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FACULTY OF SCIENCE AND TECHNOLOGY

MASTER IN CITY AND REGIONAL PLANNING

MASTER THESIS

ECO-FRIENDLY DEVELOPMENT: REUSE OF BUILDING MATERIALS (Emphasis on barriers and drivers of reuse of building materials)

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ABSTRACT

The building and construction sector has emerged with so many concepts having sustainability as the baseline to reduce the amount of carbon emissions the sector produces. The building and construction sector is a major contributor to socio-economic developments for countries worldwide, but the sector's growth takes up 30% of raw materials harvested annually is consumed, 25% of water and 12% of land resources is also consumed globally and it generates over 25% of solid waste. Additionally, this sector records about 40% of greenhouse gas emissions, this mainly consists of energy use during buildings' life cycle. The sector would benefit from finding new ways to boost its sustainability so that its growth and progress do not signal doom for future generations. One of such ways that will be examined in this study is the reuse of building materials. In Europe alone, building and construction waste makes up 1/3 of all waste generated. Reuse of building materials is possible because there are some materials whose resource value is high which means they can be reused many times before having to be destroyed or condemned. It is therefore important to explore the reuse of building materials because not only will they be reducing the amount of waste being dumped in landfills but they will be replacing primary materials and reducing natural resource depletion.

The paper aims to understand the potential for the reuse of building materials by examining the barriers and drivers that affect the reuse of building materials. In doing so, challenges being experienced by individuals and professionals in the built environment are explored such as project costs, policy control and, the likes.

The research question shaped up the objective and was a guide that helped formulate an answer for the research question; which was to understand the potential barriers and drivers affecting actors and users of reuse of building materials while also understanding the behavior practices that affect reuse. Qualitative and quantitative data gathered from interviews and questionnaires to compare previous literature is utilized to understand if there are any changes since reuse started gathering more attention. The research aimed to look at the picture of the built environment in general while using Norway as a case study.

The findings from the data gathered while compared to previous literature from not earlier than 2008 show that the barriers to reuse are still being experienced as much as they were more than 10 years ago. This suggests that the concept of reuse while growing is still developmental, there is still a long way to come from there. Drivers such as government incentives and training of built environment professionals are important for the growth of the reuse potential.

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INTRODUCTION

Since the inception of sustainability, it has been applied in many different sectors (Foundation, 2014). The building and construction sector, in particular, has emerged with so many concepts having sustainability as the baseline to reduce the amount of carbon emissions the sector produces. The building and construction sector is a major contributor to economic and social developments for countries worldwide. It generates up to 10% of national employment and 15% of a country's Gross Domestic Product at the stages of construction, use, and demolition globally (Dias, 2019). Although, on one hand, this is quite a socio-economic contribution, on the other hand, the sector consumes about 40% of the world's primary energy. For the building and construction sector's growth, 30% of raw materials harvested annually is consumed, 25% of water and 12% of the land resources is also consumed globally and it generates over 25% of solid waste. Additionally, this sector records about 40% of greenhouse gas emissions, this mainly consists of energy use during buildings' life cycle (Dias, 2019).

The sector would benefit from finding new ways to boost its sustainability so that its growth and progress do not signal doom for future generations. One of such ways which will be examined in this study is the reuse of building materials. In Europe alone, building and construction waste makes up 1/3 of all waste generated and it consists of so many materials such as concrete, wood, bricks, glass, metals as well as plastics (Høibye & Sand, 2018). Reuse of building materials is possible because there are some materials whose resource value is high while some are low (European Commission, 2008). The high ones can be reused many times before having to be destroyed or condemned while the low ones can be reproduced into new materials as there is new technology that has made this possible. It is therefore important to explore the reuse of building materials because not only will they be reducing the amount of waste being dumped in landfills but they will be replacing primary materials and reducing natural resource depletion.

Sustainable Development (Benefits of sustainable development (SDG goals))

Sustainable development is the built environment's answer for the environmental challenges that it is facing. Gro Brundtland, a Norwegian Politician on 20th of March 1987 in response to the General Assembly of the United Nations at the time gave the world the first official definition of what sustainable development is. Sustainable development according to Gro is humanities' ability to create development without impeding future generations(Brundtland, 1987). Sustainable development though does have its reaches into culture, society, economy, not just the environment. These sectors all intertwine for sustainable development to be able to progress.

The industrial revolution did leave its mark on the world forcing world leaders to face problems that they created for economic gains and could no longer ignore. Sustainable development is one of the solutions being developed continuously to solve the problems that arose thereafter, giving birth to the Sustainable Development Goals (SDG). The sustainable development goals were created in September 2015, where 193 countries signed an agreement (Pedersen, 2018) that embodied 17 different goals from 4 core sectors that could achieve successful sustainable development. These goals have helped the world see better, the areas that particularly need improvement and progress. With the damage to the planet no longer avoidable, organizations and people are getting better informed and are playing more active roles in trying to meet up with the sustainable development goals.

SDG AND THE BUILT ENVIRONMENT

The Sustainable development goals adapted by over 100 world leaders have provided a guideline for what the world should work towards for the betterment and sustainability of the earth and humans (Nations, 2016). Of the 17 listed goals the building and construction sector is being positively challenged by up to 8 of these goals, the challenge that these goals pose to the building and construction sector creates the opportunity to save energy, create jobs, strengthen communities, and much more (Czerwinska, N.D). Some of the goals which have influence and have been positively integrated into the building and construction sector are:

1. GOAL 3: GOOD HEALTH AND WELL BEING

Indoor air quality, better greenery, and improved lighting are some of the ways in which a building can promote better well-being and good health (Czerwinska, N.D). The World Health Organization has mentioned that respiratory diseases associated with poor indoor air and environmental quality is number 4 of 10 leading causes of death globally (WHO, 2020). Sustainable building development would definitely cater to these.

2. GOAL 7: AFFORDABLE AND CLEAN ENERGY

Energy savings from energy-efficient buildings or sustainable buildings is one of the ways for reducing energy costs (Goals, 2020). Ensuring the access to affordable, reliable, and sustainable energy for everyone is vital and the building and construction sector does this by creating green buildings which are powered by renewable energy (Czerwinska, N.D).

3. GOAL 8: DECENT WORK AND ECONOMIC GROWTH

The sustainable building sector has the ability to create employment as there is an increase in the building and construction sector for sustainable buildings which would require labor to deliver these demands (Czerwinska, N.D). The life cycle of the sustainable building ensures that there will be the requirement of people to construct, operate, maintain and probably renovate these structures which contribute to inclusive employment (Czerwinska, N.D).

4. GOAL 9: INDUSTRY, INNOVATION, AND INFRASTRUCTURE

Building resilient infrastructure and promoting sustainable industrialization would foster innovation in such a way that the building and construction sector would be resilient and adaptable not just in the present but also in the future (Goals, 2020).

5. GOAL 11: SUSTAINABLE CITIES AND COMMUNITIES

Buildings are the foundations and back bones for cities and communities, so it stands to reason that sustainable building is paramount for long-term sustainability (Cucuzzella, 2019).

Problem Statement

Reuse has so many branches and aspects that reach deep into sustainable development. With the huge problem that building and construction waste is posing to the world, reuse of building materials creates an avenue that allows for building materials that can be preserved and reused to do so. Whatever cannot be reused, can be repurposed for recycling to create new materials thereby preserving the primary natural resources. The maximum potential for reuse of building materials is still being discovered every day, but there is definitely the technology and room to keep growing and expanding further.

Purpose and Scope of Study

City and regional planning faces and contributes to the threat of building and construction waste. When the waste is being improperly disposed of and creates landfills, it affects valuable spaces that can be used for urbanization or better allocation. Urban planning does contribute to this through wastes from road and infrastructure maintenance. Possible reuse of building and construction materials would thereby impact city and regional planning by reducing the amount of waste discarded as well as Green House Gas emissions.

The purpose of this study is to try to answer the research question of "what are the barriers and drivers of reuse of building materials?" by examining the barriers, drivers, and impacts of reuse of building materials on users and actors as well as availability and criteria for selection of used building materials. The users are the end consumers and the actors are built environment professionals such as architects, builders, civil engineers, etc.

The scope of this study focuses on users and actors previously defined as pertaining to the study. The reason for the users and actors focused in the study is to understand what possibly prevents the reuse of building materials from expanding and being widely adapted and incorporated. Understanding the markets and different criteria for reuse is also important because another reason for the reuse of building materials not growing is the availability. The focus case study area will be countries in Europe most especially Norway.

Aim and Objectives

This Master's thesis aims to assess the potential for reuse of building materials by evaluating the barriers and drivers that reuse of building materials faces. To achieve this, some objectives have been formulated:

- To evaluate the drivers that reuse of building materials pose to users and actors
- To evaluate the barriers that reuse of building materials pose to users and actors
- To understand people's behavior towards the reuse of building materials

THEORETICAL FRAMEWORK AND PREVIOUS RESEARCH

Circular economy

An increase in population has resulted in continuous developmental growth, shelter being one of the basic amenities has given the building and construction sector the backing it needs to continue expanding. This is not necessarily a bad thing except that the negative effects the building and construction sector has on the environment is a challenge to the textbook definition of sustainability in the sense that, if the negative effects continue as it is, the future generations will not have a world to develop.

Circular economy is an answer to humans' nature to 'manufacture, use and discard'. Circular economy as defined by Walter Stahel is "sufficiency that replaces production in such a way that reuse what you can, recycle what can't be reused, repair what is broken and remanufacture what can't be repaired" (Stahel, 2016). Circular economy is a concept that embodies recycle and reuse in what is best known as a closed-loop. The concept of circular economy was initially introduced in the 1970s by Walter R. Stahel and Geneviève Reday-Mulvey in their report to the European Commission. The idea of the concept was to substitute the labor force for energy (Stahel, 2016). Walter, being an architect, had first-hand knowledge of the building and construction market at the time and thought that in substituting labor for energy, the high unemployment rate at the time could be used to combat the increasing energy prices (Stahel, 2016). A study of circular economy in some European countries showed that if implemented correctly, circular economy could reduce Europe's carbon emissions by about 70% and increase the labor force by up to 5%.

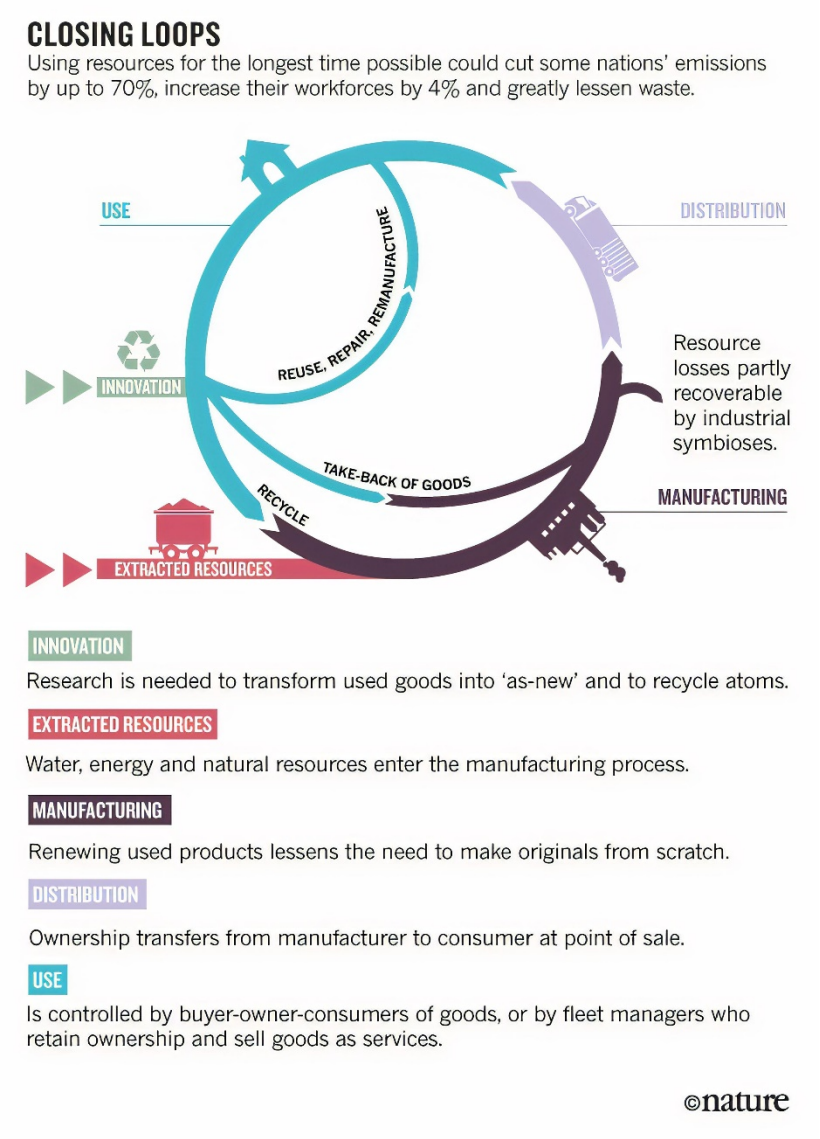


Figure 1. «A diagram interpretation of a closed loop», 2016, by Knowledge Transfer Network (https://www.nature.com/news/the-circular-economy-1.19594). CC BY Walter R Stahel (Stahel, 2016)

For the benefits that circular economy seems to possess as depicted by figure 1 above, it would stand to reason that the concept should have spread like wildfire now but it seems to be gaining very slow traction. One possible reason for this could be that for professionals like economists; creating long-lasting and sustainable wealth opposes their basic teachings where wealth is supposed to be fluid and ever-changing over time. Another reason for it not being a mainstream idea yet could be that business models built on the principles of circular economy pose a big threat to linear economies, for example carpooling poses a threat to car manufacturers in the

sense that the strengths of car manufacturing companies such as mass production, indigenous technologies as well as global supply and marketing is under the threat of less patronage because carpooling provides people a flexible, low maintenance and low-stress form of urban mobility. Even with this said, circular economy and closed looping does provide the building and construction environment the active means to deal with huge wastes generated and improperly disposed of.

