

CITIES AS MATERIAL BANKS FOR THE FUTURE

Closing the material resource loop



POLITECNICO
MILANO 1863
SCUOLA DEL DESIGN

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A. Y. 2021/2022

Supervisor: Stefana Maja Broadbent



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Master's Degree in Product Service System Design

Consolidation Thesis

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Academic Year: 2021/2022

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First Printing: December 2022



ACKNOWLEDGMENT

Foremost, I would like to thank all the people who participated as respondents in the various research methods used to understand the complexity of sustainability and the construction industry.

I would like to thank my thesis guide and mentor, Prof. Stefana Maja Broadbent, for being incredibly patient and encouraging throughout this time. She always made time to discuss the complex stages of this thesis and offer different perspectives for solving the problems faced to complete this thesis. I am certain I would have not made it so far without her help and guidance.

I thank Shamita Chaudhary, Founder of the Malba Project, for her support and willingness to participate in interviews.

A special thanks to my family for their unconditional support throughout these testing months and for always motivating me to do my best. For instilling the belief that the fruits of labor always follow a hard time. Kashish and Riam, I cannot thank you guys enough for showing so much patience with me and participating in my research. This thesis would have been incomplete without your constant trust and support in me.

Studying at Politecnico di Milano has been an incredible journey. I am grateful to have met every person, each one had a unique role in my story.

Thank you to everyone who has been a part!



ABSTRACT | ENGLISH

The Earth has an abundant yet finite number of resources. All the things needed for the survival of Human beings like food, air, water, and shelter come from these natural resources. Some of these renewable resources can be naturally replaced like plants & trees, while some are non-renewable like fossil fuels, which cannot be replaced at all. To make these resources last longer we need to use them carefully and efficiently. Depletion of resources occurs when they are consumed at a faster rate than they can be replenished. Two of the major causes of resource depletion are overpopulation and the overconsumption of resources.

Today, the linear model of resource consumption is more dominant in the construction industry: resources are extracted, processed into usable components, and then used in the construction of structures. The structures are used until they reach their end of life and then are demolished, with most of their waste dumped in landfills. With every new construction, we often use materials that require the extraction of virgin materials. This model has various environmental implications and risks to the renewability of natural resources due to overconsumption.

A transition from the linear model, where materials are extracted, produced, used, and discarded, to a circular economy model, where rather than getting discarded the materials are reused would allow the cities to recover and strengthen the existing assets to meet their comprehensive sustainability. The United Nation's Sustainable Development Goals provide the construction industry with a new lens through which global needs can be perceived as business solutions.

This thesis unravels the current flaws of the construction industry in India and explores its potential in achieving the Sustainable Development Goal with sustainable consumption and production. The aim is to analyze how Circular Economy concepts can be used inside the construction industry, using a systematic literature review of existing databases. The thesis is organized as follows: Chapter 1 introduces the global concern of resource depletion; Chapter 2 explains the UN's SDG related to sustainable consumption & production, and the current situation in India; Chapter 3 investigates the contribution of the construction industry in regression of achieving the goal; Chapter 4 unfolds the appalling situation of Construction & demolition waste in India; Chapter 5 observes the promising innovations and best practices in the world as case studies; Chapter 6 presents 'The Malba Project' a start-up working to streamline C&D waste collection in India; Chapter 7 proposes design interventions to The Malba Project incorporating the shift to circular economy model and closing the material resources loop.



ABSTRACT | ITALIAN

La Terra ha un numero abbondante ma finito di risorse. Tutte le cose necessarie per la sopravvivenza degli esseri umani come cibo, aria, acqua e riparo provengono da queste risorse naturali. Alcune di queste risorse rinnovabili possono essere sostituite naturalmente come piante e alberi, mentre altre non sono rinnovabili come i combustibili fossili, che non possono essere sostituiti affatto. Per far durare più a lungo queste risorse dobbiamo usarle con attenzione ed efficienza. L'esaurimento delle risorse si verifica quando vengono consumate a un ritmo più veloce di quanto possano essere reintegrate. Due delle principali cause dell'esaurimento delle risorse sono la sovrappopolazione e il consumo eccessivo di risorse.

Oggi, il modello lineare di consumo delle risorse è più dominante nel settore delle costruzioni: le risorse vengono estratte, trasformate in componenti utilizzabili e quindi utilizzate nella costruzione di strutture. Le strutture vengono utilizzate fino a quando non raggiungono la fine della loro vita e poi vengono demolite, con la maggior parte dei loro rifiuti scaricati in discarica. Ad ogni nuova costruzione, utilizziamo spesso materiali che richiedono l'estrazione di materiali vergini. Questo modello ha diverse implicazioni ambientali e il rischio di rinnovabilità delle risorse naturali a causa del consumo eccessivo.

Una transizione dal modello lineare, in cui i materiali vengono estratti, prodotti, utilizzati e scartati, a un modello di economia circolare, in cui invece di essere scartati i materiali vengono riutilizzati consentirebbe alle città di recuperare e rafforzare le risorse esistenti per soddisfare la loro sostenibilità globale. Gli obiettivi di sviluppo sostenibile delle Nazioni Unite forniscono all'industria delle costruzioni una nuova lente attraverso la quale le esigenze globali possono essere percepite come soluzioni di business.

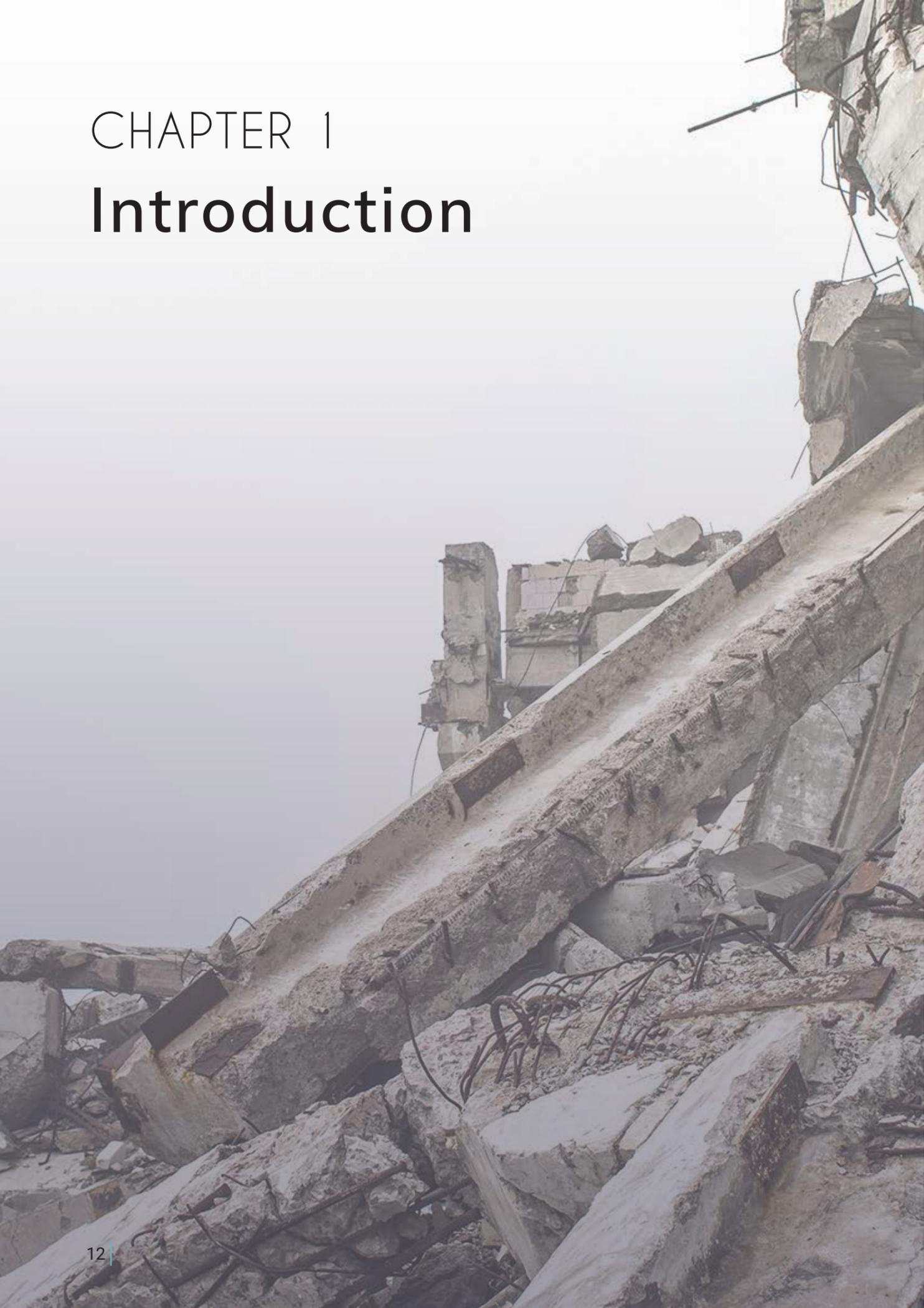
Questa tesi svela gli attuali difetti del settore delle costruzioni in India ed esplora il suo potenziale nel raggiungimento dell'obiettivo di sviluppo sostenibile con consumo e produzione sostenibili. L'obiettivo è analizzare come i concetti di economia circolare possono essere utilizzati all'interno del settore delle costruzioni, utilizzando una revisione sistematica della letteratura dei database esistenti. La tesi è organizzata come segue: il capitolo 1 introduce la preoccupazione globale dell'esaurimento delle risorse; il capitolo 2 spiega gli SDG delle Nazioni Unite relativi al consumo e alla produzione sostenibili e l'attuale situazione in India; il capitolo 3 indaga il contributo dell'industria delle costruzioni nella regressione del raggiungimento dell'obiettivo; il capitolo 4 spiega la spaventosa situazione dei rifiuti da costruzione e demolizione in India; il capitolo 5 osserva le promettenti innovazioni e le migliori pratiche nel mondo come casi di studio; il capitolo 6 presenta "The Malba Project", una start-up che lavora per semplificare la raccolta dei rifiuti C&D in India; il capitolo 7 propone interventi progettuali per The Malba Project che incorporano il passaggio al modello di economia circolare e chiudono il cerchio delle risorse materiali.

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CHAPTER 1

Introduction



The world's population crossed 8 billion on 15th November 2022. Around 50 years ago in 1970 it was 3.6 billion and 50 years later in 2070 it would be 10.5 billion as forecasted by the United Nations (Population Connection & Population Education, 2016). That means an increase of 7 billion within a century.

In 1970, the consumption of natural resources was 27 billion tons which has increased to 100 billion tons. "The world's consumption of raw materials is set to nearly double by 2060 as the global economy expands and living standards rise, placing twice the pressure on the environment that we are seeing today, according to a new OECD report." (OECD, 2018).

The world's average ecological footprint is 2.7 gha (Global Hectares). An ecological footprint is the amount of land required to fulfill the demand of resources required by the population i.e. the quantity of nature it takes to support people or an economy. Humanity's demand on nature has exceeded beyond the capacity of the planet Earth, indicating that 1.8 Earths would be required to cater to the current population demands of natural resources and ecological services. Taking the example of North America, the average ecological footprint is about 8.1 gha per person. Five times the surface area of Earth would be needed to provide the lifestyle of a North American to all the people of the world (Earth Overshoot Day, 2022). In order to sustain and provide all the basic necessities to the world's population, countries will have to reduce their consumption of natural resources.

How many Earths would we need if everyone lived like the country mentioned?

How many countries we need to meet that country's resident's demand on nature?

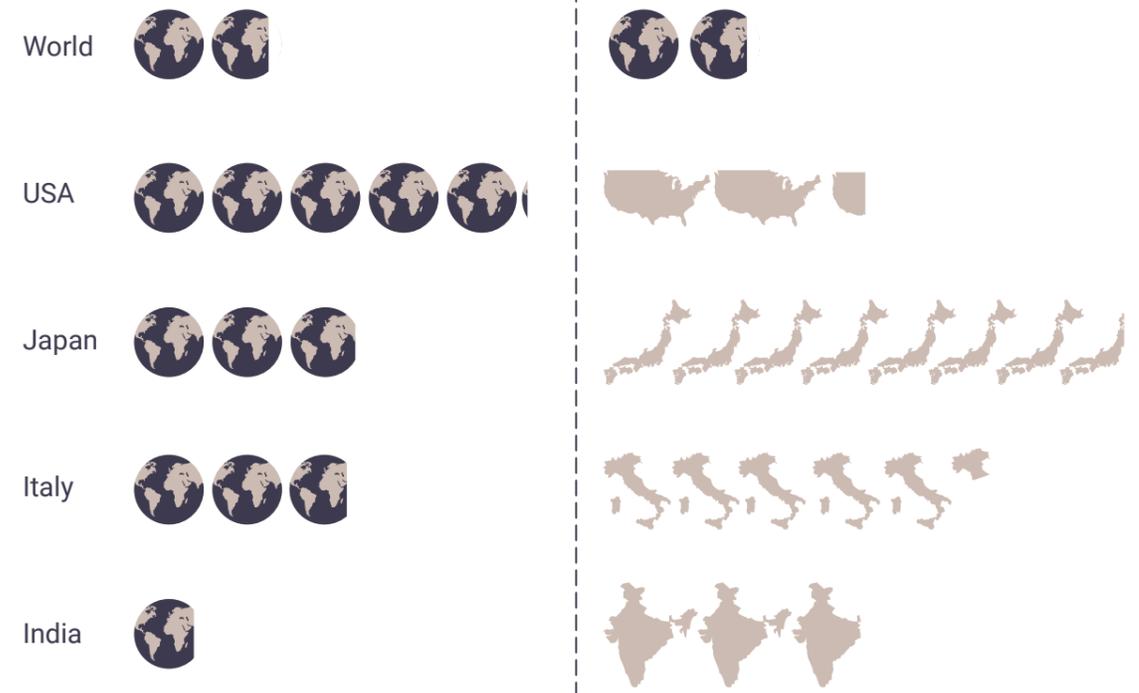


Figure 1: World Ecological Footprint.
Data Source: National Footprint and Biocapacity Accounts (2022)

1.1 Effects of depletion of natural resources

- **Climate change**- Due to irresponsible human activities, the global temperature has increased which is resulting in changes in weather patterns and disrupting the usual balance of nature. Water is becoming scarcer and deserts are expanding, reducing land for growing food. Changes in temperature cause changes in rainfall, resulting in storms, landslides, and floods.
- **Instability in the ecosystem**- Food chains are getting disrupted and then species fragmentation & extinction issues arise. The world’s population of fishes, amphibians, birds, reptiles, and mammals has declined by 58% between 1970 to 2012 and it will increase to 67% by 2022 (Causes and Effects of Depletion of Natural Resources, 2020).
- **Pollution**- The amount of pollution created greatly damages the life-support systems like air, water, and food. This results in harming the health of the planet and humans. From the process of extraction of raw materials, process & manufacturing, distribution & consumption to disposal of waste, pollution is created at every stage of the value chain of the product or its services. Waste production is a major issue that harms life on land as well as in the oceans (One Planet Network, 2022).



Image 1: Extraction and mining of Earth’s natural resources causing its depletion.
Source from left to right: (GRANDGUILLOT, n.d.), (Kumar, 2020), (Conserve Energy Future, 2014)

These environmental impacts are deeply interconnected with each other. Pollution aggravates climate change, and the instability in the ecosystem & loss of biodiversity is increased by both pollution & climate change. The unsustainable consumption and production can create consequences that rebound the effect of further depletion in the quality and quantity of the Earth’s resources. It also causes an unequal socio-economic effect, threatening livelihoods. The poorest people are directly exposed to the resource & environmental damage and have the least support to cope with the consequences.

1.2 What is Sustainable Development

Sustainable development is a term that refers to the development that meets the needs and requirements of the present without compromising the potentiality of the future to meet its own needs.

“Sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs.”

- Brundtland Report, World Commission on Environment and Development, 1987 (Enel Green Power, n.d.).

Sustainability is the foundation for the guiding global framework of international cooperation- the UN’s 2030 Agenda for Sustainable Development and Sustainable Development Goals. With the evolution of the concept of sustainable development, its focus has shifted towards, economic development, social development, and environmental protection for future generations. UNESCO formulated a distinction between sustainability and the sustainable development as follows: “Sustainability is often thought of as a long-term goal (i.e., a more sustainable world), while sustainable development refers to the many processes and pathways to achieve it.” (Wikipedia contributors, 2022).

