ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

Frameworks For A Circular Economy On Demolition Waste Management - Challenges, Barriers And Strategies: Policies Way Ahead To India

PROFESSOR: ALESSANDRA BONOLI

STUDENT: VARA PRASAD. TANGUTURI

MATRICOLA: 0000985351

DEPARTMENT: ENVIRONMENTAL ENGINEERING

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PREFACE

The information collected in this report describes the management of Demolition waste and the policies needed to implement in India. All the required work and the carryout steps settled in a framework for better understanding. This report will create sustainability and profits towards Environment, Economic and Social. This work has been completed by reviewing several papers manually through several research sources, which makes me to increase my knowledge and experience towards the understanding of the issues and solutions through this research.

This Research is written by: Vara Prasad. Tanguturi (Matricola – 0000985351) in the course Earth Resource Engineering in Environmental under the co-supervision of Professor Alessandra Bonoli (Department of Environmental Engineering), University of Bologna, BO, Emilia Romagna, Italy.

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1. ABSTRACT:

Construction Demolition waste (CDW) is one of the major concerns in India to look into since the C&D waste generation annually accounts for around 40% of the total C&D waste generation annually by the entire world. The 4R (Reduce, Reuse, Recycle and Recovery) method will help to create a sustainable environment and accelerate the circular economy.

The main aim of this paper is to create a Circular Economy (CE) on Demolition waste and its management. The waste in usage alleviates the consumption of natural resources for new production and helps to reduce CO2 emission into the atmosphere also creates employment by enhancing the technological values in management and handling. The methodology of Prisma chart flow was followed in this report to collect the literature review to satisfy the aim of the report. The novelty of this report looked over the CDW management and the government initiatives towards it.

The results of this report have been worked on the frameworks for circular economy and its management, challenges and barriers that are going to occur in the system, strategies, sustainability connectivity with CDW and the policies needed to control the effects on the environment, economic and social health due to illegal disposal and improper waste management.

KEYWORDS:- construction waste, circular economy, C&D waste in India, frameworks, C&D waste, construction and demolition waste, CDW, C&D waste management, Environmental damage, Sustainability, responsibilities of consultants & contractors, government policies, waste management planning, waste material, Sustainable waste management, 4R's, C&D Waste, Circular economy, recycling, reuse, recovery, reduction, waste hierarchy.

2. INTRODUCTION:

2.1 CDW background in India:

The increasing population amplify urbanization and becomes metropolitan areas which require infrastructure like Residential, Commercial and Public buildings also increase in the IT sector and Industrialization. Which demands construction materials in a huge quantity which amounts to a lot of capital, instead of using raw materials for the construction we can use the construction demolition waste as a source, which is sustainable and also reduce the economy of the project in total.

Construction demolition waste (CDW) generation and its management must need attention to achieve sustainable goals. The handling of waste management and turning it into a circular economy should need efficient practices but as of records and the practices that have been mentioned in the reports that have been found in the literature review search will not be sufficient for a sustainable environment.

The MoEF&CC (Ministry of Environment, Forest and Climate Change) - Information Technology (IT) launched a web-based application in 2016 to track and monitor waste management in India. The application "*Integrated Waste Management System"* collects information and assists in coordinating waste generators, recyclers, operators of disposal facilities and state agencies **(1)**.

India produces almost 100-120 MT per year which is about 35-40% of the world's C&D Waste as per recent estimation by the CSE (Centre for Science and Environment) **(2)**.

There is no proper estimate regarding the quantity of waste generation in India previously due to the lack of focus, frameworks, and proper enforcement to regulate. This report has specific recommendations to overcome the loopholes in the issue and also writes about the recovered waste material used in different sectors from demolition and landfilled **(3; 3)**.

The 4R's concept is a better option and will help to create an economic system in a business model as a substituent to material/waste end-of-life by using certain frameworks **(4)**.

According to recent studies, is observed that India manages to recover and recycle waste only about one per cent of its total generation, and that becomes changing. Developing countries (like India) should follow the usage of C&D waste generation in rural areas along with urban communities. Some national-level environmental organisations (governmental & non-governmental) include:

- Advisory Board on Energy (ABE)
- Bombay Natural History Society (BNHS)
- Central Forestry Commission (CFC)
- Department of Non-Conventional Energy Sources (DNES)
- Environmentalist Foundation of India (E.F.I)
- Industrial Toxicology Research Centre (ITRC)
- National Environmental Engineering Research Institute (NEERI)
- National Dairy Development Board
- National Natural Resources Management System
- National Wetland Management Committee
- State Pollution Control Boards (SPCB)
- Tata Energy Research Institute (TERI)
- Central Soil Salinity Research Institute

2.2 Demolition waste Generators:

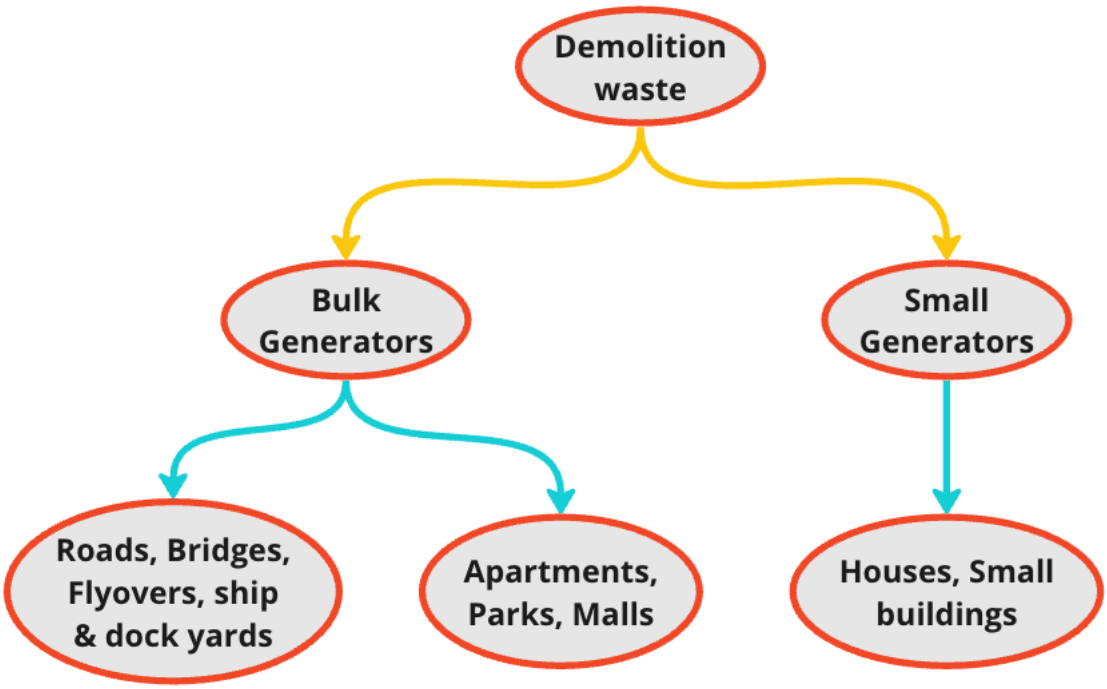

Chart 1. Demolition waste Generators

The demolition waste generation differs by type of structure and construction. So there are two kinds of generators majorly, Bulk and Small, that are listed below in the given diagram (5).

2.3 Materials of Demolition Waste:

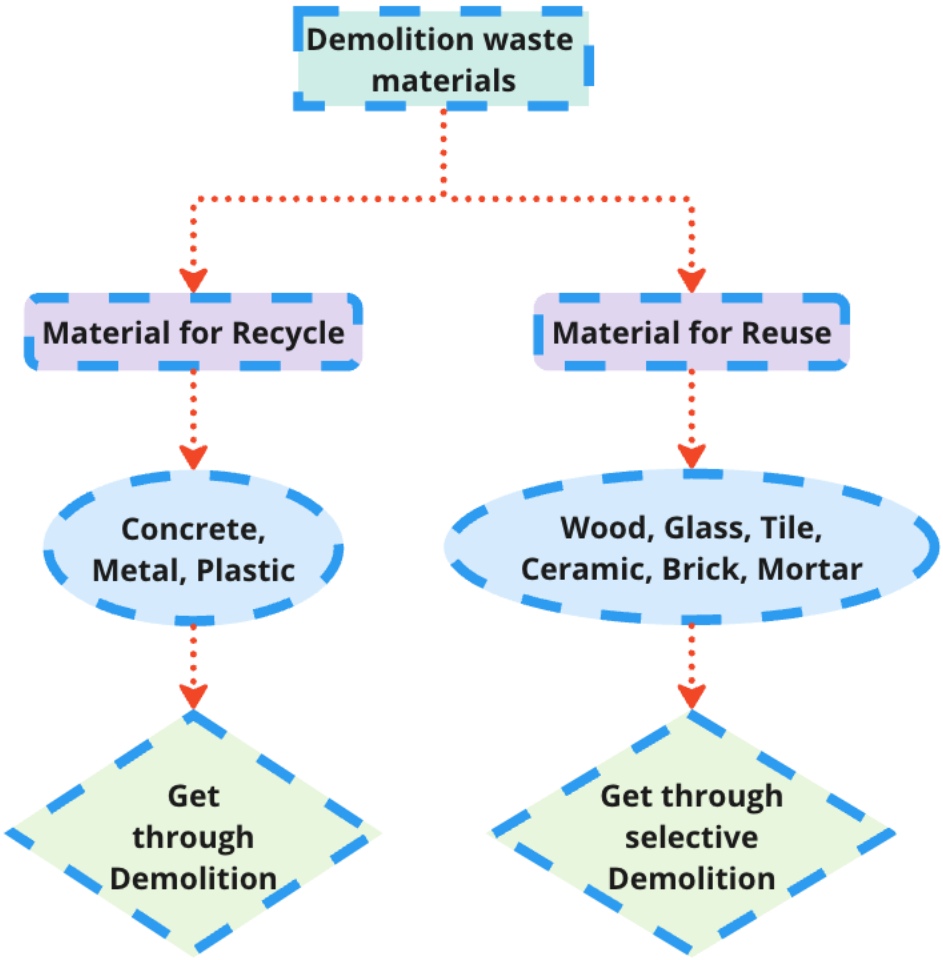

Chart 2. Materials of Demolition waste

The demolition waste material will be used mostly for reuse and recycling and the materials listed are mostly used for them. The material is recovered from the different demolition methods (6).

2.4 Components of the Demolition Waste:

Major: (7)

- Cement concrete, Bricks, Cement Plaster Steel (from RCC, door/window frames, roofing support, railings of staircase etc.)
- Rubble, Stone (marble, granite, sandstone)
- Timber/wood (especially demolition of old buildings)
- Clay (Soil from excavation)

Minor: (7)

- Conduits (iron, plastic), Pipes (GI, Iron, Plastic)
- Electrical fixtures (copper/aluminium wiring, wooden baton, Bakelite/plastic switches, wire insulation)
- Panels (wooden, laminated)
- Others (glazed tiles, glass panes)
- Plastic carry bags, sachets of tobacco and other plastics, Clothes, Cement bags, gunny bags, thermocol, etc.

2.5 Sources of Demolition Waste:

The waste material recovered from the construction demolition could be man-made or nature-made structures and is viewed in detail in the flowchart drawn below (8).

