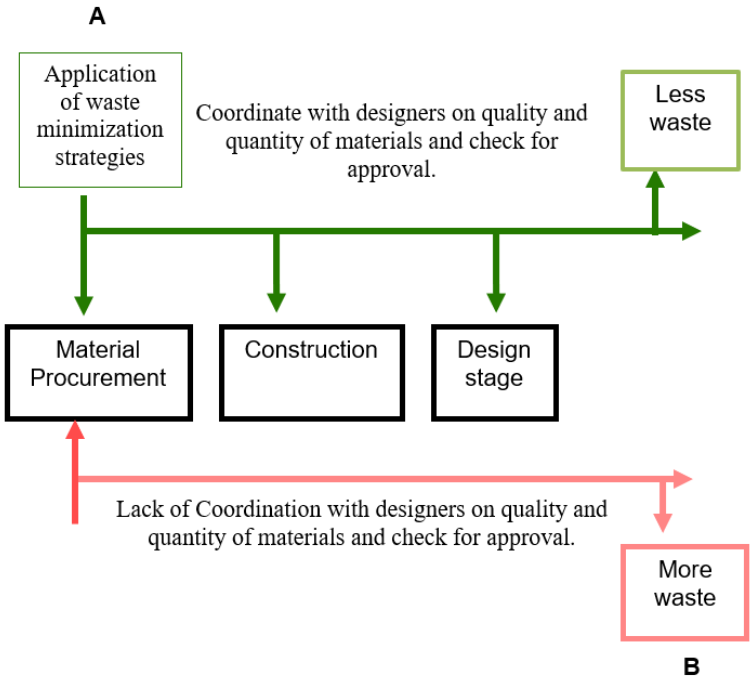

Image 8: The flow chart explains the waste arising at the design stage.

The above image explains the interior design process from design to construction and what is the best phase to implement waste management to reduce waste. There are two ways, A and B, shown in image 8, due to the incorporation of a waste minimization strategy in the design stage will help to reduce the amount of waste produced at the end of the project. In the B process, due to a lack of strategies implemented, the amount of waste produced was large, and no measures were taken. Strategies such as reusing materials on the site, maximizing material usage, and waste segregation are vital factors in waste minimization (Ajayi, 2017).

## 2.4. CONSTRUCTION WASTE

Construction waste generated from the project depends due to various circumstances. This impact is creating concern among the public as there is an increase in tremendous effects on the environment. It is essential to have proper planning developed for demolition waste management for buildings being deconstructed. The waste developed is defined as two processes, construction and deconstruction. Construction waste is caused due to the materials from building construction, whereas deconstruction is referred to waste that is caused when the building is

dismantled. In deconstruction, the process includes identifying hazardous waste from recycled and reused waste.

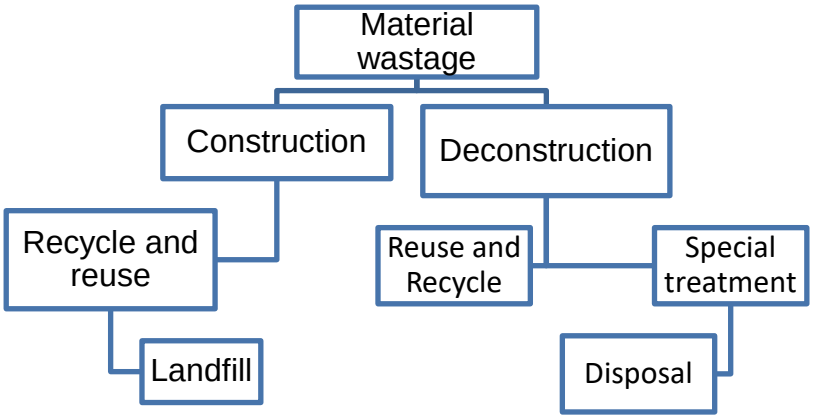


Image 9: The flow chart explains the difference between construction and deconstruction wastage and how the waste is handled (source: Ge, 2017).

### 2.4.1. SOURCES OF WASTE CONTROL:

Waste can be produced from construction and demolition, including bricks, glass, timber, concrete, Ferrous and non-ferrous metal, masonry, paper, asbestos, plastic, and timber (Image 10).

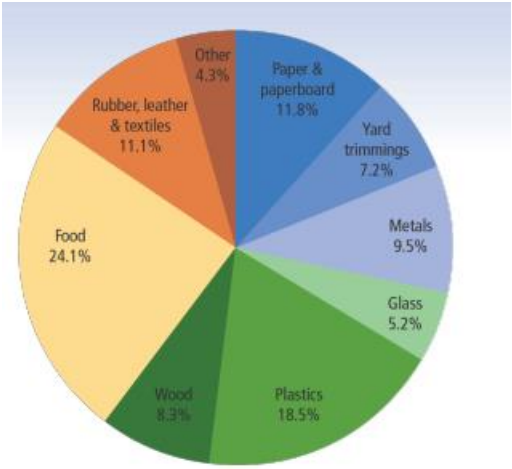


Image 10: Explains the total waste being dumped in the landfill in 2018, 146.1 million tons (EPA, 2018).

Referring to figure 10, the waste dumped in landfill is summarized; it shows that materials such as plastics, paper, and rubber are more than others, whereas materials such as wood and glass have produced less waste. Below is a brief explanation of material waste and how to control the wastage from the material source.

2.4.1.1. MASONRY:

When buildings constructed from masonry are demolished, masonry waste is produced. Instead of dumping waste into landfills, it will be recycled as masonry aggregate.

2.4.1.2. PLASTIC:

Materials can be damaged during loading and unloading, and there is the possibility of materials being damaged. To avoid damage during transportation, most fragile materials are packed in a plastic sealer; when the packages arrive on the site, these packed plastic materials result in wastage (Ajayi et al., 2017). The other type of plastic waste can be resulted from cutting plumbing pipes.

Plastic Waste can be reduced by segregating it from other contaminants. The recycled plastic waste can be used in PVC windows, panels, roofs, and floors.

2.4.1.3. TIMBER:

Timber waste is produced from the structures used for supporting the structure; consider the nature of the wood when exposed to weather conditions; it will have a lesser chance of reusing the materials (Lachimpadi, 2012). The wastage of the wood can be reduced depending on the quality of the timber. The waste can be reused in another project after adequately caring for it, cleaning, and de-nailing.

2.4.1.4. BRICKS:

Brick waste is produced from the building walls; this waste can also be produced due to transportation or during the loading or unloading of

materials. To recycle the brick waste, these are blended with other materials and can be used in the filling materials (Vasudevan, 2019).

2.4.1.5. CONCRETE:

According to Vasudevan (2019), when a new building is constructed, 18-33 kgs of concrete waste is produced; in another case, when the building is demolished, about 840 kgs of waste is generated; the other way of concrete debris is due to the lack of precast handling. Concrete can be reused as a natural replacement aggregate.

### 2.4.2. CAUSES OF WASTE GENERATION:

There are many ways to produce waste during the design and construction phases 2.5.1 and 2.5.2 explains the waste generated at each stage of design and construction, the viewing of different aspects of the process involved, such as designing contract clients, labor, etc.

2.4.2.1 WASTAGE IN THE DESIGN STAGE

Due to the lack of designers' contribution towards waste management during the design phase, 33% of waste is produced during construction (Innes, 2004). Previous studies have not explicitly addressed the causes of waste during the design stage in the literature; this study addresses as literature gap in identifying the causes and sources of waste in design stages; the sources used in the below table are 10-15 years old,

the previous studies references are used to gather all the research together for better understanding in a future study.

Table 4: Summary of design waste cause

| DESIGN WASTE CAUSES | REFERENCE |
|---|---|
| Clients briefing | Muhwezi et al., 2012. |
| Changes in design | Polat and Ballard, (2004). Poon et al., 2004a and 2004b; Kulathunga et al., 2005; Panos and Danai, 2012. |
| Designing | Innes, 2004; Poon et al. (2004a Kulathunga et al. (2005). |
| Limitations in design standards | Polesie et al., 2009 |
| Lack of experience in construction methods and process | Muhwezi et al., 2012; Panos and Danai, 2012. |
| Lack of idea in the specification | Muhwezi et al., 2012. |
| Inadequate knowledge of material procurement | Kulathunga et al., 2005; Chen et al., 2002; Innes, 2004; Poon et al. 2004b |

| | |
|---|---|
| Design constraints | Tam et al., 2007; Jaillon et al., 2009 |

The wastage during construction can be caused due to the lack of implementation of construction techniques during the design process; sometimes, the reason can be miscommunication when too many people engage in the project. Among the researchers, Poon et al. (2004) investigate the high amount of waste produced due to design rework when the construction work is ongoing. Below is the brief of waste produced due to design variation:

- Last-minute rework due to client request.
- Errors in construction documents lead to demolition or alteration in the construction process.
- Communication flaw with contractors regarding material procurement
- Uncertain weather or soil condition

During the Poon et al. (2004) research survey with 250 building designers, they found that they ranked the potential to reduce waste as the minor principal factor when selecting materials and construction methods. However, the existing literature needs more research

studies that specifically identify the design causes and sources of waste across all project stages.

### 2.4.2.2. WASTAGE IN THE CONSTRUCTION STAGE

Table 5: Causes of construction waste (Galvin & Bernold, 1994)

| WASTE AT THE CONSTRUCTION STAGE | |
|---|---|
| Construction waste | Causes |
| Contract | - Incomplete documents<br>- Errors in the contract |
| Site operation | - Poor craftsmanship<br>- Accidents<br>- Lack of supervision |
| Transportation | - Negligence during transportation<br>- Lack of protection<br>- Improper care during unloading |
| Material procurement | - Errors in ordering materials<br>- Over ordering |

| | |
|---|---|
| Material Handling | - Improper care during unloading |
| Residual & others | - Poor cutting methods for material<br>- wastage from improper cutting<br>- Packaging<br>- Weather |

The above table explains the waste caused during the construction phase. The construction waste is classified into pre-construction and post-construction stages. In these stages, different workers are involved, from stakeholders to demolition roles. Each role has its identity and significance (as mentioned in table 1).