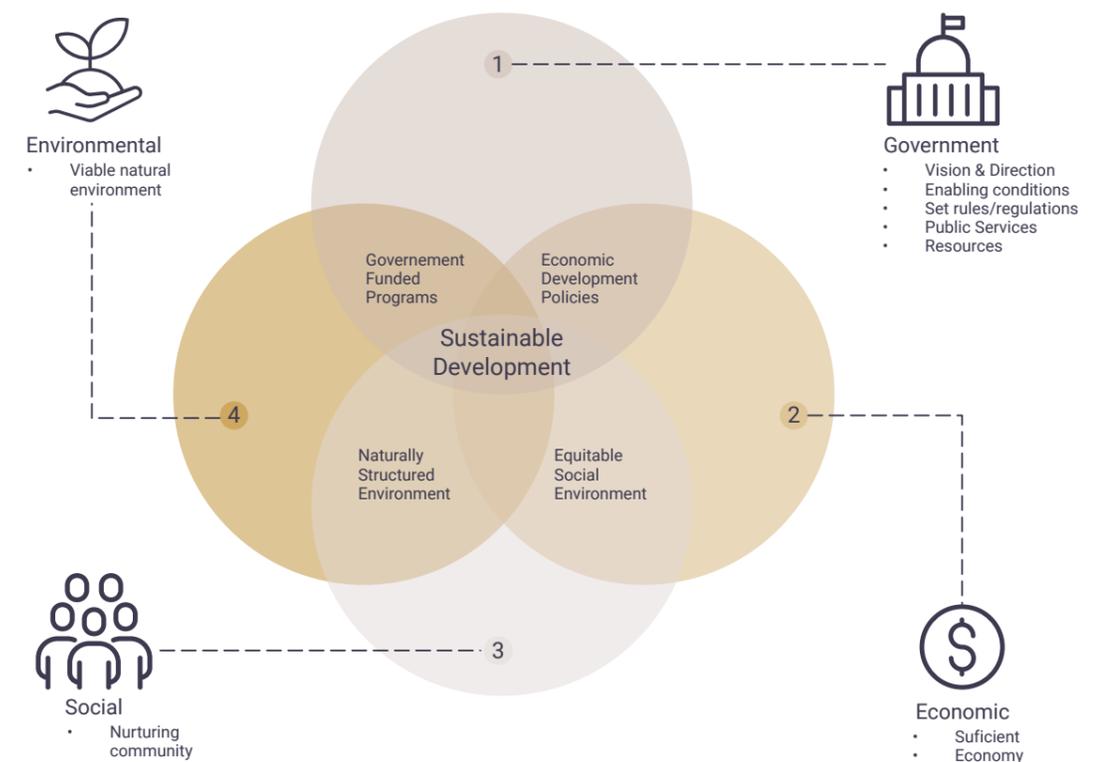


Figure 2: Venn Diagram showing interdependency of the four aspects of Sustainable Development.
Source: Author

CHAPTER 2

Sustainable Development Goals



2.1 Path to sustainable development

Since we only have one planet Earth, sustainable development needs to be turned into a concrete commitment than just a catchphrase. We need to learn to live in the limits of a single planet.

In September 2015, the UN's member states signed 2030 agenda for Sustainable Development, a plan of action for peace and prosperity for people and the planet, now and in the future. The agenda had 17 Sustainable development Goals (SDG) with 169 objectives to meet. The 2030 Agenda was put in place on 1st January 2016 and the countries were committed to achieve the goals in fifteen years.

The backbone of Sustainable Development Goals is made up of 5Ps: People, Prosperity, Planet, Peace, and Partnership.

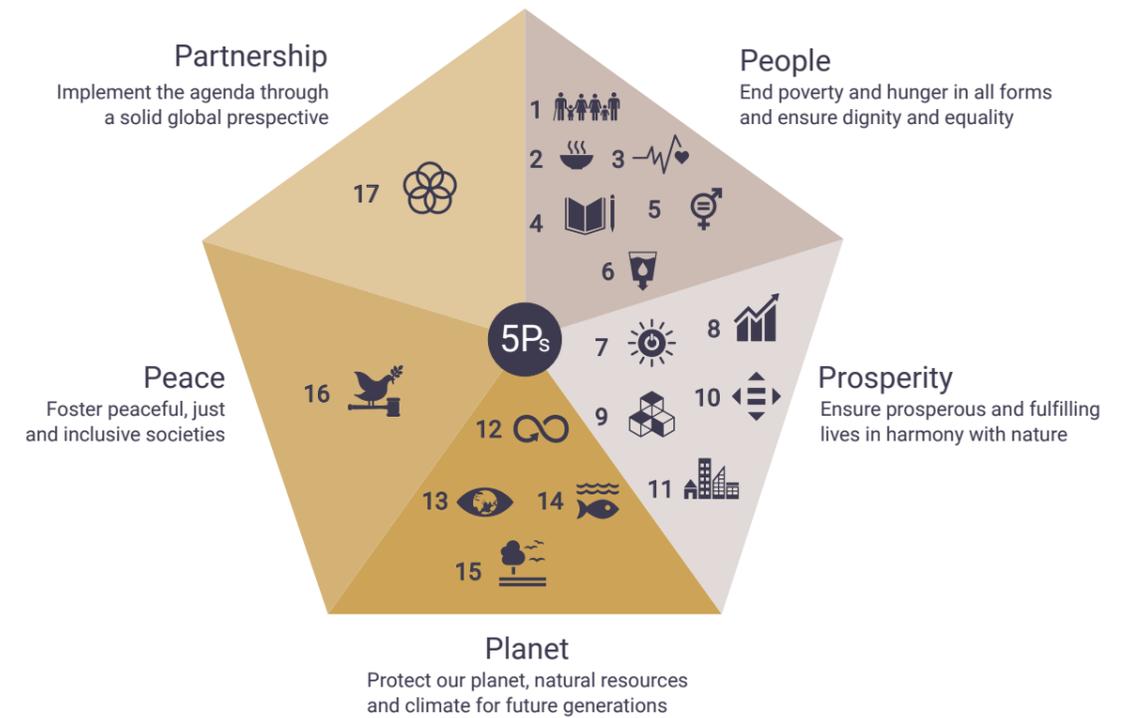


Figure 3: The 5Ps of Sustainable Development Goals.
Source: Author

2.2 Importance of SDGs

Sustainable Development Goals are important to achieve the harmony between environmental sustainability, economic sustainability, and socio-political sustainability. By gradually changing the manners in which we use and develop technologies, SDG encourages us to conserve and enhance our resources. A new set of goals assures not only the urgency of development, but the fact that it must be sustainable and boosts equality. The development will have to be universally applicable to all countries, keeping in mind the different national realities (Omer & Noguchi, 2020). It is important to understand that these 17 individual goals don't stand alone, but are linked together and influence each other.

2.3 SDG-12: Sustainable Consumption & Production (SCP)

Humanity is steering three planetary crisis: the climate crisis, the biodiversity & nature crisis, and the pollution & waste crisis. The common thread running between these crisis is unsustainable production & consumption (UN Environment Programme, n.d.).

SDG 12, focuses on the unsustainable patterns of production and consumption which are the root causes of climate change, biodiversity loss, and pollution. It is based on decoupling economic growth from resource use and environmental degradation without any detrimental effects on people. The goal includes 11 targets and 14 indicators to be achieved by 2030, where all countries take the action with developed countries taking the lead keeping into account the capabilities and development of developing countries (United Nations, n.d.). The targets range from tracking policies, and raising awareness and education, to measuring material use, recycling, and management.

Sustainable Consumption & Production (SCP) considers the complete lifecycle of economic activities, from the extraction of resources, their processing into products and materials, usage, and finally their disposal as waste or emissions. With the system approach, SCP manages to develop manages burden shift and provides overall benefits on sustainability including economic, social, and environmental impacts (UN Environment Programme, n.d.).

SCP is one of the most efficient strategies to circumvent the trade-offs and create harmony to resolve the environmental & evelopment challenges connected with the SDGs. The CSIRO's presentation at the seventh Regional 3R Forum for Asia and the Pacific, stated that economic growth of a region can continue even with the reduction of natural resource use and environmental impacts. The 3Rs, supports SCP directly and also enables decoupling across the whole supply chain while generating higher economic growth (Schandl & CSIRO, 2016).



Image 2: (from left to right) Climate change, biodiversity loss and pollution
Source from left to right: (Fraile, 2022), (Euromoney Institutional Investor PLC, 2021), (UNEP, n.d.)

2.4 SDG-12: Targets and Indicators



United Nations has indicated eight targets and three means of implementation targets for Sustainable Development Goal- 12. To meet the global goals, these 11 targets need to be used to create actions for responsible consumption and production.

● Targets in focus

Figure 4: The targets indicated by the UNs for SDG-12
Data Source: United Nations, (2022)

2.5 South and South-west Asia

In 2021, the SDG progress in this sub-region of Asia has regressed particularly in achieving the three goals: Sustainable cities & communities (Goal-11), Responsible consumption & production (Goal-12), and Climate action (Goal-13). Rapid economic growth has lifted these countries out of poverty, but at the cost of increased resource consumption, GHG emissions and waste production. Many factors have contributed to this, including unsustainable development patterns, coupled with increasing human-made crisis and high intensity of natural disasters. COVID-19 pandemic being the current ongoing challenge (United Nations, 2022).

“Progress towards the SDGs in the Asia-Pacific region has slowed as the COVID-19 pandemic and climate change have exacerbated development challenges. The region is not on track to achieve any of the 17 SDGs.” (United Nations, 2022).

Since Goal-12 is directly linked to both sustainable cities and climate action, this paper focuses on the Goal-12. As per the anticipated progress, sustainable use of natural resources (12.2) is one of the targets showing reverse trend. Material footprint (MF) and domestic material consumption (DMC) has worsened since 2015 in the whole Asia-Pacific region, making it impossible to achieve the target by 2030 if strict actions in the system and policies did not take place. The region urgently needs to reverse the material footprint and consumption trends. The current unsustainable patterns have put effects on other goals, like climate change, due to massive Green House Gas (GHG) emissions putting the region into climate emergency. In the world’s top 100 most polluted cities, 97 of them are from Asia-Pacific region (United Nations ESCAP, 2022).

There is an unprecedented growth of product demand in Asia which requires a strong shift to sustainable consumption patterns to decouple the resource use and economic growth. Though there are few conducive policies for sustainable consumption and production, there are three main causes of concern - large material footprint, lack of waste recovery and prevention systems. Opportunities to shift towards circular system approaches which could lead to multiple benefits across all three concerns is still unexplored.

Various systemic barriers have been identified in the South Asia Sub-region such as: lack of political will, weak technical capacity, reliability of data, inadequate mechanisms and systems to recognize available financial resources (European Union, 2020).

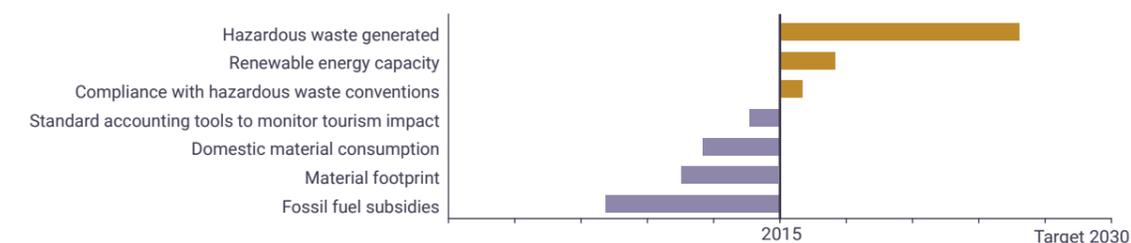


Figure 5: ASIA AND THE PACIFIC SDG PROGRESS REPORT- Graph showing the reverse trends of SDG-12 targets in South Asia Sub-region. Data Source: United Nations, (2022)

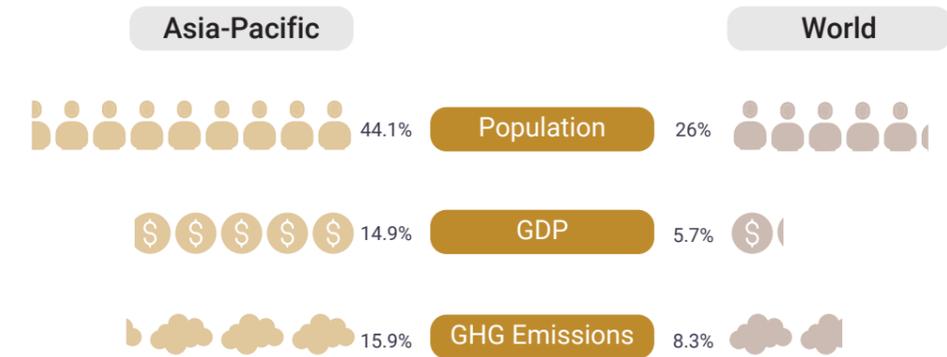


Figure 6: ASIA AND THE PACIFIC SDG PROGRESS REPORT- South and South-West Asia at a Glance Data Source: United Nations, (2022)

2.6 Situation in India

In the past 30 years, the rapid development in India has lifted hundreds of millions of its population of 1.4 billion from extreme poverty, which magnified the challenges related to SDG 12. The main reason for this is the large population size which increases the demand for resources and the low prioritization of environmental protection. The highly disastrous effects of environmental damage are already visible in India, especially in industrial and urban regions (SWITCH-Asia & European Union, n.d.).

2.7 Challenges and Barriers in India

Policy Ecosystem:

- Being a geographically, culturally and economically diverse federal country, the national policies need to be conscious of interconnectedness, complexities and cover a broad spectrum.
- Low/ medium scale of partnerships across sectors exist to conduct the research on resource efficient technologies, between businesses, industries and academia.
- The comprehensive national programs are complemented by initiatives at local and state levels targeting predominantly the individual consumption behavior, but often the general public and industry players are not aware about the systemic shift required and the necessary changes in the policies, production and consumption patterns (SWITCH-Asia & European Union, n.d.).

SCP practices

- Sustainable consumption is of high relevance in India, but a more comprehensive recognition of the relationship between consumption, production & economic growth, potential for decoupling and circularity is in the nascent stage.
- Compared to global averages, India’s collection and recycling rate is relatively low in the waste sectors. The traditional practices often integrate informal recycling of the high value materials, usually carried out under unsafe and environmentally unsound conditions.
- Circularity is rarely used as concept for business strategy development by the companies but the linear business models are considered more profitable and of less risk.

CHAPTER 3

Construction Industry



3.1 Rise in consumption in Construction Industry

The population growth and rising income has allowed people to consume more. The expected growth of cities and urbanization in the coming years would be associated with significant production of raw materials and consumption of natural resources, which can cause serious environmental and social impacts. The global demand for building materials stands well in excess of 60 gigatons per year (Werner Sobek, 2022). The global building floor area is expected to double by 2060 (Zinecker & Bourgault, 2022).

Construction industry is one of the biggest consumer of wide range of different resources. With consuming more than 40% of raw materials globally, the construction sector tops the list of material-consuming industries. Which implies that they deal with a very extensive production chain (Designing Buildings, 2022). This indeed increases the need to achieve the overall sustainable development by reducing the consumption, re-using resources where consumption is unavoidable, and re-cycling where re-use is not possible.

3.2 Why Building and Construction industry?

Construction is one of the 6 sectors which can significantly help cut down the carbon emissions to limit the global temperature rise to 1.5 degree celsius (UN Environment Programme, 2021). The built environment generates approximately 50% of the global carbon emissions, out of which 20% are caused by the building materials and construction techniques (Architecture 2030, n.d.). A large amount of resources are being constantly used during the lifecycle of the building, design, construction, operation, maintenance and demolition.

The building sector needs to lock the new norms for green materials, energy efficiency and better practices in architecture and constructions to maintain a better legacy for the future. In most of the developing nations there is still no mandatory building codes towards sustainability and most of the new construction in the coming years would happen there only.



Figure 7: In 2040, 2/3 of the global building stock will be the buildings that exist today. Without upgrades, they will still be emitting GHGs.
Data Source: IEA Energy Technology Perspectives (2021)

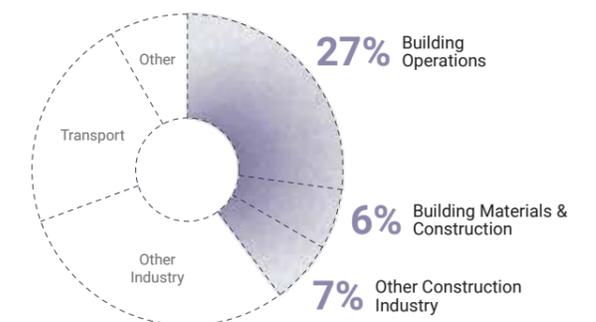


Figure 8: The built environment generates 40% of annual global CO2 emissions.
Data Source: IEA (2022), Buildings, IEA, Paris

3.2.1 Material footprint

Material footprint (MF) is the total amount of raw materials extracted to meet the final consumption demand. The growth of MF is increasing at a faster rate than population growth and economic growth. At the global level, It is important that we reverse the trend and decouple the environmental pressures of MF caused by both population & economic growth (United Nations Statistics Division, 2022).

Material Footprint (MF) and Domestic Material Consumption (DMC), should be looked at together since they cover the two aspects of the economy which are production and consumption. DMC is measured as the total amount of material used directly in the economy, without any hidden flows. While MF on the other hand refers to the virtual amount required across the whole supply chain to maintain the final demand (United Nations Environment Programme (UNEP), 2022). For instance, a country can have higher DMC because it has primary production sector for export or a very low DMC because it has outsourced most of the material intensive industrial process to other countries. Material footprint thus corrects the national material balance for international trade. This means, the net-importers cannot improve their performance by outsourcing the material and on the other hand the net-exporting countries, with lower domestic demand, will have lower MF figures compared to DMC (United Nations Environment Programme, 2021).

The DMC has increased globally, with a particularly striking rate in the newly developed nations. The main reason behind this increase is the construction of new infrastructure with the transitioning and emerging economies. A similar pattern will be followed by other developing nations in the future.