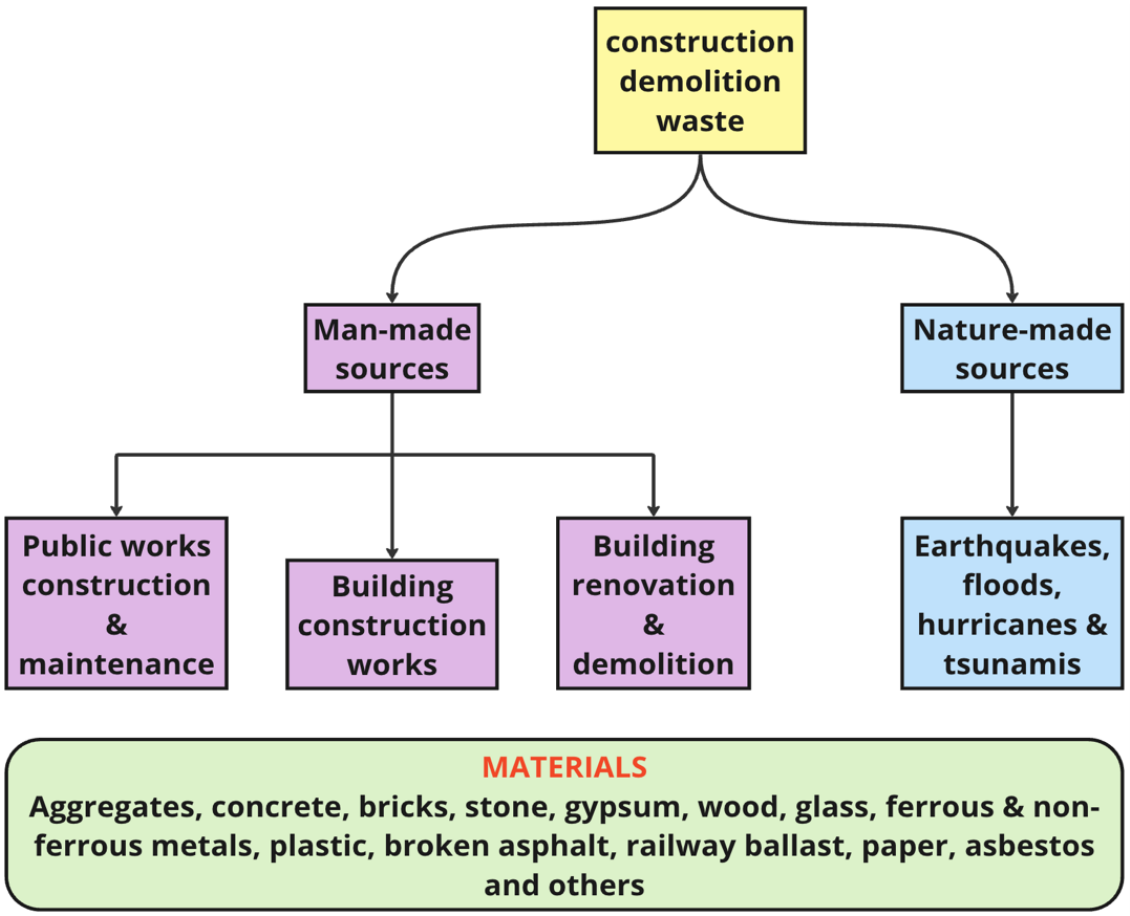

Chart 3. Sources of Demolition waste

2.6 Circular Economy (CE) Principles and System:

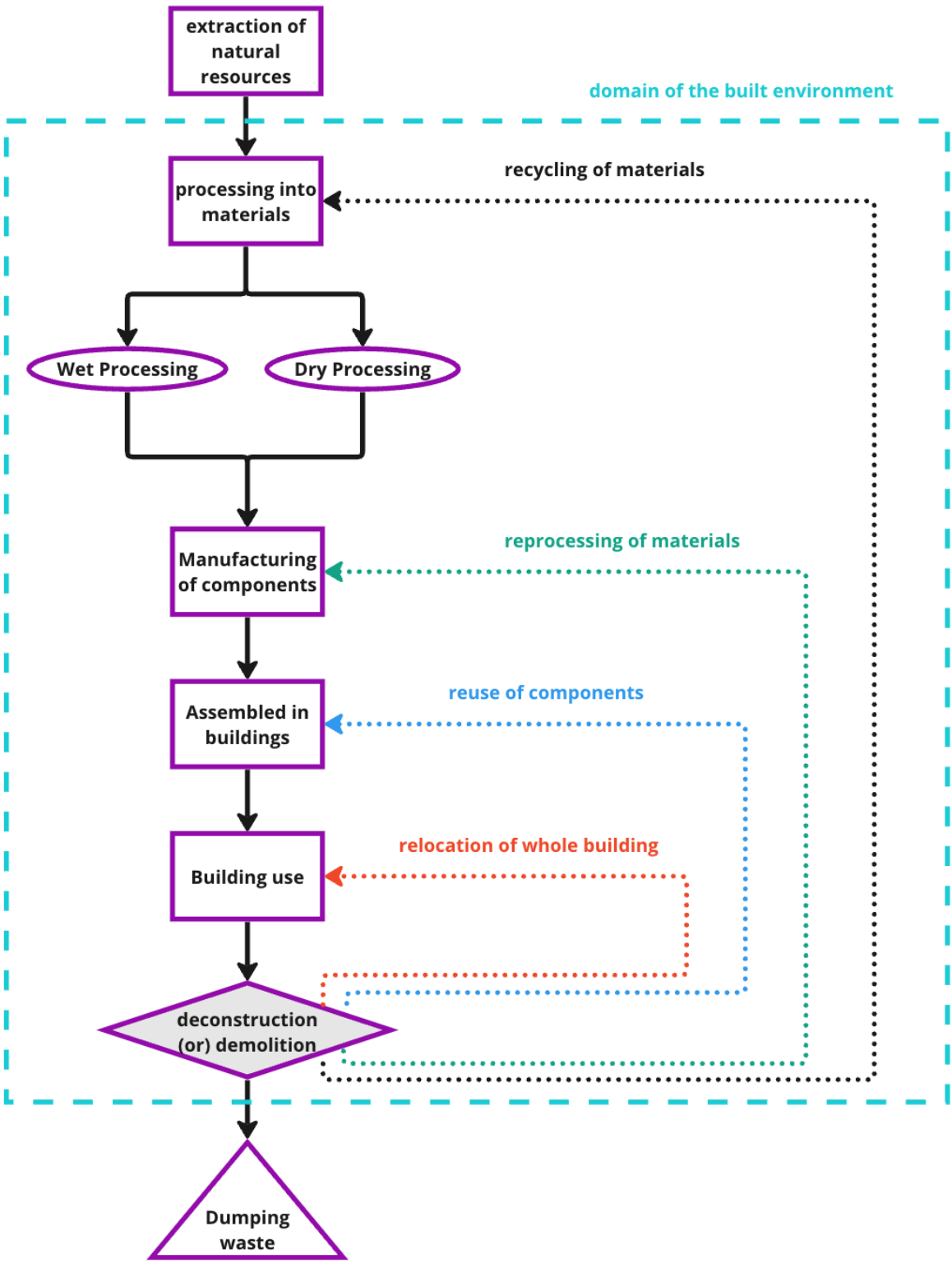

Chart 4. Framework for Waste Hierarchy

"CE principles – Reduce, Reuse, Recycle, Recovery and Disposal". These principles would help to increase the CE value by satisfying the Economic, Environmental and Social aspects. Reduction of Raw material used in the production or waste generation reduction in the circularity; Reuse the demolition

waste; Recycle the demolition waste; Recovery of waste should be less by transferring the waste to reuse and recycle and do safe disposal after treatment.

2.7 Framework for Waste Hierarchy:

The framework will give an overview of waste management (from generation to disposal) in order of importance (from left to right) in the hierarchy and tells which parts/steps can be used as a resource and which can be used as waste.

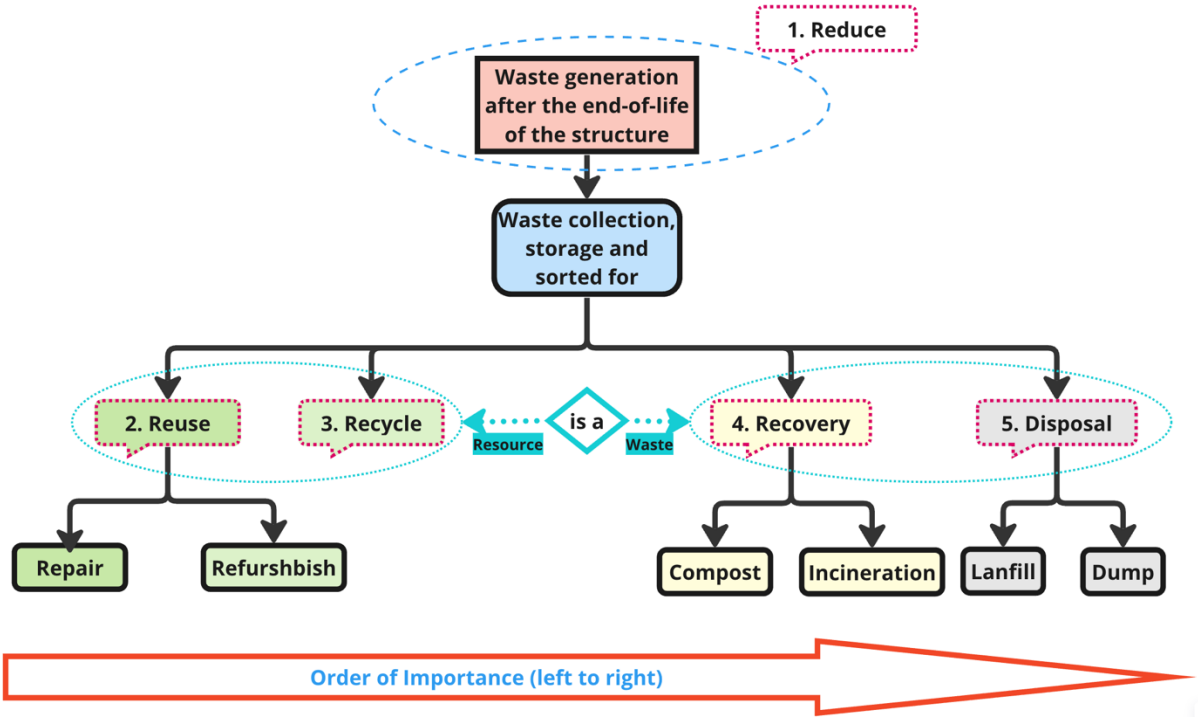

Chart 5. Framework for Waste Hierarchy

2.8 Definitions:

Reduce: Waste reduction practice is the most preferable among the 3Rs principles as its priority in the waste hierarchy and its adverse impact on the environment is the lowest among all (Huang et al., 2018; Joensuu et al., 2020) (9)

Reuse: The reuse practice is defined as all the construction materials, elements and building components collected that could be used in a specific site (Gálvez-Martos et al., 2018) (9).

Recycle: Waste recycling practice is carried out by breaking down the waste materials to form new materials or components or as part of another material (Huang et al., 2018; Ogunmakinde, 2019) (9).

Recovery: recover the construction demolition waste without any pre-processing

Disposal: getting rid of/throwing away/landfilling the waste after the 4R safely.

Circular Economy: Shifting the economy from linear to circular is a business opportunity, it strengthens the supply chains and the local communities in a socially inclusive way, climate-friendly and nature-positive (10).

Demolition: Destroying the whole building and 3R (Recovery, Reuse & Recycle) must be analyzed before the waste ends up in a landfill (5)**.**

Deconstruction: the act of breaking something down into its separate parts in order to understand its quality of usage in reuse or recycling.

Framework: Framework is a plan or steps or loop or flow or chart of a system which is prepared and used to make the system effective & sustainable (11).

Sustainability: meeting the needs of the present without compromising the ability of future generations to meet their own needs.

Construction Demolition Waste (CDW): CDW comes from the construction, renovation, expansion and demolition of all types of buildings, structures, piping networks and residential decoration activity.