The role of the interior designer with the construction team involves collaborating with the contractors and subcontractors while working on the project, and communication flaws with the contractors can create waste production. Below explains the designer's role in the construction process:

- Coordinating furniture installments in the space.
- Coordinate with architects regarding plan adjustments for the desired furniture.

- Helping with plumbing and lighting fixtures along with electric outlets.
- Reviewing construction documents.
- Overseeing the implementation of waste management during the execution
- Ensure proper site planning.
- Providing a proper storage system.
- Ensure quality and standard of materials by consultants.
- Use skillful workmanship.
- Ensure all the outstanding issues are resolved in the pre-design stage.

## 2.5. WASTE MINIMIZATION STRATEGIES:

### 2.5.1. WHAT IS WASTE MINIMIZATION

Waste minimization is a process of eradicating waste and is an entry point to sustainable development; it is a technique for avoiding or reducing wastage. Implementing waste minimization strategies will help gain recovery rates and meet targets. Implementing WMS during project execution will help demonstrate the firm's commitment to a sustainable environment. The following are the benefits of addressing waste.

i) Decreases emission of CO2
ii) Reduces cost of material
iii) Reduces the disposal cost.
iv) Reducing waste will result in fewer landfills.

v) Resource conservation.

When the waste is generated, it should be recycled, recovered, and treated or disposed of as it is unsuitable for recycling. When hazardous waste is dumped in a landfill, it should follow specific regulations provided by the Resource Conservation and Recovery Act (RCRA) (EPA, 2018). This practice evolves around the public concern and the need to control hazardous waste in landfill as they cause water contamination and various other hazardous formation.

### 2.5.2. WASTE MINIMIZING STRATEGIES:

2.5.2.1. Waste management Hierarchy:

To achieve the excellent practice of waste minimization, it is essential to achieve waste management in every step of the process from design to construction; the below image explains waste management in proper order. The purpose of following the hierarchy is to simplify the project process.

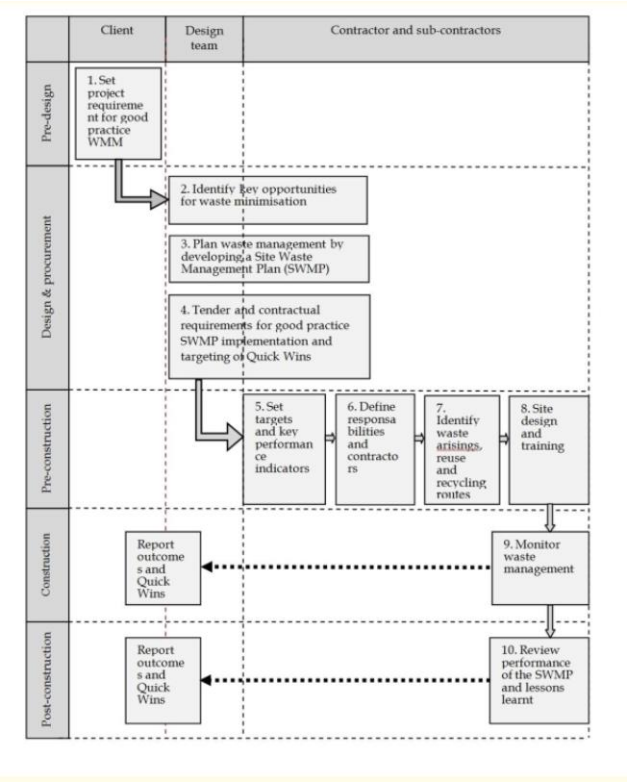


Image 11: Explains ordering of managing waste from pre-design to construction stage (WRAPa, 2009)

2.5.2.2. Circular economy:

A new, sustainable solution is required due to the production waste's increasing development. That is what the circular economy promises. A circular economy reuses materials for as long as feasible, shares resources, eliminates waste, and regenerates natural systems in place of

the make-take and the trash system that characterized 20th-century industrialism. It transforms how we create, produce, and utilize everything by reimagining the outdated system as a never-ending cycle. A circular will address various concerns, including preserving finite resources and drastically reducing waste and pollution caused due to them.

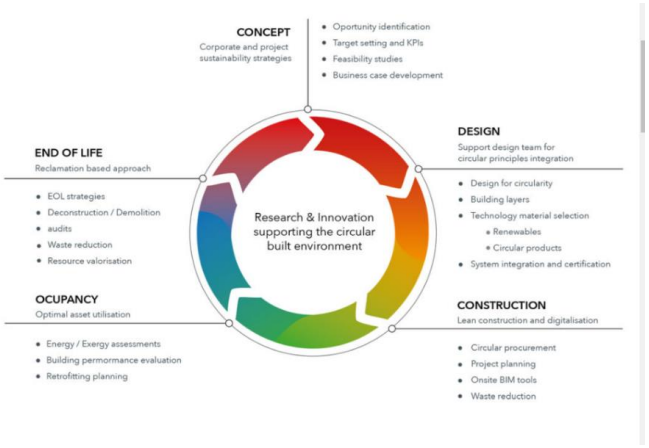


Image 12: Circular economy for the built environment, source: (Exergy, 2019)

According to Asante et al. (2021), the circular economy practice is based on the 6R principle: Reduce, reuse, recycle, recover, remanufacture, and redesign; table 6 explains the importance of the 6R principles from design to construction stage. Implementation of Circular economy (CE) at the design stage improves energy efficiency and increases the environment. Reduce and reuse is the focus of the literature

that is currently available on CE implementation strategies (Ghisellini & Ulgiati, 2020). The previous literature findings indicate that design firms should pay closer attention to CE on reduction and recovery concepts to improve the efficiency and lifespan of buildings.

Table 6: explains the importance of the 6r principles from design to construction stage source: (Asante et al., 2022).

| 6R Principle | Design stage | Construction stage | Project completion stage |
|---|---|---|---|
| Reduce | - Reduce wastage.<br>- Design using sustainable materials.<br>- Recycled materials via design<br>- Normative design practice | - Material storage<br>- On-site construction process<br>- Reduce excessive material on site.<br>- Reviewing construction documents. | |

| | | | |
|---|---|---|---|
| Reuse | - Reuse of building materials such as doors and columns | | - Recycle waste materials |
| Recycle | | - recycle materials on site. | - Recycle waste materials |
| Recover | - Ensure effective material recovery; design for deconstruction should be used.<br>- Design so that the building can be dismantled easily. | - Use prefabrication construction. | - Demolish required building.<br>- Audit recovered materials. |

| | | | |
|---|---|---|---|
| Remanufacture | | | - Use the adaptive reuse method. |
| Redesign | | | - Evaluate the performance of the material for the redesign |

2.5.2.3. Standard–Based Design:

Several research papers have established relation between construction waste and design changes; when the building materials are coordinated with building dimensions, it can prevent offcuts, reducing the waste produced (Salgın et al., 2017; Akinade et al., 2018). Standardizing the building forms, layouts, and use of materials based on the commercial sizes offered in the market could reduce the amount of waste (Ajayi et al., 2017). For instance, using standardized doors and windows can help with building coordination.

2.5.2.4. Design changes:

One of the biggest causes of construction waste is design modification. These can be caused due to design errors, budget constraints, and owners' requirements. The decision made during the initial design stage will be applied throughout the project process; if one wrong decision has been made, it affects the whole project. Design documentation should be provided in consistent descriptive language and format to ensure all the participants involved in the project can grasp the requirement, by doing this can limit reworks. Design modification could be minimized or avoided during the construction of the project's preliminary drawings (Ajayi et al., 2017).

2.5.2.5. Sustainable material selection:

Material selection plays a crucial role in interior design as it is an essential element that significantly impacts the overall look and feel of space. Material selection depends upon the usage of the space and how it is used. Materials are a crucial component of interior design because they aim to create visual interior space while focusing on space performance. The materials that make up interior design elements are crucial for constructing the image and shape of the interior spaces and their function

in integrating and connecting people with functional aspects of the interior space. The characteristics of materials can be determined by reducing the negative impact on the environment due to the materials. According to Alfuraty (2020) following can determine the character of the materials:

- Local Resources: By promoting local materials and strengthening the design identity using native materials, the designer would create harmony surrounding the environment.
- Material Durability: Finding and choosing long-lasting materials that will successfully support efforts to achieve the interior environment's sustainability.
- Material reuse: Reutilizing material conventionally or creatively to save time, money, energy, and resources. Reusing the materials can benefit nature as the products are used without processing.
- Upcycle: Employing a substance once more, but not for the original purpose. It is mainly preserved using the original product's shape, form, and material for different use.
- Recycle: Using materials obtained through garbage recycling to create new products. This procedure usually involves melting the original product, which destroys it but turns it into

something else; using such materials can decrease the overuse of natural resources. Choosing materials according to the material characteristics can create a better sustainable interior environment and contribute to the lifecycle of natural resources (Image13).

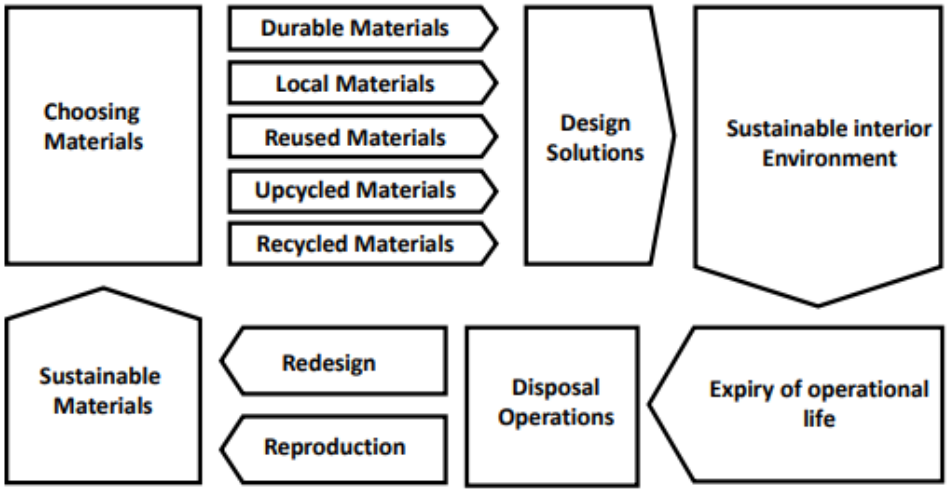


Image 13. Sustainable material life cycle source (Alfuraty, 2020)

For several years many firms have started the sustainability concept by promoting reuse, recycling, and product transparency. According to the material bank, AIA 2030 challenge calls on design firms to significantly reduce the built environment's carbon footprint by 2030; 1100+ firms have signed this industry’s commitment to reduce carbon emissions.