Waste

The Waste Framework Directive 2008/98/EC defines waste as “any substance or object which the holder discards or intends to discard or is required to discard” (Waste Framework Directive, 2008). Waste in itself can be said to be relative. There is a saying popularly informally used in Africa and also around the world ‘one man’s food is another man’s poison’, this is popularly translated to mean that what someone considers valuable, someone else could call it waste. Waste is usually considered to be an unwanted material discovered after a certain process is completed. In the case of the building and construction environment, it would be materials that are no longer relevant at a particular time after some construction or renovation processes have been completed.

Norway is a country that is quite advanced in dealing with waste management. The sorting of waste has largely contributed to this. Waste in Norway is mainly categorized into paper, bio waste, and others (Restavfall). There are also other categorizations like glass and metal.

Figure 2. «A diagram depicting waste in Norway by origin», 2021, by Statistics Norway (https://www.ssb.no/en/natur-og-miljo/statistikker/avfregno). CC BY Mary-Anne Unuode

Waste hierarchy

A waste hierarchy that was defined in the 2008 EU Waste directive helped member states better utilize their resources in order to reduce environmental impact (Sheidaei & Serwanja, 2016).

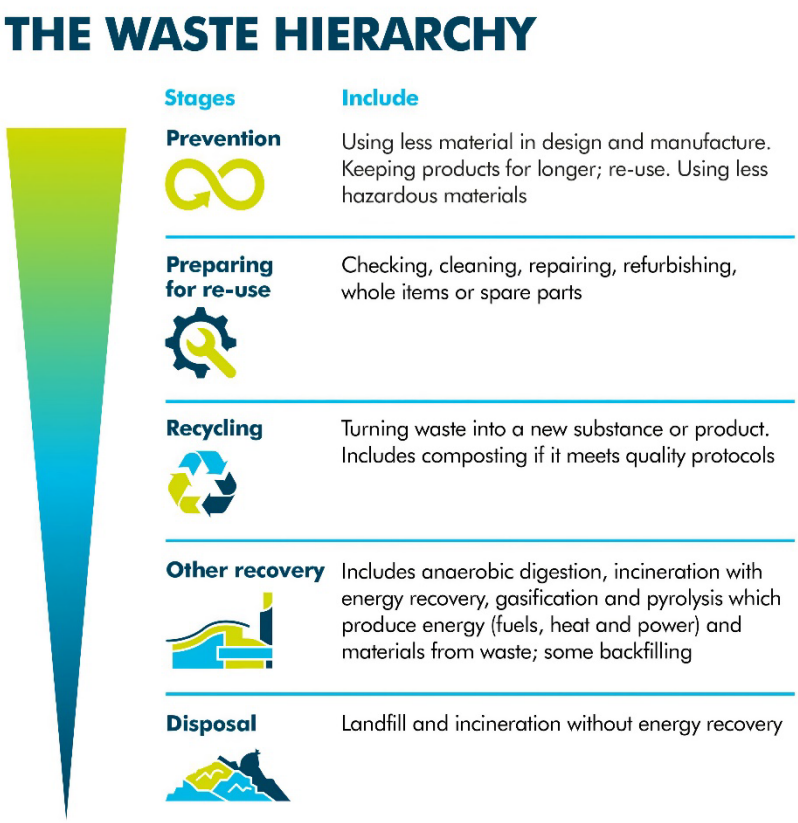


Figure 3. «A diagram of the waste hierarchy», 2020, by Cory Riverside Energy (https://www.coryenergy.com/sustainability/the-waste-hierarchy/). CC BY Cory Riverside Energy Group (Energy, 2020)

According to the waste hierarchy pyramid, the best way to achieve waste reduction or prevention is through behavioral changes and this could be influenced by the design and production of materials. Sometimes it is confused with the recycling pyramid but that is a different concept. Prevention or source reduction is at the top of the pyramid as it involves the usage of fewer materials for designing thereby reducing manufacturing, it involves long-lasting usage of products as well as usage of less hazardous materials; this is the most favorable option. The reuse part of the pyramid involves cleaning, refurbishment, and repair of spare parts or whole materials. Recycling is below reuse and it involves various methods for converting waste to new materials or products. Other recovery includes the process used to retrieve energy from other materials such as incineration and anaerobic digestion. Disposal is landfill dumping and incineration without energy recovery; this is the least favorable option.

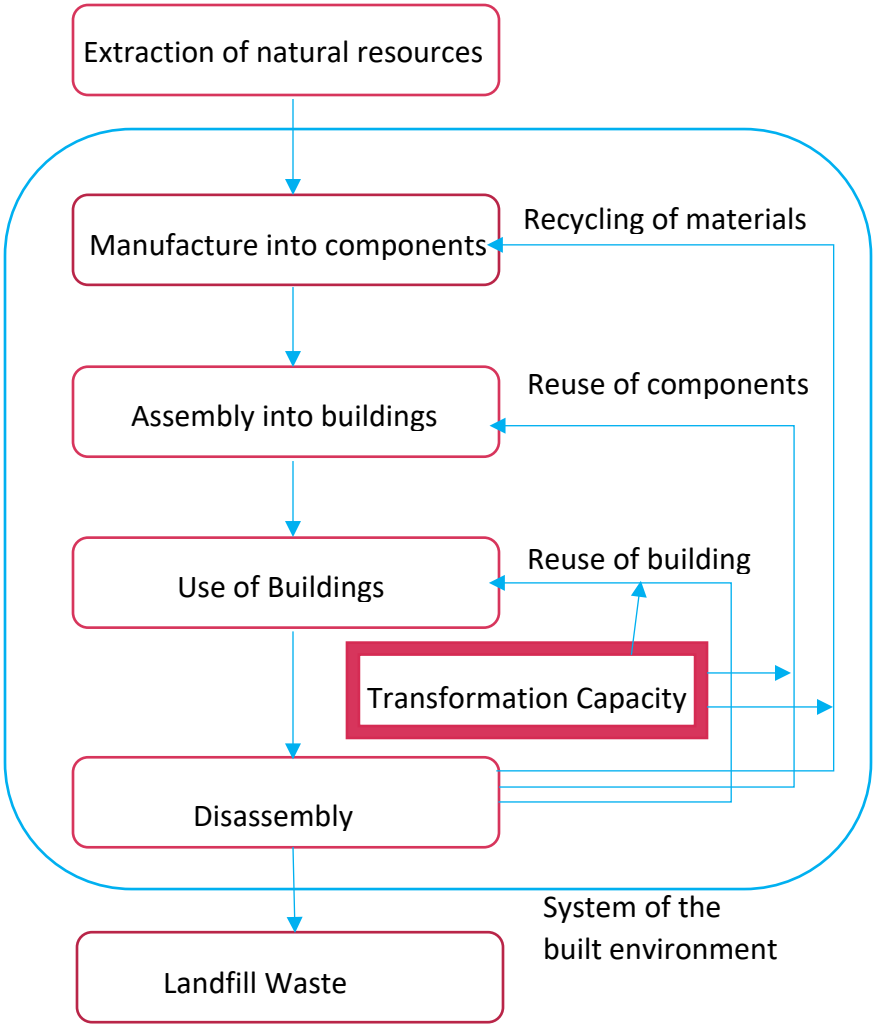
Building and Construction waste

Building and construction waste is excess unwanted waste from a completed building or construction activity. This waste could consist of so many materials such as concrete, wood, bricks, glass, metals as well as plastics. It also encompasses waste from infrastructure, road planning, and maintenance as well as construction and demolition (European Commission, 2008).

Recycle vs Reuse

This research uses the terms recycling and reuse often but the two terms have quite different meanings. For this research, the definition established for recycling is adapted from Richard Lund as a solid waste management strategy that has more environmental value than landfilling and incineration (Sheidaei & Serwanja, 2016). Recycling reduces the pressure on land that landfills create. Energy consumed during incineration as well is greatly reduced through recycling (Sheidaei & Serwanja, 2016). Also for this research, the definition established for reuse is the use of materials immediately without them having to be reprocessed. The materials can go through stages such as cleaning but they do not have to be broken down to base properties to be used again.

Reuse is a type of recycling but recycling is not reuse. This recycling hierarchy developed by Philip Crowther helps put these two terms in better concept. From figure 4 below, it can be seen that reuse can be directly incorporated into buildings without having to go through a transformation process to make them suitable for use.



Recycling of materials:

This includes collection of products for separation into their base materials to be used to make new products. For example used glass for mineral wool (Nordby, 2009).

Reuse of Components:

Building components such as doors, windows, roof tiles can be used more than once.

Reuse of Building:

Buildings in good conditions can be reused or modified on its' original site. Buildings can also be disassembled and moved just like was practiced in Norway with timber cabins (Myhre, 2000).

Figure 4. «A diagram depicting the recycle hierarchy», 2003, by Philip Crowther (Nordby). CC BY Anne Sigrid Nordby (Crowther, 2003) (Nordby, 2009)

Barriers and Drivers of reuse of building materials

The research on barriers and drivers of the reuse of building materials has grown quite a lot over the last 15 years. The more the barriers can be surpassed, the better the reuse potential of building materials will get. This is where drivers come into play because drivers are the opposites of barriers which means that better drivers promote greater conditions that overcome barriers. There are some challenges identified when trying to differentiate barriers from drivers because some situations/materials present themselves as a double-edged sword. For example, 3D

printers have been pointed out by Despeisse and some other authors in their 2017 article (Despeisse et al., 2017) to be a good example because of its resource consumption as well as its technological prowess (Hart et al., 2019).

Barriers

During this research, it was discovered that barriers can be classified based on their nature. Some academic and industrial literature also group them but these groups vary depending on the research and researcher. These barriers have been formed from reading various literature but the categorization is adopted from Jim Hart et al's article. Barriers and drivers in a circular economy: the case of the built environment (Hart et al., 2019)

Cultural Barriers

Cultural barriers have to do with social, behavioral, and managerial aspects of the building and construction sector.

1. Lack of interest, knowledge, skills, or awareness

This is the biggest problem because of the lack of progress on this barrier will continue to ensure the slow progress of building materials' reuse potential (Kanters, 2020). Especially the aspect of awareness; this goes for every aspect of the value chain which includes but is not limited to suppliers and end consumers (Hart et al., 2019).

2. Competition between businesses

This usually creates a lack of collaboration between businesses. This often leads to what is known as silo mentality; this is when businesses or business functions such as finance or marketing cannot work together openly to achieve a common goal (Hart et al., 2019). This could be a barrier because instead of business functions (could be along the value chain) working for the greater good to achieve better results, there is the need to create and design independently which could result in weaker or no progress at all (Kanters, 2020).

3. Inter-relationship between the building and construction sector with other sectors

The inter-woven relationship between the building and construction sector with other sectors can slow down development because it would mean that transformation of one sector would push other sectors to transform as well (Dantata et al., 2005). For example, the reuse of building materials could pose a transformational threat to the finance sector because there would need to be an evolvement of the sector's basic principles to keep up.