2.9 Problems and solutions peculiar to urban areas in India:

- The lack of proper bookkeeping practices about CDW and reliable data from the cities raises doubts about the accuracy of the estimates. Based on the experts' opinions and data in refereed journals, 500 million tonnes of annual CDW generation in the country looks very much possible.
- illegal disposal of almost half of the waste quantity being generated in Indian urban areas still is alarming.
- The availability of river sand has become scarce in Indian cities owing to the local ban on quarrying sand from river beds in recent years. Manufactured sand (crushed rock to fine aggregate size), a material produced during the process of quarrying and crushing for coarse aggregates, is increasingly becoming popular as a substitute for river sand. The crushed recycled fine aggregate could be pitched in as a substitute for fine aggregates instead if the recycling facilities are equipped with crushing and screening facilities that can produce fine aggregates as well (12)**.**

- The demand for aggregates in the Indian construction sector is projected to be about 2 billion tonnes of coarse aggregates and 1.4 billion tonnes of sand (fine aggregates) by 2020. Even if we consider that about 500 million tonnes of the entire demolition waste generation in the country are recycled, it can just partially substitute the demand that exists in the sector.

2.10 Road map for implementing CE in India:

After several practices in CE on CDW, the government of India have decided to highlight the circularity promotion by introducing a buy-back policy to encourage the consumers by returning the used products, for this top branding companies and local bodies are helping. To put back this kind of resource into the system certain logistics will be developed – CE in Construction demolition waste and management, digital and mechanical support, government policies, guidelines and strategies (13).

3. METHODOLOGY:

3.1 PRISMA Chart:

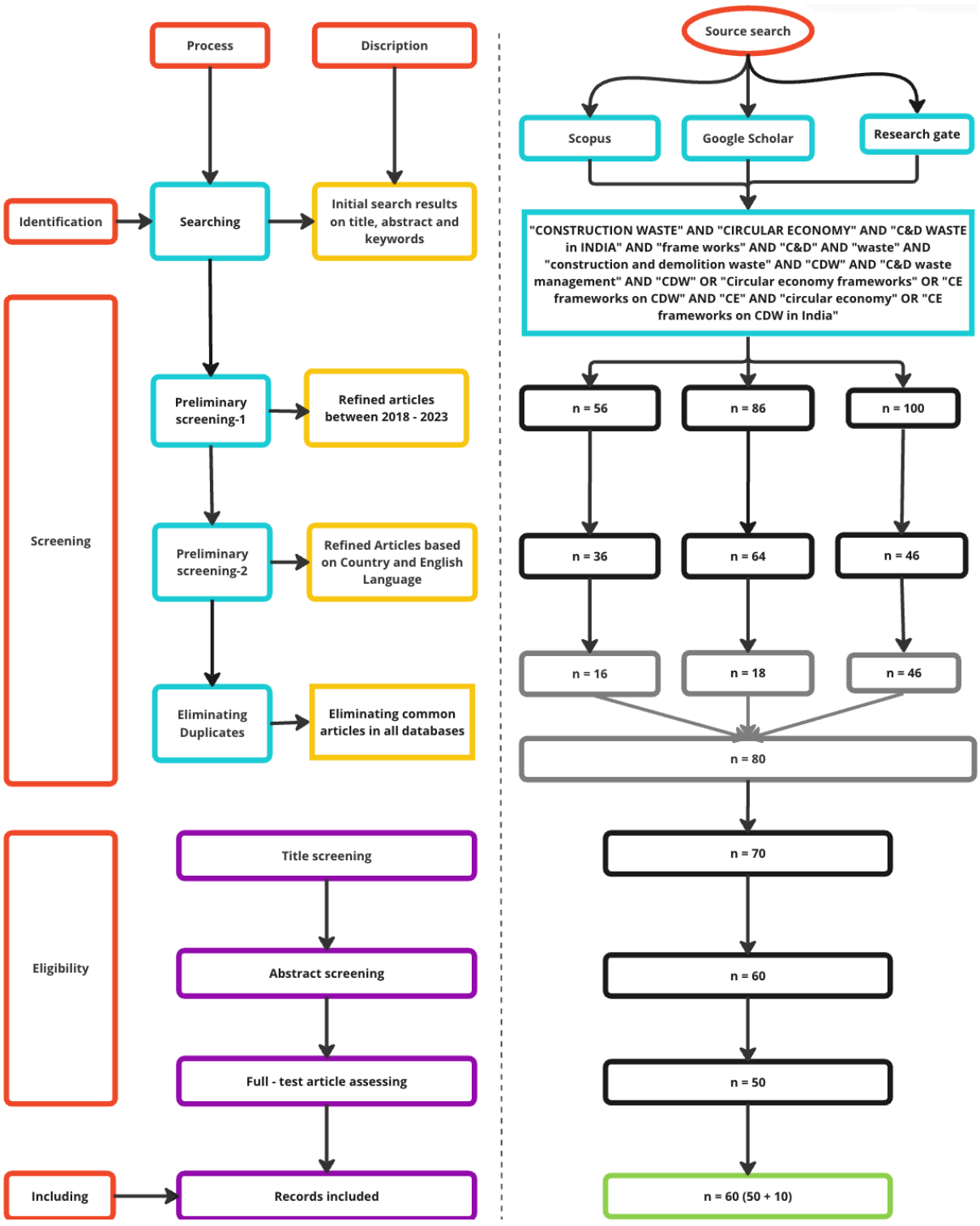

Chart 6. PRISMA Chart

Studying the research papers written by engineers, researchers, students and practitioners on Construction Demolition Waste in Circular Economy and its Management. This report followed the pattern of PRISMA chart flow to maintain the systematic approach and for easy understanding visually.

This report followed a Literature review, collected from a number of papers using the keywords of "CONSTRUCTION WASTE", "CIRCULAR ECONOMY on CDW", C&D WASTE in INDIA", "FRAMEWORKS FOR DEMOLITION WASTE", "C&D WASTE", "CDW", "CDW MANAGEMENT", C&D WASTE MANAGEMENT', "CONSTRUCTION and DEMOLITION WASTE MANAGEMENT in INDIA", "CHALLENGES and BARRIERS of DEMOLITION WASTE" and "CDWM" in the chart from different most rated and known sources – Scopus, Google Scholar, Research Gate and some additional papers/journals collected from Wikipedia and Web. The data in this report was reviewed from several papers 60 in number were shortlisted after several screenings, filters and text assessments personally. The papers collected by primary & secondary screening filters were papers in the English language & in the year between 2018 to 2023.

3.2 Literature Review:

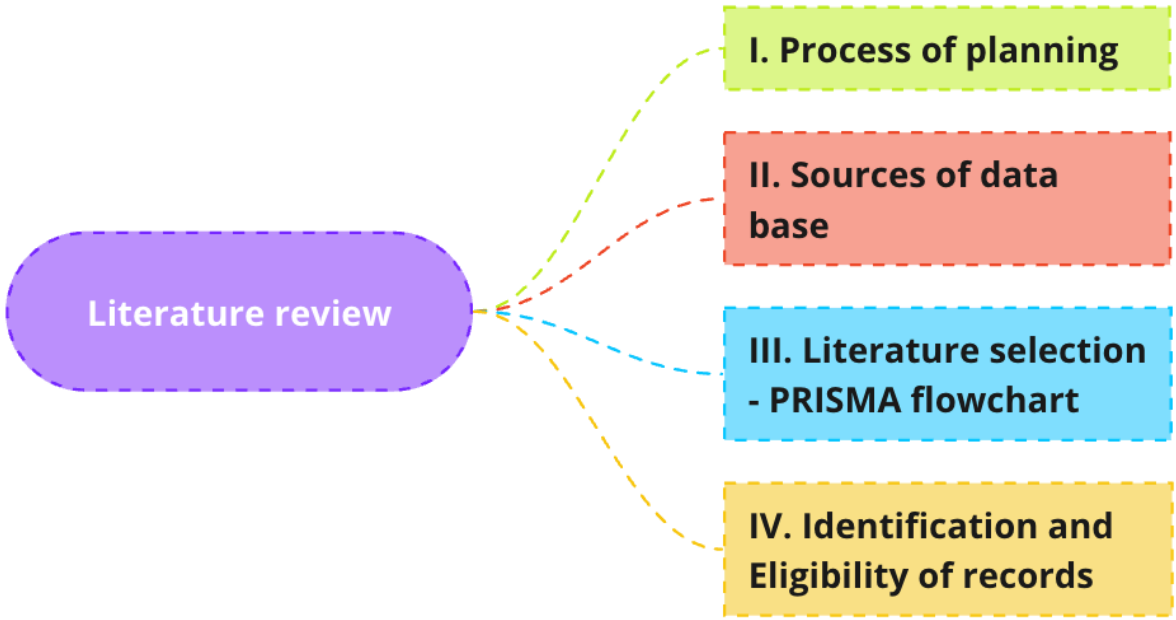

Chart 7. Literature Review

The Literature review gathered information regarding demolition waste and management; waste hierarchy; reuse & recycling; challenges, barriers, strategies

and tools required for efficient waste management in a circular economy concept will confirm that the percentage of pollution to the environment and cost of made from natural sources is higher than the cost of recycled or reused products.

The literature review was collected in a systematic way that helps to finish this report on time (14).

I. Process of planning: In this, a research question is defined based on the set of targets required to get relevant output, relevant bibliographic records and the definitions.

II. Sources of databases: To collect the required data to write the report one needs a qualified data source as a database. From them, will get the data/papers and the popular one's that are been used were, Scopus; Google Scholar; Research Gate. To satisfy the topic/ research question selected, collect as many as possible papers that should be enough and relevant.

III. Literature selection: After selecting the database and related paper collection were shortlisted based on filters and showing the results visually in a flowchart. To satisfy the report, a PRISMA chart has been followed in this report, that contains the necessary data to address the research objectives.

IV. Identification and Eligibility of Records: By following the steps mentioned in the flowchart given below, the eligible papers were identified by a screening - manual reading of abstracts and introductions thoroughly.