Any material that is used for construction purposes, is termed as building/ construction material. It can be a natural resource like clay & wood, or synthetic like bricks & cement. The synthetic man-made materials are also usually fabricated from natural resources. There are over 2000 products and materials used in construction sector mainly classified into metallic and non-metallic materials (Omer & Noguchi, 2020).

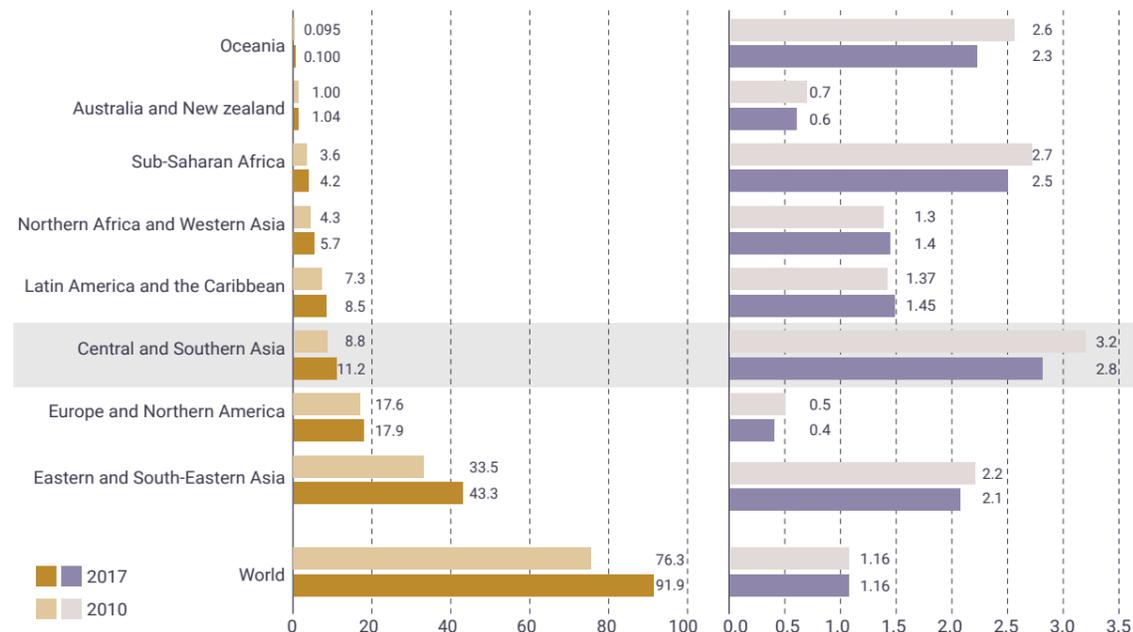


Figure 9: Domestic material consumption. 2010 and 2017 (billions of metric tons)

Data Source: United Nations Statistics Division (2022)

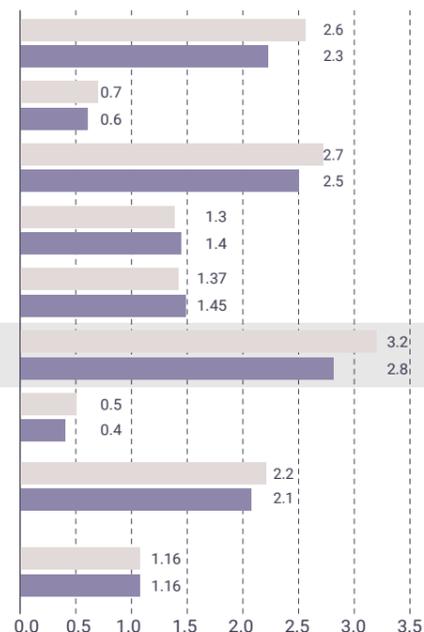


Figure 10: Domestic material consumption per unit of GDP, 2010 and 2017 (kilogram per dollar)

3.2.2 Embodied Carbon

Embodied Carbon is the carbon footprint of a building material referring to the greenhouse emissions emitted from the lifecycle of the material that is, from manufacturing to transportation, installation, maintenance, and its disposal. It is the carbon footprint of a building project before it becomes operation and eventually its demolition, waste transportation and recycling it. With the new construction as projected to take place within next few decades, it is important to understand the critical role played by the embodied carbon. The operational carbon can be reduced with time with the advancement in the use of renewable energy sources and in the building energy upgrades, but the embodied carbon is locked in the building as soon as it is built (Architecture 2030, n.d.).

Achieving zero embodied emissions, would require some strict actions on:

1. Reuse of the building materials, including new construction with design for deconstruction plans, recycling of materials where reuse is not possible, and renovation of old structures.
2. Reduce the use of new materials, optimization of materials, and use of low-zero carbon emitting materials.
3. Use of carbon sequestering materials including the design of carbon sequestering sites.



Figure 11: Actions required to achieve zero embodied carbon emissions. Data Source: Author

3.2.3 Waste Generation

Demolition of old structures, to fulfill the demand of growing population and make space for new structures, generates a large volume of waste. The most common way to dispose off this waste is to dump it in a landfill, which can pollute the air and water. Million tons of waste is generated annually by the building and construction industry, resulting in large carbon emissions in the built environment (Omer & Noguchi, 2020). This innumerable amount of construction and demolition waste is a critical issue for the construction industry. To cope with the sustainable goals, the waste reduction strategies should be applied from the early design stage of the project and engaging organizational learning methods.

In a past few years the demand for green building and environment friendly materials have increased dramatically. Adding to it the varied nature of SDGs has opened the opportunities for building materials to show its impact in the fulfillment of sustainable development.

CHAPTER 4

Construction & Demolition Waste (India)



India generates an approximately 150 million tones of construction and demolition waste annually, as stated by Building Material Promotion Council (BMPC), with only 1.3% capacity to recycle or recover the waste (CSE, 2020).

In 2017, 53 cities of India were expected to set up recycling facilities for the construction & demolition waste, but till 2020, only 13 cities were able to do so. The director general of Centre for Science and Environment (CSE) Sunita Narain has said in a round table meeting that “A significant proportion of construction waste can be recycled and reused and brought back to construction to substitute naturally sourced material. This demands a circular economy that can turn C&D waste into a resource. This can help reduce energy intensity and environmental footprints of buildings and infrastructure.” (CSE, 2020).

There are various governmental acts and policies working towards the achieving the Sustainable Development Goals. The Bureau of Indian Standards (BIS) has approved the usage of recycled concrete and processed demolition waste. The Construction and Demolition Waste Rules, 2016 have mandated the segregation of demolition waste, reuse and recycle of waste construction materials. The Swachh Bharat (Clean India) Mission has also recognized the need for management of Construction and Demolition waste.

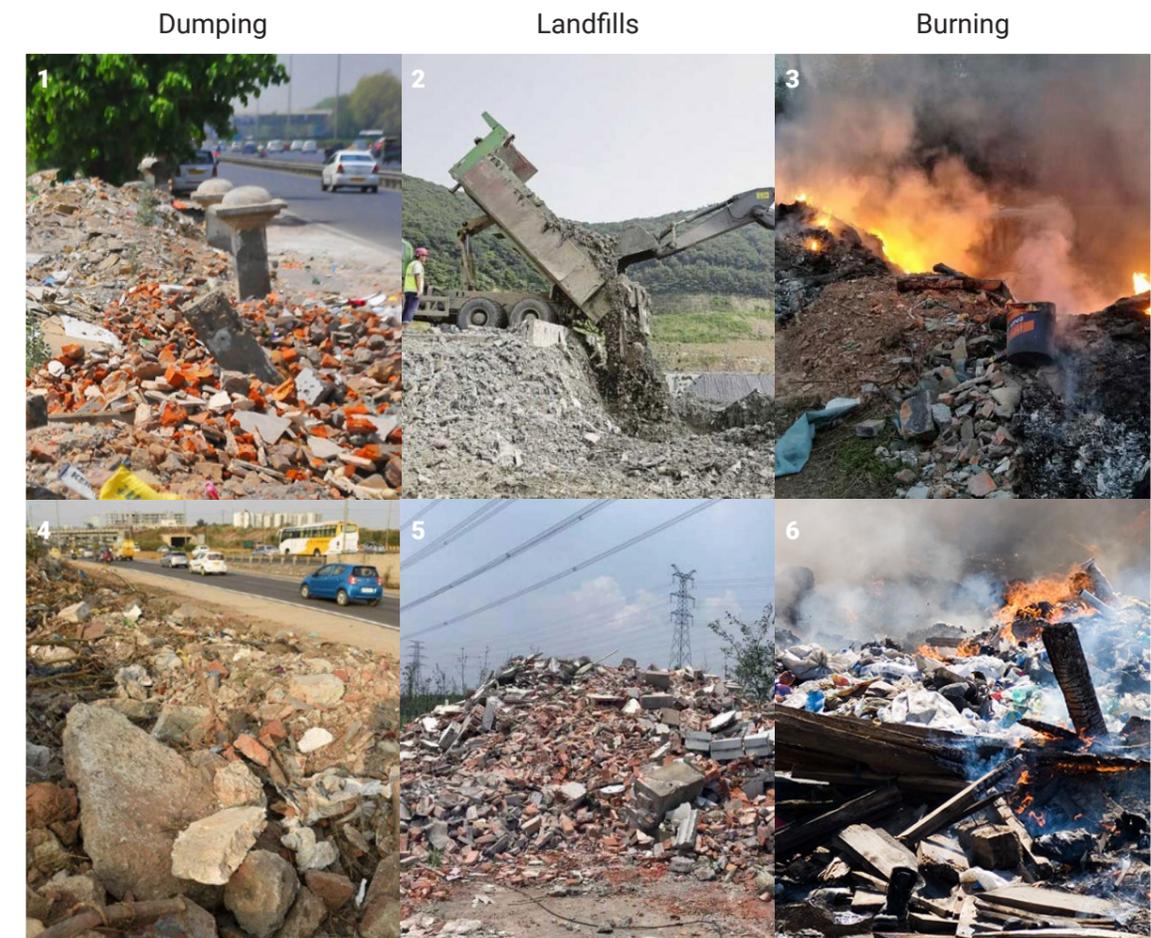


Image 3: Current situation of C&D waste management in India - Dumping, Landfills & Burning.
 Source: 1 (Chandan, 2022); 2 (FTM, 2022); 3 (FTM, 2022); 4 (TOI, 2020); 5 (FTM, 2022); 6 (CCAC, n.d.)

4.1 What happens after the demolition: Current situation

When a construction site is demolished in India, materials like steel, iron, wood, wires which are bigger in size and larger in quantities are separated on the site by the informal sectors & workers. These materials are then sold to the local vendors at a very minimal price. The local vendors then further sell the materials like steel and iron to the recycling companies. Materials like wood, is sold to the furniture vendors who reuse it in making the furniture or other small things. The material that remains on the site is considered as the construction and demolition waste which is also called “Malba” in Hindi (Indian language). This waste is collected, taken by waste haulers and dumped to landfills. Few of the major factors involved here are that the government allocated collection points are very far from the cities & not in the public domain, the waste haulers are not allowed to travel outside from their region because of issues with their documents, and demand of bribes from the guards at the collection points. Sometimes the collection point comes in between a residential area, because of unplanned development of the area, which causes problems of air pollution for the residents and they protest against dumping the waste on those locations and the points are eventually closed.

One of the main reasons for rampant illegal dumping in India is lack of awareness and incentives to manage the waste properly. There is no clarity in which categories the waste needs to be segregated on the site. Hence, it gets dumped in the nearest empty spot (open spaces, forests, drains, roadsides etc.) leading to environmental damage. It further leads to drain clogging, flooding on streets, mobility obstructions and air pollution. It often gets mixed with the municipal solid waste, obstructing their recycling process, and leaches into the soil and groundwater. Various pan-India surveys on this topic, show that people wish to get rid of the Malba waste and want to see their cities cleaner, but they don't know how & what to do about it.

4.2 Why to care about C&D waste?

- **Effects our urban fabric:** As landfills have exhausted their capacities, low-lying areas, vacant plots, and even streets are a common target for dumping the C&D waste generating a visual clutter.
- **Air we breathe:** Not only the C&D activities create a large amount of air pollution, but also dumping of waste emanates dust in air. Life expectancy in Indian cities have dropped to almost 8-10 years due to air pollution (Sirur, 2021).
- **Contamination of groundwater:** C&D waste in landfills ends up getting mixed up with other household waste to create chemical leachate that percolates into groundwater and food systems. It is also dumped in wetlands and water bodies disrupting the ecosystem.



Image 4: (from left to right) Effects of C&D waste to urban fabric, Air pollution & water contamination. Source from left to right: (The time lock, 2019), (Hussain, 2017), (CSE India, 2019)



Figure 12: Actions required to achieve zero embodied carbon emissions. Data Source: Author

4.3 Challenges with managing C&D waste

- **Estimation of C&D to design systems:** To plan an adequate system and infrastructure for its management, Indian cities need a full-scale assessment and quantification data of C&D waste generation. A significant portion of waste is diverted to informal land fillings which has zero accountability and is beyond the Municipalities.
- **Collection and transport of C&D waste:** These is a substantial inconsistency in C&D waste transportation practices in the Urban Local Bodies (ULB). In some regions it is the responsibility of waste generator to deliver the C&D waste at their own expense to the designated collection point. People tend to avoid getting into such situation because the commute can become uneconomical and are also asked to pay unofficial usage fees by the caretakers of the collection points. In some regions on the other hand, waste collector services are provided. People can allocate a date and time with them on payment.
- **Low involvement of state government:** State government's active involvement is needed for land allotments and financial assistance for devising waste processing facilities. Local level policies need to be framed to supplement the rules and regulations for C&D waste. "State government agencies such as PWD, Housing Development Board/Authority, City Development Authorities, public sector utility companies etc. involved in significant construction/demolition work need to coordinate with ULBs for proper disposal and buying & selling of recycled/ reusable products." (CSE, 2020).
- **Lack of awareness and apathy of construction industry:** NITI Ayog's C&D waste strategy report strikingly shows the lack of awareness on this matter across the nation in construction industry. Implementation is a challenge in large scale projects due to different contractors assigned for different phases on construction. Rules specify that the construction waste should be utilized on the site itself, wherever feasible. But rules also make the waste generator responsible for managing it. The documents are forged to comply with the rules between the developer and the third party. The project owners are not aware and neither do they have the direct control over it. Responsibilities and requirements need to be specified clearly in the contracts for a project with proper proofs.

- **Pricing and taxes on recycled C&D waste products:** Though the departments like BIS (Bureau of Indian Standards) and CPWD (Central Public Works Department) have approved the quality of recycled building materials, their pricing remains a major obstacle. Recycled C&D waste is taxed higher (18%) than conventional building materials (5%), making it economically unviable for most of the costumers.
- **Demolition management:** According to the TIFAC's 2001 report of C&D waste, of all the demolished materials, about 25% from old buildings and 75% from new buildings can be recovered for reuse if managed properly. There is no regulating system been developed by the ULBs to monitor the demolition contractors. There is a lack of official guidelines on resource recovery from the C&D waste during demolition.

4.4 Schemes and regulations

- **Swachh bhara mission (SBM):** With the motto of 'Clean India', this mission was initiated by the Ministry of Housing & Urban Affairs (MoHUA) in 2014. One of the targets of this Pan-India campaign was the remediation of all the landfills and dumpsites in the country. The mission also includes the establishment of bye-laws for 'planning of deconstruction'.
- **Guidelines on environmental management of construction & demolition (C & D) wastes:** New rules were issued by the Central Pollution and Control Board (CPCB,) published on 29th March, 2016 by the Ministry of Environment, Forest and Climate Change (MoEF & CC) that a site waste management plan (SWMP) has to be drafted and submitted to the local authorities by the construction projects producing more than 20 tons of C&D waste in a day or 300 tons in a month.
- **Guidelines for Sustainable Habitats (GSH):** A report for the guidelines on 're-use of recycled C&D waste' was released by the Central Public Works Department (CPWD) in 2014. The guidelines include measures and precautions for recycling of Construction & Demolition Waste, and also highlights the need for deconstruction plans. It also provides guidance for recovering valuable products that can be reused without further processing.
- **Ministry of Urban Development (MoUD):** In 2012, the urban development ministry issued a circular to set-up recycling centers in cities with population more than 1 million and established related governance rules.
- **Bureau of Indian Standards (BIS):** BIS is the responsible governmental department for preparation of the specifications and codes for the recycled products. "The updated IS:383(2016) recommends a replacement, of 25% in PCC, 20% in RCC and 100% in lean concrete, with recycled aggregate." (Swetha K., T.P., & Kumar M.V.N., 2022)
- **Building Materials & Technology Promotion Council (BMTPC) & Ministry of Housing and Urban Affairs (MoHUA) :** BMTPC formulated regulations on C&D waste utilization specifically in government projects. MoHUA also issued an order to utilize C&D waste products if they are available within 100 kilometres radius of the construction site.

4.5 Construction and Demolition Waste Management Rules 2016

he 'Construction and Demolition Waste Management Rules 2016, were notified by the Ministry of Environment, Forest and Climate Change on 29 March 2016. These rules are an initiative to tackle the issues of pollution and waste management and are applied to everyone who generate the C&D waste.