4. Lack of value chain corporation

This has to do with the early stage incorporation of all actors involved in reuse projects. It is important that all actors are involved from cradle to grave (sourcing for materials to finishing and maintenance of the reuse projects) to make the process easier for the professionals involved.

5. Time Required to Dismantle Materials

The amount of time required to dismantle materials to be reused from their sources is always unpredictable but longer than is usually anticipated. It also requires a lot of effort and this, in turn, affects the timing scheduled for building and construction projects (Dantata et al., 2005).

Regulatory barriers

Regulatory barriers have to do with policies, regulatory information, incentives as well as legislative regulations.

1. Inconsistent regulatory framework

There is a lack of a consistent regulatory framework which centers on the lack of universal agreement for policy support when it comes to the reuse of building and construction materials (Dantata et al., 2005). There are also very few targets that are not associated with the diversion of landfills. Julie Hill points out that the United Kingdom policy has "'largely ignored the upstream consequences of resource extraction… particularly if those are outside UK borders" (Hill, 2015).

2. Lack of flexibility in building codes and regulations

Most regulations and building codes focus on operational energy use while excluding the use during the lifespan of the building. Incorporating the reuse of building materials into existing regulations can be difficult mainly due to energy performance requirements (Kanters, 2020).

3. Handling and categorization of waste

This is also another troublesome barrier because reuse of building materials prides itself on not needing to be reprocessed. When the handling and categorization of waste are not properly done either due to inadequate laws or regulations or from the disobedience of laid laws and regulations on building and construction sites, more problems are created. This then promotes the need for a special sorting stage to be incorporated before reuse can be achieved.

4. Lack of incentives for reuse of building materials

Different kinds of literature have stated that lack of incentives could also be a reason for the potential of reuse being stifled (Chileshe et al., 2018 and Hart et al., 2019). There are no general incentives proposed by these authors though but from prior research, tax incentives and producer responsibility are good incentives (Chileshe et al., 2018).

Financial Barriers

Financial barriers involve financial issues as well as market/availability issues.

1. Short term Investments

This promotes capital profits over operational longevity. This means that there is a fuel for rapid investment returns which hinders transactions with greater social and economic goals that have longer financial returns (Hart et al., 2019).

2. Steep initial investment costs

The high cost of design with reuse materials is a huge deterrent to reuse growth and potential. This is due to various reasons such as sourcing for the reuse materials, the time the reuse materials need to be purchased, where they will be stored, where the materials are purchased from and all these, in turn, have a direct effect on labor costs (Gorgolewski et al., 2008).

3. The low end of life value on building materials

This is a particular challenge to the long-lasting nature of the reuse of building materials. This is because there is uncertainty about the future value of some materials (Gorgolewski et al., 2008). This can affect the purchasing value of certain raw materials as well.

4. Low numbers of pilot projects

Pilot projects refer to projects that are being done with reused building materials. The lack of case studies in pilot projects passes a message of inability to achieve a large-scale reused building material project which is one of the goals of the circular economy in the built environment (Chileshe et al., 2016b). Although pilot projects are increasing every day, there is insufficient and poor communication within the built environment on prior knowledge, processes, and progress (Hart et al., 2019).

5. Limited Funding

Access to funding and finance has largely gathered many general complaints when it comes to this barrier. It could be from the lack of faith in reuse potential or some other causes.

6. Market awareness

There is a lack of information about the availability of used construction products that are possible to buy. This is necessary because at the inception stage of a design it is important to incorporate where materials are being purchased and distributed from (Hart et al., 2019). Scheduled time for projects can affect the supply of common or desirable (dimension and quality) reuse materials (Kambiz et al., 2020). If the demand for reuse materials increase so will the market awareness and the growth and availability rate (Chileshe et al., 2016b).

Sectoral Barriers

Sectoral barriers include design construction, ownership, maintenance, reuse, and disposal of buildings and infrastructure in the built environment.

1. The complexity of the built environment

The complexity of buildings and the built environment can be a challenge as there is sometimes a lack of accountability and some decision-makers being exempted from bearing the consequences of their choices. A comment on this adopted by Jim Hart and his co-writers (Hart et al., 2019) retrieved from (Zimmann et al., 2016) says that "complexity is one of the defining features of the built environment. Built environment assets tend to have long lifecycles in which multiple actors with diverging priorities and incentives interact... Multiple stakeholders and long lead times also mean there is rarely continuity of ownership and control." This break in the administrative burdens and sometimes supply chains further complicates the built environment.

2. Long lifespan of products and materials

The life cycle and lifespan of building materials and components are also subject to the complexity of the built environment above. This is because with changes in the built environment there is no guarantee that the quality of a product is ensured. This also creates uncertainties with the future value and ownership of products and materials.

3. Technicalities regarding material recovery

An adequate depiction of this would be proper separation of bricks especially those bonded with OPC. Moving products from one technical cycle to another could be problematic at times. Peter Hopkins et al says it is important to clear a site immediately after building construction or demolition to hasten the recovery of materials that are still fit to be reused (Hopkins et al., 2019).

4. Insufficient use of design tools, information, and metrics focused on reuse or recycling directly
5. The conservative and adversarial nature of the built environment

The building and construction sector in the built environment has been accused of the above multiple times. The sector is sometimes wary of innovation which causes it to stifle new ideas that might be perceived to have huge financial risks. There is usually a risk-allergic approach to certain things that can be considered a huge barrier to innovation as pertaining to the potential of reuse of building materials.

6. Overdesigned Structures

The use of reuse materials to design a completely new project requires the incorporation of new structural elements as well as the reused ones. This is due to the architectural and structural integrity of the new building. This however results in the new materials being over-dimensioned to compensate for the lower or unknown strength of the reuse materials causing the new building to be over-designed (Gorgolewski et al., 2008).

Drivers

The importance of developing drivers is more potent when comparing them to how many barriers that there are. Drivers can best be described as the best ways to counter barriers. These drivers have been collated from different literature but have been categorized like the barriers above.

Cultural Drivers

1. Collaboration between businesses, stakeholders, and agencies

This will promote a wider and greater chance for holistic development. Instead of businesses all working in different directions to get the same goal, they can work together. They can eradicate the problems of the lack of integrity in the reuse materials and unknown availability (Chileshe et al., 2016b)

2. Formation of long term partnerships

Forming long-term relationships and partnerships is a great way to develop cohesion in the value chain. It creates effective alliances focused on the same goals without a negative approach to building and construction.

3. Competitiveness among Companies

Encouraging and promoting the green images of companies using different methods such as ranking can get companies to reduce the amount of building, construction, and demolition waste to boost their green and public images (Chileshe et al., 2016a).

Regulatory Drivers

1. Regulatory Reform

This is quite important for skills and innovation to be put to the best use. A lot of literature has highlighted the restrictions that some regulations put of reuse in the built environment. Obstructive regulations need to be developed and put into effect.

2. Incentives for reuse of building materials

One of the best ways to get humans to take active action and participation in innovations and developments is incentives. This can be in the form of fiscal incentives such as VAT reduction on projects that are refurbished, regulatory incentives for deconstruction and reuse (Chileshe et al., 2018), or other such incentives (Hart et al., 2019)

3. Early Incorporation of Reuse Stipulation

By stipulating that organizations or individuals wanting to create new projects or renovation projects must have a certain percentage of reuse that must be incorporated/ fulfilled from the beginning of the project, this will increase the rate of reuse (Tingley et al., 2017).

Financial Drivers

1. Life Cycle Costing

Whole life cycle costing and new evaluation techniques which incorporate the environmental, social, and political sectors increase the emphasis on the asset value of the materials (Hart et al., 2019).

2. More Pilot Projects

It is important to appreciate the progress being made in the built environment as it is to continue developing more ways of reusing building materials. For every stage that has been reached more avenues to test them should also arise. Temporary structures are the best ways to implement this. For example, short-term events or programs that require a large capacity like the Olympics

are great events for pilot testing (Kambiz et al, 2020). More experimentation leads to fault findings which lead to developments.

3. Lower Prices of Reuse Components

Various researchers such as (Dunant et al., 2017 and Chileshe et al. 2018) have expressed that the reduced cost of used components can contribute to cost savings in building and construction projects. (Kambiz et al., 2020) also reviewed a literature to this effect titled 'Component reuse in the building sector', where other similar articles were peer-reviewed and use to access reuse in the built environment.

4. Increased Prices of Landfilling

An increase in the cost of landfilling waste would have a direct effect on the reuse of waste from construction and demolition sites (Chileshe et al., 2016a).

Sectoral drivers

1. Material Information

Better information on materials such as their characteristics, origin, and specific details can go a long way to increasing the reuse materials' demand (Kambiz et al., 2020).

2. Clear Vision for reuse of building materials

This driver is very self-explanatory. The future of reuse should be envisioned, accepted, translated, and put into direct practice instead of remaining mere principles.

3. Technology and Innovation

Innovation is the key to the future, this stands to reason then that the key can unlock new opportunities. The sharing of markets for the underused products can be further developed. Resource recovery can also be better developed.

4. Development of secondary logistics infrastructure.

Marketplaces for used materials, used materials' storage, and upcycling facilities can solve practical issues pertaining reuse of building materials for new construction or demolition sites.

5. Training of Built Environment Workers

Training in efficient deconstruction and dismantling processes and the proper ways to separate and handle reusable materials is important as this knowledge is not common and leads to mishandling of materials that could have been salvaged (Tingley et al., 2017).

THEORY OF PLANNED BEHAVIOUR

The questionnaire survey has been fashioned using the Theory of Planned Behavior to assess the users' and actors' attitudes, behaviors, challenges, and barriers as regards the reuse of building materials. The theory of planned behavior has been used by researchers who have similarly investigated recycling behavior (Gadiraju, 2016; Wan et al, 2012; Davies et al, 2002). These researchers employed the theory of planned behavior in the recycling context to access behavioral patterns in their subjects but they also modified the theory to suit their various needs and research purposes.

The theory of planned behavior by Icek Ajzen proposes that there are three possible beliefs that influence human behavior. These are Behavioral beliefs "beliefs about the likely consequences and experiences associated with the behavior", Normative beliefs "beliefs about the normative expectations and behaviors of significant others" and Control beliefs "beliefs about the presence of factors that may facilitate or impede the performance of the behavior"(Ajzen, 1991).

a. Behavioral beliefs have to do with attitude and what an individual thinks about performing a certain behavior. "Attitude generally refers to the favorability of an individual toward certain behaviors" (Gadiraju, 2016).
b. Normative beliefs have to do with subjective norms in other words external social pressure and the rate of acceptance of that behavior influenced by external factors (Gadiraju, 2016).
c. Control beliefs have to do with a person's perceived control over their behavior which affects the individual's ability to perform a certain behavior. This behavioral variable was

added after Icek reviewed his initial theory and added it to account for people's perceived need to have control over their actions (Ajzen, 1991).

These three beliefs then point towards a person's behavioral intention leading to a certain behavior. This research did not modify the theory as other previously mentioned researchers have done for the reason that the originally proposed theory fit the needs of the current research. The theory variables were a natural guide in formulating the questionnaire, efficiently dividing it into various topics, further discussed in the methodology.