4. RESULTS:

4.1 Principles of Circular Economy:

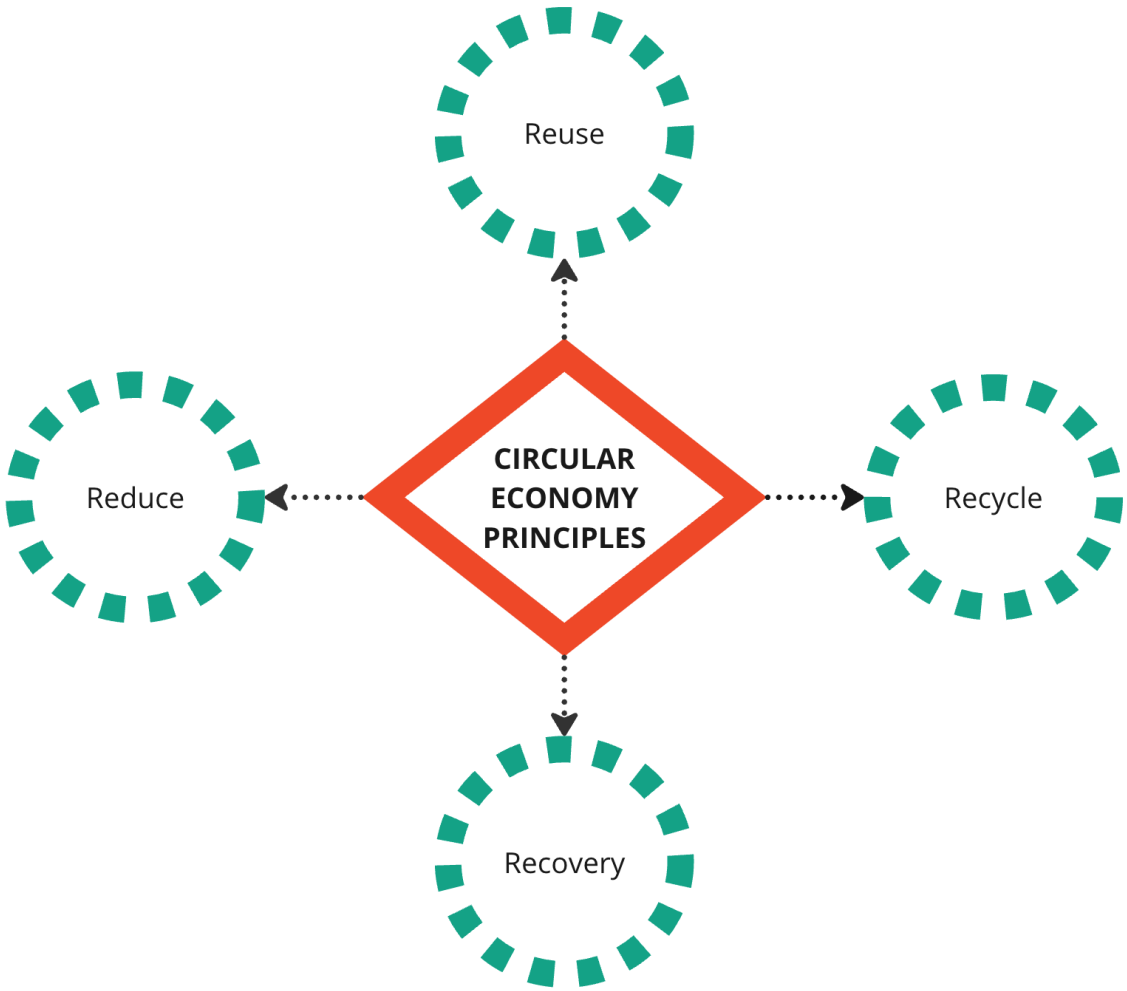

Figure 1. Principles of Circular Economy

The most well-known and followed fundamental concepts in Circular Economy by all the stakeholders are the 4R principles. Increasing the number of principles in the waste management hierarchy could reduce the disposal of waste and helps to create sustainability. This report worked on the Principles of Reduce, Reuse, Recycle, Recover and Disposal (15).

4.2 Waste Hierarchy:

Waste Hierarchy would help to minimize the loss of waste and also play an important role the in performance assessment of CDW management, this report on Construction Demolition Waste is especially and also written about each one of them listed in the hierarchy below.

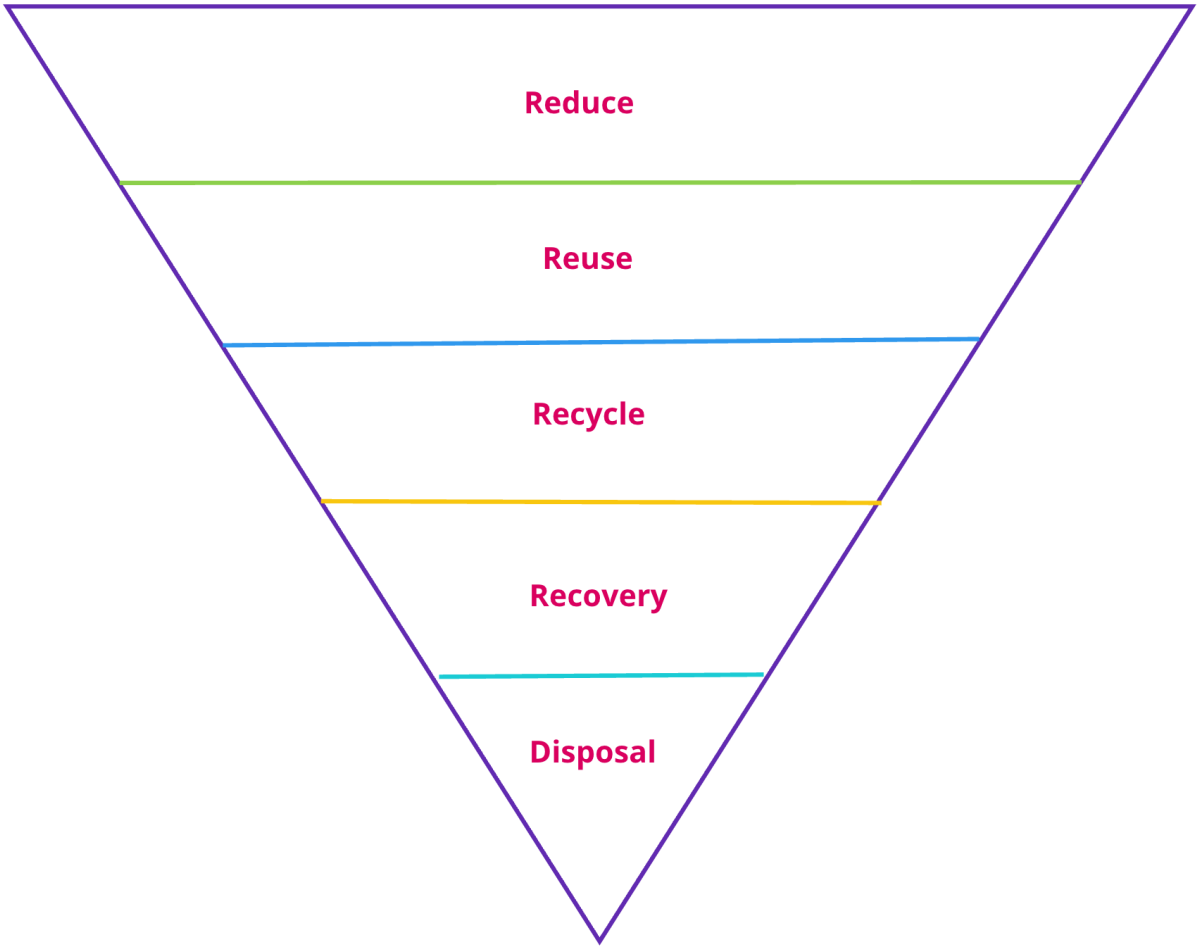

Figure 2. Waste Hierarchy

1. Reduce: CDW reduction is not developed well mainly due to a lack of design standards, low-cost for disposal and inappropriate urban planning. The reduction of original material from nature can save resource reserves, supply insufficiency in future generations reduced, help in circular economy and save the environment with the help of efficient design, planning and execution in each stage from the acquisition to the distribution of materials internally by using technical and mechanical support. The following options of reuse and recycling were the main reasons for waste increment (16).

2. Reuse: The reuse option will give economic and environmental benefits. Sometimes, good-sized precast elements are obtained during demolition or destruction, which has a greater potential for reuse and no need for treatment.

Brick: After the demolition, it can be reused directly into the construction sector again by removing the attached mortar on it with the help of manual or mechanical power operated by humans.

- Can be used as brick pavers and for landscaping (17).
- Used for the production of precast elements like paver blocks, kerb stones, and interlocking tiles by mixing with cement and using them as a concrete mix (17).

Tiles: Instead of doing the destruction of tiles which are attached to walls and floors, will go for demolition directly only because of not sure that are able to remove them with proper size and shape, if the material properties are great and able to remove, those can be reusable directly with a small finishing works.

- Even though tiles have good properties sometimes there are some damages or broken pieces will generate during the extraction, those can be reused for artistic purposes like decorating the outer fencing walls, pathways and parking areas. Example: Nek Chand's Rock Garden in Chandigarh, India (17).

Wood/Timber: Before the demolition of the structure/building, contractors/ owners decided to destruct and dismantle the wood products of doors, windows, tables, etc. carefully for reuse directly in original form as "framing lumber" because of having a good quality of durability in service than the life of building (18).

Metal: After demolition, the steel from the waste can be collected manually with the help of magnets or with the help of machinery. It generates zero waste material because all the material can reuse if it is in good condition to make new products for durability and strength purpose (17).

- While making new products like fire hydrants, and steel furniture we need to check the quality of the material.

Mortar: Crushed mortar waste can be used as a fine aggregate in concrete masonry blocks, non-loading bearing partition walls and also in ornamental urban elements (18).

Concrete: 25-100% of concrete waste can be used as aggregates in new concrete after the processing. It is the major waste material in the volume. These recycled aggregates are used for backfilling excavations and crushed concrete waste as fillers (replace 10% of the cement quantity) in asphalt concrete (19).

3. Recycle: Before recycling the waste, materials need to be tested because of the different types and different properties. when there is no way of using the waste directly in construction without any changes or treatment, we follow recycling. By using recycled materials in the construction industry again after certain treatments, it will help to achieve sustainable development in terms of economic (reduction in project cost and generate economy), environmental (minimise the utilization of natural resources) and social (help to raise the awareness to the public towards waste management).

Concrete: 25-100% of concrete waste can be used as aggregates in new concrete after the processing. It is the major waste material in the volume. The aggregates produced from the concrete waste are called Recycled aggregates (RA), which have a water absorption rate 6 times higher than the normal aggregates produced from natural resources. (19)

- In constructions, this recycled aggregate can be used up to 50%, depending on the strength required and load-bearing conditions (20).
- By doing this we can improve the workability, compressive strength, and elasticity module and also can the concrete durability (20).

Wood: Wood has a great demand in markets, it has multiple options to perform a better role in recycling when there is no way to use it without changes in it. Based on the sources of generation, characteristics and composition, the waste could use or replace the original material in the insulation resistance structure/concrete up to 50% (20).

- Convert the damaged or non-reusable wood into glulam and use it in chip or fibre-based products like tables, boards and panels, etc (20).
- Wood particles or fibres used in board production, animal beds (19).
- Also used to produce energy and some companies used it in the paper industry from recycled chips. Chipped or shredded wood is used as a sewage sludge bulking medium and in lime pellets (17).
- recycled wood can also be used in erosion control, fertilizer amendment in composting and energy recovery. And also a demand for wood flour as a low-cost filler in the wood fibre-plastic composite lumber (18).

Glass: Crushed (if it is not reusable again in total) or broken (during the destruction) glass pieces from the CDW can be used as the purpose aggregates,

either coarse (CGA – Coarse Glass Aggregate) or fine (FGA) in the concrete again. (21)

- Mixing glass with cement will reduce the GHG of CO2 and NO2 production in the concrete by creating a pozzolanic reaction (21).
- In order to fulfil the thermal stability requirement of buildings we use glass as an aggregate because of having high thermal conductivity than the traditional aggregates (21).
- Also improve the mechanical properties of the concrete, water absorption and reduce the shrinkage limit by using both coarse and fine sizes of glass in specified ratio (21).

Plastic: Residential buildings don't produce much quantity of plastic waste during demolition. Based on the sources of generation, characteristics and composition, the waste either rigid or mixed could use or replace the original material in the insulation resistance structure/concrete up to 5 - 50% (20).

- Adding PET (Polyethylene Terephthalate) known as plastic to concrete, reduce shrinkage cracks occurring in concrete due to change in moisture and increase ductility (21).
- Adding plastic to concrete will become lightweight by maintaining the original strength even more and being resistant to corrosion. Being lightweight, concrete will reduce the dead weight of the structure and also lower the other engineering properties of Elasticity modulus, Tensile strength, density, workability and slump (21).

Ceramics: Ceramics are also recyclable

- 10 - 20% of the ceramic waste of coarse grains can be used in concrete as a substitute for natural coarse aggregates. which increases the compressive and mechanical strength of concrete, while the specific weight decreases without affecting the water absorption. And this concrete can be used in drinking water deposits and in the production of pipes. it has no adverse effect (pH or electrical conductivity) on water quality for human consumption. (18).
- Because of its porous nature, maximum water penetration rather than absorption and also has poor elasticity due to the hardness (21).