The following table represents the rules & responsibilities to be followed by the waste generators & the local authorities along with their implications on C&D waste management. (FAO & Ministry of Environment, Forest and Climate Change, 2019)

C & D Waste Management Rules, 2016	Implications
<p>Responsibility of waste generators</p> <ol style="list-style-type: none"> 1. Every waste generator is responsible for the collection, segregation and storage of the C&D waste. The waste needs to be deposited to the collection centers (designated by the Urban Local Bodies) or handover to the authorized processing facilities. The waste generators need to ensure that there is no littering or deposition of waste to prevent the public obstructions. 2. The waste generators who generate more than 20 tons in a day or 300 tons per project in a month should submit a waste management plan before starting the construction or demolition to get approvals from the local authorities. 3. Waste needs to be segregated into major streams such as- concrete, soil, steel, wood, plastics, bricks & mortars and the concerned authorities should be kept informed regarding the activities from planning to implementation stage. 4. Payment to be done by the waste generators for collection, transaction, processing, and disposal. 	<p>Envisage public's contribution along with the government and service providers</p> <p>Segregation and channelizing the C&D waste will improve the utilization and management of all kinds of waste.</p> <p>Ensure sustainability of waste management system.</p>
<p>Responsibility of Local authorities:</p> <ol style="list-style-type: none"> 1. Allocation of collection points, placing containers for proper collection of waste, removal at regular intervals, transportation to relevant sites for processing. 2. Sanctioning of detailed waste management plan. 3. Provide appropriate incentives to the waste generator for salvaging, processing and recycling waste. 4. Establish a database and update it once a year. 	<p>Seek special attention from local bodies for appropriate management of the waste outputs. Put in-place the institutional framework and strengthen the system by legalizing the process.</p>

Table 1: C&D waste management rules 2016 and its implications.
Data Source: FAO & Ministry of Environment, Forest and Climate Change (2019)

CHAPTER 5

Case Studies



Rotor dc Belgium

Rotor is a cooperative design practice that comprises two entities: an architecture and design firm founded in 2005 in Brussels, which critically investigates the organization of material environment through research and design; and another is a spin-off Rotor Deconstruction founded in 2016, which sells non-functioning building components for upcycling.

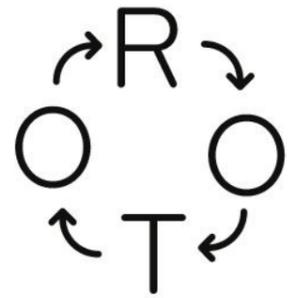


Image 5: Rotor's Logo
Source: (Rotor, n.d.)

5.1.1 Rotor Deconstruction

The team dismantles, processes and trades the materials and building components salvaged from quality buildings undergoing transformation or demolition. Rotor DC also provides assistance to building owners, contractors and architects on ways to integrate these elements in their projects. The design office Rotor allows to explore conceptual aspects of reusing the salvaged components. Thus, the projects by Rotor are making the case for circular economy. The main interest of the company is to probe the material heritage in a critical way and leave its mark. Reusing and salvaging the materials not only involves technicalities, but also the architectural disciplines in traditional forms. Architect Tristan Boniver stated in an article published on Domus 1058 that "Reuse goes way back in the history of architecture. At the moment, we at Rotor are realising how linked we are to the past. The upcycling of architectural elements is a very ancient practice, but it would seem as if modernity had made us forget about it. We think it's useful to rediscover techniques, approaches and old ways of doing things in order to deal with contemporary questions. We are experiencing a reconciliation with the field of architecture, which we used to sometimes criticise or reject" (Peluso, 2021).



Repair and transformation of lighting equipment



Reprocessing of high quality 'urban' wood



Planning and organizing of salvage operations in large and complicated buildings



State of the art method for removing mortar from ceramic tiles



Preparing and cleaning for reuse of furniture, hardware & sanitary equipment

Figure 13: Rotor dc's areas of specializations
Data Source: Author

5.1.2 Key Points

- The cooperative company is entirely owned by its employees. For large scale reuse of building materials, collaborations with contractors, non-profits and other companies is a crucial part for becoming a central part of the regional ecosystem. The shop trades materials from several suppliers such as demolition contractors and real estate companies.
- Trading in salvaged materials helps reduce the quantity of demolition waste while offering quality building materials without damaging the environment.
- The economic value of the material and components decreases and are much cheaper than the new ones of the same quality but their social value increases many folds as they come with a great story, a deep patina or simply a clear conscience.
- They sometimes offer pieces for sale that were conceived by renowned designers, or created by skilled craftsmen, or made using technologies now out of reach, though such pieces come with higher price. But they can be reachable to the gentry that won't usually use salvaged materials.
- Proper documentation of ownership is required on all the materials that transit through their shop.
- The building materials and techniques of construction have evolved significantly. Rotor DC develops deconstruction techniques, logistical systems and remanufacturing installations for contemporary building materials, with a focus on finishing materials.
- The salvaged materials/ products are upgraded to full-fledged construction materials in their workshop, to make them re-usable in new construction projects.
- Both individuals and companies can contact Rotor Dc for assistance.



Image 6: Process team dismantling floor tiles and wall claddings safely in order to retain their maximum value.
Source: (Rotor, n.d.)

5.1.3 Services

- Material selling: Rotor Deconstruction provide a one-stop shop for the sale of second hand materials at reasonable prices. We want to encourage the construction sector (independent contractors, general contractors, building owners, developers) who wish to engage in the trade of second-hand materials.
- Product rental: RotorDC provides recovered furniture and decorative elements for rent. The service is aimed for stage professionals who are looking for reclaimed furniture and decorative elements for their ephemeral set-up projects.
- Ceramic tile cleaning and sanitary products cleaning: The service is provided to homeowners and professionals who wish to reuse them in a project. The elements are cleaned of all traces of limescale/ mortar and residues and therefore ready for re-use.



Figure 14: Rotor dc's Team Organization
Data Source: Author

5.1.4 Challenges and Opportunities

- The main challenge for the same is the economics and logistics . How to bring the materials and products to a standard value and put them back in the market for commercial approach?
- Resistance in legal aspects are usually faced.
- Working through projects, they faced a challenge of knowing in advance about what type of material/ component will be available by the time it would be required. They developed a system that would adapt to the unknown and standardized the uncertainty.

5.1.5 Takeaways

- One stop shop for salvaged building materials and components, from dismantling to processing to sales for new construction.
- Building components from renowned structures and designers are sold separately maintaining the economic and cultural value of the product.
- The material and product availability is updated in advance on the online shop for designers, architects and customers and foresee how to use them in their designs.
- Products are also available for renting.

Build Reuse USA



Image 7: Logo
Source: (Build Reuse, n.d.)

Working towards a world without waste.

Nonprofit organization established in 1994, encouraging the recovery, reuse, and recycling of building materials in the United States. Committed to developing social investment and workforce development programs in the deconstruction industry.

MISSION

Empower communities to turn construction and demolition waste into local resources.

VISION

Transform the communities by creating a building industry in which used and excess materials become an asset and waste is no longer acceptable.

5.2.1 Core Values

The members and supporters of Build Reuse believe in the following values:

- The linear economic model presently used for relying on consumption of new materials and products is highly unsustainable.
- The reuse and recycling of building materials needs to be recognized as a key component of sustainability goals. A circular economy is one of the critical and most important component to achieve the net zero emissions by 2050 in the building and construction industry.
- Reuse identifies and prioritizes existing community values. Reinvesting the inherent wealth of existing materials back into the community can solve multiple problems like creating employment and economic opportunities, addressing urban blight, and contributing to achieving affordable housing goals.
- Reusing is the most impactful when implemented locally. Shifting to an economy with justifiable and ethical supply chains centered on reuse and repurposing creates local jobs, builds small businesses, and empowers disenfranchised members of our communities.

5.2.2 Deconstruction Contractor Training & Educational Resources

As one of there unique services, Build Reuse is also developing programs around deconstruction curricula, accreditation, and continuing education.

In 2012, Build Reuse put forward a textbook- 'Introduction to Deconstruction', developed primarily to serve as the foundation of comprehensive building deconstruction training programs. It is a critical and important resource for any individual or company who is interested in entering the field of deconstruction, or simply for improving their existing practice. Organized around ten core competencies of deconstruction practice, the book covers all aspects of a project from evaluating the site & identifying potential hazards, to planning & executing the complete structural removal of a building. The book is the most comprehensive guide available today.

Build Reuse has developed a National Registry of Deconstruction Trainers to provide transparency and clarity around the qualifications of training programs in the field. The registry was conceived through the consensus of renowned deconstruction instructors across the country (USA) and lays out all the industry-wide standards necessary to teach the skills and management competencies for supervising deconstruction projects.

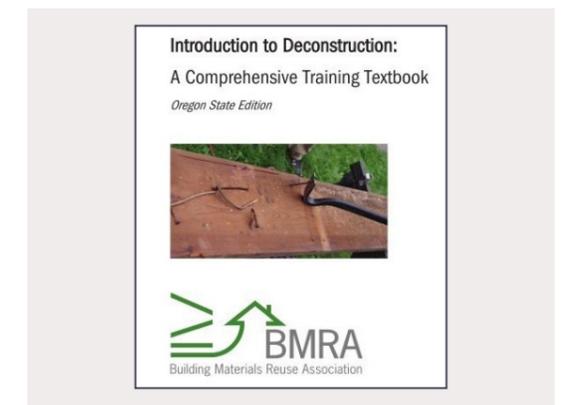


Image 8: Deconstruction and training workbook
Source: (Build Reuse, n.d.)

5.2.3 Takeaways

- Partner with a e-commerce website to sell the salvaged building materials and components online.
- Provides training programs for Deconstruction and also published a foundation book for individuals or companies entering in the industry or to improve their existing practices.
- Spread community awareness through newsletters, regular conferences and providing resources.
- Materials and components can be donated at different collection centers.

Retro First UK

"The greenest building is the one that already exists"
- AJ's RetroFirst Campaign



Image 9: Logo
Source: Architects' Journal

5.3.1 About

A campaign started by The Architect's Journal to promote retrofit & reuse existing buildings over demolition in the built environment. More than 200 architecture practices, organizations and individuals have declared their support for the campaign.

The AJ's campaign proposes a vital reduction in the consumption of raw materials and energy in the built environment through the adoption of circular economy principles. It demotes unnecessary and wasteful demolition of buildings as much as possible and promotes low-carbon retrofit as the primary & default option. Since the replacement of buildings is sometimes necessary due to structural constraints and community growth, it also supports deconstruction – a more sustainable alternative to demolition whereby buildings are dismantled with the goal of maximizing the reuse potential value of their materials and components.



POLICY

Promote the reuse of existing building stock and reclaimed construction material by introducing new clauses into planning guidance and the building registration.



TAX

Cut VAT rate on refurbishment, repair and maintenance from 20% to 5% or below.



PROCUREMENT

Stimulate the circular economy and support a whole-life carbon approach in construction by insisting that all publicly funded projects look to retrofit solutions first.

Figure 15: Three demands of Retro First
Data Source: Architects' Journal

5.3.2 Takeaways

- Prioritise existing buildings over demolition and rebuild.
- Policy implications that insist that all public buildings should look into retrofit solutions.
- Tax/ VAT deductions for recycled and reused building materials and components.
- Support systematic deconstruction over demolition, maximising the reuse potential of their materials and components.

Re4 Europe



Image 10: Logo
Source: (RE4, n.d.)

REuse and REcycling of CDW materials and structures in energy efficient pREfabricated elements for building REfurbishment and construction.

5.4.1 About

The main basis of this project is to develop RE4 i.e. REuse, REcycling, pREfabricated and REfurbished, energy-efficient building concepts that can be easily assembled or disassembled for future use, containing up to 65% in weight of recycled and reusable materials from construction & demolition waste. The reusable structures would range from 15-20% for existing buildings to 80-90% for the RE4 prefabricated building concept.



Image 11: Demo site installation work in progress.
Source: (RE4, n.d.)

5.4.2 Vision

The project aims to promote innovative technological solutions and strategies for the development of prefabricated elements with high degree of recycled materials and reused materials & components from the demolished buildings. The primary goal of the project is to develop energy efficient building that is produced from C&D waste, thus minimizing environmental impacts in building and construction industry.

Such building components will be suitable for both new construction and building renovations. The new building designs will be used to demonstrate the solutions developed and support the dissemination of the project. The demonstration activities will be carried out in different climatic zones to validate that the concept is indifferent from climatic conditions.

5.4.3 Mission

- Increase the percentage of recycled and reused materials/ structures from C&D waste.
- Increase the technical and economic value of materials and structures derived from C&D waste.
- Minimize the future C&D waste coming from the next generation of buildings.
- Increase the building energy efficiency.

5.4.4 Concept of the project

The concept primarily focuses on the development of innovative sorting technologies for C&D waste. This first stage of the recycling process determines the amount of recycled material and also the possibility to properly close the product loop maximizing its value. This fraction/material/structure from C&D waste will be investigated and processed with 3 different technologies-casting, extrusion and moulding. Then it will be transformed in the new and adapted prefabricated components shown in the figure. The prefabricated components developed in the RE4 project will be finally assembled into a RE4 prefabricated energy-efficient building concept designed for an easy installation and dismantling.

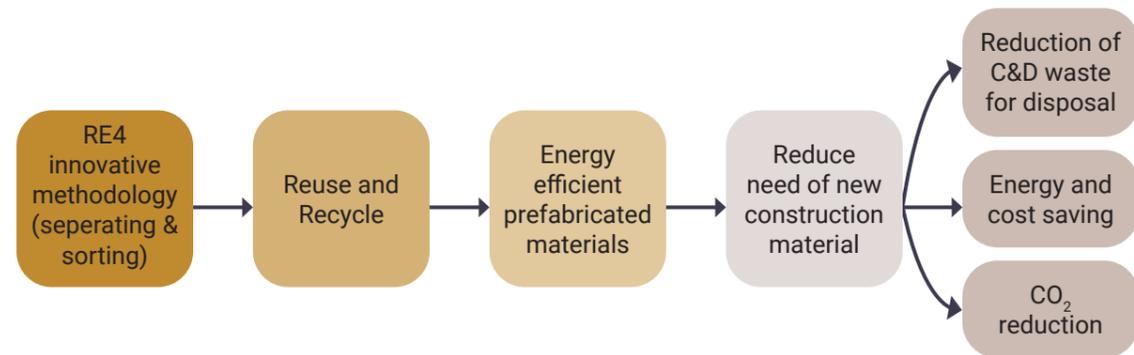


Figure 16: Steps of the concept
Data Source: Author

5.4.5 Objectives of the project

- Development of creative design ideas for smart prefabricated building component assembly and disassembly into prefabricated energy-efficient building units. The ideas would be created in a way that would make it simple to construct several applications for various architectural typologies (e.g. residential, commercial).
- RE4 industrial demonstration, testing & evaluation, and replication in specially built mock-ups of dual-story building archetypes in Europe, the proposed RE4 solutions for future structures will be put on display.
- Future uses and sustainability of RE4 prefabricated goods are improved. The following goals are aimed from a quantitative perspective: lower resource consumption (minimum percentage of recycled materials in final product up to 65%), improved resource efficiency (CO2 savings of over 30%), energy savings of 20%, and lower waste generation and C&D waste disposal in landfills.
- Development of a BIM-compatible DSS and platform for CDW estimation and Management. By calculating the types and quantities of C&D waste that will be produced during construction and demolition, together with potential usage possibilities and relevant logistical references, a BIM-compatible tool is created to assist owners and construction/demolition companies.
- Development of business plans for industry exploration. An effective value chain will be promoted by the growth in scope and allure of C&D waste recycling and reuse for the construction and renovation of energy-efficient buildings, generating lucrative commercial prospects for all parties concerned.