According to a few research studies, interior designers choose materials according to the client's selection and price; some clients do not wish to consider sustainability as they might be higher in price. Some clients lack knowledge of sustainable materials' importance and their contribution to waste management (Lee et al., 2013). Material selection plays a vital role in sustainable outcomes in interior design projects. Many designers/Architects rely entirely on manufacturers' specifications and lack knowledge of material specifications and their environmental impact. Implementing new methods in material specification and elaborating their sustainable behavior will benefit the design community. Most designers have limited knowledge of the specified materials, as most rely on the manufacturer's cut sheets. The manufacturer's information does not provide complete information containing the necessary data. (Moussatche et al. 2002).

2.5.2.6. Material selection tools:

One of the ways to overcome the waste minimization barriers is the assessment tools which also help minimize the designers' time and effort. The main advantage of using tools is that they calculate everything ahead of time and eliminate unnecessary waste; it also satisfies both client and designer by providing an environmentally friendly design within budget

limits for the client (Wael & Ashour, 2017). The below pattern reviews the literature on resources and tools that are used for the selection of material

Red listing: Many standards and certifications of green buildings utilize red listing, although they have slightly different chemical inclusion criteria and usage guidelines. Using this method makes it easy to determine the hazardous materials; it plays a vital role in the material selection process for interior designers. This online material database allows interior designers to choose eco-friendly materials and products. These details contain information such as the potential material application and the manufacturer's contact information. This red list is provided by one of the leading firms in interior design, Perkin + Will, which is created for designers (Redlist, 2011).

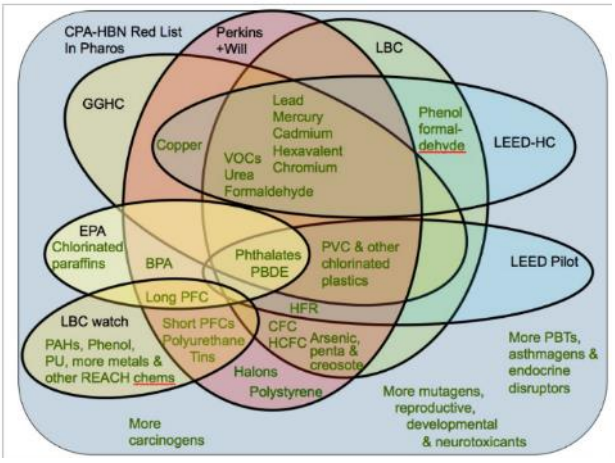

Image 14: Venn diagram shows the overlap of various re-list recommending excluding chemicals from building products.

- Green spec: green specs allow designers to access information regarding material and meet LEED credits and help meet certifications. This online product guide helps to create your project folder and share it with the design team; though this is a primary material database, it is a reliable resource. Every material database that was looked at highlighted one unique feature that they provided that other databases did not; green spec takes excellent pleasure in the rigorous material selection procedure that a manufacturer must go through to be listed in the green spec database uses five high- level environmental performance criteria to identify which building has sustainable products in their project. The materials listed in the green spec database have been thoroughly evaluated each material.

Image 15: Source: Greenspec.co.uk

- Material Connexion: This is one of the unique material selection tools for interior and architecture professionals; this database provides information on material description, characteristics, and manufacturing information; they also have an onsite material library for designers to overview the latest material and products.


Image 16: Source: Materialconnexion.com

- Todl Green: According to TODL (2013) allows the designer to create a folder with material and product images along with sustainable information and manufacturer contact. This material database also allows showing visual presentations for clients regarding materials basics and products.
- Material bank: The material bank is another data with material details, sustainability, and manufacture specifications. This database is free for design professionals. It provides information on the material along with free sample orders. The material information, such as environmental performance factors, is provided with the technical data sheet.


Image 17: Source: Materialbank.com

2.5.2.7. Adaptive Reuse:

In interior design, adaptive reuse is defined as one of the effective ways of waste minimization. The materials that are categorized for reuse are refurbished into the building structure. To create sustainably responsible designs, the strategy centers on design methodology and techniques used in interior design practice. This method complies with the ecologically sustainable mandate by reducing waste in the built environment (Celadyn, 2019). Below is an example of adaptive reuse design.

Image 18: Before- cold storage turned into bike manufacture office

(Source: IIAD.EDU)

Image 19: After-cold storage turned into bike manufacture office (Source:

IIAD.EDU)

2.5.2.8. Designing out of waste:

An essential opportunity for waste minimization is to design waste out during the first stage of construction. The waste management strategy is the one that controls the system and process, so there is no trash to manage. Elimination or reducing waste generated at each stage of the construction process is the main objective. This covers design, planning, specification, procurement, site preparation, and construction. Waste estimation is necessary for waste management; calculating the quantity produced can be used as a project reference. Waste can be classified as:

- The amount of waste relative to the total amount of waste.
- Percentage of material acquired.
- Total cost of waste percentage.

The methods mentioned above describe the amount of waste created.

2.5.2.9. Reducing waste and preventing pollution:

NIH (National Institute of Health) manages its system through NEMS (NIH environmental management system). They divert the waste in landfill by 50% of construction and demolition debris. NIH creates an annual

sustainability plan and informs the Department of Health and human services, their parent government body, about its progress. According to the executive order outlined (EO) 14057, “catalyzing clean energy industries and jobs through federal sustainability,” NIH should follow the waste and pollution reduction.

Waste and pollution reduction strategies implemented by NIH are as follows:

i. Reduce source waste by eliminating and recycling waste during production.
ii. Eliminative fugitive emissions.
iii. Reduce and recover fugitive emissions.
iv. Promote landscape management programs to eliminate toxic and hazardous chemicals or materials.
v. Ensure the recycling equipment is available.

2.5.2.9. Artificial Intelligence:

In recent years, AI (artificial intelligence) has taken a significant turn in all industries, including construction. Using AI, researchers can record 2,280 building projects that were demolished and can find out how m of building materials were recovered with 97% accuracy (New methods and

technologies to reduce construction waste, 2023). This could be helpful while performing pre-demolishing audits.

2.5.2.10. BIM (building information modeling):

BIM Software helps in monitoring recycling and recovery plan for materials during construction. 3D technology will help reduce money, time, and material waste.

### 2.5.3. CONCLUSION:

The literature review in this chapter reveals the importance of sustainability and how to achieve it through waste minimization strategies. If interior designers appropriately follow a circular economy, waste minimization can be achieved, reducing the cost generated due to waste. This chapter also discusses how designers can adopt and maintain, making waste reduction a vital component of the design process. Significant changes in waste management and minimization are being made due to new guidelines and targets set by the government, making the current trash disposal process very expensive. Due to the cost, the design organizations have developed waste management technologies and strategies to stop producing waste in the pre-design stage rather than after being dumped in a landfill. Although there is General agreement in

the literature that the design process contributes significantly to the generation of on-site waste, the current thinking of waste minimization practice is heavily focused on providing a framework for the upcoming tools and methods to incorporate and sustain waste reduction initiatives in design projects.

# 3.0. METHODOLOGY

## 3.1. DATA COLLECTION METHOD

In this research study, secondary data are used for the data collection; the purpose of using secondary data is because of existing data provided by researchers earlier from the sources such as articles, meetings, government statistics, journals, conference videos, etc., covered during the literature study (see table 7).

Table 7: Differentiating between primary and secondary data.

| Points | Secondary data |
|---|---|
| Definition | The secondary data is data that has already been collected beforehand. |
| Sources | The reports such as statistics, government reports, historical data, etc. |
| Research age | Previous |
| Specifications | Does not require the specific needs of the researcher. |
| Cost | Free |
| Control over data | Low level |
| Rights | The researcher is not the data owner; the information is accessible to everyone. |

| | |
|---|---|
| Control | There is no scope for solving specific problems. |

### 3.3.1. Sampling design

The online survey for this study targeted participants with a design background, such as professors and working professionals. The sampling design for this study is shown in image 20. There are two sampling methods: probability and non-probability (Datta, 2018). The probability sampling procedure is designed so that every individual has an opportunity for an equal selection in responses; the purpose of the probability sample is to generalize the results; in this sampling, the process is not proportional to the population. `Whereas in non – probability, the sample can be chosen in many ways, which is very convenient. This non – probability sample is considered less expensive and economical in usage. The participants for this sample type are selected based on the researcher's requirements.

In this study, non-probability sampling is applied to select the participants; the purpose of this sampling process is due to readily available participants and the simple process without any necessary budget requirements. Under non-probability sampling, convenience methods style is used as the researcher selects the targeted respondents,

who can be contacted conveniently online without revealing their original identity in the study.

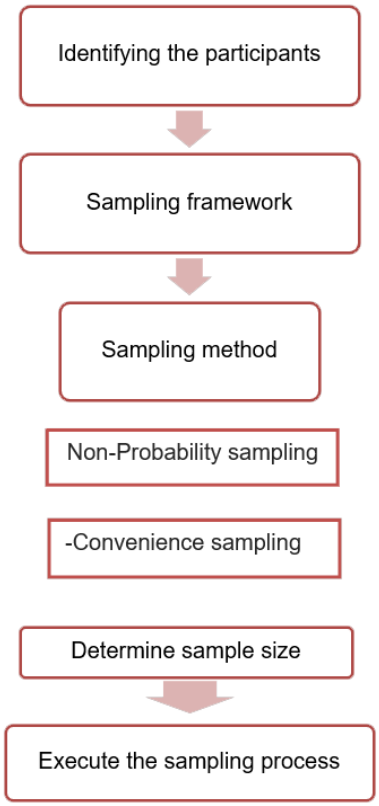


Image 20: Sampling design used for data collection.