Fired bricks: These are the second most CDW in volume and this waste has greater opportunities to use again because of high durability.

- The brick debris can be used as fines in place of sand in concrete (21).
- Broken bricks from demolition are mixed with other binders and used as sub-base coarse in roads, construction fill, and lightweight concrete (18).
- Concrete prepared from crushed brick aggregate will perform better engineering and thermal properties but has greater shrinkage than ordinary concrete (17).

Tiles: The contractors or engineers shall not choose the destruction option to remove the tiles, only because of their physical and mechanical properties. For example, sometimes seepage behind walls due to pipe leakages at joints/connections will change the physical appearance and it can't be reusable.

- Broken tiles are used as aggregate after crushing in concrete as a partial replacement for gravel and crushed stone and are also used as creative items of artefacts on table tops and special effects in driveways and pedestrian subways. Example: Nek Chand's Rock Garden in Chandigarh, India (17).

Metal: Aluminium and steel can be recycled multiple times because of their composition and has a very great market to them and will be.

- Recycling aluminium waste will consume very less energy than the energy consumption of new/natural resource aluminium because of the process required to change the raw material into metal. And also has good melting behaviour and can be moulded into any shape (17).

4. Recover: Recovery will be the last step in the hierarchy always. Because in order to create a successful circular economy and make the CDW sustainable, the framework should utilize the maximum amount of waste (means recovery amount of waste should be less) in circularity to produce valuable output then only the Circular economy concept becomes useful.

5. Disposal: After the reuse and recycling of waste the remains are used in an incineration plant and the residues reach safely disposed of after the treatment. Due to of inert nature of demolition waste, there is no possibility of chemical and biological reaction/pollution to nature (except industrial construction waste). This

is the reason most of the stakeholders will choose landfill and levelling options for waste disposal (22).

4.3 Circular Economy on CDW:

To transform the linear economy into a circular by using materials after the end of the life of buildings. After the end of the life of the structure, deconstruction and demolition activities are involved to recover the material used in circularity and then the recovery is transported to the treatment plant after material sorting, it is used for reuse and recycling will be done in industry and then supply to a site in the construction again.

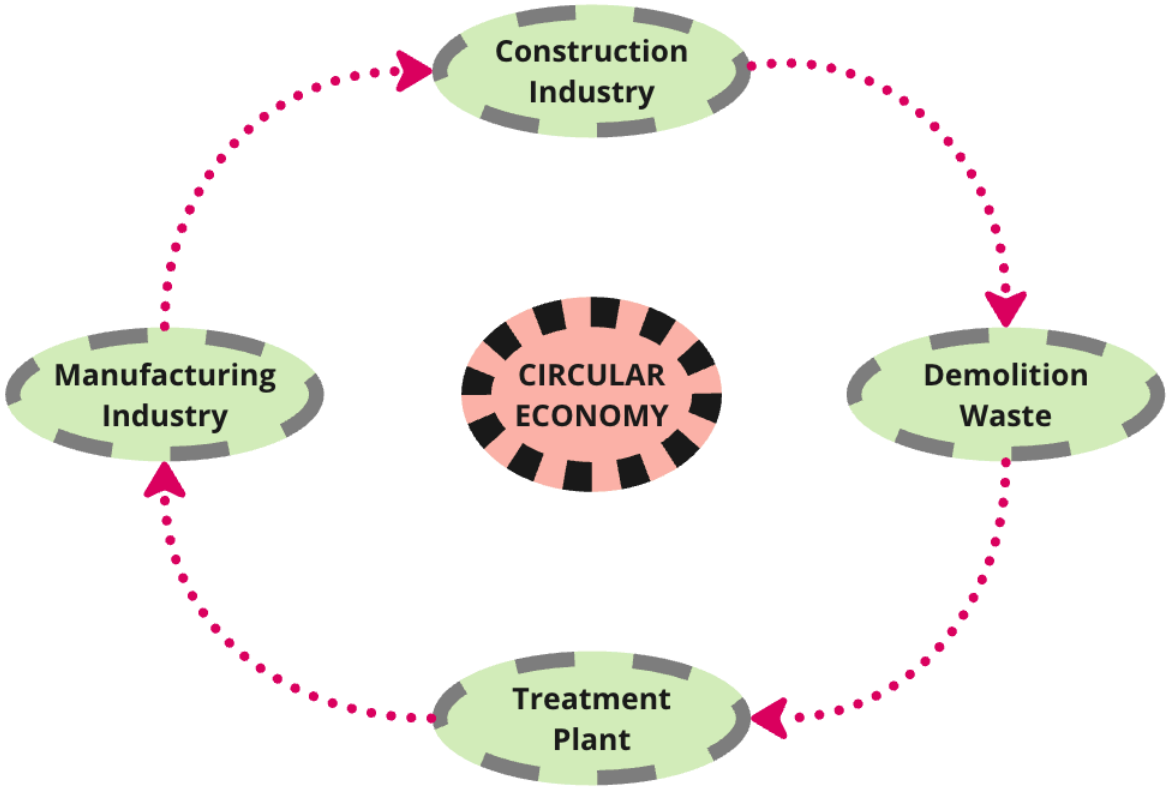

Figure 3. Circularity on CDW

4.4 Framework for Demolition waste management:

Once the civil construction is utilised until the design period and more, either it will go for remodelling if it has a good ability to continue or else will go for the demolition option (end-of-life).

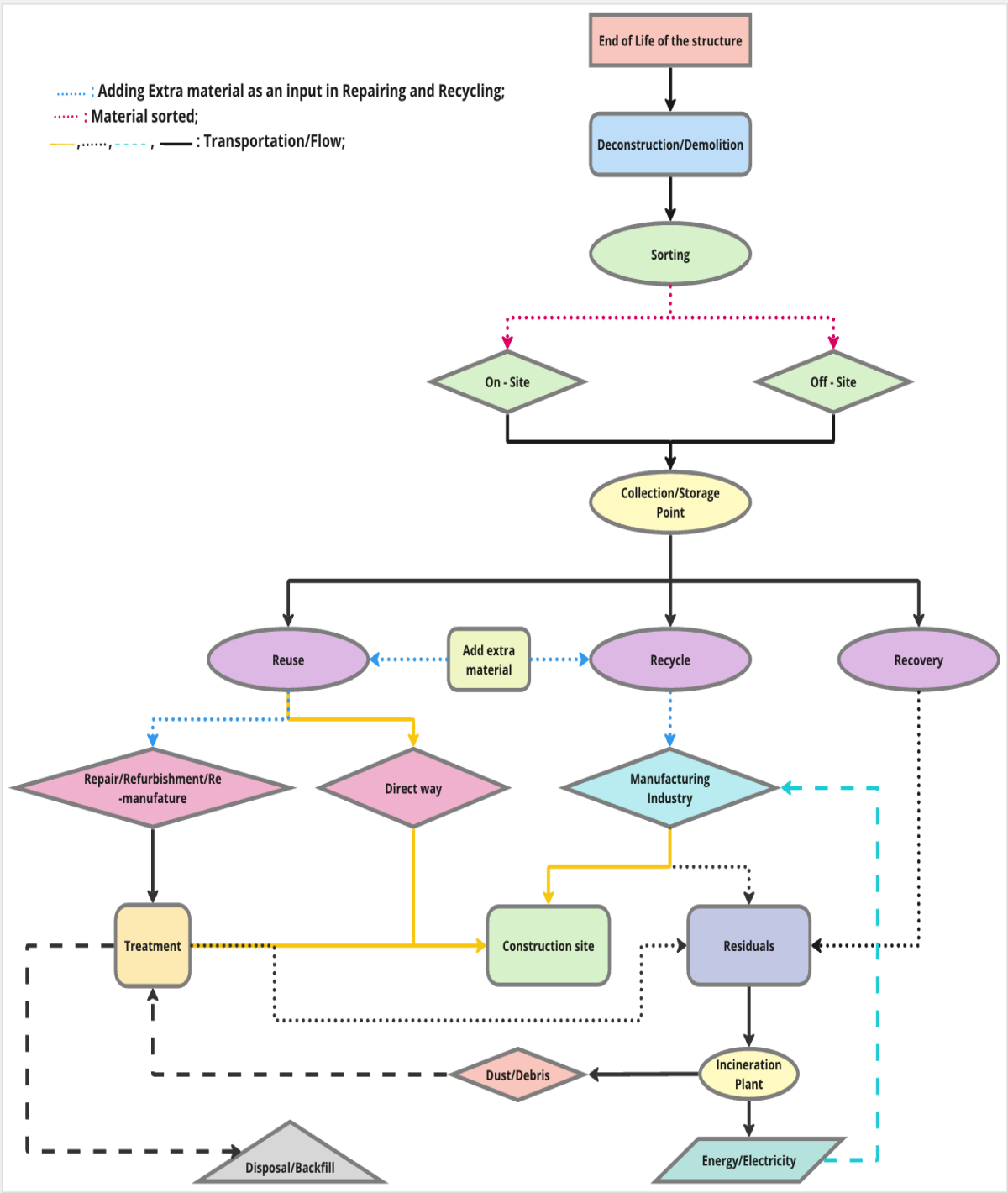

Chart 8. Framework for Demolition waste management

Before the demolition, the removable and reusable materials like windows, glasses, doors, etc. directly into the construction again with minor changes and will be removed by the deconstruction. After that materials were sorted in on-site or off-site locations and then transferred to the storage point from there material will be used directly or by doing minor repairs in construction if it (storage point) has reusable material. To recycle the waste, need extra material as input to form

a new product in the manufacturing industry. Once the material was used in the reuse and recycling steps, the residues will generate and which can be transported to the incineration plant to produce energy and that energy can be stored or connected directly to the manufacturing plant for operation, at the end the dust particles will be recovered and sent to disposal or landfilling safely after the treatment, to make sure no effect to planet (21).