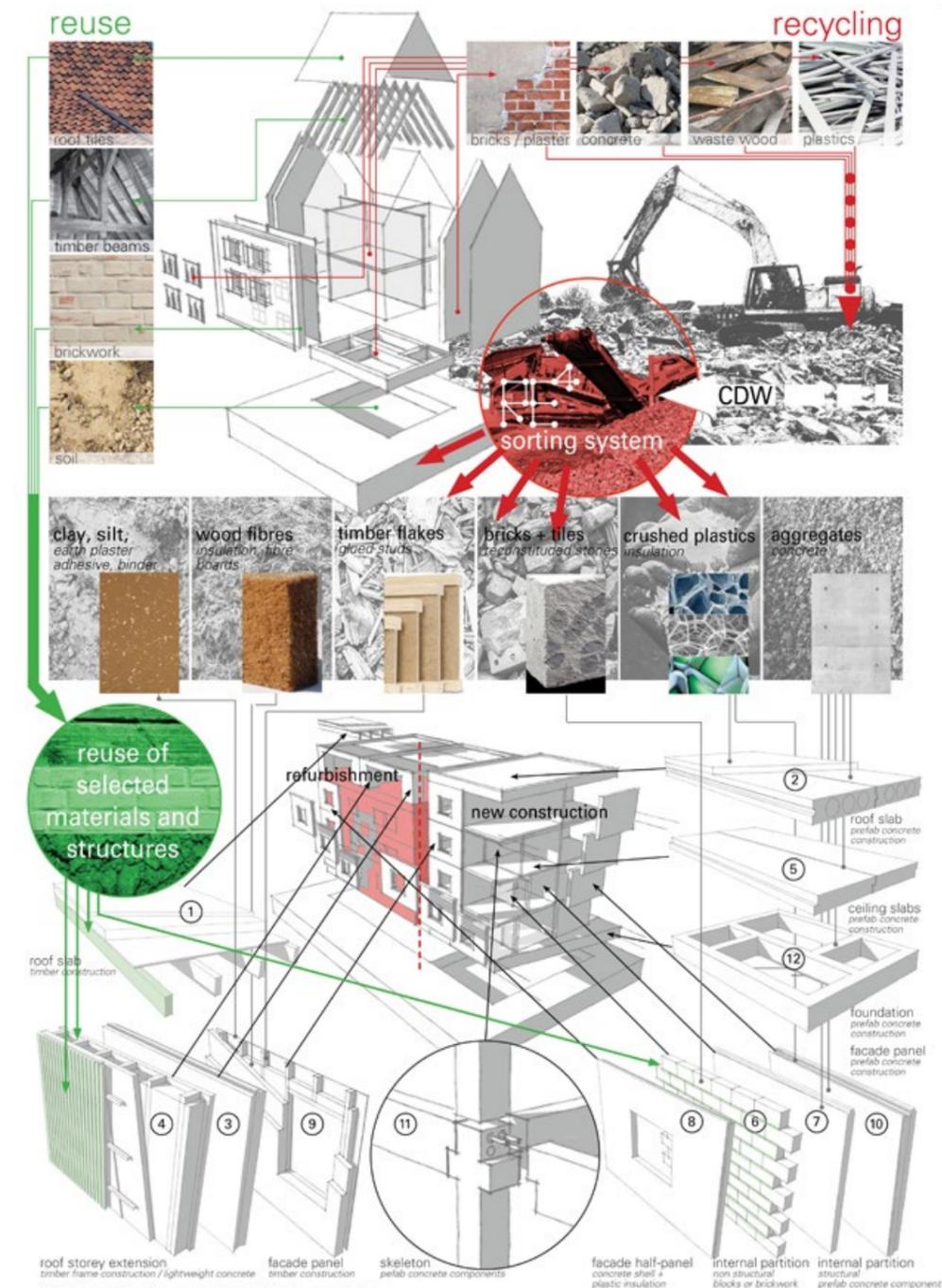


Image 12: Overall concept
Data Source: (RE4, n.d.)

5.4.6 Takeaways

- Advanced methodology for sorting recyclable materials and reusable components from demolished buildings.
- BIM-compatible platform to calculate the C&D waste of the building that will be produced when it might get demolished.
- Developing prefabricated structures from the recycled and reusable components to close the future loop of building materials.

City Loops Europe



Image 13: Logo
Source: (City Loops, n.d.)

5.5.1 About

A European Union funded project to pilot a series of demonstration actions to close the loop for construction & demolition waste and bio-waste in Europe. Currently it brings together seven European cities- Apeldoorn, Bodø, Mikkel, Porto, Seville, Høje-Taastrup and Roskilde aiming to become circular cities in which no resource goes to waste, driving the transition to the circular economy.

The cities are structuring their pilot in three phases:

1. Inception and preparation phase, including a series of preparatory analysis and stakeholder mapping and participatory planning
2. Demonstration phase, during which the solutions will be implemented and tested
3. Replication phase, when the CityLoops measures will be upscaled at regional and European level

The actions and solutions range from tools for predicting future C&D waste, to campaigns for raising awareness, circularity decision making tools, 3D visualization tools for simulating the impacts and procurement guidelines for bio-waste products. A total of ten demonstration actions shall be implemented, which will test over 30 new tools and processes.

Circular procurement is the key aspect of CityLoops, helping each city identify which procurement activities could be used to strategically support the actions undertaken to tackle construction and demolition waste (CDW) and bio-waste.

Circular City Indicators: A comprehensive set of indicators for cities, including guidance on how to measure them. At the end of project this will result in the evaluation framework based on a series of circularity and sustainability factors.



Figure 17: Key points
Data Source: Author

5.5.2 CityLoops Tools for Demolition

- **3D GIS Visualization:** This tool visualizes the city's structures, materials, emissions and energy flows in real time. It integrates qualitative data such as SDG indicators. The purpose of the tool is (1) to allow for future scenario planning by considering the surrounding context and simulated impacts, and (2) to present advanced data in a visual way for involvement of citizens and non-specialists in city-planning.
- **3D modelling to track onsite CDW flows:** The tool uses a camera drone with a photogrammetry software to model and monitor demolition sites using image-based scanning. It produces point clouds to be used for 3D visualizations and 3D calculations of buildings and material quantities, as well creates maps and other GIS data about the site.
- **Lifecycle CO2 calculators for concrete, soil and mixed CDW:** In the demonstration project processes will be monitored and the tool will be used to calculate the CO2 impact of moving soil, or other (bulky) construction materials, from a site. On the other hand, the emission savings can also be calculated for the case if these materials are not moved.
- **Pre-demolition screening procedure:** This procedure identifies a pre-demolition inventory and material audit conducted to identify building components and materials with reuse or recycling potential. It details out how to identify and evaluate the residual value of a component. The key step to which is the identification of materials (as containing harmful substances, or having residual value).
- **Selective demolition procedure:** The procedure explains how to conduct a selective demolition to select and preserve maximum value of the building components and materials with reuse/ recycling potential, by following a series of chronological steps to dismantle components or materials without damaging them.

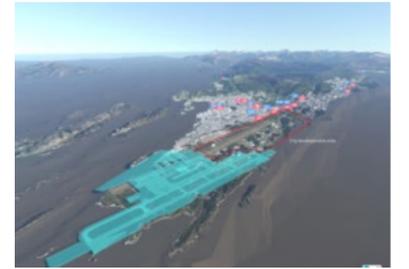


Image 14

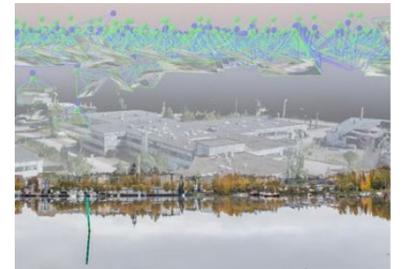


Image 15



Image 16



Image 17



Image 18

Image 14-18: Depicting the tools for demolition used by City Loops.
Source: (City Loops, n.d.)

5.5.3 Høje-Taastrup (Denmark)

The demonstration actions of Høje-Taastrup (HTK) focus on circular practices in public construction projects, as well as on influencing construction & demolition projects for private buildings and sites not directly owned by the municipality. This would enable HTK to see what impact the municipality can have by getting involved at the various phases of the projects and to develop planning and decision-making frameworks using these cases.

Implementations of various demolition actions:

- The municipality shall be in close dialogue with the demolition companies and the developers, along with other potential buyers of the materials from the demolition.
- Recoverable materials will be incorporated into new buildings or crushed on-site and used as filler, or in other building projects.
- The demolished concrete will be recycled completely, undergo quality testing, crushing and storing. Recycled concrete shall then be used in future construction projects in the city.

5.5.4 Apeldoorn (The Netherlands)

Apeldoorn plans to renovate its old neighborhoods that were built between 1965 and 1985. The public spaces and roads in these neighborhoods were typically built of materials such as concrete and asphalt that have a high circular potentiality. Through CityLoops, it aims to build the capacity of retaining these resources for the city which will demand new business models and accounting methods, but also create new financing methods.

Implementations of various demolition actions allowing Apeldoorn to become a circular city:

- Prior to demolition materials will be scanned to identify their quantity and quality. This information will be stored in a material databank.
- Opportunities would be identified for reusing and/or transforming the materials for use within the new construction projects or elsewhere in the city.
- Materials will be stored in a new material depot and will also be marketed through an online construction materials marketplace.
- Citizens shall be informed and involved in the project through the use of the Openstad online platform.

5.5.5 Takeaways

- Pilot projects on various cities of different climatic zones for experimentation of the concept and creating a model that can be replicated and scaled to other regions.
- Multiple tools designed to support the systemic demolition process ensuring that materials and components retain their maximum value after demolition for reuse.
- Complete documentation, qualitative and quantitative data collection is necessary to facilitate the use of materials and components in future.

5.6 Implications from the Case Studies

The following table illustrates the main and distinct features from all the above described case studies along with what advantages would they provide for systemic approach to manage the construction and demolition waste.

Case Studies	Distinguishing feature	Advantages
Rotor DC, Belgium	One-stop shop (demolish, process, sell).	Ease of customer service and experience.
	Prior updates about the materials on the online shop. Products for renting.	Designers and architects can design new buildings according to the available materials.
Build Reuse, USA	Deconstruction training programs and books.	Spread the awareness and empower the industry to adopt the deconstruction methods.
	Donation of material at collection points.	Cost-effectiveness
Retro First, UK	Tax reduction policies.	The sales of the recycled and reusable materials will increase.
	Policy insisting to look into Retrofirst solutions before start of any public project.	Imposing the law will help mainstream the process.
RE4	BIM compatible platform.	Efficient calculations for types of C&D waste materials.
	Advanced sorting techniques.	Maximizes the value of reusable materials.
	Prefabricated structures from salvaged materials.	Closes the loop for future of building and construction industry.
CityLoops	Pilot projects that can be replicated.	Testing of tools in various cities with different climate zones.
	Advanced documentation for C&D waste (qualitative and quantitative).	Facilitates the use of materials in future construction projects.

Table 2: Distinguishing features and advantages implied from the case studies.
Data Source: Author

CHAPTER 6

The Malba Project



6.1 The Malba Project

Established in September 2021, The Malba Project is India's first on-call service for construction and demolition (C&D) waste. It is a Delhi based start-up which helps the society by getting them rid of the C&D (Malba - Hindi term) waste dumped illegally on the streets or if people have Malba at home due to renovation work, by the My Malba application. The app offers a quick pick-up and tracking services to ensure the waste goes to right collection points and also collects the data about it. The application also spreads the knowledge about how to sort the waste after demolition, provides free marketplace for salvaged reusable materials, and a transportation service (waste haulers) to take the remaining C&D waste to the designated collection points and finally to the recycling plants.

6.2 What problems does it solve?

The project is about research and advocacy on the subject of Construction and demolition waste. Along with the research they are also developing solutions to tackle the problems associated with it. Currently focussing on two of the following problems:

1. Prevention of illegal dumping
2. Streamlining C&D waste collection

6.3 How do they address the problems?

MyMalba application removes the middleman from the process of segregation, collection and transportation of Malba & provides complete transparency about the payment and tracking of the waste. It directly connects the waste generator to the waste picker. It also educated the public, workers and contractors about the C&D waste management.

1. Incentivize to sort, salvage and minimize your waste (what ways?)
2. Schedule a pick up through the app, and pay the picker directly.
3. Track your waste, and ensure it is taken to the city's designated collection point and not dumped in rivers or open lands.



Streamlining Waste Collection: Works in collaboration with the Municipal Corporation of Delhi (MCD) for streamlining the C&D waste collection system by properly managing the city's 'working' collection points and transportation.



They have partner with the waste haulers of the area, completed their legal documentation work, to avoid any restriction in movement from one area to another. They provide a door-to-door pick-up service for all small and big waste generation.



The My Malba map, helps to locate the closest waste collection center and recycling plant & match the nearest waste hauler to pick up your waste hassle-free. It can also identify the illegal dumping spots reported by the public.

Figure 18: Key points of the service that help to solve the problems addressed.
Data Source: Author

6.3.1 Streamlining waste collection

Streamlining C&D waste collection system together with the Local Government Bodies and partnering with the local waste haulers of the area to provide door-to-door pickup service for small to medium waste generators.



Image 19: Streamlining waste collection
Source: Author, (Malba Project, 2021)

6.3.2 Malba Map

First-of-its-kind consolidated map in India, for the C&D waste infrastructure. It locates the closest collection points and recycling plant facilities. It also identifies the illegal dumping spots as and when reported by the residents.

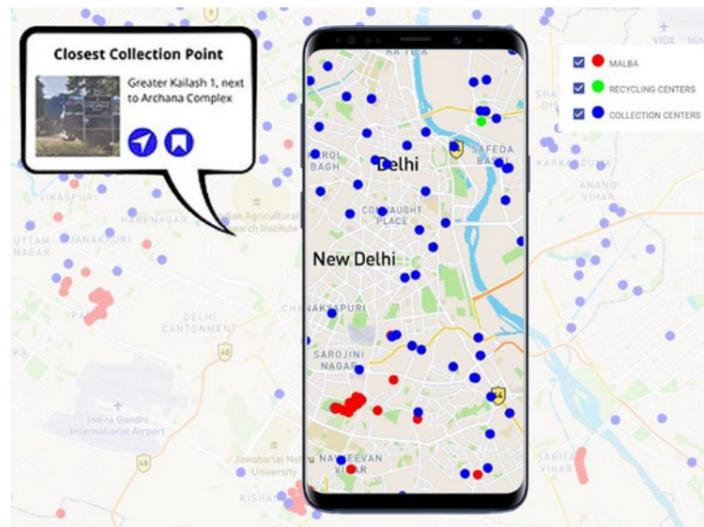


Image 20: Malba Map
Source: Author, (Malba Project, 2021)

6.3.3 Material Exploration & Circular Architecture

Research and experiment on C&D waste materials to create new building materials, Malba Project looks at architecture from circular perspective.



Image 21: Material Exploration
Source: Author, (Malba Project, 2021)



Image 22: Malba Economy, challenges in the business model
Source: (Malba Project, 2021)

6.4 Business model Challenges

The C&D recycling plants in India earn money by processing the waste and selling the building materials that are made from the waste processed. Although there is a very little margin in this, the companies however are setting up the plants looking at it from the future perspective. They believe that these operations will become big once the process becomes mainstream, though at the moment they are operating in losses.

They are counting on the Government of India, that in the coming 5-10 years they will mandate people to dump the waste at the plants for appropriate waste management. One of the ways to move ahead with this could be by linking the C&D waste to permissions and building clearances. Which means, if the contractors don't have the receipt for the recycling plants, they won't be allowed to proceed the construction work. There needs to be some control and incentives for the demolition contractors promoting them to dump their waste at the recycling plant. In some countries outside India, the waste generators get paid to dispose their C&D waste at the recycling plants which is a good incentive for the waste generator and it helps to make the system become mainstream at the initial stages. Currently, in India, it is the other way around. The waste generator has to pay for their waste to be collected, transported and dumped at the collection points from where it is taken to the recycling plants.

6.5 Interview with the Founder

About the founder: Shamita Chaudhary

Along with the founder of Malba Project, Shamita is an Architect and a circular economy expert. The project's journey started in 2018 on a trip to Himalayas, where heaps of debris covered the natural landscapes, and was compelled to rethink her professional choices. The thought of how to inculcate the circular economy in built environment drove her develop a business model which focuses on two ends of the construction value chain, from design to demolition or end-of -design.

Purpose of the Interview:

A one-on-one online interview was held with the founder of Malba Project to acknowledge the journey of the young and one-of-its-kind service. The main aim was to have a better understanding of the business model, challenges faced and what is the scope of circular economy in C&D waste.

“The collection points are fake and exist only on papers. Anywhere ULBs see an empty land, they designate it as the C&D waste collection point, because they are legally obliged to.”

- Shamita Chaudhary

“The guards responsible for the security of collection point didn't allow the waste haulers to pass and dump the waste directly. They were asked to dump the waste outside in some open area and told that it will be collected later from there.”

- Shamita Chaudhary

“The Municipalities refused to provide us the funding for the project because they don't find the issue urgent enough to take actions. On papers their is not much problem in management of C&D waste because there is no data available for it.”

- Shamita Chaudhary

“Streamlining the C&D waste in Delhi is becoming a successful model as we are able to manage more than 600 tones of waste just from a small sector of Delhi on a daily basis. Imagine the amount of waste that can be properly streamlined from all over the Delhi, and scaled up to pan India level.”

- Shamita Chaudhary

“We want to concentrate on circular built environment using concepts such as material passports to eventually close the loop of building materials and resources.”

- Shamita Chaudhary

Outcomes of the Interview:

- One of the major issues with managing the C&D waste in India is the lack of awareness. The common man is unaware of the complete and proper method of disposing of the waste and is wants to avoid the legalities involved, considering the prevailing misconduct behavior in India. Also the workers being uneducated don't follow the rules and regulations properly as stated by the government.
- There are less waste collection points in the large cities opposing the government's commitment.
- Due to the inorganization and involvement of the informal sectors, collection of data for small and medium construction and demolition is not possible.
- The Municipalities and the Urban Local Bodies don't want to invest in this sector until an emergency situation is announced and usually turn a bling eye to the situation.
- Since the intervention of Malba Project, hundreds of tons of C&D waste is being managed properly from few sectors of Delhi (the capital city of India).

CHAPTER 7

Design Interventions



7.1 Design Incorporations to Malba Project

Malba Project is currently working towards solving one of the major problems with Construction & Demolition waste in India, streamlining the waste generated by connecting the waste generator to waste collector and ensuring that it goes to the approved collection points, from where the waste collectively taken to the recycling plants.

In addition to this service of streamlined C&D waste collection, there are questions which need to be solved for getting closer to close the loop and minimize the C&D waste production and digging up raw materials instead of using what is already available above the ground.

- How might we create a balance between the C&D waste production and diminishing raw materials?
- How might we reduce the C&D waste?
- How might we use less raw materials in construction and building industry?
- How might we make reusable building materials and components mainstream?