### 3.3.2. Sampling size

The targeted audience was acquired from the University of Oklahoma directory focusing on alumni students and current students pursuing bachelor's or master's degrees who are currently enrolled in

courses related to design. The number of participants considered for this study is limited due to time constraints.

The total number of participants considered is 60 members; these members are classified as students, design professionals, and faculty. This study's research scope is not restricted to participants with a design background in countries other than the United States.

### 3.3.3. Participants

The participants approached by the researcher for this study are from India and the United States; this study may also include participants in the United States with a design background in other countries; the responses from various country experiences are collected to have global exposure to the research. The participants are not limited based on gender, race, working experience, or firm size. These individuals could be anyone from the design industry, starting from consultants, contractors, site supervisors, project managers, civil engineers, architects, interior designers, etc. (see image 21).

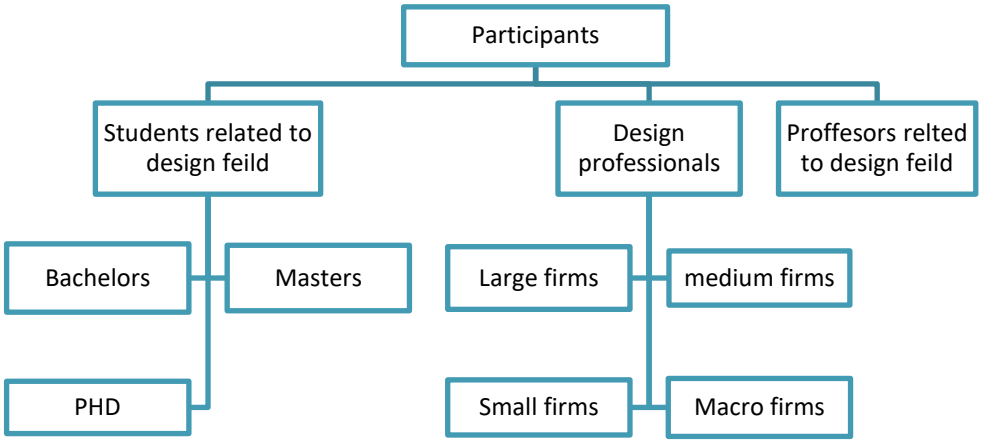


Image 21: explains the grouping of the participants.

### 3.3.4. Instruments

This survey was conducted using the online survey tool Qualtrics experience management provided by the University of Oklahoma, allowing the data collection process clearer and more reliable results. The results were exported from the online survey management tool to an excel sheet. This data is stored in a secured location by the researcher on their computer. The data analysis was done based on the question; incomplete responses will be filtered out.

### 3.3.5. Method of contact

Participants for this study were approached after receiving approval from Oklahoma Institutional Review Board (OUIRB) through Outlook and LinkedIn. Through outlook, the most significant ratio of participants is obtained by targeting a specific department or college at the University of

Oklahoma. A URL was attached for the participants to access the survey and the consent form in the recruitment e-mail. The participants can only access the survey if they are from related fields such as interior design, architecture, and construction; if not, they cannot proceed further.

## 3.4. SURVEY QUESTIONNAIRE

Survey questions were derived from the investigation done during the literature review. The questions focus on understanding individual knowledge about sustainable concepts, especially strategies for waste minimization. The survey framework consists of a consent form at the beginning of the survey along with the IRB approval number; it continues by the sections which consist of four parts: 1) Respondents' demographic information, 2) respondent's knowledge of sustainability during education, 3) respondent's involvement in organization and certificates 4) respondents take waste minimization responsibilities (refer to survey questions along with consent form in Appendix A).

### *1) Respondents' demographic information*

The first part of the survey questions, right after the consent form, investigates participants' education information and understanding of their background in the design field; this section aims to compare the

participant's experience results across the survey. The first part consists of information such as:

- Education background
- Experience in the design field
- Current role
- Area of specialization
- Type of firm
- Project size working/worked on

2) *Respondents' knowledge of sustainability during education*

After gathering information about participants' design background in the next part, they were questions that focused on their education on what type of sustainable concepts were taught/ are being taught during their education in bachelor's, master's, or during their Ph.D. study, if the concepts were taught what kind of approach was taken to initiate sustainable subjects in the curriculum.

3) *Respondents' involvement in organization and certificates*

With the education and experience information, part 3 consists of a series of questions about their involvement in organizations and certificates, such as in table 8,

Table 8: organization and certifications included in the survey.

| Organization | Certificates |
|---|---|
| ASID (American Society of Interior Design) | NCIDQ (National Council for Interior Design Qualification) |
| USGBC (United States green building council) | WELL |
| NEWH | LEED (Leadership in energy and environment design) |
| IIA (Indian Institute of Architecture) | |
| IIDA (International interior design association) | AIA (American Institute of Architecture) |

4) *Respondents' understanding of waste minimization strategies.*

Upon gathering the participant's background experience, the next phase focuses on the main research topic, a sequence of questions focusing on the participant's perspective regarding waste minimization concepts. Each question is framed in a ranking format one as low and five as high.

- Waste caused during the design phase.
- Waste caused during construction.
- Origins of waste.
- What are factors that are important in waste minimization.

*5) Waste minimization responsibilities taken by respondents.*

In the final part of the survey, participants were questioned on their experience of using waste minimization strategies during their professional field; if they had implemented the strategies they used were questioned if they opted no, what are the reasons for not considering waste minimization should be explained, with the help of these results the barriers that designers facing can be listed out and can come up with solutions to resolve this issue. In the second part of the questions, participants were asked as structured below,

- At what stages do you apply waste minimization strategies?
- Waste minimization usage in the respective countries
- What are the measures that can be taken to minimize waste?

The third and final part of the survey includes questions that need to be answered in the ranking format. This ranking format is to understand participants' experience with barriers they faced and the waste minimization strategies they implemented from the construction to the design stage. The survey concluded by providing optional suggestions or comments on the topic if the participant is interested in sharing more about their experience related to research.

Once the participants complete the survey, it will be submitted for analysis and later can be downloaded by the researcher for the next step of the research study, that is, data analysis, as explained in section 3.3. The survey questions are in Appendix A.

### 3.5. EXPECTED SURVEY OUTCOME

1) What are the waste minimization strategies that are used in various countries

2) What type of waste minimization strategies can designers use to minimize waste in their country

3) What are the barriers faced during the implementation of waste minimization strategies

4) How efficiently are sustainable concepts being incorporated in the design college curriculum

### 3.6. CONCLUSION

For this research study qualitative method is approached. The survey and literature study results are combined in the next chapter. This chapter elaborated on sampling design with sections such as target participants, sampling technique, sample size, data collection, instruments, and methods of approaching participants.

‘

# 4.0 RESULTS AND DISCUSSION:

## 4.1 INTRODUCTION:

The Response rate focused on the interior design, architecture, and construction industry participants. As presented in the tables and pie charts, the responses to the survey are obtained from the questionnaire; the questions in the survey regard the participant's knowledge, background, and experience regarding waste minimization strategies. The principal investigator gathered all the data to proceed with the analysis. The study contributes to determining what waste minimization strategies can be incorporated to promote sustainable interior design practice. The survey questions are split into five ways:

1) Demographic information
2) Respondents' knowledge of sustainability
3) respondents' involvement in organizations and certifications
4) Respondents' familiarity with waste minimization
5) Respondents' responsibility for waste management

## 4.2. SURVEY

### 4.2.1. Demographic Information:

The survey had 68 responses; 60 respondents could adequately respond to the study. At the same time, invalid, incomplete responses

were considered spam and discarded. Most participants have experience of around 0-25 years in related fields such as architecture, interiors, and construction (see table 10).

The survey possessed professional and educational information on the interior design, construction, and architecture background of the respondents involved; 68% with professional experience, and 32% were students. All the respondents' feedback was based on waste minimization strategies implemented by the individual and their educational background regarding sustainability. The respondent demographic distribution of participants' backgrounds is shown in the table below.

Table 9: Demographic table of respondents

| Parameter | Category | Percentage |
|---|---|---|
| Education background | Bachelor's degree | 49% |
| | Master's degree | 37% |
| | Doctorate | 10% |
| Working experience | 0-5 years | 50% |
| | 6-10 years | 28% |
| | 12-25 years | 22% |
| Area of specialization | Residential | 39% |
| | Commercial | 32% |

| | | |
|---|---|---|
| | Hospitality | 7% |
| | Railway | 1% |
| | Historic preservation | 2% |
| | Urban design | 1% |
| | Civil and infrastructure | 2% |
| Designation | Principal designer | 17% |
| | Principal Architect | 10% |
| | Project manager | 25% |
| | Junior Architect | 14% |
| | Interior designer | 16% |
| | Project engineer | 2% |
| | Educator | 6% |
| | Project BIM manager | 1% |
| | Intern | 10% |
| Project budget involved | 1-10 million | 26 % |
| | 10-15 million | 26% |
| | 50-100 million | 6% |
| | 100 + million | 11% |
| | Less than 1 million | 30% |

Most participants have a bachelor's degree 49%, a master's degree was second highest at 37%, and the least was a doctorate at 10%, as mentioned in table 10.

Respondents in the survey have spent their career in Interior design, Architecture/ Construction management. The respondents' profession is distributed as follows Principal designer, Principal Architect, Project manager, Junior Architect, Interior designer, Project engineer, Educator, Project BIM manager, and Design Intern, with a more significant number of project managers comprising 25% along with architects 24% and interior design consist of 33% of total respondents. Most participants worked on residential, railway, urban, civil, historic preservation specialist, and commercial projects, such as healthcare and education (see table 10).

Respondents' demographic information investigates their education and professional background. It is essential to know their experience in their respective backgrounds to compare results across the survey. The survey later investigates the knowledge and familiarity with sustainability and waste minimization during their education and practice; in the following sections, respondents were asked to rank the factors regarding causes and implementation of waste minimization strategies.