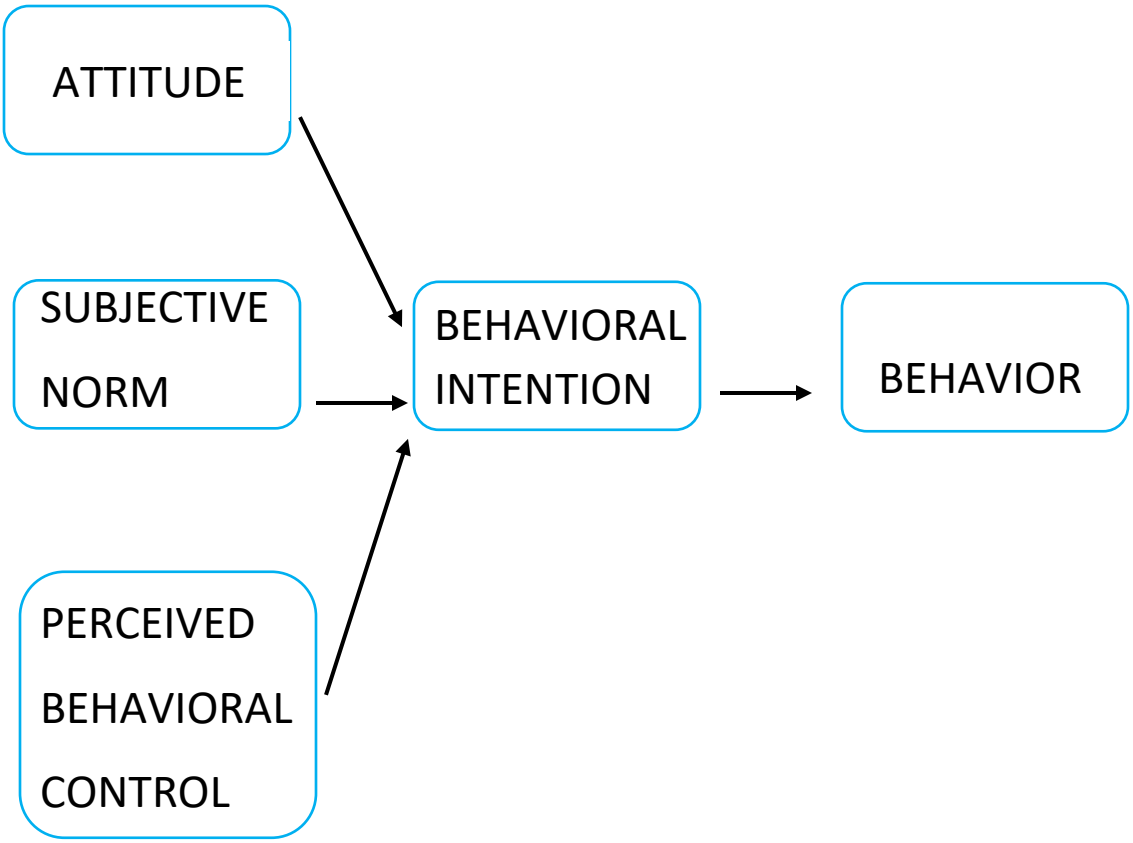


Figure 5. «A diagram interpretation of the Theory of Planned Behavior», 1991, by Icek Ajzen CC BY Mary-Anne Unuode

METHODS AND METHODOLOGY

Research Approach

The research is carried out in different stages using a holistic process of combining both qualitative and quantitative means of data collection. It focuses on studying the barriers and drivers of reuse of building materials. Theories and data related to building and construction waste are discussed in the literature review.

COUNTRY OF INTEREST

Norway is a country in Northern Europe that is on the western half of the Scandinavian Peninsula. The country shares land borders with Sweden, Finland, and Russia (Gudmund et al., 2021).

Between 2018- 2019 12.22 million tonnes of waste was generated in Norway (SSB Norway, 2021a), of that figure about 2 million tonnes of waste from the building and construction industry, which includes construction, rehabilitation, and demolition waste (SSB Norway, 2021b).

Norway in alignment with the Paris Agreement is also looking for ways and solutions to reduce greenhouse gas emissions. The construction sector is a good place to start, if waste and greenhouse gases can be reduced concurrently, then a faster way to achieve the emission targets will be discovered.

Despite the fact that there is a growing market in Norway leaning towards the reusability of building materials, there is still not sufficient research to be found on the topic (Sintef, 2020). In recent literature, knowledge about the reuse of building materials in the Norwegian context has been supplied mainly by industry reports written by professionals or persons who have no scientific background.

Presently, there are clear regulations, policies, practices, and documentations for building materials that are new but, none of the same assessment systems or regulations and practices exists for building materials that can be reused (Sintef, 2020). “Most of existing policies and regulations are either complex, lack integration or are fragmented over the different policy levels” (Sintef, 2020). Gathering and adapting knowledge from other countries which are making

good progress on the growth of reuse of building materials is good but can also be tricky. This is due to the specific national conditions in Norway which would require international experience to be contextualized and adapted to be relevant in the Norwegian building and construction industry. This shows that there is an ever-evolving need for research and knowledge in particular aspects that will be relevant in Norway.

Data Collection Methodology

Qualitative Data

Qualitative data collection allows for the exploration of ideas and experiences in depth. Some qualitative data in the research includes scientific and credible data examined in the literature review.

In-Depth Structured Interviews

The interviews allowed the researcher to gather in-depth knowledge while focusing on the interviewees' perspectives. The interviews focused on professionals working on pilot projects; pilot projects being projects that are already being constructed, have been constructed, or redesigned using reused products.

A total of eight interviews were carried out over three pilot projects, professionals working on and involved in these pilot projects such as architects, the owner, or engineers were the people interviewed. These pilot projects are all located in Norway. A total of 214 questionnaire surveys were gathered over a period of one month shared with respondents all over the world to be filled electronically.

INFORMANTS PROFESSION AND ROLES	**NAME/GENDER**
Manager for municipal waste company working with Circular house	Trond- Male
Project manager for Circular House	Jon- Male
Project leader for Circular House	Eva- Female

Architect and Project leader for Grensesvingen 7	Haukur- Male
Environmental consultant for Skur 38	Michael- Male
Architect and project leader for Skur 38	Joachim- Male
Assistant Project Manager	Silje- Female
Site manager and project leader for Skur 38	Vegard- Male

Table 1. Table of the interview informants with their names and roles in their respective projects.

The interviewees were approached via email and online video meetings were set up. The meeting took on an average of 1 hour to 1.5 hours to conduct. The interviewees were chosen based on their roles in the various pilot projects that were contacted. The interview was meant to focus on the main actors that were involved in pilot projects.

INTERVIEWS AND THE ANALYSIS (THEMATIC ANALYSIS)

A total of eight interviews were carried out over three different pilot projects. Professionals working on and involved in these pilot projects such as architects, the owner, or their representatives, or engineers were the people interviewed. These pilot projects are all located in Norway.

The interviews were analyzed using the thematic analysis in psychology developed by Braun and Clark (Braun & Clarke, 2006). This analysis is a qualitative analysis method popularly employed in psychology. In their paper, Braun and Clarke explain that thematic analysis even though not a widely acknowledged analytical method, it is still popularly used and they compare it to other methods used for qualitative analysis by locating themes or patterns in qualitative research. This makes it very good for analyzing data such as interviews.

Thematic analysis is a good approach to qualitative analysis whereby people's views, opinions, ideas, experiences, or knowledge is to be deduced from the qualitative data. This is what makes it appropriate for analyzing interview data, survey responses, and the likes (Caulfield, 2019).

To conduct a thematic analysis, there are various approaches but there are four common approaches employed (Caulfield, 2019).

1. Inductive Approach

   This approach usually is led by the themes determined from the collected data. This means that ideas, opinions, or frameworks are determined and developed from the data gathered.

2. Deductive Approach

   This approach usually means approaching the data with some pre-existing ideas or opinions expected to be found in the data. This means that the data gathered is used to support or disprove a preconceived idea. This approach is what is employed in this research.

3. Semantic Approach

   This approach analyzes the direct and entire content of the data gathered. This means that there is no hidden meaning or undertones being perceived in the data. All information is being analyzed as gathered and interpreted at face value.

4. Latent Approach

   This approach analyzes subtext and assumptions being underlined in the data collected. This means the data collected is used to reveal hidden statements and assumptions.

In using thematic analysis though, the researcher needs to be careful not to miss delicate information in the collected data. This is because the analysis relies heavily on the researcher's judgement and thus can be quite subjective. This being said, it can be difficult to use just one approach when analyzing data which is the reason that this general six-step approach listed by (Caulfield, 2019) makes employing thematic analysis more understandable.

1. Familiarization

   Knowing and understanding the data gathered is important. Because a lot of qualitative data might be from transcribed audios, a lot of personal notes and accurate transcription is needed to get familiar with the data (University of Auckland, 2019). In this research, familiarization

occurred during the transcription process of the audio to written text. There was no challenge at this stage since there were written pointers by the researcher as well as the audio so transcription was easier.

2. Coding

Coding involves highlighting sections from the data gathered which could include sentences or phrases and creating shorthand labels also known as codes to be able to describe the data/content (Caulfield, 2019). The coding was done by looking for similar patterns and comments mentioned by the interviewees repeatedly as well as comments made individually.

3. Generating themes

Using the codes, patterns are then identified to arrive at themes. Themes are usually collated codes that can be used to review each candidate or individual's theme (University of Auckland, 2019). This is a process that was particularly challenging in this research because grouping various diverse codes and opinions into a particular theme was difficult.

4. Reviewing themes

To ensure that the themes are relevant and accurate, they are cross-checked with the original data gathered (Caulfield, 2019).

5. Defining and naming themes

As the name suggests, the themes are given a name that accurately formulates what the theme truly means. Working out the scope and focus that each theme has (University of Auckland, 2019). The themes were named using similar backgrounds of codes.

6. Writing up

The written representation of the analysis of the data then follows, using the extracted data and the analyzed data to contextualize the write-up in relation to existing literature (University of Auckland, 2019).

The interviews were being done in collaboration with the REBUS research team in Norway; the REBUS team is a research team from the company SINTEF, located in Norway and they're also currently researching on reuse of building materials. The REBUS team provided the structure of the interview which focused on the challenges and barriers that actors discovered while working on pilot projects.

Quantitative Data

The method of data collection focuses on measurable data and statistics. It groups people to explain a particular phenomenon.

Online Survey

The survey allowed for the gathering of specific information that gives a micro view of the problem of masses and other actors as regards the reuse of building materials. The survey tries to examine the recycling culture and attitudes that can influence the reuse of building materials. The survey has been fashioned using the Theory of Planned Behavior to assess the users' and actors' attitudes, behaviors, challenges, and barriers as regards the reuse of building materials.

The survey was created using SurveyXact provided by the University of Stavanger and distributed online through social media. The survey was shared with the researcher's peers, lecturers, and associates in different organizations. These people were then encouraged to forward to as many people as they could. This influenced the result gathered from the survey. There was a total of 217 respondents for the questionnaire. The questionnaire was created and shared over a period of one month. The number of people who answered the questionnaire from within Norway was 132 and the number of people who answered from outside Norway was 85. The questionnaire aimed to include respondents from outside Norway to have an idea of what the behavior and attitudes are towards reuse.

The questionnaire was not restricted to individuals of other fields outside the built environment even though there were interviews conducted with professionals in and affiliated with the built environment. This was done to get the opinion of a diverse range of respondents and to get more knowledge and ideas on what other built environment professionals have to say on the topic of 'reuse'. Of 217 respondents, 116 have at least 2 years' experience in the built environment field

which means they are either architects, engineers, surveyors, etc. 101 are respondents of other professional backgrounds, and this gives an almost equal distribution of respondents. The respondents who have no prior built environment background most likely have no professional knowledge in the field of building and construction and can give an avid view of personal attitudes, experiences, and knowledge which has had no prior influence from their professional background.

TOPICS IN THE SURVEY

The topics in the survey were broadly divided into four sections. A copy of the questionnaire survey is attached to this research as an appendix

1. Attitude

This section examined what individuals thought about performing a certain behavior. This is because the more favorable an individual is towards reuse, the greater the intention to reuse increases (Gadiraju, 2016). This section had questions asking individuals about where or not they reuse materials that are possible to reuse or they throw them out after their initial purpose/use has been fulfilled and their past involvement with reuse materials.

2. Subjective Norm

This section examined what individuals thought about social or external pressure on performing a certain behavior. Some literature such as (Gadiraju, 2016) mention that the more favorable an individual's subjective norm is influenced towards reuse, the greater the intention to reuse is. This section had questions that inquired about how and what the influence of external forces such as social media, peers, and family has on the individual's ability and willingness to partake of reuse.

3. Perceived Behavioral Control

This section examined what the individual's controlled ability to perform a certain behavior is like. The questions in this section inquired about the individual's inclusive controlled behavior that is willing to partake of reuse. This section had questions that inquired about the individual's willing incorporation of reuse in their direct life, such as housing arrangement, new building

construction. If they agreed, what their concerns would be and if said concerns were settled in some way or the other, if their willingness to reuse would increase.

4. Behavioral Intention

This section examined the intended behaviors that individuals were going to express in the future after their past questions. The questions in this section hammered on their future behaviors such as their increased likelihood to reuse, what could affect that, and if they expressed low interest in increasing their reuse from the current state.

Ethical Considerations

The data collected was collected and prepared with the utmost consent and/or privacy of all informants. The interviews were recorded but only after an NSD approval was given. This was done to ensure that the information and privacy shared would be used responsibly.