Rethinking the C&D waste as an opportunity to reduce the usage of new materials extracted from the earth's depleting natural resources is a way to answer most of the raised questions.

How might we implement resource management to reclaim the materials present in the urban built environment of India and make them available for new construction?

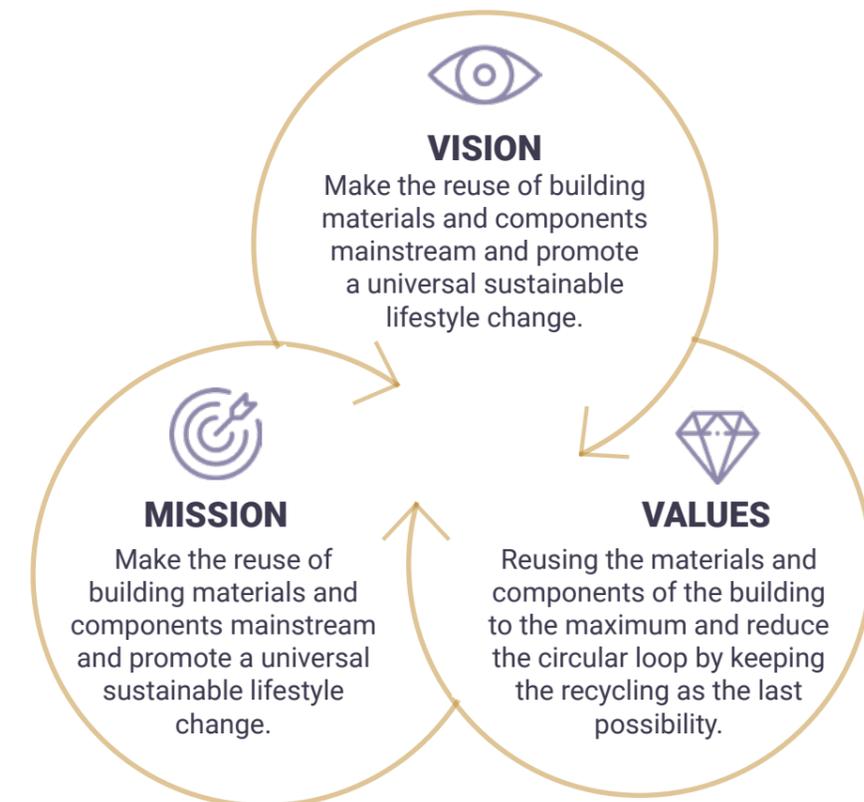


Figure 19: Reformed Vision, Mission and Values of the Malba Project
Data Source: Author

7.2 Circular Economy

In the living world, there is no landfill. One species' waste is another's food. Things grow and die, the nutrients flow and return to the soil. But as humans, we have adopted a linear method. We take, make, use, and dispose. The construction industry works on this linear economy model of consumption and production. The raw materials are extracted, which are processed into building materials & products and assembled in the construction site. The assembly of the materials is done in a way which cannot be deconstructed and at the end of life of the building have to be discarded to landfills or incinerated, adding to the mismanagement of construction and demolition waste (Benachio, Freitas, & Tavares, 2020).

Circular economy is rather characteristically regenerative in nature. It substitutes the end-of-life of a product/ material with strategies to cascade it back into the system. The components and parts can be deconstructed acting as the material banks for new constructions. Being a relatively new concept in construction industry specially in Indian context, there are various complexities with this model since buildings are unique projects and have large supply chains.

Kirchherr et al. (2017) analyzed 114 definitions of circular economy and present a unified definition as follows – "A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/ distribution and consumption processes. It operates at the micro-level (products, companies, consumers), meso-level (eco-industrial parks) and macro-level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations." (Kirchherr, Reike, & Hekkert, 2017)

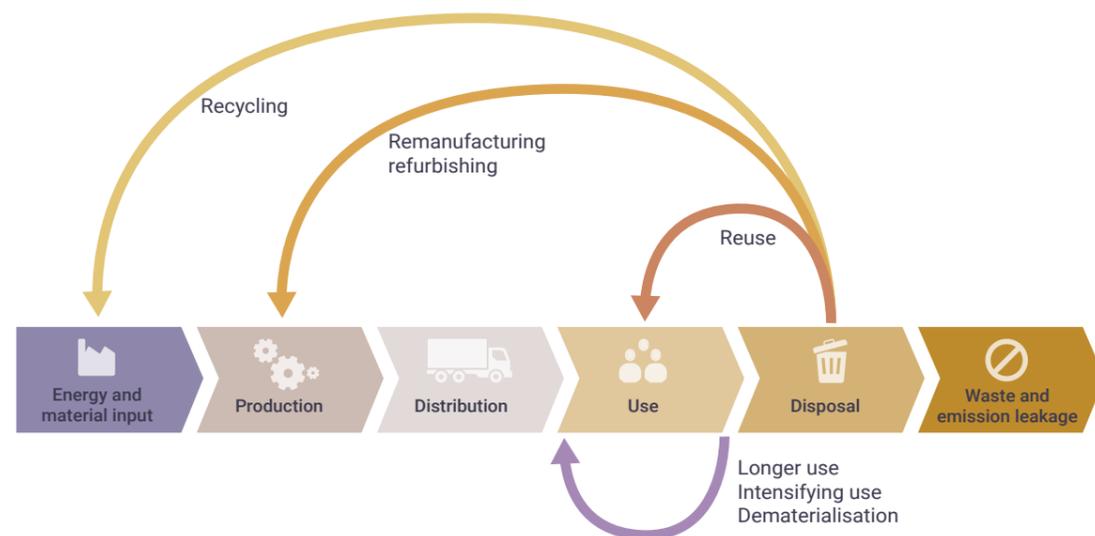


Figure 20: A linear vs circular economy
Data Source: Wikipedia

7.3 Shift from linear to circular economy

Circular economy is a long term perspective, aiming at a systemic change across all scales. It is equally a consumer or demand-side responsibility as it is about supply-side management.

Shifting the economy from linear to circular is a business opportunity for India as it not only strengthens the supply chains but also the local communities, in a way that is socially inclusive, climate friendly and nature positive. The aim achieved through circular economy is a sustainable model of consumption and production by optimizing the resources and reducing & recovering the waste by extending the product lifecycles.

The shift towards circular economy model in production and consumption of resources will also reduce land & water pollution (SDG14,15), lead to innovation in industry infrastructure & reduce greenhouse gas emissions (SDG 7, 9, 13) and increase job opportunities to reduce poverty & inequality (SDG 1, 8, 5, 10) (United Nations, UN Escap, & UN Environment, 2018).

The Asia region being the major global production center, has a vast potential to become a model for sustainable manufacturing, consumption of materials & products, and takeback system. Many Asian countries have started to address the SCP goal from the perspective of circular economy and 3R (Reduce, Reuse, Recycle) with an extensive scope of boost and advancement.

7.4 The 9R Framework

The days of the infamous 3Rs - Reduce, Reuse & Recycle are now a history. Now we hear about 5Rs, 6Rs and even 9Rs revolving around the concept of circular economy. The 9Rs in construction industry stand for - Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover.

The 9R framework is environmentally preferred hierarchical approach for closing the material loop. The smaller the loop, the lesser inputs are required to close it, and thus more circular the model is. The strategy gets less circular as the loop gets longer and is less preferable.

The shortest loop in the R-framework is of Refuse, Rethink and Reduce (R0-R2). This involves eliminating the probability of creating waste at the design stage itself through strategies like designing for disassembly, smart manufacturing techniques and material passports for building materials used.

The medium loop includes Reuse, Repair, Refurbish, Remanufacture, and Repurpose (R3 – R7), applied to extend the lifespan of the materials and products used in the structure. The flexible parts like doors, windows, furniture, even service installations can be dismantled carefully and reused elsewhere. Repairing, refurbishing and remanufacturing can elongate the material lifespan making them compatible for same or different purposes.

Recycle and Recovery (R8-R9) are the parts of the longest loop in the 9R framework. The waste materials and products of the building require technical equipment and energy to generate a new value. As compared to other strategies these don't maintain the original value & structure and can be re-applied anywhere. The recycled materials are not used in the same level despite the energy and effort inputs since the materials are usually downcycled reducing the original quality.

7.5 Recycle or Reuse?

Repurposing or reusing a product or material multiple types in various ways reduces the amount of waste that gets tossed in the landfills and also decreases manufacturing needs.

Recycling requires breaking down the product to a raw material to reuse it in a different form and make new products. recycling is a way to mitigate the environmental problems rather than eliminating it, since it s process consumes relatively large amount of energy like sorting, melting, purification, granulation and extruding. Another aspect of recycling is release of toxic pollution or waste.

Upcycling and reusing on the other hand involves reusing the waste material in their current state without the requirement of breaking it down. There is significantly less amount of toxins produced because the process mainly includes cleaning and assembly/ disassembling of the parts. Reusing and upcycling reduce the need for recycling and thus are a healthy option for the environment.

Environmental impact: Reuse provides a perfect environmentally preferred alternative to waste management because it reduces pollution and limits the use of new resources. Reusing requires fewer resources, less energy, and less labour as compared to recycling. Social Impacts: For many years, reuse has been an important way of getting basic amenities to the disadvantaged people. They get clothing, building materials, other necessary items at a cheaper price. Reuse and upcycling also helps in generating employments and educational programs. Economic impacts: It creates a less burden on the economy by reusing materials and products rather than creating new products from virgin materials. It is also an economically viable way of acquiring the products in need (Kumar M, 2021).

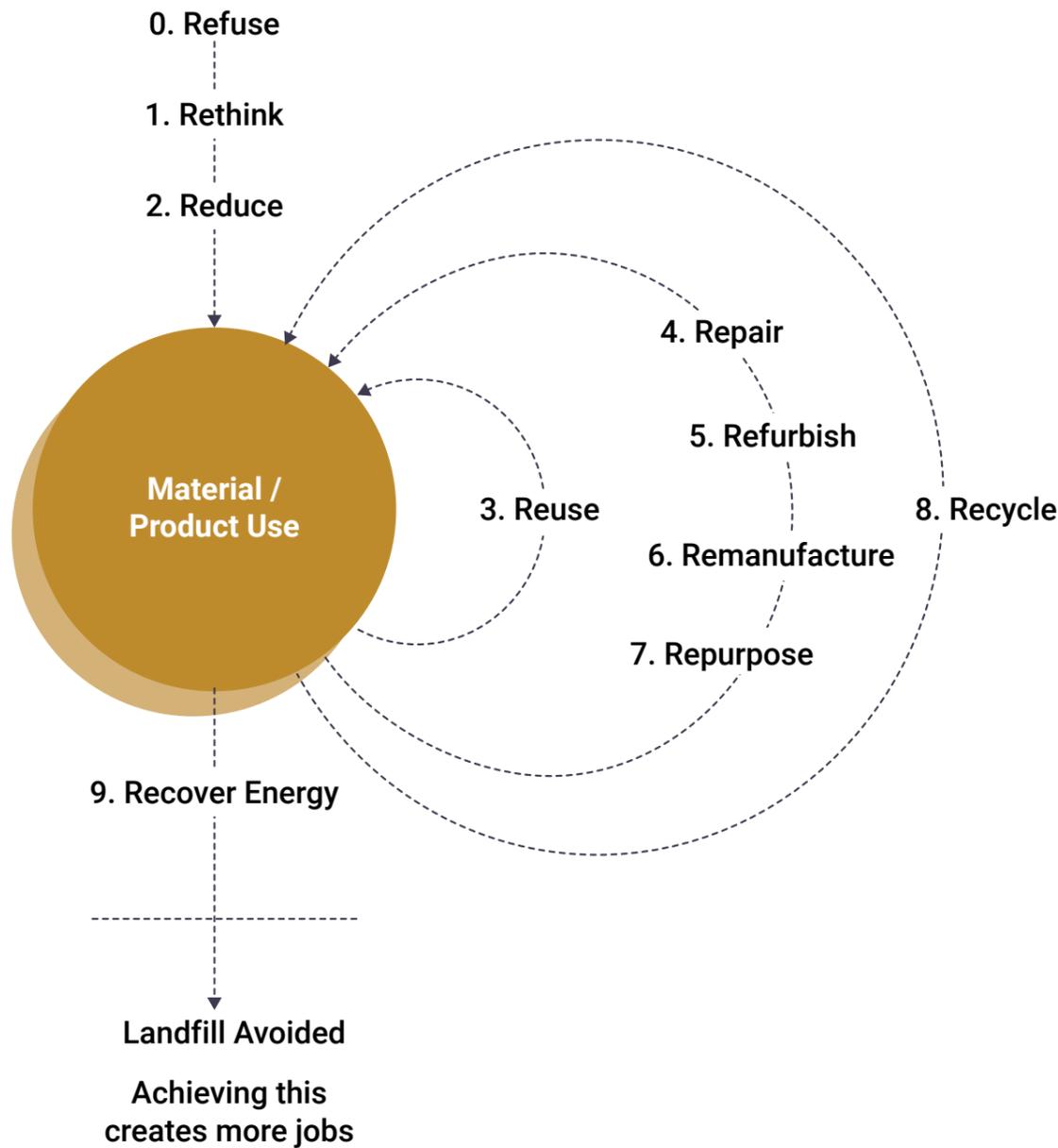


Figure 21: The 9R framework for circular economy
Data Source: Author

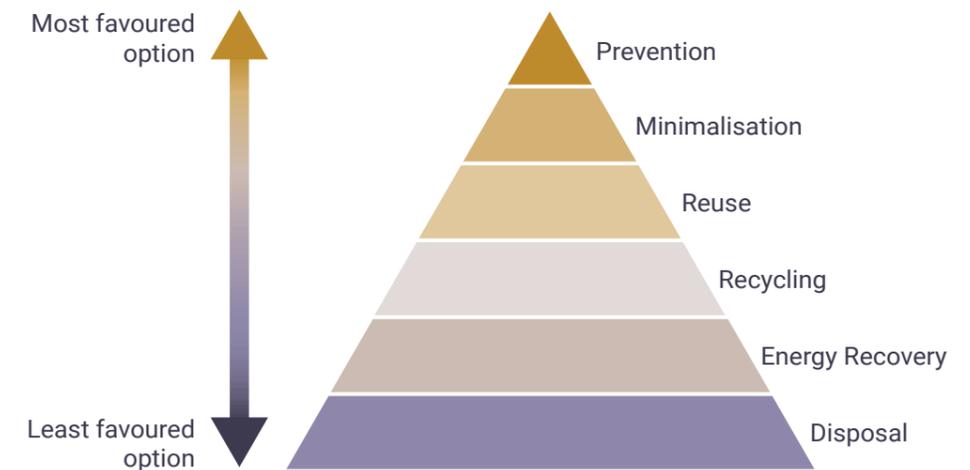


Figure 22: The most favoured option: Reuse or Recycle?
Data Source: Author

7.6 Urban Mining

“Urban mining is the process of recovering and reusing a city’s materials. These materials may come from buildings, infrastructure, or products that have become obsolete.” (Metabolic & Blok, 2021). Urban mining is not a new concept, usually the metal in cars and electronics are recycled, but the climate emergency requires it to be scaled-up and applied proactively. Considering the whole city as a ‘mine’ and identifying usable materials and products, ensuring much of their financial and environmental value is retained. The primary step for urban mining is physical surveying for the materials and products that can be valuable as high quality secondary material. Any material, product or component of the city can become a part of the urban mine.

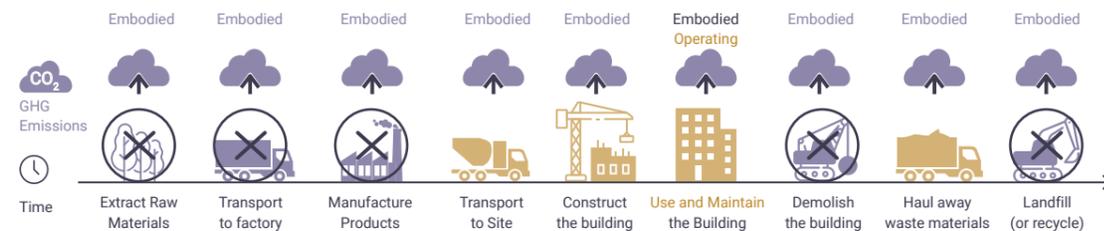


Figure 23: The carbon-emitting steps avoided by using urban mining
Data Source: Mc Cown Gordon Construction

7.6.1 Urban Mining in India: opportunities and challenges

India’s focus is taking up again on sustainable and circular economy, which makes the adoption of urban mining crucial and more relevant. It will help the country to meet its carbon and pollution reduction targets. Apart from its environmental benefits, exploring urban mining as an alternative to geological mining will help avoid various economic and social issues.

The C&D waste in India constitutes of mainly soil, sand and gravel; bricks and masonry; concrete and other materials. The building components of which are valuable like wooden frames, metal fittings, steel are removed from the demolition site by the informal sectors. In the current situation a very small amount of waste is used for low-lying areas like broken bricks are used as the filling material of floors & roofs. There are few pilot programs in progress in Delhi and Ahmedabad for collecting, segregating & converting waste into building materials. These need to be scaled and implemented in other urban regions of India as well.