The respondents' choice of work options and years of experience was extensive. Small and medium firms employed 26% of participants, whereas large firms engaged 19% of people. Among them, 5% were consultants, and 11% were freelancers. Participants involved are from different occupation types (see table 10).

Participants' experience level ranges from zero to 25 years in their respective fields. 50% of participants have 0-5 years of experience, and 28% have 6-10 years of experience. The remaining 22% have 12-25 years of experience. (Refer to table 10)

Table 10: Respondent's location work

| |
|---|
| United States |
| India |
| Africa |
| London, UK |
| Saudi Arabia |
| Egypt |

Table 10 explains the percentage of respondents from various countries. The reason for targeting multiple countries is to combine all the strategies implemented in their countries as a list. From the above table, 50 % of respondents are from India, 37% are from the United States, and

the other 2.2% are from each country, such as Africa, the United Kingdom, and Egypt.

### 4.2.2. Respondents' knowledge of sustainability:

PI (Principal Investigator) has gathered information on respondents' knowledge of implementing waste minimization strategies and sustainability in their practice. The questions also address the participants' educational background and training regarding sustainability. Of the respondents, 63% had formal education and training, while 33% had no education or training in sustainability (see image 22). Additionally, 4% of the participants needed a formal education background or training in interior design, architecture, or construction. Below, image 23 illustrates at what level of education the respondents were introduced to the sustainability concept. 41% of participants were instructed on sustainability during their bachelor's degree, 26% were taught during their master's degree, 12% were educated during their professional practice, and the other 12% were introduced during continuing education. An additional 9 % were educated during their experience in organizations such as LEED green associate and chair of the American Institute of Architects (AIA) Central Oklahoma Committee on the Environment.

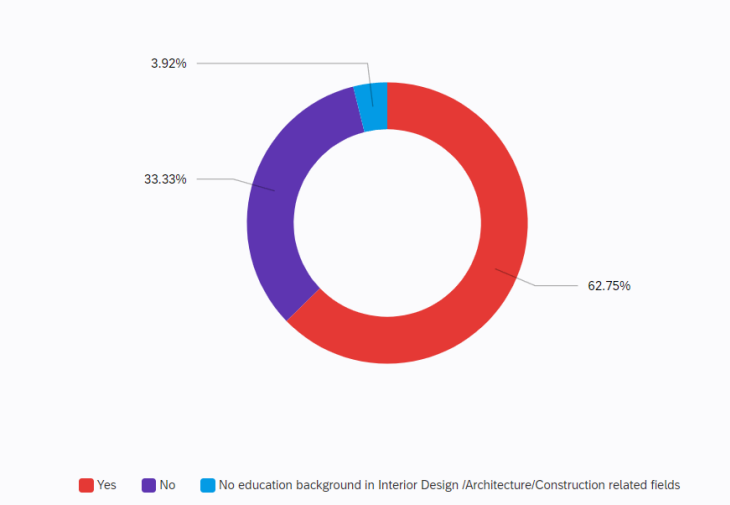


Image 22: Participants' formal level of education/ training on sustainability.

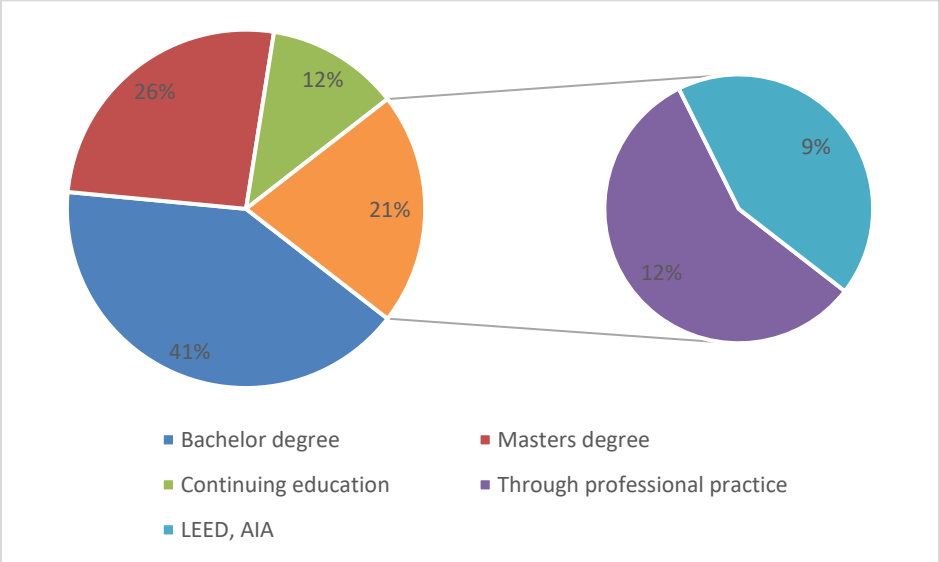


Image 23: Respondents were taught about sustainability at the level of education.

This part of the section also involves questions regarding the courses they are taught regarding sustainability during their education. This question aims to understand if education promotes environmental responsibility and encourages ethical practice. Waste minimization is a crucial aspect of sustainable design as it eliminates hazardous waste harmful to humans. Encouraging sustainable education is essential for designers as it can be a foundation for their professional practice. Appendix B explains the approach to guiding the respondents about sustainability in relative fields, focusing on eco-friendly materials, green buildings, sustainable environmental design, lean construction, and following LEED guidelines.

The other courses mentioned by the respondents are environmental culture and economy, and the focus was on what materials are more friendly to the environment (Environmental perspective); also, how to improve suburban areas to have access to more facilities and better-quality houses (cultural perspective). Another response was that Historic preservation is a sustainable construction approach simply because one is saving an existing building and reusing the "embodied energy" of the materials. One of the participants mentioned that sustainability was not a buzzword 30 years back in the few institutions, professors have used practical approaches such as:

1) Passive design
2) Material durability
3) Solar shading
4) Orientation of building.

Appendix B shows that colleges/universities from the respective countries have initiated sustainable concepts in their curriculum for the betterment of the environment, based on the number of responses received from the survey.

### 4.2.3. Respondents' involvement in organizations and certifications:

Participants were questioned regarding their involvement in the organizations such as the following (see image 24):

1) ASID (American Society of Interior Design)
2) USGBC (United States Green Building Standards)
3) NEWH
4) IIDA (International Interior Design Association)
5) IIA (Indian Institute of Architects)
6) AIA (American Institute of Architects)

Other mentions of participants include:

7) IGBC (Indian Green Building Council)
8) WELL building.

9) ASSP (American Society of Safety Professionals)

10) RIBA (Royal Institutes of British Architects)

11) ARB (Architecture Review Board)

12) AGC (Associated General Contractors of America)

13) ASPE (American Society of Professional Estimators)

14) NAWIC (National Association of Women in Construction)

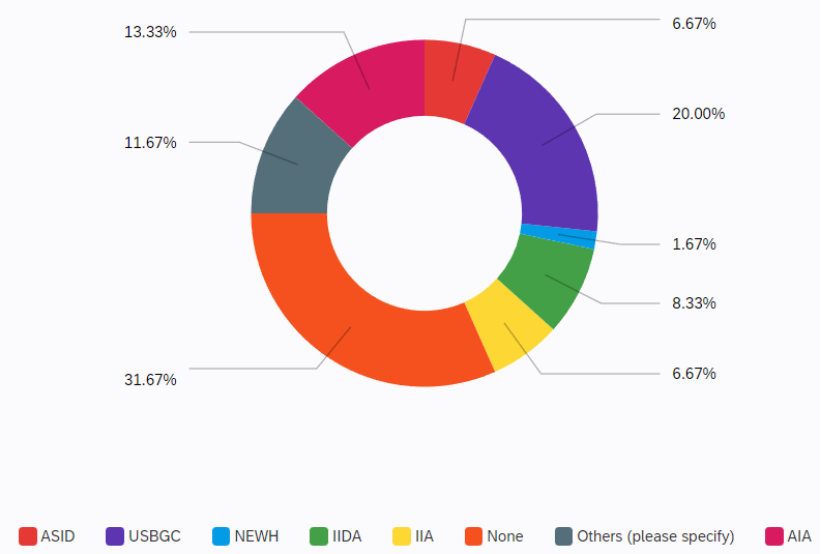


Image 24: Respondents' participation in an organization related to Interior design/architecture /construction management.

In the study, 30% of the participants were not involved in any organization, and the remaining 6.7% were involved with ASID, 20% with

USGBC, 2% with NEWH, 7% with IIA, and 14% with AIA. The highest number of participants are involved with USGBC AND AIA, and the lowest number are involved in organizations such as NEWH and ASID.

67% of the participants do not have any certification, 19% of participants held LEED certification, remaining 2-3% of participants obtained Occupational Health and Safety (OSHA), National Council of Architecture Registration Boards (NCARB), WELL, the council of Architecture (COA), American institutes of Constructors (AICP), Certified professional constructor (CPC) (See image 17).

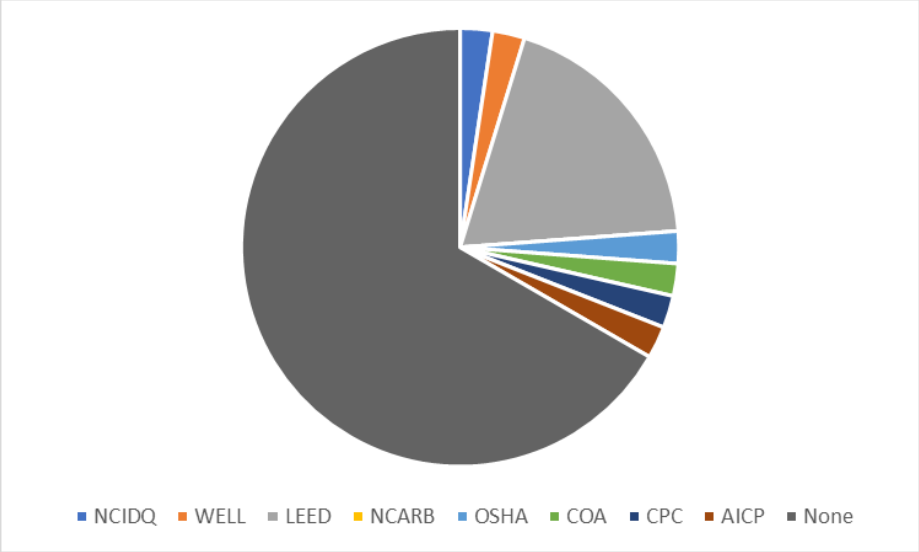


Image 25:Certifications held by interior design/ architecture/ construction management participants.