DATA ANALYSIS

Introduction

Accurate data is necessary for proper analysis. The data gathered for the study was retrieved over two months. The data is gathered from a series of interviews and a questionnaire survey. A total of eight interviews were carried out over three pilot projects, professionals working on and involved in these pilot projects such as architects, the owner, or engineers were the people interviewed. These pilot projects are all located in Norway. A total of 214 questionnaire surveys were gathered over one month shared with respondents all over the world to be filled electronically. There are strength and weaknesses to disbursing and gathering data from in and outside Norway, some are:

STRENGTHS	**WEAKNESSES**
Diverse opinions from different building sectors across the world	The questionnaire didn't gather the specific countries other than Norway, so specific country comparison isn't possible

Different cultural influences on behaviors towards reuse and recycling	Varying advancement levels as regards reuse and recycling.
	Generalizations based on specific topic areas cannot be done due to the varying cultural practices in the built environments in different countries.
	Reuse of some building materials is limited or restricted in varying countries due to factors like the weather and economical maintenance.

Table 2. Table of strengths and weakness from collecting questionnaire data from in and outside Norway

Qualitative Data (Interviews)

Some of the main key findings from the data gathered in the interviews are:

1. Availability of materials market

   The availability of the market to buy reuse materials is grossly lacking. Several interviewees mentioned that the need for a market with open access where materials that can be reused can easily be purchased or bargained for will go a long way in reducing the challenges with reuse.

2. Cost Implications of incorporation of reuse in building projects

   The cost implication of reuse projects is perhaps the greatest setback that reuse faces. The cost implication of reuse projects even at preliminary stages such as the dismantling of source materials can be estimated to be above 1 million NOK. This type of cost implication ensures that private individuals will not venture into reuse in the near future.

3. Lack of sources/database for reusable materials

   The lack of sources for a database that can be shared amongst sites also poses a problem. The database currently being popularly used is known as “LOOP FRONT”. This database currently is being employed by various organizations but it has been expressed as heavy and not user-friendly. There are ongoing plans to expand the database to become a form

of a marketplace as well in the future but semantics such as regulations is currently hindering the process.

4. Certification and documentation restrictions that affect reuse potential

   The various policies, regulations, and restrictions that govern the reusability of building materials are making it difficult for reuse to be widely employed.

5. Time for Implementation of Reuse Projects
6. Awareness of reuse of building materials to not just the masses but also to built environment professionals as there is a gross lack of experience working with reuse projects currently.

THEMATIC ANALYSIS OF THE INTERVIEWS CONDUCTED

CATEGORY DIVISION	DEFINITION
Motivation	These refer to the drivers, the reasons that the pilot projects decided to embark on the reuse of building materials incorporation.
Reuse Potential	This refers to the materials and types of building that the interviewees thought are suitable.
Challenges	This refers to the barriers that the reuse of building materials has posed to interviewees during the process of building or renovation of pilot projects.
Informants' Future Recommendations	These refer to the recommendations made by the interviewees for the future and what they thought could be changed for there to be growth in the potential for reuse of building materials.

Table 3. Table of thematic analysis categorisation

Motivation

These refer to the drivers, the reasons that the pilot projects decided to embark on the reuse of building materials incorporation.

Circular House

The circular house project had a lot of reusable waste from their associating local waste company (GIR) which saw a lot of building and demolition materials. They soon discovered though that to be able to accurately and efficiently salvage and use the materials, they needed to approach the 'donor buildings' which is their term for the pilot project before demolition. Their donor building was an old barn approved for demolition which "had some very well preserved and good quality lumber/wood whose dimensions were really good" (Eva (Female) - Project leader for Circular House). Eva mentioned that there was a stipulation for the reuse of building materials in one of the contracts made with an actor involved in the project.

Grensesvingen 7

The owners of the building wanted to contribute and be a part of sustainable development. Reuse though was not part of the original agreement when the project begun, it was something that was decided between the different actors and stakeholders involved with the project to be incorporated. "The ambitions for the building were high initially but became higher with the need to incorporate reuse of building material" (Haukur (Male) - Architect and Project leader for Grensesvingen 7). Some of these ambitions included achieving BREEAM excellence which was achieved, this building was one of the first in Norway to achieve this goal. One of the main motivations and goals of this rehabilitation project was to use as little concrete as possible since the original building's concrete structure was in good condition.

Skur 38

The main ambition of the project was to be a pacemaker pilot project for reuse as there still is not enough experience on reuse pilot projects. Another ambition for the project was the high emission target ambitions. "This building that is being rehabilitated is one of the first buildings in Norway that was constructed with reinforced concrete (having iron reinforcements in the concrete structure). One of the major aims is to make the building 20% more energy efficient to reach BREEAM excellent goals" (Vegard (Male) - Site manager and project leader for Skur 38). They also had the ambition to keep as much of the original building as possible while not using too many new materials and maintaining a modern aesthetical outlook. The project also aimed to not reuse materials that contain harmful substances to humans. Aim to build a structure that

has parts that are easy to move around for the sake of the future potential of reusing those materials. BREEAM energy efficiency excellence and FutureBuilt motivations are used as a guide in the project and FutureBuilt also provides a platform and marketplace for the project to sell the materials that it can not use such as windows and doors for others to reuse them. They're motivating the project to find and use new systems that wouldn't be used normally like systems and materials that are easy to move around.

Reuse Potential

This refers to the materials and types of building that the interviewees thought are suitable for reuse.

Circular House

According to the interviewees in this project, wood was the material with the biggest potential for them. This could be because there was an excess of it provided by a well-preserved old barn. Concrete was also expressed as a material with great potential for reuse as pertaining to this pilot project. Building components have also been salvaged from the donor building. "Due to the project being an experiment and a prototype, there is constant thinking process on what can be reused" (Eva (Female) - Project leader for Circular House).

Grensesvingen 7

According to Haukur, the only interviewee for this pilot project in this research, the material with the biggest potential was concrete this was because the original structure of the building which was constructed in the early 1980s was in good condition and was not altered in any way. Some steel structural components were also kept and reused which Haukur expressed saved a huge amount of cost for the total cost of the project. The building was being rehabilitated in a part of Oslo where the owners wanted to incorporate the new building into the environment and also make it ecologically lighter and they tried to achieve this by reusing as much of the original building as possible. The project however was spared from the challenge of improper documentation and policies guiding such as they had accurate and complete documentation from the original design.

Skur 38

The material with the biggest potential for reuse in this pilot project was the concrete structure of the original building, this enabled the project to use way less concrete. Wooden elements and details which were mostly used for the façade and some aesthetics have been salvaged to be reused. One of the aims of the project is to make the construction feasibly prepared for future purposes. “Materials reusability doesn’t necessarily depend on the materials but on how the materials were fastened and what quality was the original material” (Joachim (Male) - Architect and project leader for Skur 38)

Challenges

This refers to the barriers that the reuse of building materials has posed to interviewees during the process of building or renovation of pilot projects.

Circular House

As the main source material in the project to be reused was the wood from an old barn, there were certain documentation and requirements to be presented and fulfilled. This is the “CE Marking”, they needed someone who would assess the wood since they had no marking for the wood as it was a barn built in the 1930s. “With the CE Marking absent, it was difficult to justify the reuse of the wood for structural purposes” (Jon (Male) - Project manager for Circular House). Reuse is still a very manual project currently and this was a challenge experienced in the company due to the need to carefully salvage the materials. The knowledge of marketplaces as well and databases are needed as well, currently the database commonly being used is called LoopFront. LoopFront is a database that has the potential to become a marketplace but can be difficult to navigate.

Grensesvingen 7

Due to the ambition of using as much of the original structure as possible, there were challenges with load-bearing construction and renovating a particular floor of the building whose original function was to house ventilation pipes and ductwork without destroying much of the main structure. According to Haukur, “that took time and was very cost-intensive due to the timeline

which was not followed due to the lack of skill of the workers" (Haukur (Male) - Architect and Project leader for Grensesvingen 7). The pressure from the environmental and ecological ambitions placed from the owners on the contractors and other actors involved also added stress on making the work approval worthy. Achieving BREEAM excellence was an ambition in the project so there were a lot of requirements to be fulfilled for that to be possible, requirements like life expectance calculation of the building, material sources, generated waste sorting, etc.

Skur 38

The project has been able to get a lot of materials that have been salvaged from the original structure but due to the aesthetical ambition as well as other similar ambitions, the actors and contractors in the project have been sourcing for materials from companies that are willing to subsidize some of their unwanted materials but have been met with reluctance and refusal. The change in the building function has brought about some technical challenges like "Its old wall design also makes it difficult to achieve the required soundproofing for office buildings as there are much higher ratings today compared to when the building was constructed and remodeled. This makes them need to demolish the interior wooden partition walls" (Vegard (Male) - Site manager and project leader for Skur 38). The cost of the building is also another challenge in the project due to the timeline being dynamic and the project trying to be a pacesetter for reuse of building materials but this is making the cost of the building too dynamic to have a cost estimate currently. Also breaking the habits of the built environment professionals working on the projects because the building is not a new construction but a reuse project. Some other challenges mentioned are the regulations regarding the risk carriers because the risks largely fall on the landlords right now which can deter people from reusing building materials and the total change of mindset in how old materials are perceived

Informants' Future recommendations

These refer to the recommendations made by the interviewees for the future and what they thought could be changed for there to be growth in the potential for reuse of building materials.

Circular House

Incentives were the most spoken-about means of encouraging individuals to partake of reuse of building materials. These incentives could benefit both private individuals and organizations as well. Regulations and policies from the government that enforces the inclusion of reuse of building materials in both the construction and renovation of buildings. Public awareness for the reuse of building materials has also been mentioned by Eva as still, some built environment professionals are still green-eared about the whole process and what it entails.

Grensesvingen 7

Better material knowledge and availability is an important aspect mentioned here by Haukur. "How to recirculate materials, where to get even used materials to reuse, which is something that is quite essential to get to know" Haukur. Taking the advancement of the sustainability of the built environment has to always be a foundation when embarking on building and construction projects.

Skur 38

More individuals and/or organizations need to be willing to embark on more reuse pilot projects as this will build experience and impart knowledge which in turn would lead to the growth in the potential of reuse of building materials. Already existing knowledge from other professionals needs to be disbursed better for the knowledge to be more mainstream.

INFORMANTS	GENDER	CODES
Manager for municipal waste company working with Circular house	(Male Trond)	Readily available materials. Governmental policies. Cost of the project
Project manager for Circular House	(Male Jon)	Readily available materials. Material Documentation. Governmental policies.

Project leader for Circular House	(Female Eva)	Readily available materials. Contractual stipulation. Continuous material evolution. Material Documentation. Automate the reuse process. Governmental policies. Public awareness. Cost of the project
Architect and Project leader for Grensesvingen 7	(Male Haukur)	High building ambitions. Readily available materials. Contractual stipulation. Renovation know-how. BREEAM excellence goal guidelines.
Environmental consultant for Skur 38	(Male Michael)	Renovation know-how. BREEAM excellence goal guidelines. Built environment professional reuse attitude adjustment. Cost of the project Incentives for pilot projects.
Architect and project leader for Skur 38	(Male Joachim)	Materials assembly. Planning for the future. Lack of mainstream information circulation. More reuse pilot project.
Assistant Project Manager	(Female Silje)	Lack of mainstream information circulation. More reuse pilot project. Readily available materials

Site manager and project leader for Skur 38	(Male Vegard)	High energy ambitions targets. Some readily available materials. Reluctance of supply chain companies cooperation. Lack of mainstream information circulation. More reuse pilot project.

Table 4. Table of the thematic analysis based on the informants and the codes derived from their comments

The codes from above are categorized into themes to be easier integrated into the research.

CODES	THEMES
Readily available materials. Continuous material evolution. Materials assembly.	Material availability and evolution
Governmental policies. Material Documentation.	Policies
High building ambitions. Contractual stipulation. BREEAM excellence goal guidelines.	Building ambitions
Renovation know-how. Built environment professional reuse attitude adjustment.	Training
Cost of the project Incentives for pilot projects.	Project Costs

Table 5. Table of the themes derived from the codes gotten from the informants.

The above themes have a great synergy and prove that the barriers and drivers mentioned in the literature review are still similar barriers and drivers discovered in the pilot projects. This goes to show that for the reuse potential to grow, these challenges have to be tackled, and even though

there are more pilot projects currently, there still needs more experience. Drivers and barriers being two sides of a coin show that the drivers can be better utilized to reduce the barriers.

The only barriers mentioned in the data not found in the literature review are the building ambitions, these include the goals and ambitions that the projects set for themselves individually or are influenced into setting, e.g, achieving BREEAM rating. This factor is not a barrier but more a driver as expressed by the interviewees with experience in this because the BREEAM rating has a set of guidelines that help in forging a sustainable building using different factors which includes reuse of building materials.