4.4.1 Simplified framework to evaluate the CE on CDW:

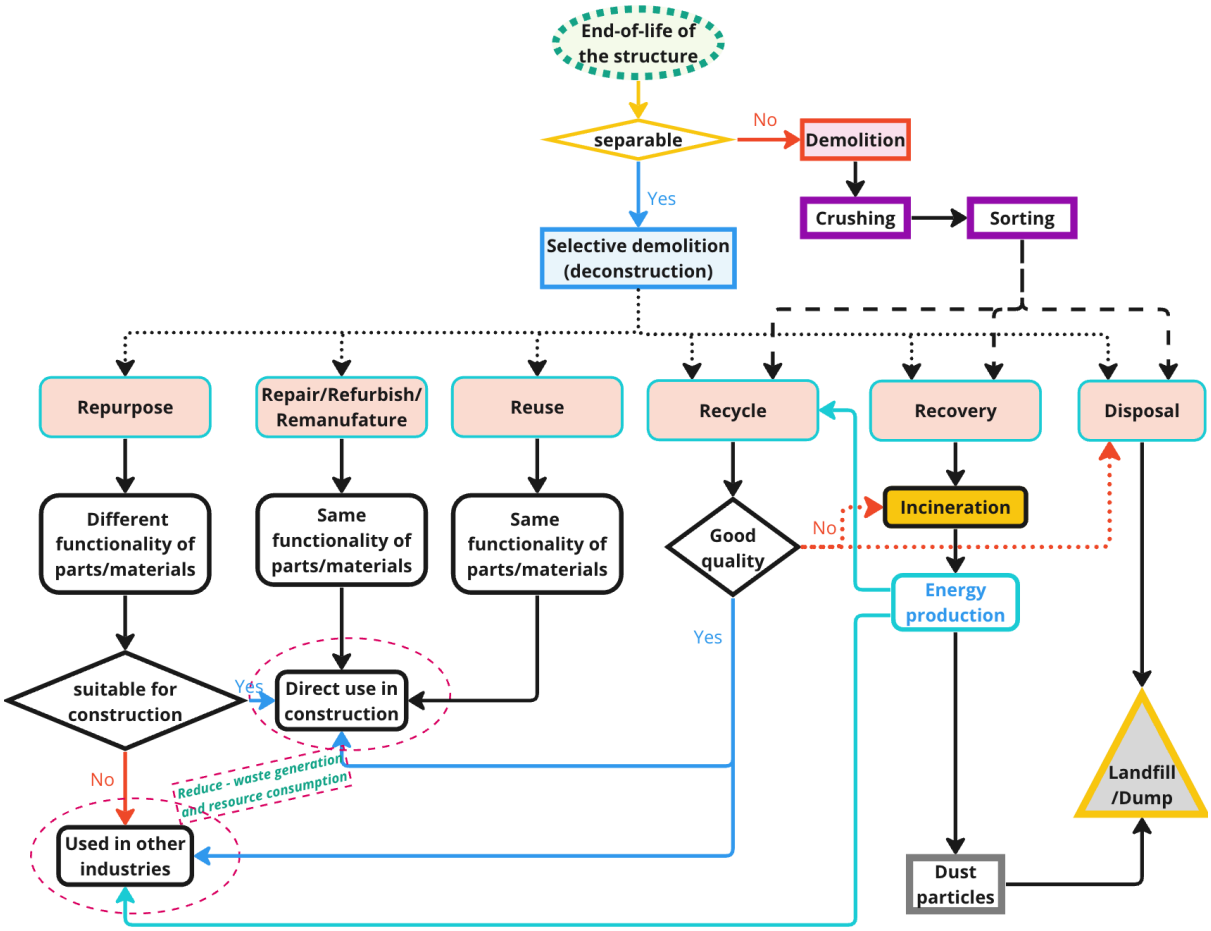

Chart 9. Simplified framework to evaluate the CE on CDW

Sorting the Reuse material into Repurpose, Repair/Refurbish/Remanufacture can save working time and capital and energy (human - physical or machinery - mechanical and mental). Also can reduce - the loss of waste and consumption of raw materials. And mentioned in detail the possibilities of existence and non-existence of material/product involvement at different stages and also showed the possibilities of different outputs, reuse in different sectors and at the end of the residual waste material should go to either landfilling or dumping (23).

4.5 Onsite Recycling:

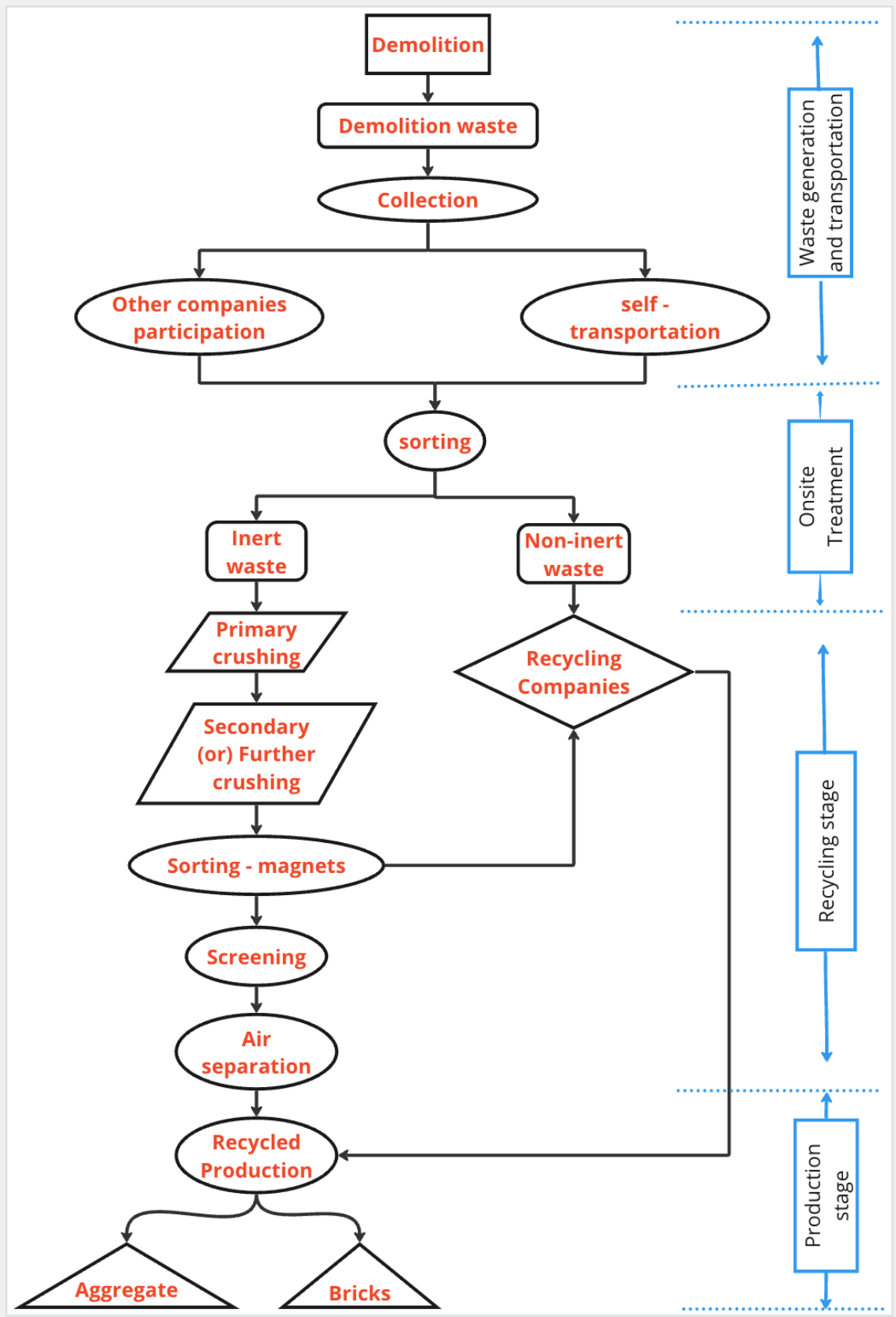

Chart 10. Onsite Recycling

Once the waste material is transported/shifted to the storage point, then the material collectively sends to reuse or recycling options. If the circumstances like a storage area, transportation, labour power, etc and the environment have no effect were available and suitable then the stakeholders and customers will go for an on-site recycling (11).

There are other hands from outside along with the owners of the project (customer & contractor team) in the waste collection and recycling/manufacturing industry. After the waste is collected, the waste material will be sorted as “Inert waste - also known as public fill - mainly includes construction debris, rubble, earth, bitumen and concrete”; “Non-inert construction waste - usually comprises bamboo, timber, vegetation, packaging waste and other materials”. The inert waste shall undergo crushing after that the material is segregated through magnets and screening to get the required sizes of portions and transferred to the production of aggregates, tiles and bricks mainly. The non-inert waste should be directly transferred to the production industry through recycling companies. The whole scenario is divided into stages in the flow chart for a better understanding of the viewer's (11).

4.6 Offsite Recycling:

The both on-site and off-site recycling flow charts are almost similar to each other with little adjustments. Once the waste is collected from the demolition sites and/or dump yards and/or roadsides the waste material will be sorted as “Inert waste - also known as public fill - mainly includes construction debris, rubble, earth, bitumen and concrete”; “Non-inert construction waste - usually comprises bamboo, timber, vegetation, packaging waste and other materials”.

The inert waste shall undergo crushing only after the pre-treatment by the other hands from outside and then the material is segregated through magnets and screening to get the required sizes of portions and transferred to the production of aggregates and bricks mainly and also even dust & mortar can be used. The non-inert waste should be directly transferred to the production industry through recycling companies. The whole scenario is divided into stages in the flow chart for a better understanding of the viewer's (11).

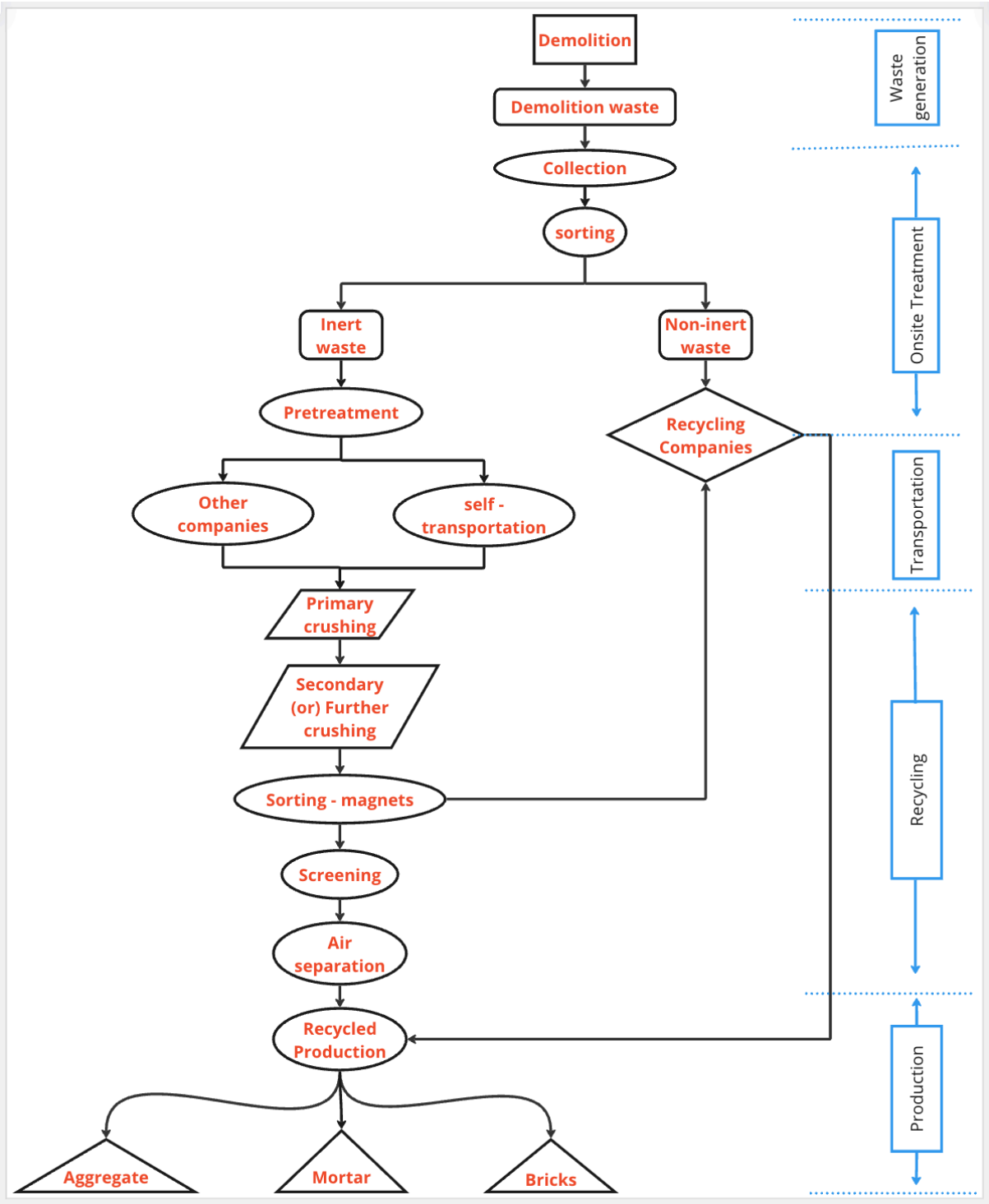

Chart 11. Offsite Recycling

4.7 Institutional Framework for CDW recycle management:

This simple framework of Institutional gives information regarding the actions of the city (ULB), District, State and Central Authority bodies and their actions and the relationship among them will make sure that each one of them is responsible for the activities related to the construction and demolition waste in their

jurisdiction and should be informed to the higher authorities in special cases by maintaining regulations for the related action. (24)