### 4.2.4. Respondents' familiarity with waste minimization:

*4.2.4.1. waste during construction and design waste:*

Participants were requested to rate seven variables contributing to most occurring material waste during the design or construction phase. The scale ranges from high to low, with High as a significant cause of waste, neutral as minimal waste, and low as zero waste. The participants ranking results are analyzed based on the level of ranks given to each variable. Table 13 shows the results obtained from participants' ratings.

Table 11: According to participants, the most frequently occurring causes of waste during the design and construction phase are ranked from variables that produce high levels of waste.

| Variable | Most frequently occurring cause of waste, according to participants |
|---|---|
| Insufficient information or missing information in construction documents | 1 |

| | |
|---|---|
| Last-minute design change | 2 |
| The on-site operation, including material handling | 3 |
| Lack of specification | 4 |
| Delays due to missed information in construction documents. | 5 |
| Material procurement | 6 |
| Client proposed changes | 7 |

The results show that “insufficient information or missing information in construction documents ranks highest in producing waste. Moreover last, “the minute design change” is ranked second; “on-site operation” and “lack of specification” are ranked third and fourth. “Material procurement” and “client proposed changes” are ranked least in design and construction waste generation.

*4.2.4.2. waste during design phases:*

Table 12: According to Participants, the most frequently occurring causes of waste during the project phases.

| Variable | Most frequently occurring cause of material waste during the project phase |
|---|---|
| On-site construction | 1 |
| Construction document development | 2 |
| Design development | 3 |
| Project briefing | 4 |

Table 12 explains that informants were requested to rate the four variables from low to high, with high as most waste produced and low as zero. Most respondents expressed concern that “on–site construction” is a major significant factor causing waste during the project phase caused due to during the planning and designing, and “construction document development” is ranked second highest in material waste. Design development and project briefing are ranked the least.

*4.2.4.3. Minimizing material waste:*

This section allows participants to rate the strategies to minimize material waste from low to high, with low as zero waste produced and high as significant waste. From the findings of this section, “Quantity and quality of material” are ranked as the highest factor that is more efficient in minimizing material waste; this is because of over or under-ordering of materials, and even If the material is ordered according to the proper number and the quality the material is not excellent then it won’t be suitable for the project. “Material resources” is ranked second high; this is because of not using the resources and “project duration” and “human resources” due to limited time for the project, the team rushes to complete the work without focusing on waste management, which leads to waste products in the same way due to lack of human resources or no skilled labor can also lead to material wastage, and the last two are considered the minor factors in minimizing material waste (See table 13).

Table 13: According to participants, the ranking of factors contributing to waste minimization is high to low.

| Variable | Ranking |
|---|---|
| Quantity and quality material | 1 |
| Material resources | 2 |
| Project duration | 3 |
| Human resources | 4 |

4.2.5. RESPONDENT'S RESPONSIBILITY FOR WASTE MINIMIZATION

*4.2.5.1. Participants' experience in Implementing waste minimization strategies:*

Participants were asked if they have implemented material waste minimization strategies in their firm or during their practice, 34% of participants have implemented, and 66% have yet to implement any strategies during their practice.

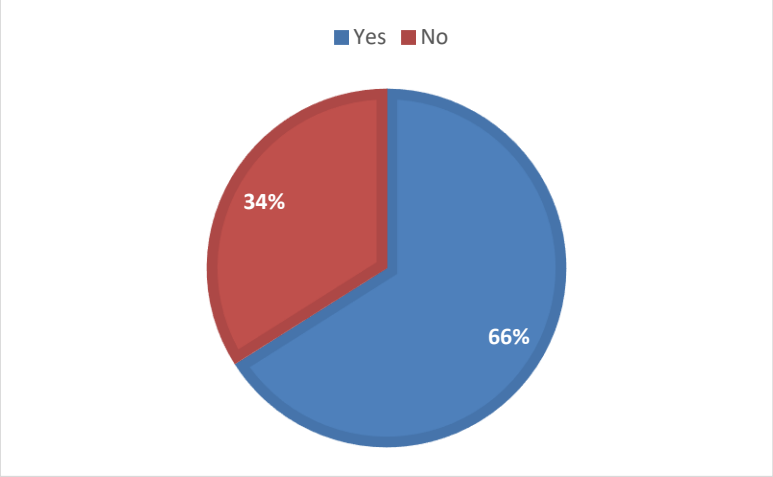


Image 26: Pie chart illustrating waste minimization strategies implemented by participants during their practice.

Table 14 below explains the strategies implemented in their practice, if they opted for “yes,” and if they opted for “no,” what are the reasons for not implementing them.

Table 14: what are the strategies implemented in their practice.

| Yes | No |
|---|---|
| - Use eco materials, for example, a bison sheet ramp instead of a concrete ramp. | - Contractors are not involved in waste management decision-making. |

| | |
|---|---|
| - Proper communication with contractors, subcontractors, and design with the design team. | - Waste minimization is not considered a project priority |
| - Material Procurement | |
| - Re-use materials such as wood panels for formwork until their shelf life has been exhausted and sell them off as “firewood” for coal to ensure reduced environmental waste. | |
| - Implementing Lean techniques | |
| - Material procurement | |
| - Implementing a return policy, such as providing bonuses to the project managers to encourage them to return and save the company’s money. | |

4.2.5.2. Implementing waste minimization strategies during the design to the construction phase.

The construction stage is chosen as the most considered stage by the participants to implement waste minimization strategies; 40% of the respondents state that the waste minimization strategies were implemented during “onsite” and during the “design stage”.17 % of the participants mentioned that they implement waste minimization strategies in all stages that are from pre-design, design, construction, onsite stage.9% of the participants have selected that they have not implemented the strategies in any stages of the process.

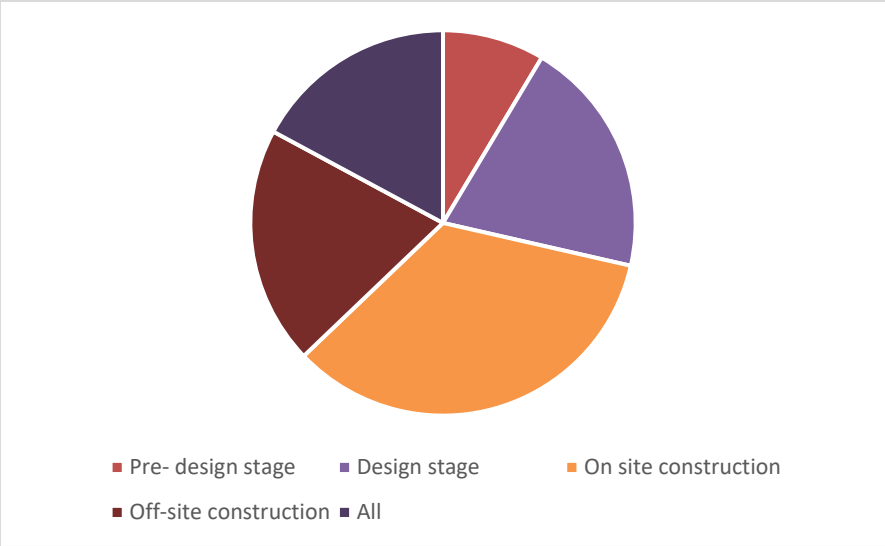


Image 27: Pie chart illustrating which stage is mainly considered to implement waste management strategies.

*4.2.5.3. Implementation of waste minimization strategies in participants' countries.*

Participants were asked to select how satisfied they were with the government or the forms taking the initiative to implement waste minimization strategies. 14% of the participants are happy with the strategies implemented in their country, and 32% are dissatisfied with the measures to minimize waste. 56% of the respondents have selected a neutral opinion. Table 15 explains the reason few participants have mentioned to support their statement.

Table 15: The table explains the reasons for implementing waste minimization strategies and the reasons for not implementing the strategies.

| Satisfied | Neutral | Dissatisfied |
|---|---|---|
| - Reuse of materials | - Economic forces affect material conservation | - Zero implementation of waste minimization practice in the long run |

| | | |
|---|---|---|
| - Creating awareness in firms | - Not sure what strategies are implemented | - Lack of planning for storage and shipping of materials |
| - Education curriculum | - Lack of knowledge | - Lack of communication between designers, contractors, and subcontractors |

*4.2.5.4. Efficient strategies used for material waste management according to the participants':*

Participants were asked to select what type of strategies are considered in their firm during the design and construction process. “Material usage” is considered the highest consideration comprising 19% of participants, and the second selected highest variable is material cost. 18% of participants selected “material quality,” 16% of participants chose “sustainability,” and 8% of participants considered “safe.”. 12% of

participants opted for “standard measurement,” and the remaining 8% of them have chosen “hazardous waste.”

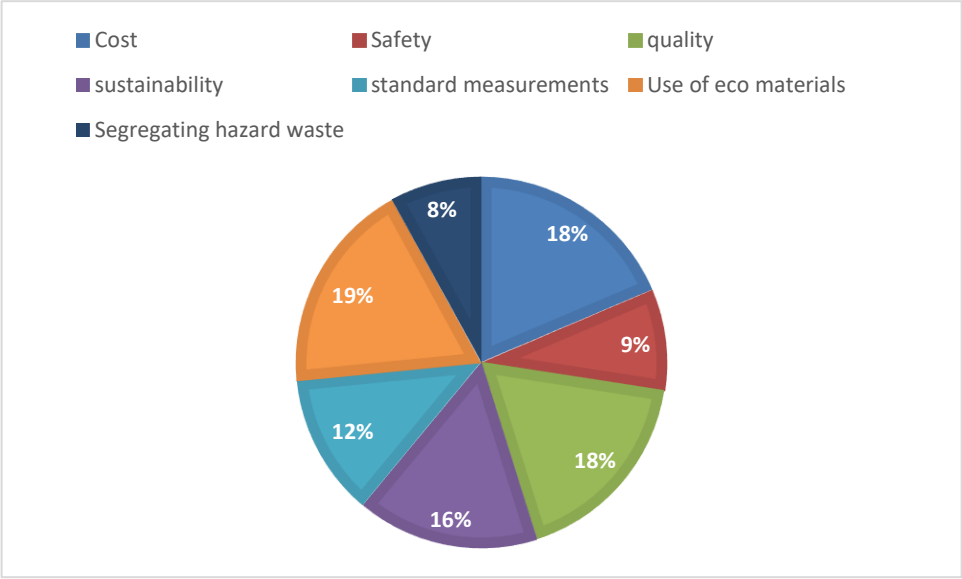


Image 28: Pie chart illustrating participants’ strategies during their practice.