Quantitative Data (Questionnaire)

There was a total of 217 respondents for the questionnaire. The questionnaire was created and shared over one month.

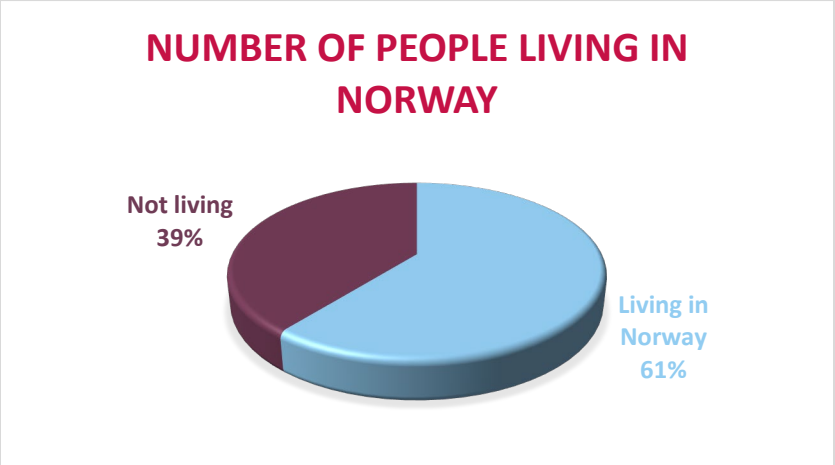


Figure 6. Chart showing the percentage of questionnaire respondents who live and out of Norway.

The number of people who answered the questionnaire from within Norway was 132 and the number of people who answered from outside Norway was 85. The questionnaire aimed to include respondents from outside Norway to have an idea of what the behavior and attitudes are towards reuse.

The questionnaire was not restricted to individuals of other fields outside the built environment even though there were interviews conducted with professionals in and affiliated with the built environment. This was done in order to get the opinion of a diverse range of respondents and to

get more knowledge and ideas on what other built environment professionals have to say on the topic of 'reuse'. Of 217 respondents, 116 have at least 2 years' experience in the built environment field which means they are either architects, engineers, surveyors, etc. 101 are respondents of other professional backgrounds, and this gives an almost equal distribution of respondents. The respondents who have no prior built environment background most likely have no professional knowledge in the field of building and construction and can give an avid view of personal attitudes, experiences, and knowledge that has had no prior influence from their professional background.

		Reuse Items instead of throwing them away		
		No	Yes	Total
Live In Norway	No	9	76	85
	Yes	31	101	132

Table 6. Table showing the number of respondents in and out of Norway against the number of respondents who reuse items instead of throwing away reusable waste.

The above table shows a crossbar information of the number of people who live within and outside Norway who reuse items instead of throwing them away. The majority of respondents who do not live in Norway are from Nigeria in Africa. Norway is a country that is known to have an implemented structure for recycling. Nigeria is not a country that has an implemented structure for either reuse or recycling, so it is interesting to see that there is an internal reuse culture. This information goes to show that there is most likely a positive reuse attitude both in people who live within and outside Norway, this based on assumptions drawn from the data as there is no extensive knowledge of the reuse culture outside of Norway known by the researcher.

	Involved with Reuse of Building or Construction Materials

		No	Yes	Total
Built Environment Background	No	58	43	101
	Yes	28	88	116

Table 7. Table showing respondents with built environment background against those involved with reuse of building and construction materials.

The above table shows a cross bar information of the number of people with built environment backgrounds who have been involved with the reuse of building materials. This goes to show that the likelihood of people who have no prior background or knowledge of the built environment getting involved with the reuse of building materials is lower than people who have prior knowledge or background.

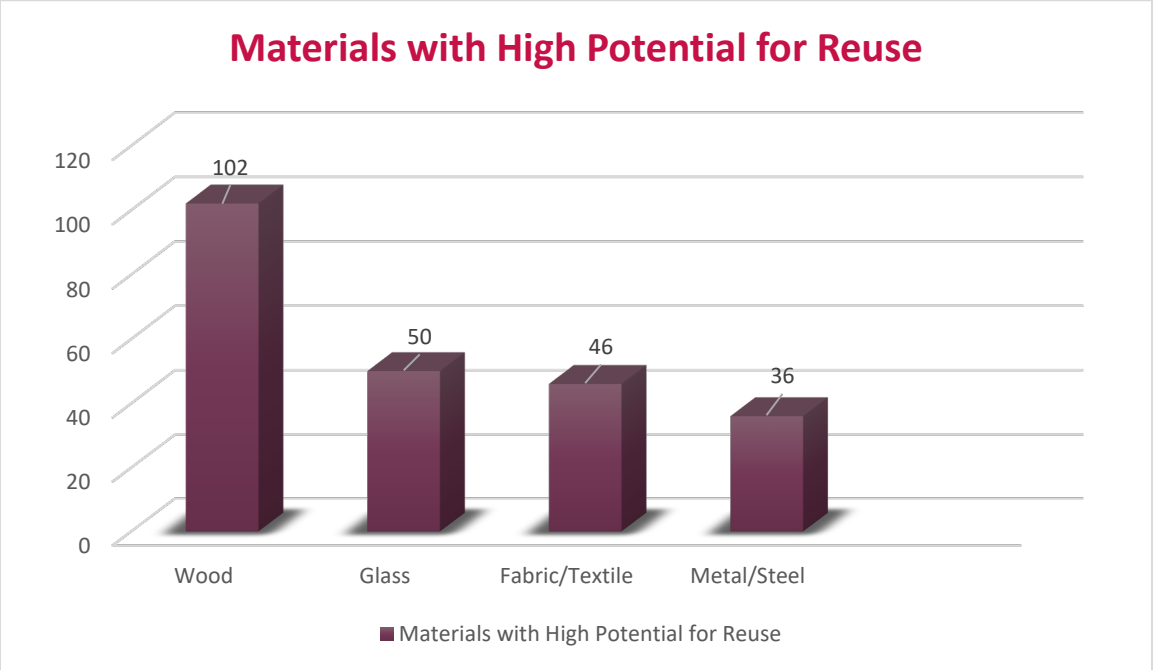


Figure 7. Chart showing some materials which respondents think have the highest potential for reuse.

The chart above shows the potential of different materials asked of the respondents. Of 131 respondents who had experience with working with the reuse of building materials, wood was the most popular material to be reused. This shows the high potential of reuse for wood. This answer was also expressed with the interviewees.

		Concerned About Climate Change		
		No	Yes	Total
Reuse Items Instead of Throwing them away	No	11	29	40
	Yes	13	164	177

Table 8. Table showing respondents who reuse items against those concerned about climate change.

		Concerned About Waste Pollution		
		No	Yes	Total
Reuse Items Instead of Throwing them away	No	5	35	40
	Yes	7	170	177

Table 9. Table showing respondents who reuse items against those concerned about waste pollution.

The above tables show a set of crossbar information that shows the relationship between the number of people who reuse items and those who are concerned about climate change and waste pollution. This information gives an insight into possible base attitudes that drives the respondents to reuse. By doing so, the perceived behavior section of the theory of planned behavior used to fashion the questionnaire helps gives an insight into the probable reason that people reuse, it could be because they care about climate change and want to contribute to waste management.

	Concerned About Climate Change		
	No	Yes	Total

Live in Norway	No	4	81	85
	Yes	20	112	132

Table 10. Table showing respondents who live in and out of Norway against those concerned about climate change.

The table above suggests that even though a majority of the respondents are leaning towards managing the environment due to the damage caused by climate change, there is still a small percentage of people who are not concerned about the effects and advancements of climate change.

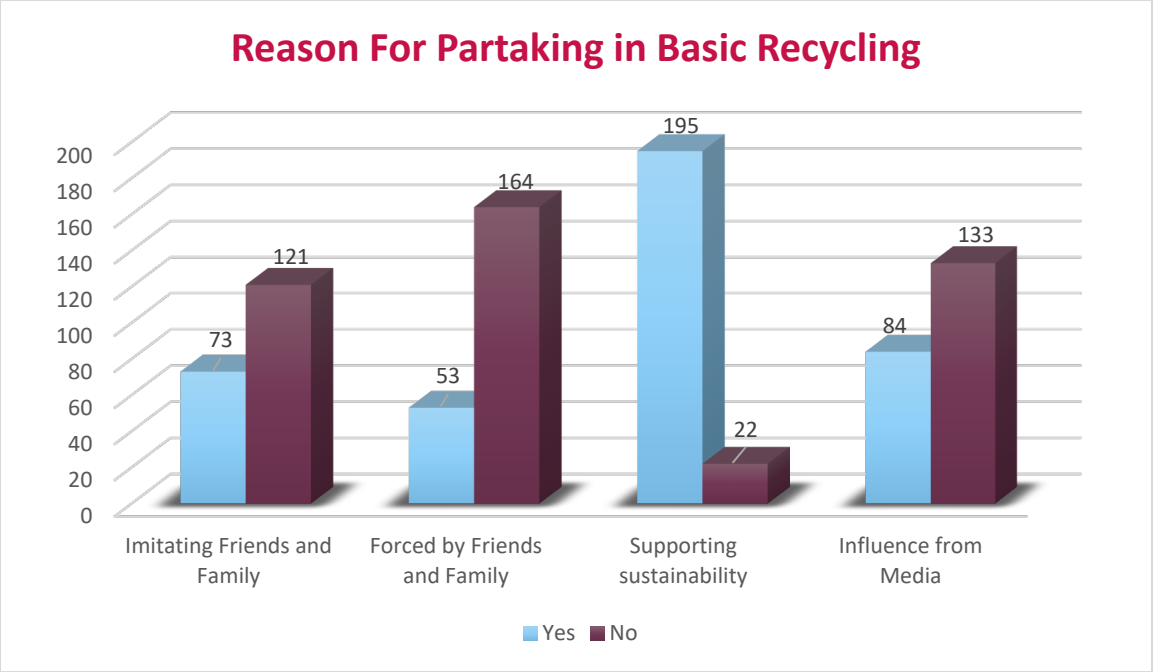


Figure 8. Chart showing respondents reasons for partaking in basic recycling

Basic recycling in the context of the thesis refers to waste sorting and management. The above chart shows various possible reasons why individuals partake in basic recycling. It goes to show that most of the respondents are not coerced into partaking in recycling but there is still a good number of people who are influenced by their immediate circle to partake in basic recycling. This being said, the number of people who would recycle more if they saw other people recycling more was about 70% of the respondents. Understanding people's behavior towards recycling can give an idea of how they would behave with reuse.

Figure 9. Chart showing the frequency that respondents reuse waste currently.

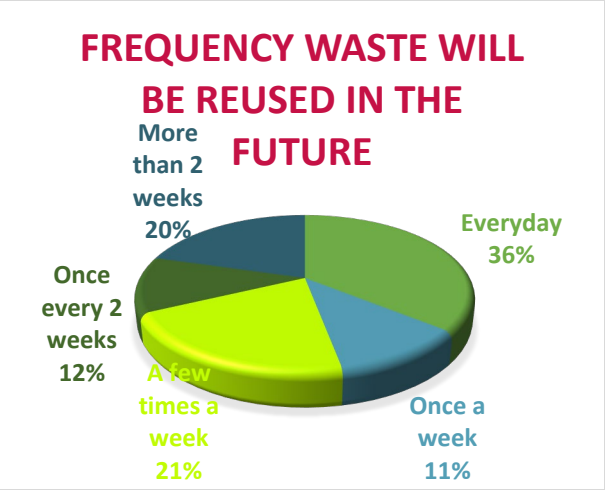


Figure 10. Chart showing the frequency that respondents will reuse waste in the future.

There is not much difference between how people are reusing waste currently and in the future how they would reuse waste. This would almost suggest that the potential for reuse is at the best it can be presently, till there is more innovation or means to increase the reuse potential.

Figure 11. Chart showing respondents thoughts on reuse of building materials

There is a positive response to the reuse of building materials on a general basis but when it came to the incorporation of building materials into immediate physical surroundings like homes, the

response was not as positive as respondents express their fear of the building structural integrity as well as displeasure with 'not new' materials being incorporated into the building.