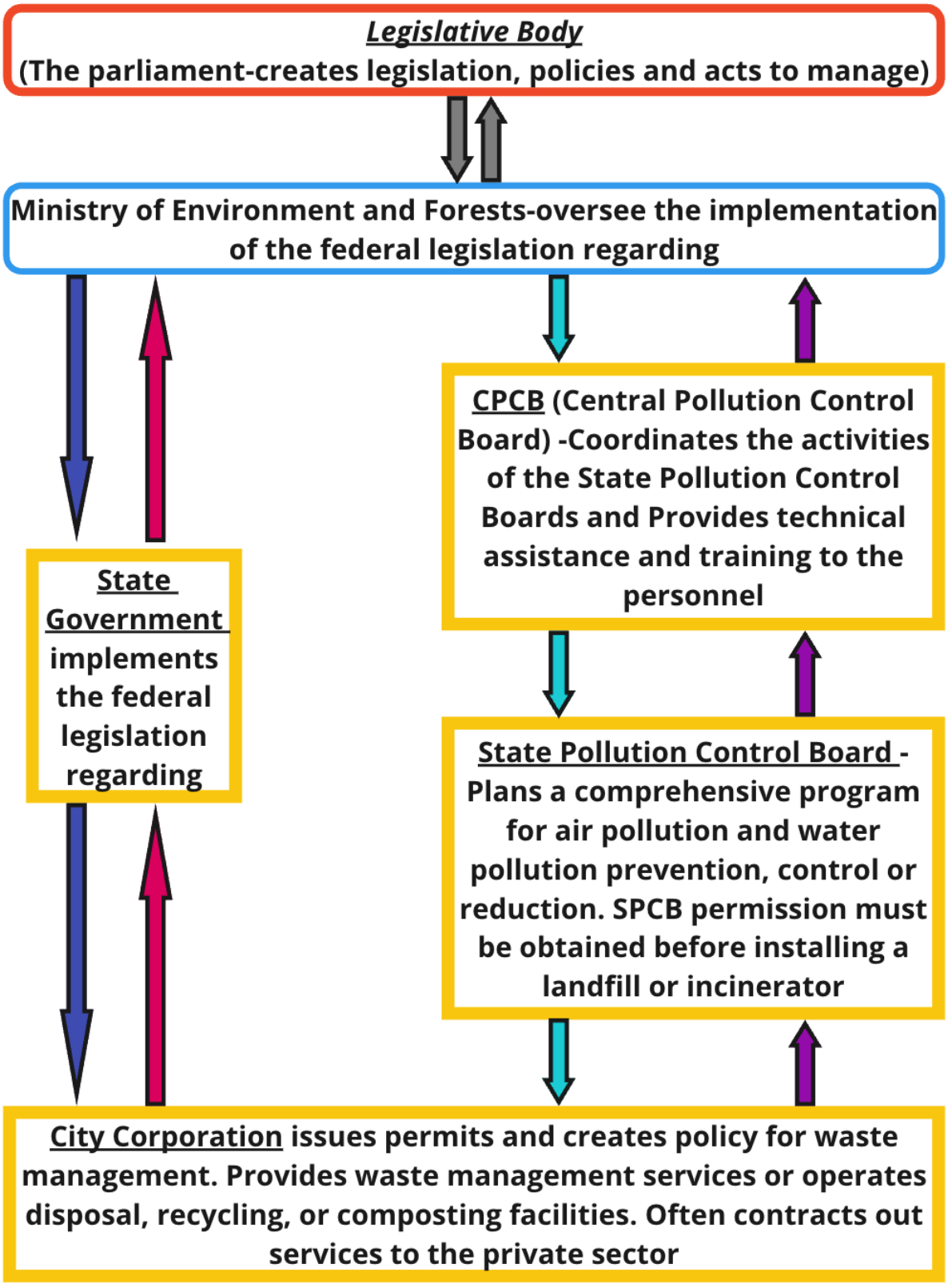

Chart 12. Institutional framework

4.8 Material Flow in Circular Economy:

Construction materials were produced from the raw materials which occur naturally in nature in the initial stages and those materials were to be used in the construction sector. After a certain time of use, the structure becomes tearing off and needs certain refurbishment/repair to bring back the stability and texture for future survival which helps in using raw material reduction in total. If the repair was not helpful to bring back the structure's life no longer then will go for selective demolition directly and the demolition waste will be sorted based on the use – like reuse and recycle. The reusing material will be removed from the by deconstruction before the demolition. The material for recycling will use different processes to make a new product from it and also there is a use of certain percentage of original raw materials from Earth that could be used to provide stability and durability to the products and this circle repeats (21).

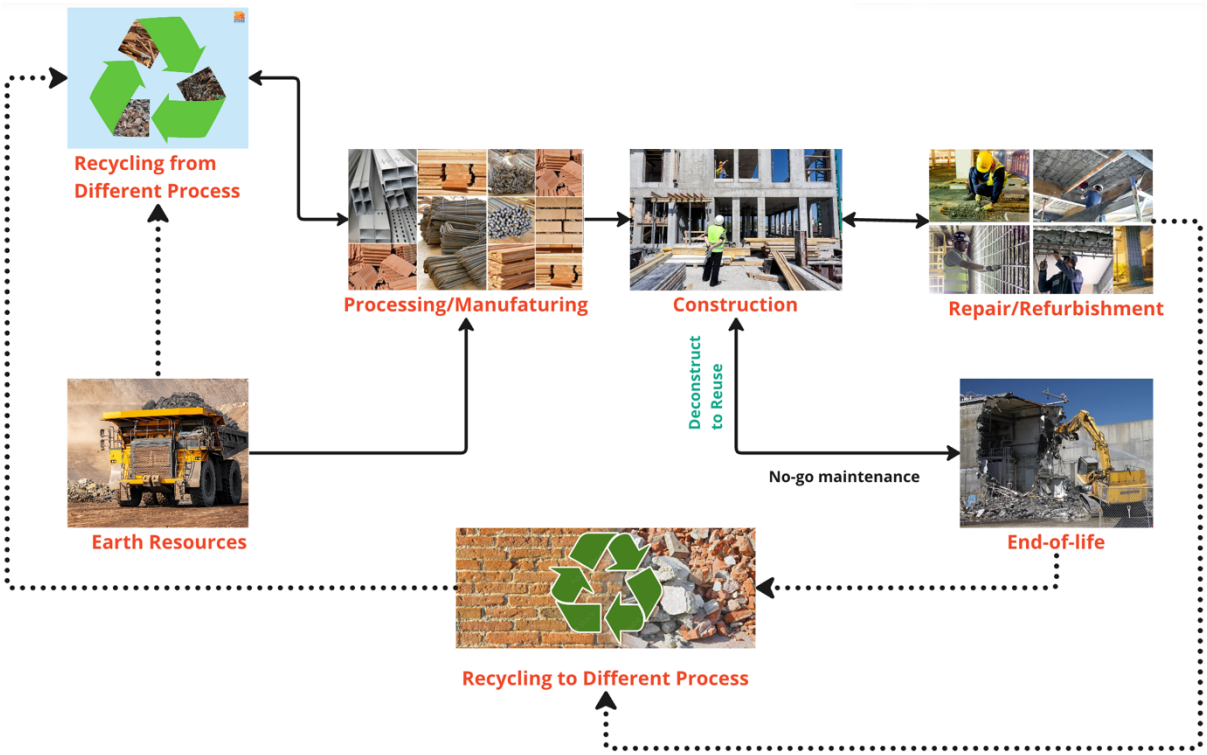

Figure 4. Material Flow in Circular Economy

4.9 Closing the Loop:

The framework given below will show how to close the loop in a waste hierarchy. To produce or make building materials, need natural resources in the initial stage and those were used in the construction sites to build. The first and most rated step in the hierarchy is “Reduce – reduction of using natural resources” and

looking for alternative sources like “reused” & “recycled” materials in the production of new materials by adding an amount of natural resources in the production and those are considered as secondary building products and could be used in some part of the construction area. Reusing the building materials in construction, special attention is required for demolition (selective) and needs minor treatment (refurbishment/repair) before use. Before going for recycling, the material is sorted (recyclable and non-recyclable) to save energy (electrical, mechanical and capital). The waste “recovery” should be minimum – which means most of the collected waste after the end-of-life of the structure, should be transferred to or used in options like reuse, recycling and the remaining residues will be used to produce energy by incineration/burning. The dust particles from the incineration plant and fine material from the reuse & recycling were disposed of or landfilled safely after the treatment and the emerging amount of emissions during or after this entire loop will enter into the atmosphere/environment (24).

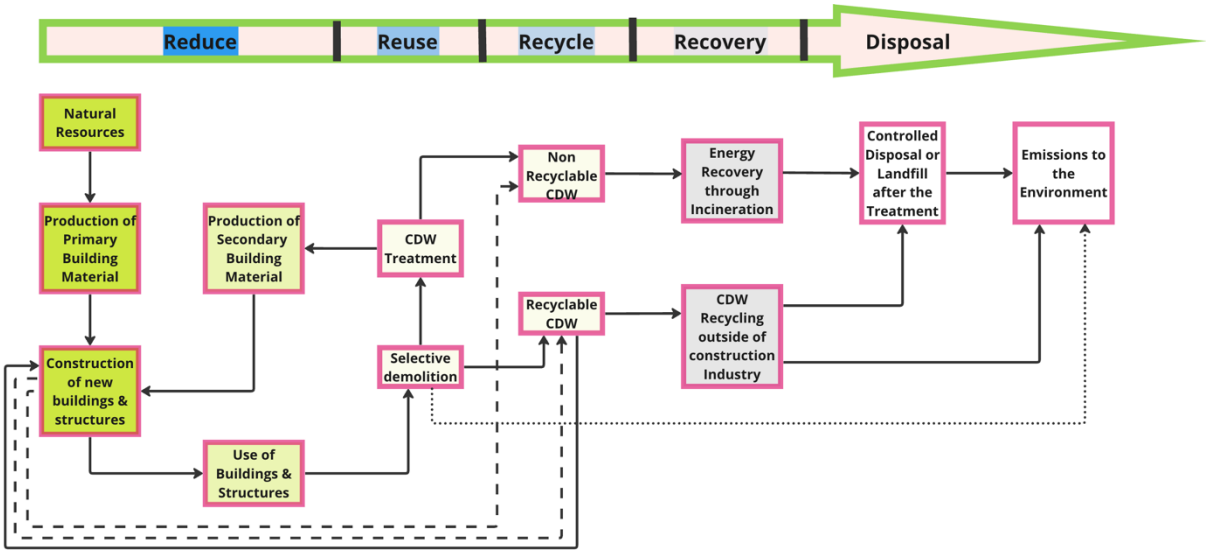

Chart 13. Closing the Loop

4.10 Conceptual Framework for Effective Management of Construction Demolition Waste (CDW):

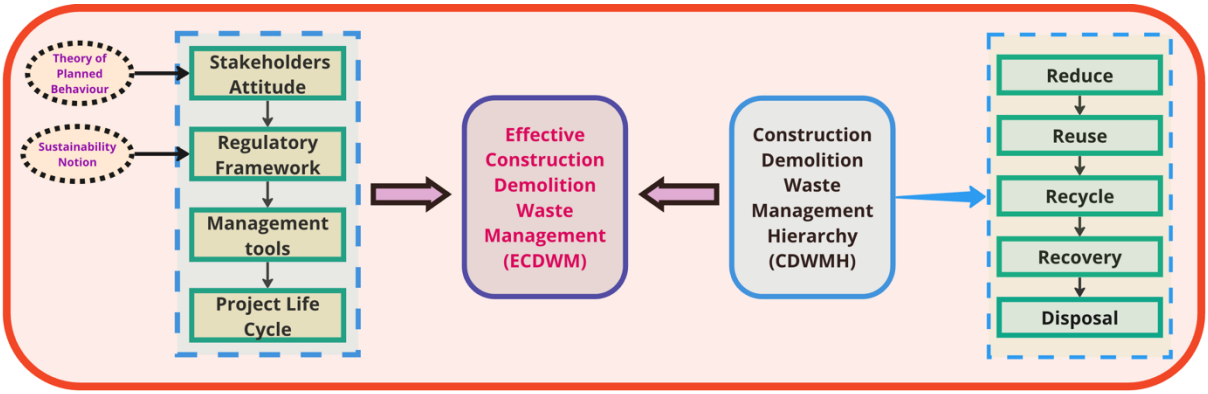

Figure 5. Conceptual Framework for Effective Management of Construction Demolition Waste

Majorly the four factors (CDW stakeholder's attitude, CDW regulatory framework, CDW management tools and CDW project life cycle) that have been mentioned in the above framework will show an impact on Effective Construction Demolition Waste Management (ECDWM). Also, the Construction Demolition Waste Management Hierarchy (CDWMH) will play an effective role in influencing the ECDWM including (Reduce, Reuse, Recycle, Recovery and Disposal) (25).