*4.2.5.3. Barriers faced by the participants during the implementation of waste minimization strategies.*

Table 16 explains the participants’ barriers while implementing waste minimization strategies.

| Variable | Ranking |
|---|---|
| Improper waste management planning | 1 |
| Client's lack of knowledge/interest in waste minimization | 2 |
| Inadequate training in waste minimization strategies | 3 |
| Limited project budget | 4 |

65% of the participants have selected that's "Improper waste management planning" as the highest barrier faced during the implementation of waste management, second highest is "Clients' lack of knowledge/interest in waste minimization," comprising 55% of participants selecting this variable. The least faced barrier is "Inadequate training in waste minimization strategies" and "Limited project budget."

*4.2.5.4. Best strategies for waste minimization by the participants.*

Table 17: The table explains the participants' best waste minimization strategies.

| Variable | Ranking |
|---|---|
| Waste prevention design | 1 |
| Adaptive reuse | 2 |
| Recycling | 3 |
| Use of environment-friendly materials | 4 |
| Designing out of waste | 5 |
| Assessment tool | 6 |

Among the six variables, participants were asked to choose the best waste minimization strategies based on their practical experience.66% of participants chose “waste prevention” as an efficient strategy for waste minimization, second highest was “adaptive reuse,” which was selected by 52%. Recycling was selected by 46% of the participants. The least considered strategies are “designing out waste” and using “assessment tools.”

*4.2.5.5. Measures are taken to implement waste minimization strategies.*

30% of the participants have chosen “Education/awareness “as one of the best measures that can be taken to minimize waste, second highest is “use of recycled waste materials, which is selected by 25% of respondents. “Implementation of waste management training (seminar, workshop, or student level competition)” was selected by 23% of participants, and “Technology adaptation” was selected by 22%. Two of the participants mentioned “use of incentive, grants to close the cost gap between status quo and less wastage” and “disincentives.”

*4.2.5.5. Participants’ experience related to waste minimization strategies:*

Table 18: explains the participants’ views on waste minimization strategies.

| **Participants’ experience in implementing WMS** |
| --- |
| Reuse of existing materials |
| Designing out of waste |
| Reuse existing materials |
| Reorientation |

| |
|---|
| Proper construction documents |
| Monitoring on-site |
| Material procurement |
| Waste management awareness in professional practice |

# 5.0 RECOMMENDATION AND CONCLUSION:

## 5.1 INTRODUCTION:

This chapter is this study's conclusion, explaining the significance of the survey and literature review findings and answering the research questions. The study findings provide a preliminary understanding of interior designers' motivations and perspectives regarding sustainable interior design techniques. From the study, different perceptions among the participants have been revealed. This chapter also discusses addressing the research questions from the survey findings.

## 5.2. Research questions:

The scope of the study is defined by the research questions, which are:

I. Strategies to minimize waste in design practice.

II. What are the barriers faced by design to achieve waste minimization?

III. Which project phase contributes to the most material waste?

The study aims to achieve the following strategies:

3. To explain the most appropriate ways interior designers can use the available strategies to minimize waste. What are the strategies?

4. To focus on challenges designers face during project implementation.
5. To focus on the strategies that can be implemented during the design phase to minimize waste during construction.
6. This study generalizes waste minimization strategies used in multiple countries with the help of survey findings.

To meet the above-stated aim and research questions, the principal investigator conducted an online questionnaire to support the study. The survey summary is based on participants' knowledge of waste minimization strategies and their education in sustainability. Few of the participants have applied WMS in their practice and considered it as one of the essential things to be implemented in their project; few were not encouraged in their firm or stooped themselves from implementing due to the budget. The survey also discusses the barriers faced by the participants during the implementation of waste minimization strategies in their project.

The design stage is second highest in contributing to material waste; these can be caused due to various reasons such as:

i) Material selection: If the materials chosen for a project are inappropriate or suitable to the design, it can lead to unnecessary purchases and create waste.

ii) Faults in design choices: Material waste can be caused due to poor design choices, for example, overuse of materials or complicated design that needs more materials.

iii) Lack of material reuse: If the design team does not consider reusing the potential materials, it may lead to waste.

iv) Material calculation: The design team should calculate the required material accordingly to avoid unnecessary purchases.

The validity and reliability issues were addressed in several ways, such as through:

i) Perspective of researcher:

Even with the background in the design field and opinion towards sustainability and waste management, the researcher has not imposed personal opinions on the participant; also, the method of approach was done in such a way that there is no need to disclose participants' information. All the participants who were contacted were from a design background, few with motivation toward

sustainability, and few were not. The questions in the survey had options for participants to provide additional information regarding their experiences in implementing sustainability practices. The survey outline was designed so participants feel flexible in answering the questions without feeling forced.

ii) Data collection:

After receiving the responses from the survey findings, researchers gathered data for the analysis process, which included participants' perceptions towards sustainability. The results of the finding were explained in chapter 4, results, and discussion, which can be used for the cross reference of the data.

iii) Peer review & Audit trail:

The committee members evaluated the research study process to ensure the findings and methods of data collection. The researcher conducted the audit trail to validate the survey and literature study findings. This method aims to understand if the findings from the two studies are consistent. From the study results, the opinions from the literature and survey support each other regarding waste causes and minimization strategies.

## 5.4. Conclusion & limitations:

The research identifies multiple strategies designers can use based on participant responses, data analysis, and existing literature. These strategies, currently employed by the participants in their work, are detailed in chapter 5.2.1. However, the conclusion also notes challenges that designers encounter when implementing waste minimization strategies outlined in chapter 5.3.3.

Despite these challenges, sustainability and waste management strategies have evolved. It will be intriguing to see how material waste can be reduced and what new strategies will be introduced to achieve a sustainable future.

A few conclusions about the factors influencing waste minimization strategies in interior design from the generalization of literature and survey findings. Findings from the literature are primarily focused on the data, which are ten years old; the survey finding is concerning regarding the current situation. Over the years minimizing waste during construction has been considered the most recognizable practice, even now. For instance, all the participants believe that more waste is generated during construction and mention that the cause is due to improper construction drawings, lack of communication, lack of knowledge regarding sustainable

materials, etc., which are like the findings from the literature. Educational experience varied among the participants in the survey; each had their formal education in sustainability during educational training, job, organization, and certification. A lack of knowledge regarding sustainability concepts can also lead to improper knowledge of implementing them, causing waste. The design stage is second highest in contributing to material waste; these can be caused due to various reasons such as:

v) Material selection: If the materials chosen for a project are inappropriate or suitable to the design, it can lead to unnecessary purchases and create waste.

vi) Faults in design choices: Material waste can be caused due to poor design choices, for example, overuse of materials or complicated design that needs more materials.

vii) Lack of material reuse: If the design team does not consider reusing the potential materials, it may lead to waste.

viii) Material calculation: The design team should calculate the required material accordingly to avoid unnecessary purchases.

However, this research is subjected to limitations such as the survey's sample size; due to time constraints, the number of people

targeted needed to be increased. The content which can be used for future study has been identified. With limited research on this topic implementing qualitative study was a suitable approach used in this research. Even though the researcher selected participants, the results of the participant's responses may not be accurate. This can be due to participants' lack of interest in the survey.

### 5.5. Research recommendations:

The survey responses are significant findings for determining the strategies utilized by interior designers, architects, and construction managers. However, the study had limitations regarding participant numbers due to time constraints. In future research, expanding the targeted audience could provide a better understanding of their experiences and perspectives. Although the study researched participants with similar backgrounds across multiple countries, the responses were limited to an overall view of these countries. To gain a more comprehensive outcome, future research target respondents in other countries; obtaining more detailed information if new strategies are implemented other than existing ones requires conducting interviews alongside questionnaires to verify the responses.

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## APPENDIX A – SURVEY QUESTIONS

Informed consent forms

I am Harshini Pulli, a graduate student in the Division of Interior Design at the University of Oklahoma. I invite you to participate in my research about waste minimization strategies if design and construction. You were selected to participate in the survey because of your professional involvement in design and construction. You must be at least 18 to participate in this research.

If you agree to participate, you will complete a 15-minute online survey. There are no risks or benefits to participating in this research. Data collected through the online platform has privacy and security policies for keeping your information confidential. There is a risk that the external organization, which is not part of the research team, may gain access to or retain your data or IP address, which could be used to re-identify you. Assurance can only be made regarding their use of the data you provide for purposes other than this research.

Your participation is voluntary, and your responses will be anonymous.

We might share your de-identified data with other researchers or use it in future research without obtaining additional assent from you. Even if you choose to participate now, you may stop participating anytime and for any reason.

If you have questions about this research, please contact Harshini at 623-272-9876 or harshini@ou.edu. Contact the University of Oklahoma – Norman Campus Institutional Review Board at 405-325-8110 or irb@ou.edu with questions, concerns, or complaints. Please print this document for your records.

By providing information to the researcher(s), I agree to participate in this research.

IRB #____15492_____ IRB Approval Date __2/27/2023___

**Demographic information**

Are you currently involved or involved in the design/construction profession?

○ Yes

○ No

*Skip To: End of Survey If Are you currently involved or was involved in the design/construction profession? = No*

Do you have education and professional experience in Interior Design, Architecture, Construction, and related fields?