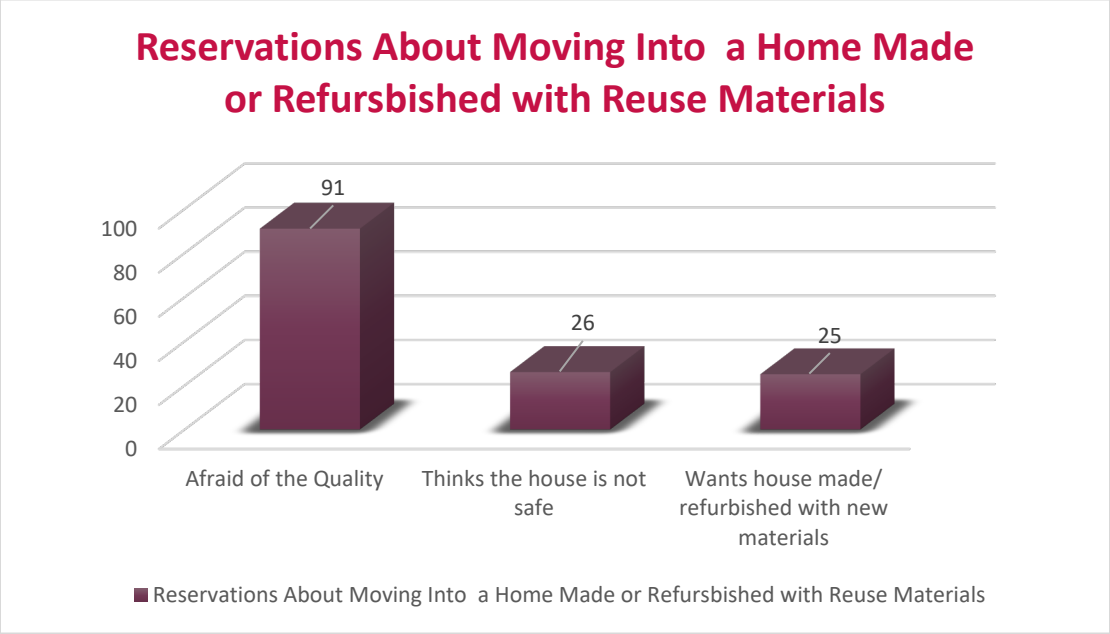


Figure 12. Chart showing respondents' reservation with reuse of building materials.

Although respondents felt like if they had the opportunity or liberty to build their home from scratch, they would give reuse of building materials a chance, depending on factors like cost, quality of reuse materials, and availability of reuse materials.

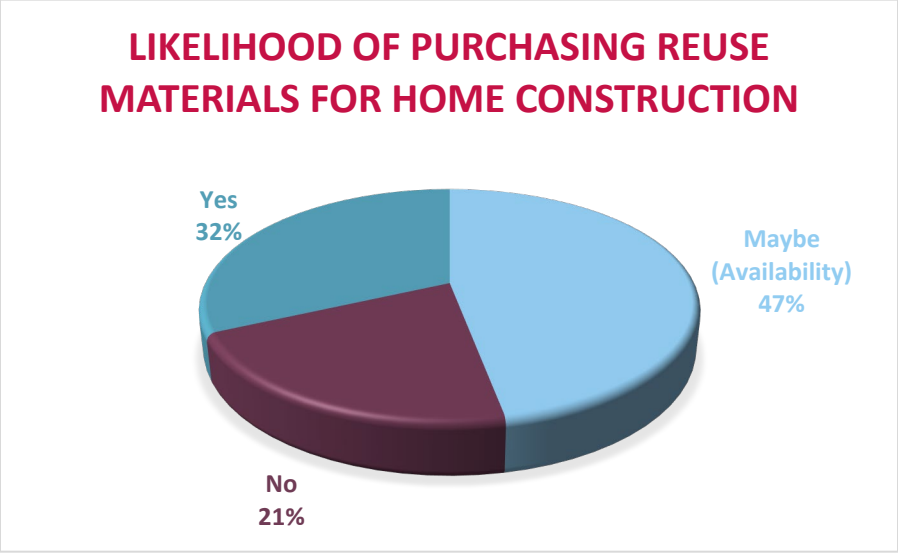


Figure 13. Chart showing respondents' likelihood to purchase reuse materials

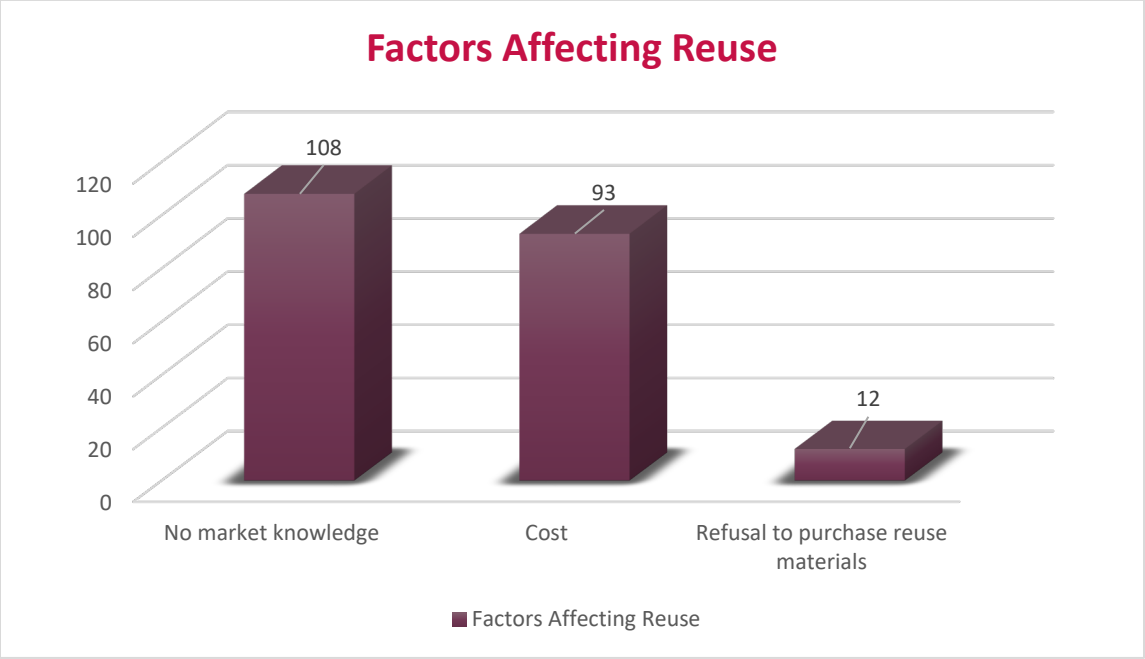


Figure 14. Chart showing factors affecting reuse as demonstrated by the questionnaire respondents.

The two main challenges that reuse is facing currently are cost and market knowledge or availability of reuse materials. This is also a major challenge pointed out by the interviewees for the thesis. This suggests that these are areas that should be the main focus for reuse potential to grow. This does not mean that these are the only challenges that reuse faces; other challenges include, aesthetic quality, commercialization of the reuse sector, more knowledge on reuse potential, its challenges, and advantages.

When respondents were questioned about if some of the challenges such as the ones shown above were resolved if their willingness to reuse will grow and there was a significant turnabout in the reluctance to reuse building materials.

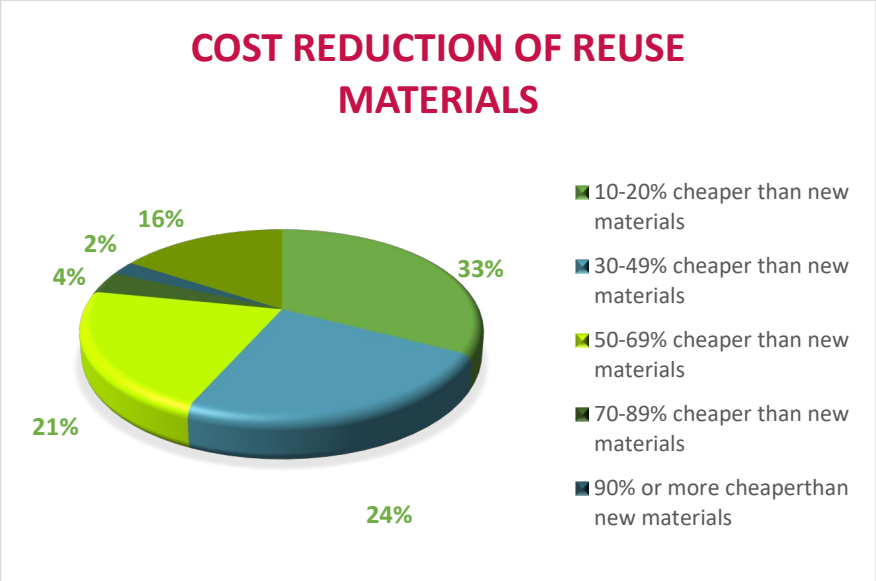


Figure 15. Chart showing respondents' likelihood to purchase reuse materials depending on cost reduction

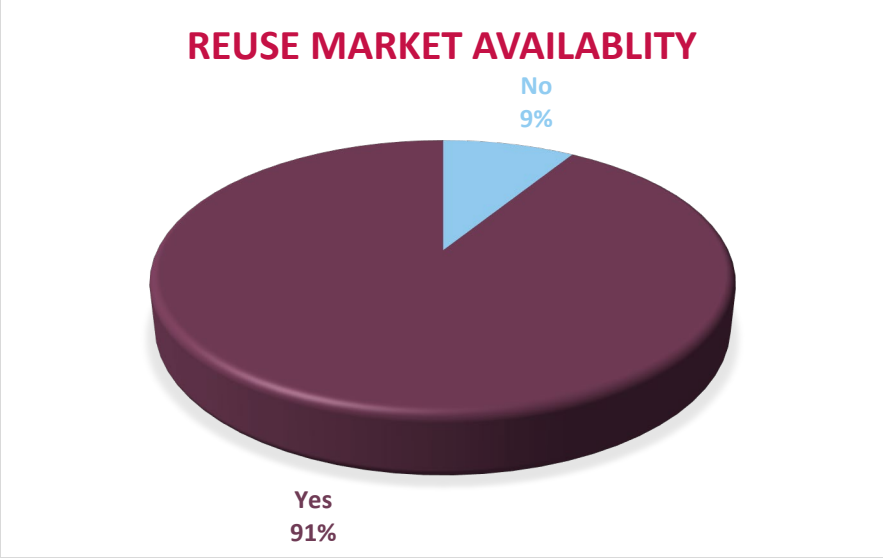


Figure 16. Chart showing respondents' likelihood to purchase reuse materials based on better reuse market knowledge.

These charts above go to show that if there are fewer challenges to the implementation of reuse of building materials, there will be significant growth in the potential of reuse of building materials.

RESULTS AND COMPARATIVE ANALYSIS BETWEEN BOTH SURVEYS AND DISCUSSION

The purpose of this study is to understand the potential of the reuse of building materials. A holistic approach using a qualitative and quantitative analytic method to compare with previous literature reviews was employed in the paper.

RESULTS FROM THE INTERVIEW AND SURVEY

The interviews and survey were created using the objectives of the paper as a foundation. The objectives formulated were:

- To evaluate the challenges and barriers that reuse of building materials pose to users and actors
- To assess the availability of reuse materials
- To understand the behavioral criteria that influence reuse of building materials

The data from the interviews was to aid with the first two objectives of this research paper and the questionnaire aided with the last two objectives in the paper.

The interviews focused on pilot projects in Norway. The results from the interviews enumerated some issues which were synonymous with barrier data examined in the literature review. The issues are:

:

1. Lack of availability of materials market
2. Heavy cost Implications for the incorporation of reuse in building projects
3. Lack of sources/database for reusable materials
4. Certification and documentation restrictions that affect reuse potential
5. Time Intensive Implementation for Reuse Projects

The questionnaire survey created was shared with the researcher's peers, lecturers, and associates in different organizations. These people were then encouraged to forward to as many

people as they could. This influenced the result gathered from the survey by providing diversity in the respondents which gave input from cultural, socio-economic, and physical backgrounds from different countries. Some key findings from the questionnaire are enumerated as follows:

1. There is a lack of availability of reuse materials knowledge and markets
2. The attitudes and behaviors towards reuse are favorable which could increase the growth of reuse
3. Growth of the reuse of reusable materials in the future as compared to now
4. The criteria for reuse would increase once factors such as increased market knowledge, reduced cost of reuse materials, and increased material availability are favorable

For the growth potential of the reuse to be evaluated, the current state of reuse needs to be taken into account as well as the barriers and challenges that the growth potential is facing. The data collected just buttresses what the literature review has already enumerated in the barriers and challenges section.