Although urban mining has a great potential in India considering the rate of demolitions and new constructions taking place, there are several challenges in its implementation and resource recovery.

- Domination of informal sectors to recover the resources from the demolition site. Firstly, while they are efficiently able to recover the materials of high value with minimal investment and equipment, they carry out the exploration and recovery processes in unsanitary conditions which can effect their health negatively. Secondly, they extract only the materials & product which they deem valuable to them and can be processed easily with the basic technology they have. The remaining waste is discarded like any other C&D waste, openly dumped or burned down. In this informal process a significant fraction of valuable waste goes unprocessed and unrecovered.

- Low public support towards facilities that manage the waste due to their unsanitary conditions.
- Lack of technical expertise in the city departments to develop a well-planned resource recovery systems and its implementation.

7.7 Deconstruction over Demolition

Demolition is the most adopted method worldwide to recover materials from unused buildings, even though it makes the separation of material streams extremely difficult and doesn’t allow the salvaging of whole building’s components. A more efficient alternative that can retain the value of building components is ‘deconstruction’. It involves selective dismantling and removal of material from the building and structures without mixing of materials and degrading them to waste. Following the circular economy principals, the deconstruction method preserves the building components to their finished state as close as possible.

Deconstruction is the process in which a structure is dismantled to maximize the recovery of reusable materials. Also called as ‘construction in reverse’ or ‘unbuilding’, deconstruction ends a building life by selective disassembly of all its structural and non-structural components. In contrast to it, the conventional method of demolition uses mechanical equipment like bulldozers or explosives resulting in minimum to null reusability.

- Demolition is a public health issue. The activities involved generate dust and particulate matters which can travel 400 feet from its source, which is connected to elevated blood lead levels and asthma. Deconstruction on the other hand has the potential to reduce this effect of demolition. Through careful disassembly, it allows for proper identification of harmful materials that can be segregated appropriately.
- Though compared to demolition, deconstruction requires intensive labor and individuals with specialized skills & knowledge, it also feeds a larger reuse economy that is indirectly supporting jobs in material warehousing, retails & sales, and material manufacturing. Deconstruction can be a tool for workforce development, especially for underprivileged communities that face barriers to employment.

DEMOLITION	DECONSTRUCTION
<ul style="list-style-type: none"> • Materials, products and components are destroyed • The waste ends up in local landfills • No tax benefit • No community benefit 	<ul style="list-style-type: none"> • Materials, products and components are salvaged • Waste is diverted from landfills and reused for new constructions • Tax-deductible receipt provided • Help build a sustainable community and increase the affordability of building materials

Table 3: Comparison of Demolition and Deconstruction
Data Source: Author

7.8 Building Components

A ranking of materials, with a physical and technical dependency, can be defined with the building layers. The framework is characterized by the building, system and component hierarchy.

- Various elements and materials together assemble the component functions at the component level.
- The components carry out the system functions like insulation, finishing etc. at the system level.
- The building level represents the primary function carried out by the group of systems like partitioning, load-bearing etc.

The dependencies of these building layers suggests that the building is composed of three lifecycles: The cycle of the building, the cycle of its components and the cycle of materials used to manufacture the components. Even though these cycles become a unit during the building is in use, but it is not the same before its construction and after demolition. Mainly the service life of the material, the component or building comes to an end. At the End of Service Life (EOSL), there is a potential to extract the material and components for their unconsumed value. The end-of-life disposal strategy can be replaced with a suitable R-strategy (reduce, reuse, recycle, refurbish, remanufacture), so that the material's life can be prolonged and a significant amount of C&D waste can be reduced in the building industry. Although the new construction methodology has to ensure the 'Design for Reuse' strategies so that the future buildings don't face the same fate, a large proportion of building have already been constructed. Buildings constructed in the past can be identified as the material and component reservoirs, turning the 'waste to resource' and closing the material loop for future.

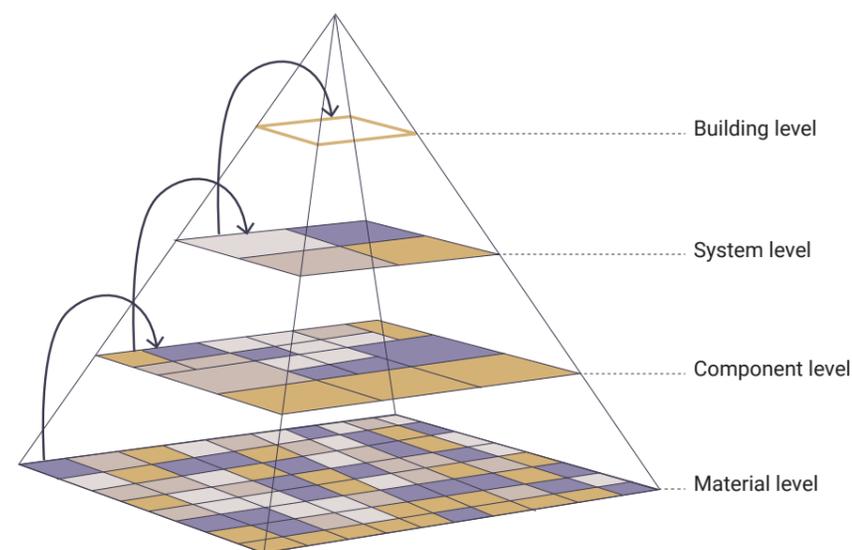


Figure 24: Dependencies of building layers
Data Source: Author

Using the Urban Mining method, of harvesting the materials from the buildings to be demolished, the deconstruction contractor can retain the value and keep the materials in the loop for a longer period. The materials extracted are sold through the online store of Malba Project and MSMEs (Micro, Small & Medium Enterprises). Repairing, refurbishing or remanufacturing (using recycled materials) can add value to these products, though the main priority is to keep the shortest loop of reusing directly with minimum processing required. Finally, these materials and components are brought by its new consumer. This value generation not only retains a higher economic value for the C&D waste but also provides a new livelihood source in the Indian economy.

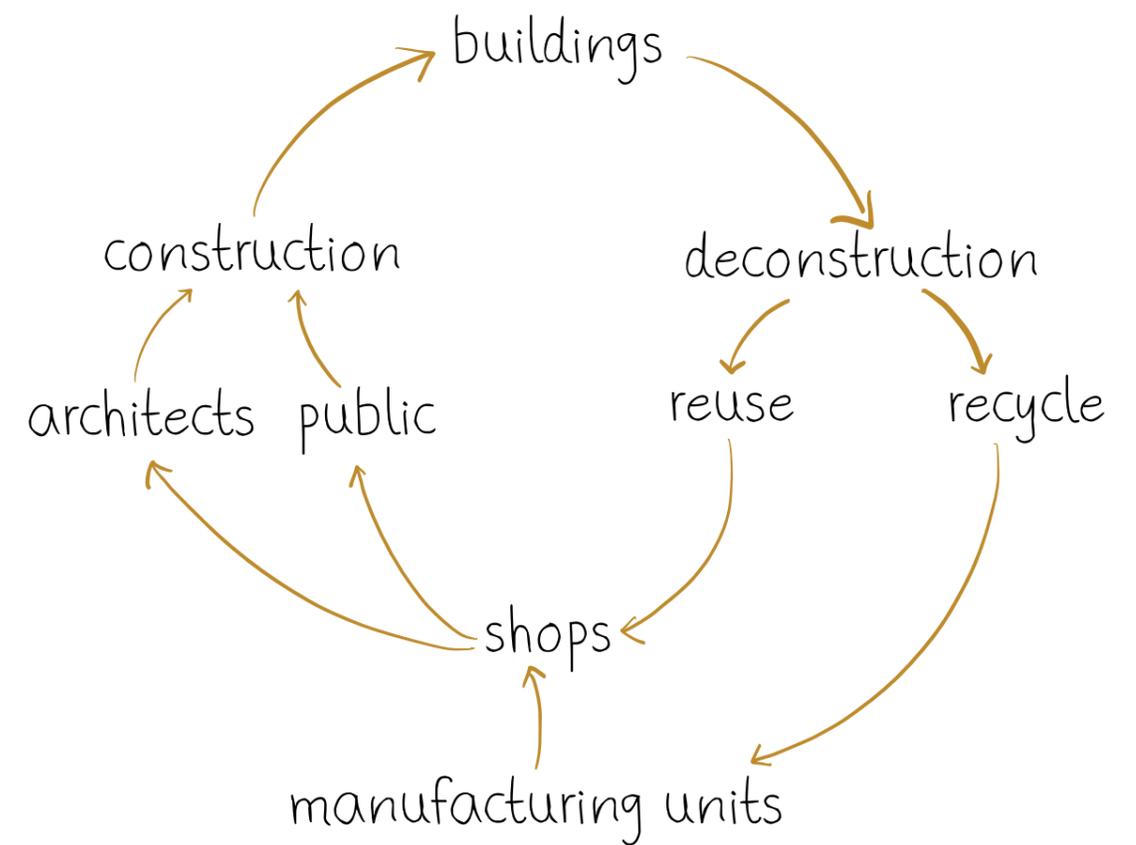


Figure 25: Dependencies of building layers
Data Source: Author

7.9 Proposed concept for The Malba Project

The following concept flow depicts the steps with their short description in a scenario in which a structure need to be deconstructed and what services can Malba Project provide to their clients.

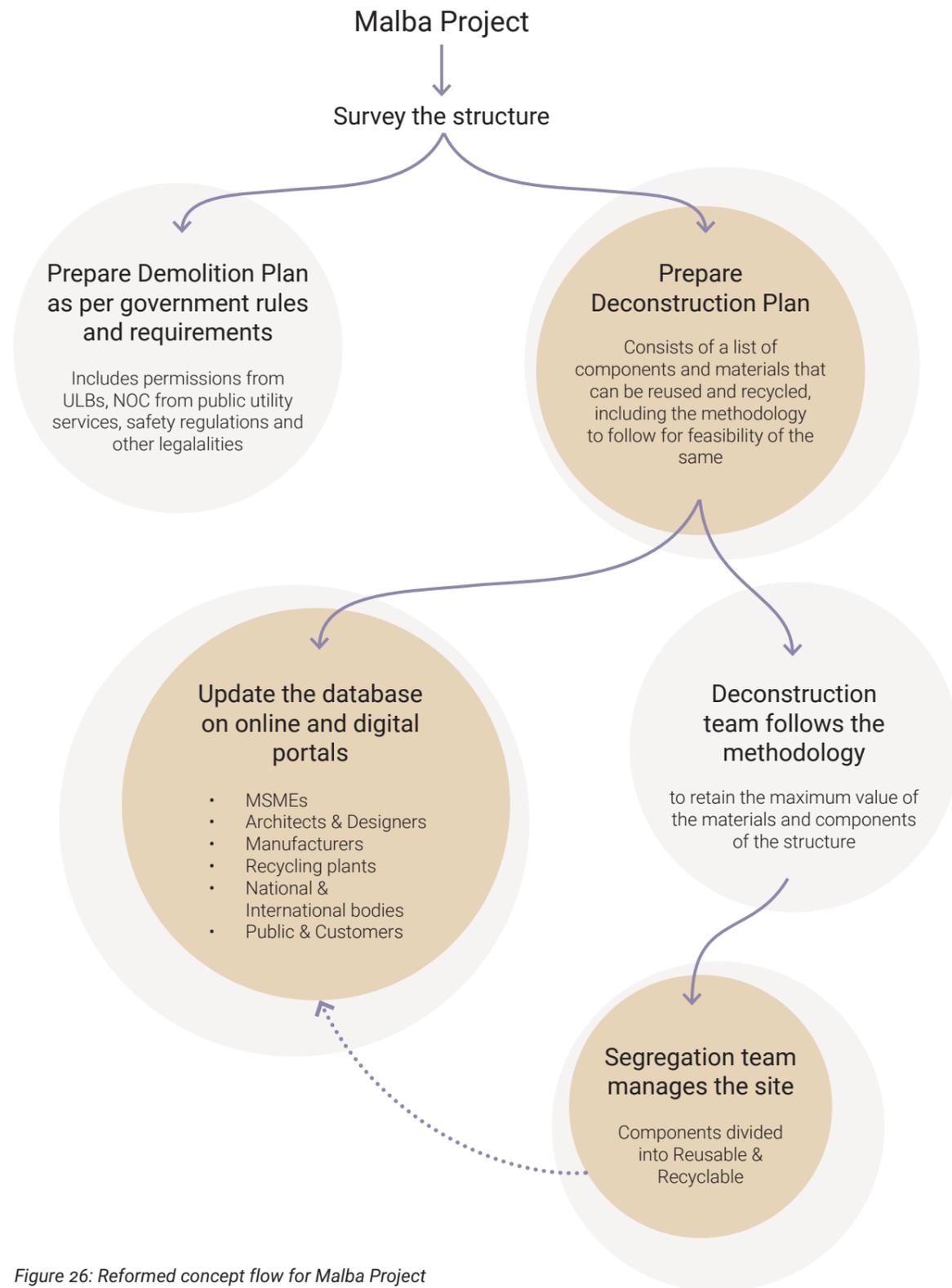


Figure 26: Reformed concept flow for Malba Project
Data Source: Author

7.10 Key Elements

To accomplish the targets and indicators defined by UN's Sustainable Development Goal-12, The Malba Project provides a one-stop service redefining the conventional method of demolition into a structured system of deconstruction & segregation of building components to salvage them and close the material resource loop. Thus, portraying the urban built environment of Indian cities as 'Material Banks' which can be exploited for the future development without misusing the depleting natural resources.

7.10.1 Prepare Deconstruction Plan & Execution

With very less percentage of structures constructed with latest technologies which can make the deconstruction easier, most of the buildings and structures in India are constructed using regular methods and technologies. Most of the demolitions taking place are of old structures which would require a thorough survey of the site to identify the building materials and components and develop a methodology of disassembly of the structure with appropriate techniques.

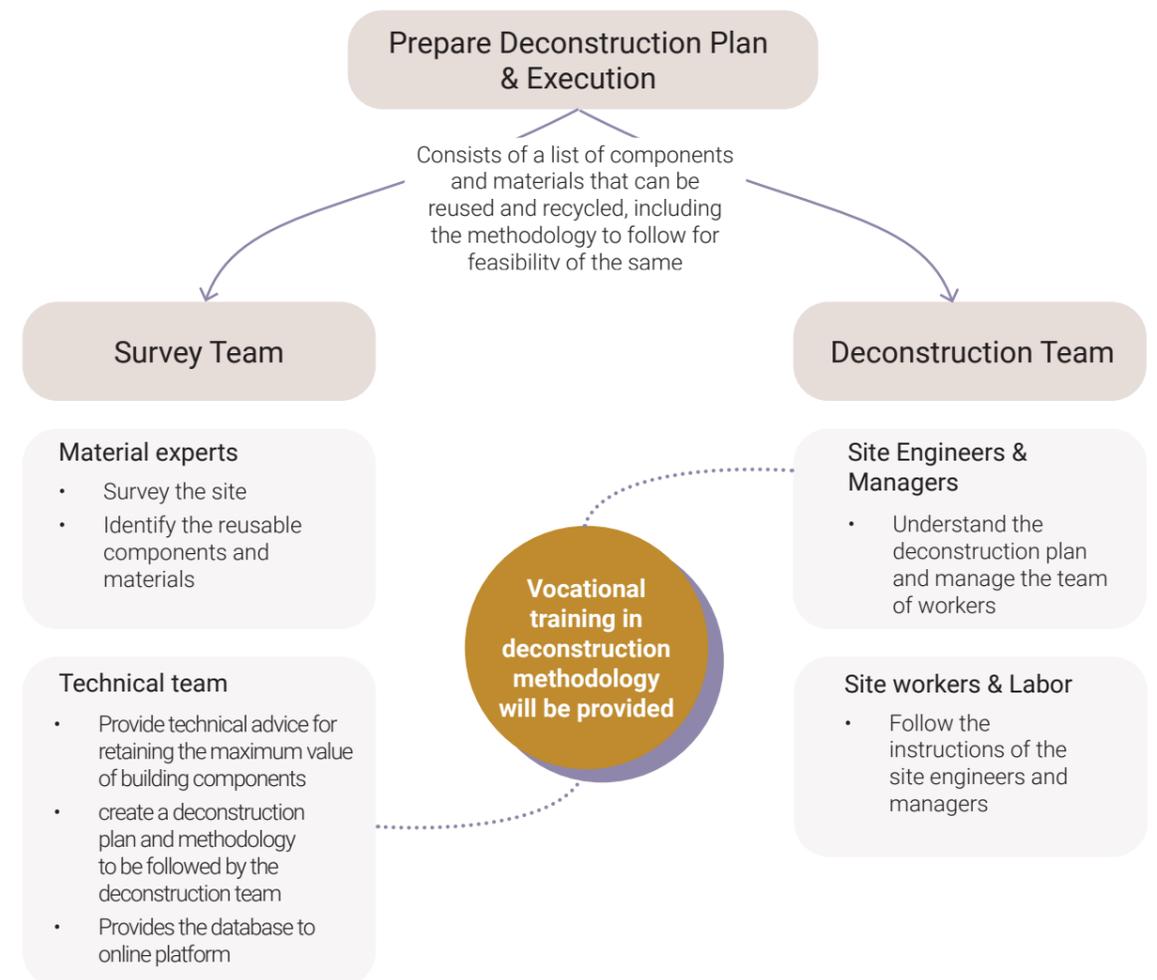


Figure 27: Structure of teams and their roles in 'preparing the deconstruction plan'
Data Source: Author

7.10.2 Online and Digital portals

With very less percentage of structures constructed with latest technologies which can make the deconstruction easier, most of the buildings and structures in India are constructed using regular methods and technologies. Most of the demolitions taking place are of old structures which would require a thorough survey of the site to identify the building materials and components and develop a methodology of disassembly of the structure with appropriate techniques.