○ Yes

○ No

Please select your highest level of education.

- ○ Bachelor’s degree
- ○ Master’s degree
- ○ Doctorate
- ○ Others (Please specify)

  _____

- ○ No formal education in Interior Design /Architecture/Construction or related fields.

If you are a student, choose your current education status. If not, the student, please select not applicable.

- ○ Bachelors
- ○ Masters
- ○ Doctorate
- ○ Others (Please specify)

  _____

○ Not applicable

Please select how many years you have been involved in Interior Design/Architecture/Construction.

0 3 5 8 10 13 15 18 20 23 25

| | |
|---|---|
| Click to write Choice 1 () |  |

Please select your occupation type

- ☐ Large Firm
- ☐ Medium firm
- ☐ Small firm
- ☐ Consultant
- ☐ Freelancer

Please select your occupation type

- [ ] Large Firm (>250 employees)
- [ ] Medium firm (51-250 employees)
- [ ] Small firm (1-50 employees)
- [ ] Consultant
- [ ] Freelance
- [ ] Others (please specify)

_____

- [ ] Not applicable

Please select the area of specialization.

- [ ] Residential
- [ ] Commercial

- [ ] Healthcare
- [ ] Hospitality
- [ ] Educational
- [ ] Others (please specify)

_____

- [ ] Not applicable

Which of the following best describes your current designation?

- [ ] Principal Designer
- [ ] Principal Architect
- [ ] Project Manager
- [ ] Intern

☐ Others (please specify)

_____

☐ Not applicable

Select the average project budget you have been involved with.

☐ Less than 1 million dollars

☐ 1-10 million dollars

☐ 10-50 million dollars

☐ 50-100 million dollars

☐ 100+ million dollars

☐ Others (please specify)

_____

☐ Not applicable

Please enter the location of your current project—state/Country.

---

**Respondent's knowledge of sustainability**

Do you have any formal education/training on sustainability?

- ○ Yes
- ○ No
  - ○ No education background in Interior Design /Architecture/Construction related fields.

*Display This Question:*

*If Do you have any formal education/training on sustainability? = Yes*

Yes

No

○ No education background in Interior Design /Architecture/Construction related fields.

*Display This Question:*

*If Do you have any formal education/training on sustainability? = Yes*

At what level of education were you introduced to sustainability?

☐ Bachelor's degree

☐ Master's degree

☐ Continuing education

☐ Through professional practice

☐ Others (please specify)

What approach was taken to guide you regarding sustainability concepts in your education? Please mention the subjects taught related to sustainability.

**Respondent's involvement in organization and certificates**

Please select all the organizations you are currently involved with or were involved in in the past.

- [ ] ASID
- [ ] IIDA
- [ ] AIA
- [ ] USBGC
- [ ] NEWH
- [ ] IIA
- [ ] None
- [ ] Others (please specify)

Please select the certifications you currently hold.

- [ ] NCIDQ
- [ ] NCARB
- [ ] WELL
- [ ] LEED
- [ ] None
- [ ] Others (please specify)

**Respondents' familiarity with waste minimization**

Based on your familiarity with waste minimization, please rank the following question from low to high.

According to you, which of the following is the most frequently occurring cause of waste during the design and construction of a project? Please rate each item from low to high.

| | Low (1) | Medium (2) | High (3) |
|---|---|---|---|
| Last-minute design changes | ☐ | ☐ | ☐ |
| Client proposed changes | ☐ | ☐ | ☐ |
| Lack of specification | ☐ | ☐ | ☐ |
| Insufficient information or missing information in construction document | ☐ | ☐ | ☐ |
| Delays due to missed information in construction documents | ☐ | ☐ | ☐ |

| | | | |
|---|---|---|---|
| The on-site operation, including material handling | ☐ | ☐ | ☐ |
| Material procurement | ☐ | ☐ | ☐ |
| Others (please specify) | ☐ | ☐ | ☐ |
| Other (please specify) | ☐ | ☐ | ☐ |
| Other (please specify) | ☐ | ☐ | ☐ |

According to you, what is the most frequently occurring cause of waste during the design phase? Please rank each phase from low to high based on the origins of waste in each stage.

| | Low (1) | Medium (2) | High (3) |
|---|---|---|---|
| Project briefing | ☐ | ☐ | ☐ |
| Design development | ☐ | ☐ | ☐ |
| Construction document development | ☐ | ☐ | ☐ |
| Off-site construction | ☐ | ☐ | ☐ |
| Others (please specify) | ☐ | ☐ | ☐ |
| Others (please specify) | ☐ | ☐ | ☐ |

| | | | |
|---|---|---|---|
| Others (please specify) | ☐ | ☐ | ☐ |

What are the factors that are important in minimizing material waste?

Please rank each point below from low to high. (Please answer all)

| | Low (1) | Medium (2) | High (3) |
|---|---|---|---|
| Project duration | ☐ | ☐ | ☐ |
| Material resources | ☐ | ☐ | ☐ |
| Human resources | ☐ | ☐ | ☐ |
| Quality and quantity of materials | ☐ | ☐ | ☐ |
| Others (please specify) | ☐ | ☐ | ☐ |

| | | | |
|---|---|---|---|
| Others (please specify) | ☐ | ☐ | ☐ |
| Others (please specify) | ☐ | ☐ | ☐ |

RESPONDENT'S RESPONSIBILITY FOR WASTE MINIMIZATION.

Have you / your firm implemented material waste minimization strategies during project implementation? If YES, please mention the strategies; if NO, please explain the reason for not applying.

○ Yes _____

○ No _____

*Display This Question:*

*If A. Have you / your firm implemented material waste minimization strategies during project implementation... = Yes*

At what stages do you apply waste minimization strategies?

- [ ] Pre-Design stage
- [ ] Design Stage
- [ ] On-site Construction
- [ ] Off-Site
- [ ] All
- [ ] None
- [ ] Others (please specify)

_____

According to you, rate the waste minimization strategies implemented in your country or state.

○ Satisfied ((Please specify reason)

_____

○ Neutral (Please specify the reason)

_____

○ Dissatisfied (Please specify the reason)

_____

Select the material waste minimization strategies implemented in your firm.

☐ Cost

☐ Safety

☐ Quality

☐ Sustainability

☐ Standard measurements

☐ Use of eco materials

☐ Segregating hazardous waste

☐ Others (please specify)

_____

Rate the barriers faced during the implementation of waste minimization strategies. Please rank each item from low to high based on importance.

| | Low (1) | Medium (2) | High (3) |
|---|---|---|---|
| Inadequate training in waste minimization strategies | ☐ | ☐ | ☐ |
| Clients need to gain knowledge/ interest in waste minimization. | ☐ | ☐ | ☐ |

| | | | |
|---|---|---|---|
| Improper waste management planning | ☐ | ☐ | ☐ |
| Limited project budget | ☐ | ☐ | ☐ |
| Others (please specify) | ☐ | ☐ | ☐ |
| Others (please specify) | ☐ | ☐ | ☐ |
| Others (please specify) | ☐ | ☐ | ☐ |

According to you, what are the best waste minimization strategies? Please rank each item from low to high.

| | Low (1) | Medium (2) | High (3) |
|---|---|---|---|
| Adaptive reuse (1) | ☐ | ☐ | ☐ |
| Designing out of waste (2) | ☐ | ☐ | ☐ |
| Waste prevention (4) | ☐ | ☐ | ☐ |
| Recycling (5) | ☐ | ☐ | ☐ |
| Use of environment-friendly materials (7) | ☐ | ☐ | ☐ |
| Use of assessment tool (8) | ☐ | ☐ | ☐ |

| | | | |
|---|---|---|---|
| Others (please specify) (6) | ☐ | ☐ | ☐ |
| Others (please specify) (9) | ☐ | ☐ | ☐ |
| Others (please specify) (10) | ☐ | ☐ | ☐ |

What measures can be taken to create awareness of waste minimization in the design/construction profession (select all that apply)?

☐ Education / Awareness

☐ Technology adaptation

☐ Use of recycled waste materials

☐ Implementation of waste management training (seminars, workshops, student-level competitions, etc.)

☐ Others (please specify)

_____

☐ Others (please specify)

_____

☐ Others (please specify)

_____

Q20 G. Please share any experience you have related to waste minimization.

_____

## APPENDIX B: RESPONDENT'S EDUCATIONAL BACKGROUND IN SUSTAINABILITY

| Courses | About |
|---|---|
| Life cycle | - Evaluates how much environmental impact products have. |
| Sustainable construction | - Recognize the idea of sustainability in the built environment.<br>- Identifying various sustainability frameworks in use around the world. |
| Lean construction | - Lean construction educates construction professionals about minimizing cost on each project and applying strategies for the project's overall development. |
| Environmental impacts | - |
| Historic Preservation | - Implementing energy-efficient |

| | |
|---|---|
| | strategies for historic buildings to achieve a sustainability approach. |
| Climatology | - Understanding climate change allows designers to create environmentally friendly projects. |
| Green building | - Green building educates on how designing, planning, and construction balance social, environmental, and economic benefits. |
| Sustainable building material | - The course aims to promote the circular economy by exploring material sourcing, the use of eco–materials, and methods to assess environmental impacts. |
| Interior construction | |
| Lighting design | |

| | |
|---|---|
| Architecture Theory & Criticism | - The course includes examining the various types of research connected to the built environment. Students are introduced to architectural criticism through readings, discussions, and assignments. |
| Professional Practice | - Understand accepted standards of practice, professional work environments, and awareness of the interrelationships that influence design, design responsibility, and ethics.<br>- Establish effective strategies when collaborating as team members or serving in leadership roles within integrated design practices and becoming a life-long |

| | |
|---|---|
| | learner. |
| Indoor controls | - Course discusses the control of energy and incorporating controls into the project. |
| Indoor environmental quality | - |
| Environment and human behavior | - The course aims to understand the relationship between the environment and human behavior.<br>- to learn how we research the environment-human behavior relationships |
| Cradle to cradle | - Cradle to cradle certification approach offers a constructive roadmap for ongoing innovation related to human-centered products and service design's economic, environmental, and social concerns. |