Knowledge from the literature review is roughly no older than 2008 and the challenges that the potential of reuse was facing at that time is still being experienced currently in the year 2021. This shows that the growth of reuse though developing and becoming mainstream, is still slow. Most likely slow enough not to be making a big enough impact in the building and construction environment.

DISCUSSION OF FINDINGS

The survey created gave some insight into the current state of reuse especially from the respondents. There is a high favorability of reuse and recycling currently due to the fact that the populace is supporting sustainability but there are some who are still being coercing into it by peers, family, and media. Although there was expressed increase in the frequency by roughly 10% of reuse in the future expressed there is no way of being sure this is carried out.

One major issue that reuse is facing is that individuals only think of it as a good way to support sustainability but do not actively practice it, an example of this is from the survey where the response to the thoughts on the reuse of building materials is quite high but the willingness to

incorporate it into personal lives like a new home building or as part of materials for renovation was quite low. This was due to a majority being afraid and skeptical of the quality as well as not trusting the durability of the material. This is fed from the belief that “materials need to be new to be good”. This is a mentality that needs to be changed which can greatly impact the reuse potential of building materials.

Another major issue noted is the cost of reuse building projects. This issue is perhaps the greatest issue experienced since it reaches all corners of a reuse project. Firstly, it is time-intensive to carefully dismantle the materials from their sources which leads to increased labor, especially for a country like Norway which ‘money is time’. Secondly, the cost of inclusion of reuse materials could be a huge deterrent to reuse potential as factors such as distance for the transportation of the material, the documentation needed for the use of the materials, or the likes could contribute to the final total cost of a reuse project.

From the data gathered and the literature review, factors which could push the growth potential of reuse are of various forms but some of them are the training of built environment professionals to handle the reuse materials and more market knowledge which is very essential as more people could be interested and invested in the reuse of building materials if they know where and how to purchase items.

Policies that govern documentation and ratings that materials sometimes need to be provided for the materials to be deemed suitable for use can sometimes be time-consuming and cost-intensive to achieve. There is documentation such as ‘CE Marking’ which is required for some materials such as wood to be reused but to get these marking for materials which are gotten from old buildings can be quite tasking as the lack of original paperwork which contains specifics and a material ledger is missing. There has been expressed a way that this can be bypassed is if the materials being sourced to be reused are under the same owner.

CONTRIBUTIONS OF THE STUDY

This research has contributed to understanding the barriers and drivers that the building and construction industry is facing currently and what could possibly be done to grow the potential for reuse in the future.

LIMITATIONS OF THE STUDY

Some limitations experienced in the process of researching this paper are few but had some underlying influence on how the research and data gathered was interpreted.

Non- differentiation of the specific countries in which respondents outside of Norway answered. This prevented the specific comparison between the countries, although it was verified that a majority of the survey respondents outside Norway were from Nigeria because the researcher's contacts and connections reached extensively in Nigeria to be able to gather relevant information.

The case in point country of Norway does not have sufficient literature on the potential of reuse of building materials which could have helped immensely in the research. This is quite damning considering the growth in reuse pilot projects that are being carried out currently in the country.

The questionnaire didn't gather the specific countries other than Norway, so specific country comparison was not possible in the research. Generalizations based on specific topic areas cannot be done due to the varying cultural practices in the built environments in different countries. Reuse of some building materials is limited or restricted in varying countries due to factors like the weather and economic maintenance and these choices could have influenced the answers provided by the respondents.

CONCLUSION

The research question in this paper is "what are the barriers and drivers of the reuse of building materials?" Some major barriers have to be addressed as they are currently impeding the growth of reuse of building materials, some of which are the cost of reuse projects; this is the biggest challenge that has reaches into various aspects of a building and construction project. This can however be resolved through governmental incentives. Other barriers include training of built environment professionals on working with reuse materials, the policies which guard things like material documentation, and the market for reused materials. Drivers that are very notable which can help with combating the barriers are life cycle costing, more pilot projects which breed knowledge and experience with reuse projects also governmental incentives could go a long way

in motivating individuals and not just big corporations in embarking on reuse projects also material markets will be very useful.

The potential for reuse of building materials currently has room to grow as it has basically remained the same since the year 2008. Reuse of building materials has the potential to be a way for the waste in the building and construction industry to be utilized and not just discarded. Currently, the waste that reuse takes care of is not as advanced as the possible potential. The barriers and drivers with reuse have to be adequately managed for the growth potential to grow.

The barriers examined in the literature review were supported by the data gathered and this goes to show that over the last 10 years, even though there are more pilot projects, the barriers are not being eradicated or even reduced yet. These barriers need to be managed properly, especially the knowledge of reuse of building materials by built environment professionals which could potentially reduce the handling time needed for reuse projects. The cost of the project is perhaps the biggest challenge, these can be tackled by incentives that governments can set up to help make reuse more mainstream which in turn could properly monetize the whole process. Although there are currently drivers in the reuse sector, these drivers need to be adequately cultivated to grow and match the market around them for reuse potential to grow.

Reflections and further research

Incentives could benefit both private individuals and organizations to partake in the reuse of building materials. Regulations and policies from the government that enforces the inclusion of reuse of building materials in both the construction and renovation of buildings. Public awareness and built environment professionals' training for reuse of building materials is necessary as some built environment professionals are still green-eared about the whole process and what it entails. Better material knowledge and availability is an important aspect. Taking the whole advancement of the sustainability of the built environment has to always be a foundation when embarking on building and construction projects. More individuals and/or organizations need to be willing to embark on more reuse pilot projects as this will build experience and impart knowledge which in turn would lead to the growth in the potential of reuse of building materials. Already existing knowledge from other professionals needs to be disbursed better for the knowledge to be more mainstream. For the future,

there needs to be a comparison of the state of reuse of building then and in the past. This will then bring to light what issues still need to be resolved and what measures have been introduced to deal with them. More knowledge and experience from professionals in the built environment need to be circulated better for a wider knowledge platform and base.

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APPENDIX- QUESTIONNAIRE SURVEY

DESCRIPTION:

This questionnaire is part of research for a Master's Thesis in City and Regional Planning department at the University of Stavanger. The research is focusing on recycling of building materials most especially reuse.

The main objective of the questionnaire is to get insight into the potential of reuse of building materials by trying to examine:

a. Users perspective on recycling and reuse (with a focus on building materials)
b. Gain insight into the experiences and challenges built environment personnel encounter as regards recycling of building materials
c. Identify general areas of concern and challenges relating with recycling and reuse of building materials

THEORY OF PLANNED BEHAVIOUR

Attitude

What does an individual think about performing a certain behavior?

1. Do you live in Norway?

(Goals) ❑ Yes

(2) ❑ No

2. If yes, what city in Norway do you live in?

(Goals) ❑ Oslo

(2) ❑ Bergen

(3) ❑ Trondheim

(5) ❑ Stavanger

(4) ❑ Tromso

(6) ❑ Others _____

3. Do you have a built environment profession/background (i.e. Architect, Civil Engineer, Builder, Construction Manager, etc.)

(Goals) ❑ Yes

(2) ❑ No

4. If yes, how long have you been practicing?

(Goals) ❑ 0-2 years

(2) ❑ 3-5 years

(3) ❑ 5 years and above

5. Do you reuse certain items instead of throwing them away (e.g. turning them to home décor or everyday usage?)

(Goals) ❑ Yes

(2) ❑ No

6. Have you been involved with reuse of building or construction materials? (These could include doors, windows or other building materials)

(Goals) ❑ Yes

(2) ❑ No

7. If yes, what type of building materials were they?

(Goals) ❑ Wood

(2) ❑ Glass

(3) ❑ Fabric/Textile

(4) ❑ Metal/Steel

(5) ❑ Others _____

Subjective Norm

What do others think about an individual performing a certain behavior?

8. Are you concerned about climate change?

(Goals) ❑ Yes

(2) ❑ No

9. Are you concerned about waste pollution?

(Goals) ❑ Yes

(2) ❑ No

10. Have you ever used a recycled product?

(Goals) ❑ Yes

(2) ❑ No

11. Do you recycle because your peers and close relations do it?

(Goals) ❑ Yes

(2) ❑ No

(3) ❑ Maybe

12. Do you recycle because you want to support sustainable environment?

(Goals) ❑ Yes

(2) ❑ No

13. Do your friends and family have to force you to recycle?

(Goals) ❑ Yes

(2) ❑ No

14. If you partake in recycling, do your friends or family approve of you doing so?

(Goals) ❑ Yes

(2) ❑ No

15. Do you recycle because of the Media or a particular campaign?

(Goals) ❑ Yes

(2) ❑ No

16. If you do not recycle, if more people recycled would you do it then?

(Goals) ❑ Yes

(2) ❑ No

17. Have you ever purchased an item knowing it's recycled or made from recycled products?

(Goals) ❑ Yes

(2) ❑ No

(3) ❑ Maybe

(4) ❑ I do not think I ever will

18. If yes, what was the reason you purchased it?

(2) ❑ I like to contribute to sustainability

(3) ❑ I didn't know it was recycled

(4) ❑ Someone made me buy it

(5) ❑ People are buying it, so I did

(6) ❑ Because it is cheaper

(Goals) ❑ IF YOUR ANSWER IS NO (FROM ABOVE), PLEASE CLICK THIS OPTION

19. If no, what is the reason?

(2) ❑ I felt like the item isn't new

(3) ❑ I have never come across a recycled item to buy

(4) ❑ I've never known where to buy recycled/reused items

(5) ❑ IF YOUR ANSWER IS YES (FROM ABOVE), PLEASE CLICK THIS OPTION

Perceived Behavioral Control

Can an individual perform a certain behavior?

20. What do you think of reuse of building materials?

(2) ❑ Great- It is essential as it reduces waste and environmental pollution

(3) ❑ Good- They could come in handy

(4) ❑ Neutral- I don't really care

(5) ❑ Bad- I don't feel too comfortable with that

(6) ❑ Not acceptable- New is always better

21. If you were moving to a new home, and you hear that the home has been made completely out of reused building materials would you be more cautious about the building?

(Goals) ❑ Yes

(2) ❑ No

22. If yes, is it because

(2) ❑ You are afraid of the quality of the materials

(3) ❑ You think the house is not safe

(4) ❑ You want new materials in the house

23. If you happen to be building a new home, would you go for reused building materials (such as windows, doors, etc)

(2) ❑ Yes- It would be cheaper

(3) ❑ No- I'm building a house, I'd like new things

(4) ❑ Maybe- I wouldn't mind if I knew where to buy them

24. Would the quality of the reused building materials prevent you from buying them?

(Goals) ❑ Yes

(2) ❑ No

(3) ❑ Maybe

25. If the quality of the reused building materials was proven acceptable would it still prevent you from buying it?

(Goals) ❑ Yes

(2) ❑ No

Behavioral Intention

26. How frequently have you reused waste in the past few months?

(2) ❑ Everyday

(3) ❑ A few times a week

(4) ❑ Once a week

(5) ❑ Once every 2 weeks

(6) ❑ Longer than that

27. How likely are you to reuse waste in the future?

(2) ❑ Everyday

(3) ❑ A few times a week

(4) ❑ Once a week

(5) ❑ Once every 2 weeks

(6) ❑ Longer than that

28. What do you think would most likely affect you reusing in the future?

(2) ❑ No market knowledge

(3) ❑ Cost

(4) ❑ I don't want to purchase reused or recycled items

(5) ❑ Others (Can elaborate) _____

29. Will you start thinking of buying a reused material if the price:

(2) ❑ The same price with new materials

(3) ❑ 10-29% cheaper than new materials

(4) ❑ 30-49% cheaper than new materials

(5) ❑ 50-69% cheaper than new materials

(6) ❑ 70-89% cheaper than new materials

(Goals) ❑ 90% or more cheaper than new materials

30. What would you say is your challenge with reusing of building materials (It doesn't have to be large things like windows or doors, it can be things like curtain hangers, used heaters, etc.)

(2) ❑ I don't know where to purchase recycled materials

(3) ❑ I don't want to purchase recycled materials

(4) ❑ I don't have sufficient knowledge of whether they'll be good or not

(5) ❑ Others _____

31. If reused building materials were easily available, would you buy them more?

(Goals) ❑ Yes

(2) ❑ No

32. Do you feel there are particular types of building materials that are easier to recycle? (This could mostly apply to the built environment professional but if you have any opinions please go ahead and share them)

(Goals) ❑ Yes

(2) ❑ No

33. If yes, Could they be?

(2) ❑ Wood

(3) ❑ Glass

(4) ❑ Fabric/Textile

(5) ❑ Metal/Steel

(6) ❑ Others _____