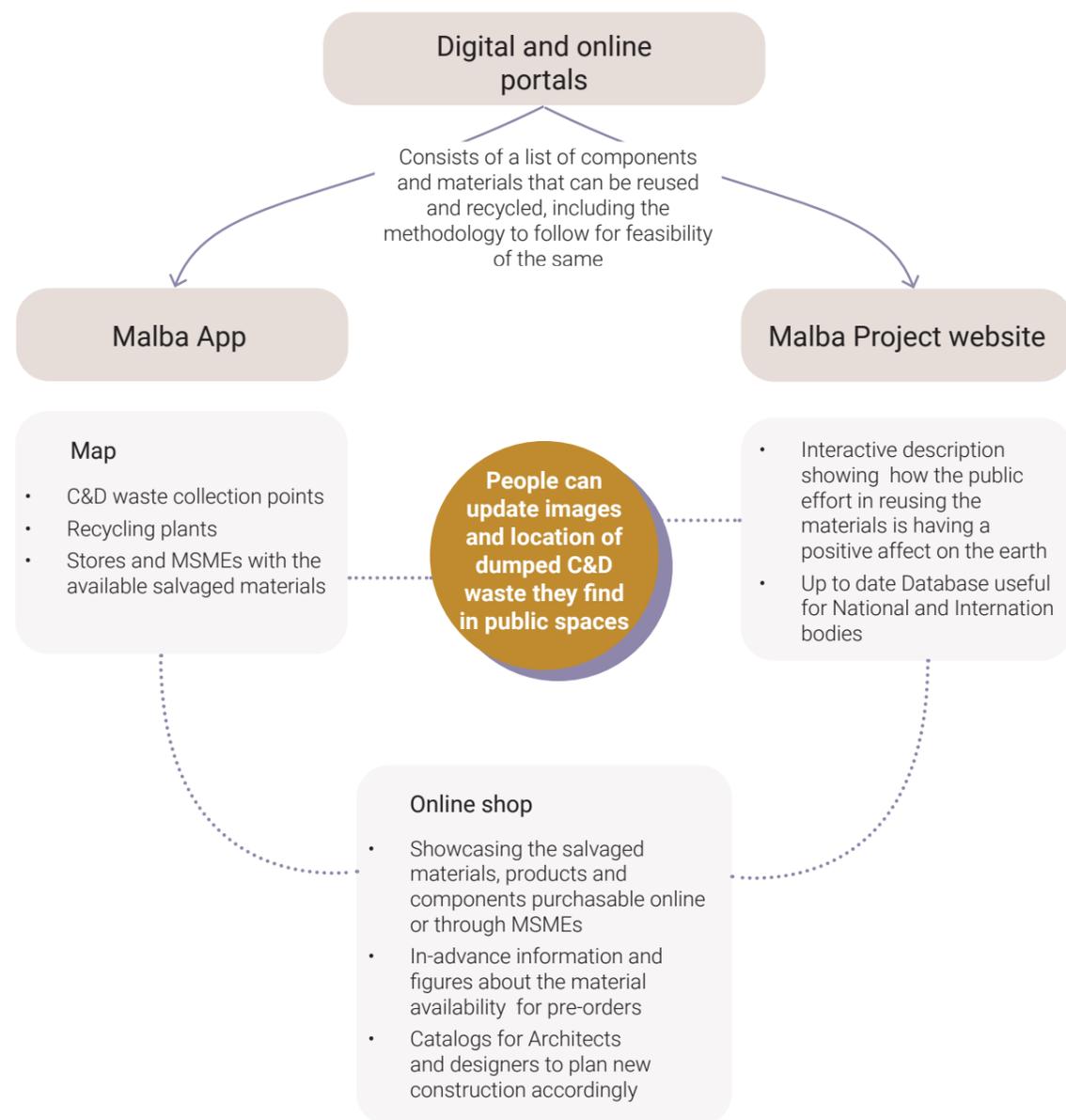


Figure 28: Structure of 'digital and online portals'
Data Source: Author

7.10.3 On site Segregation & material Salvage Management

As the deconstruction team follows the methodology retaining the maximum value of the components listed in the plan, the segregation team sorts the reusable materials, products and components. The components and products including doors & windows, glass panels, partitions, furniture, sanitary fixtures & fittings, pipes, wires and electrical equipment, HVAC installations, steel reinforcements etc. allows for easier extraction. On the other hand extraction of bricks and concrete reinforcement requires advance technologies due to their irreversible bonding and dependence on other building layers. As a result even after careful removal, most of their parts are either used as rubble in new construction or recycled and remanufactured into pavement blocks, concrete bricks, curbstones, and other products. With such a framework that adds value to the materials as per the 9R framework, all the C&D waste can be utilized to support the economy.

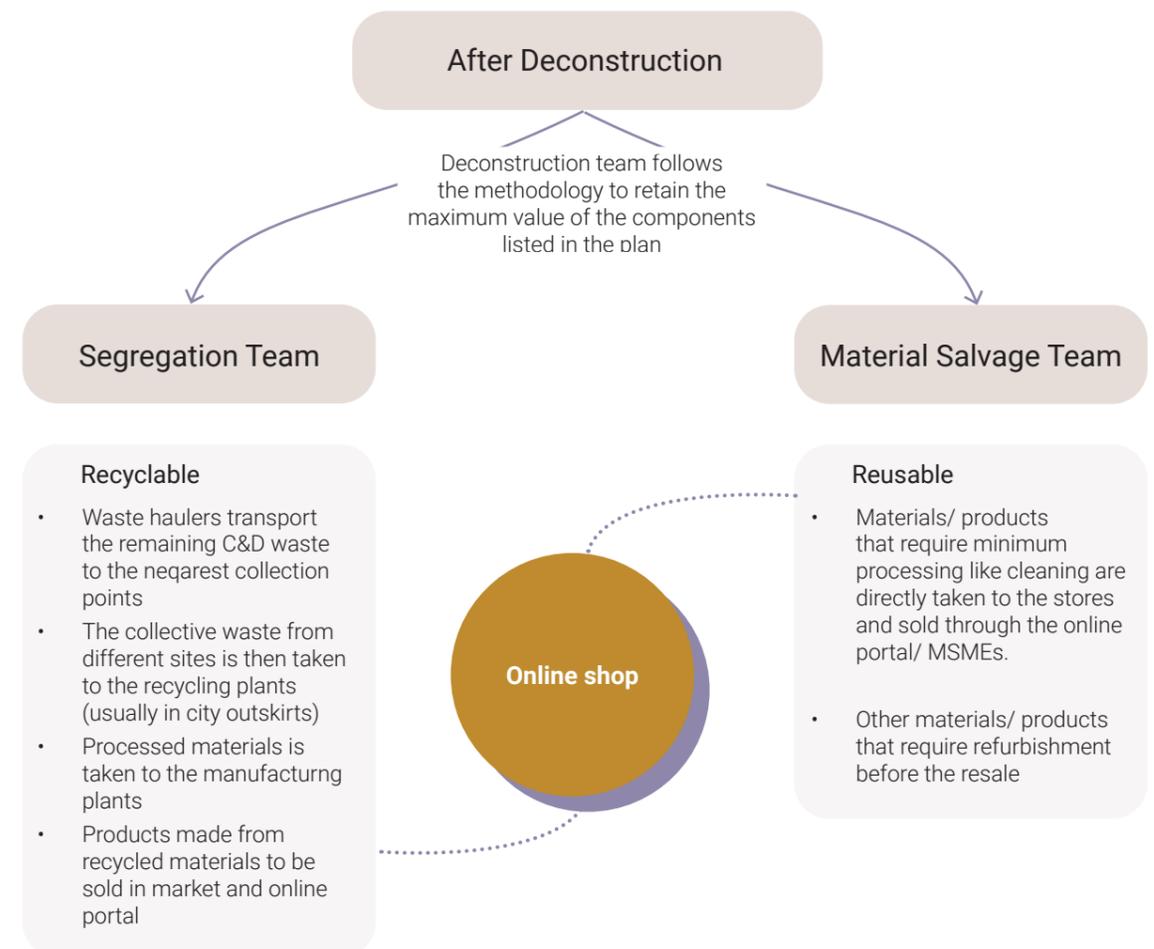
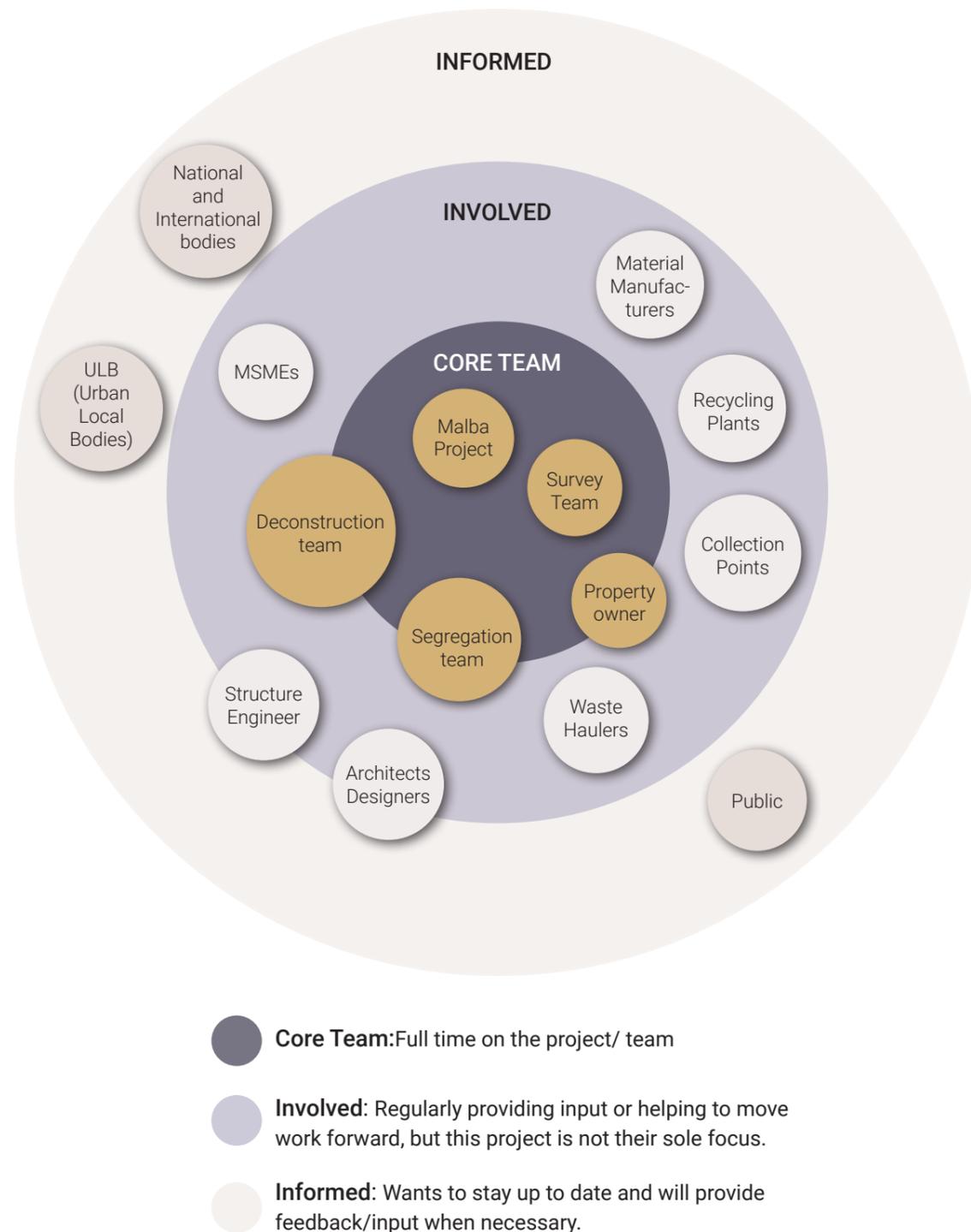


Figure 29: Structure of teams and their roles for 'after deconstruction phase'
Data Source: Author

7.11 Stakeholder Map

The map represents how each stakeholder can help make the service operative. How involved they should be and what are their respective roles.



7.11.1 Stakeholder Roles

Malba Project: The core team constituting of service providers. The team will manage the online platform and the digital application. The survey team involving the material experts and site engineers. Vocational training for Deconstruction Methodology and material reusability shall be provided to the engineers and workers to gain appropriate skills & knowledge.

Deconstruction Team: Malba Project will partner with local deconstruction companies and provide them with a vocational training for deconstruction methodology to upgrade their current practices. The team will follow the plan created by the survey team for deconstruction.

Segregation Team: Malba Project will partner with local segregators and provide them with vocational training for material reusability and how the building components can retain their maximum value. The team will segregate the deconstruction materials into reusable and recyclable.

Recycling Plants: Process the C&D waste and distribute the recycled materials to the manufacturing units, SMEs and for selling through the online platform.

MSMEs (Micro, Small & Medium Enterprises): Spread the awareness for using reusable materials and components through promoting these materials to their customers. Provide space for displaying of materials and components from the material bank. Provide catalogs to the architects and designers. Their location will be available on the digital application for the customers to buy the product/ material directly.

Architects and Designers: Regular updates and information will be provided to the architects and designers about the materials and components available through the digital platforms. They shall provide awareness to the public about reusing the materials and design the future structures for deconstruction.

Government/ ULB (Urban Local Bodies): Policy implications for using a minimum percentage of reusable materials in new construction and promoting deconstruction of buildings rather than demolition. Rankings and incentives from Leadership in Energy and Environmental Design (LEED), Green Rating for Integrated Habitat Assessment (GRIHA), and Indian Green Building Council (IGBC) for Architects and construction contractors.

National and International Bodies: Provide incentives to people who are putting an effort towards achieving the UN's SDG. Provide technology and resources to avoid any barriers in the fulfillment of the goal. Malba Project will provide the database from the online and digital platform for management.

Figure 30: The Stakeholder Map
Data Source: Author

Conclusion

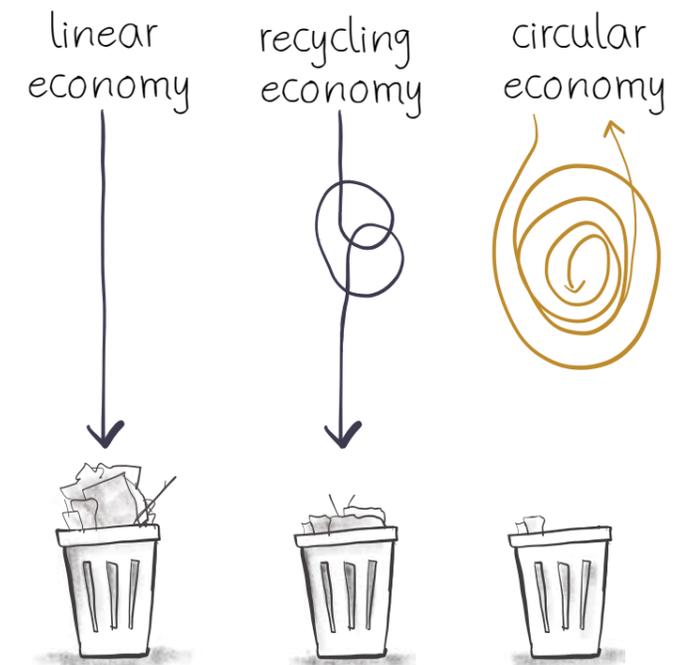


The Sustainable Development Goals offers a new direction for the global community, incorporating social, economic and environmental sustainability into the policies and strategies. The construction industry can act as a driver towards SDG's realization only if sustainable considerations are amalgamated into the project delivery, processes, standards and practices. The construction & demolition activities impact negatively on the environment by consuming large amount of natural resources and producing extensive volumes of waste. It is thus crucial to adapt practices like circular economy to maximize reuse of resources and reduce the waste generation.

The SDG-12's achievement in the South Asian region will require new investments in sustainable infrastructure. Developing the right policies and systems taking the circular economy into account, will not only generate employment opportunities, but eradicate poverty and improve people's standard of living thus supporting other SDGs. Various Governments outside India are adapting deconstruction policies to achieve their sustainability goals. Other than closing the consumption loop of building materials, it has potential to create stable jobs which are socially approved, foster community connections and contribute to sustainable construction practices.

Further discussions with the Malba Project team, regarding reformation of the system incorporating additional features to the existing service, lead to the dialogue for considering the proposal for the second phase of the service. Although, being a young project it is not feasible at the moment but with further developments, governmental support and funding from investors can help with the realization of the project.

Together we can change the idea that the waste is inevitable. We can look at cities closely as the material banks and determine what can be salvaged for the new development while protecting the rights of future generations.



Don't let your resources turn into Malba! It is essential that we believe in reuse first and produce new second.

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