This framework would be framed in a way that defines, both CDWMH & ECDWM were affected by each other and the reason is to fulfil the following objectives (i & ii) with logic (25).

i) How does the contributing factors of ECDWM affect ECDWM? (this should be reflected in the form of reduction, and/or reuse, and/or recycling, and/or recovery, and/or disposal of CDW)
ii) Which strategy is more effective? For instance, in case BIM affects ECDWM, this impact is reflected through CDWM hierarchy (which strategy is more applicable and more effective?)

The above conceptual framework is also supported by the factors like "Theory of planned behaviour (reflects the stakeholder's attitudes)" and "Sustainability notion (reflects CDW regulatory framework from a sustainability perspective)". Based on this entire framework consideration, 5 hypotheses (named H1, H2, H3, H4 & H5) are developed based on the theoretical evidence (literature, article, previous research experience, etc.) to explain how contributing factors one could impact the other one and also examine whether this theory will work or not.

H1: ECDWM stakeholder's attitudes on CDWMH: There are various kinds and different classifications of stakeholders. Some researchers consider the broad classification that includes – researchers, contractors, public or private agencies, engineers, architects, consultants, vendors, local bodies, etc in the CDWM and some scholars consider less and more specific like – contractors, clients and consultants. Examples: architects & engineers will work on CDWM through the design and frameworks and researchers & contractors will work on waste generation, reduction, reuse, recycling, recovery and disposal activities. This confirms that CDW stakeholder's contribution is necessary and significant for the hierarchy and management in its (25)**.**

The stakeholders that are involved in the CDWM are differentiated into main and sub-mains (involved and informed) for the visual knowledge (10).

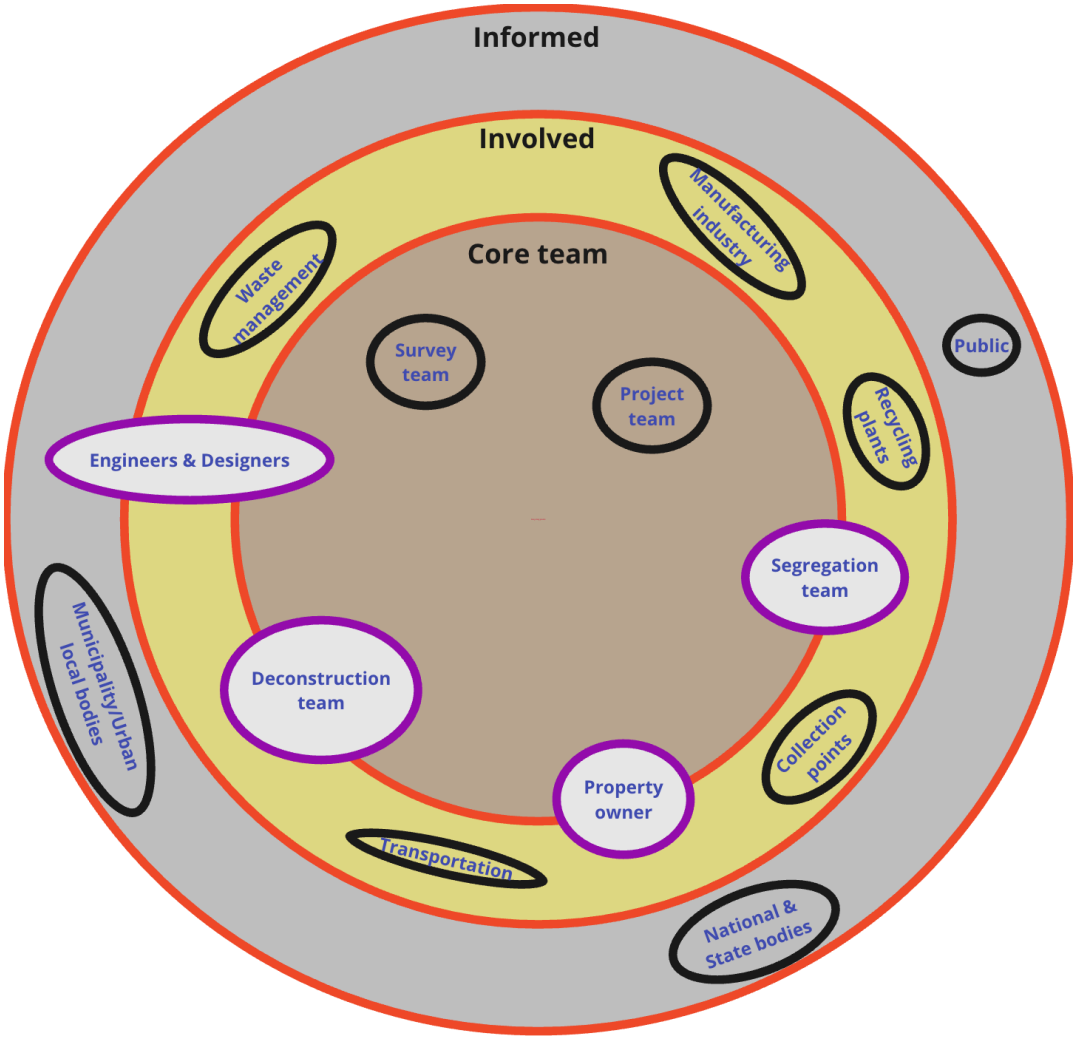

Figure 6. Stakeholders participation

Core team/Main team: Full time on the project and team.
Involved: Regularly providing input or helping to move work forward, but this project is not their sole focus.
Informed: Wants to stay up to date and will provide feedback/input when necessary.

H2: ECDWM from a sustainability (Environment, Economic & Social) perspective on CDWMH: These sustainability aspects were used to assess the impact of the regulatory framework (E.g: tax on waste disposal and landfilling, health and safety regulations, reward-incentive mechanism, awareness) on CDWMH (reduction, reuse, recycling, recovery & safe disposal of CDW). Several studies and works have been noticed from a sustainability point of view on CDWM, which means H2 is considerable (25)**,** (26), (27).

H3: ECDWM tools on CDWMH: Based on the research of (Mr Kabirifar et al., 2020), the CDWM tools were classified mainly into 3 groups:

i. IT-based tools in CDWM - Radio Frequency Identification (RFID), Building Information Modelling (BIM), Global Positioning System (GPS), Geographic Information System (GIS) and Big Data (BD).
ii. CDW management approaches - Lean principle, Circular Economy, Plan for Site Waste Management, Zero Waste Management and Green Rating System
iii. CDWM technologies – Modularization and Industrialised Building Systems (IBS).

Several studies have been conducted to know the impact of CDWM tools on CDWMH. These applications, technologies and tools were used to reduce, reuse, recycle, recover and dispose of CDW effectively. This study considers the effect of CDWM tools on the CDWM hierarchy by drawing the H3 (25)**.**

H4: ECDWM project life cycle on CDWMH: There are varieties of models of life cycles for CDWM made by the researchers and in their research concept, design, construction, execution, maintenance, and demolition exist.

This whole scenario has been divided into 4 phases by one scholar is - the pre-construction phase, the construction phase, the renovation phase and the demolition phase. Another scholar classified the CDW life cycle into 3 main

groups – the planning and design stage, the procurement stage and the construction and demolition stage.

Many studies have addressed the effect of the project life cycle on CDWM. The study on H4 concludes the effect of the CDW project life cycle on the CDW hierarchy will be considered.

H5: Effect of CDWMH on ECDWM: CDWM hierarchy including strategies of reduce, reuse, recycle, recover and disposal has been considered the most effective way to manage CDW. By drawing H5, the impact of the CDWM hierarchy on CDWM effectiveness leads to a performance assessment of CDW effectiveness based on the prioritization of the given CDWM hierarchy

4.11 Government of India Initiatives towards CDW Management:

1. In the year 2014, the government of India started a journey towards a "clean India" programme called Swachh Bharat Mission (SBM) under the Ministry of Housing and Urban Affairs (MoHUA), which also cares the C&D waste and its management as per the BIS (Bureau of Indian Standards). This mission has a rule that if the C&D waste was available within a 100km of radius from the ongoing project, you should utilize and it also targets remediation of all the landfills and dumpsites in the country. BIS IS: 383 have used the construction demolition waste in percentage as Coarse and Fine aggregates in concrete up to permitting limits according to the using concrete Design or Compressive strength. (10)
    a. For plain concrete, we can use up to 25% of waste as recycled aggregates
    b. For M25 (Grade or Mix or Design or Compressive Strength of reinforced concrete is 25MPa), up to 20%
    c. For grades ≤ 15, use up to 100% of waste as recycled
2. National Building Code (NBC) of India 2005: Part 11 of NBC 2005 on "Approach to Sustainability". (10)
3. Local body's involvement: Municipalities, planners and investors help with waste management, treatment and in-use. (10)
4. Guidelines on environmental management of C&D wastes (prepared in compliance with rule 10 sub-rule 1(a) of c & d waste management rules, 2016) by the central pollution control board (CPCB) and Ministry of Environment, Forests & Climate Change (MoEF & CC). (28)

5. Cities with a population of more than 1 million are allocated waste recycling centres by the Ministry of Urban Development (MoUD) in the year 2012 with a set of rules. (28)
6. Building Materials &Technology Promotion Council (BMTPC): BMTPC formulated regulations on C&D waste utilization specifically in government projects and issued guidelines to control boards over the handling, recycling and reusing of waste percentage in projects. (28)
7. India strongly belief's that waste management will help to achieve the Sustainable Development Goals (SDGs) with innovative technology and framework. (29)
8. Central Public Works Department (CPWD) guidelines on C&D waste management, 2014 -for sustainable habitat. (30)

4.12 Government policies for CDW handling:

The government will make policies according to selected sectors with all the considerations which apply to all in the respective sectors and they are called stakeholders technically. These policies will have duties, rules and regulations. The "C&D Waste Rules 2016" report will specify the rules and duties of several people or departments or stakeholders, which are explained below in detail. (31)

1. **Waste Generator:** Deposit or Store the waste on his premises or in designated locations suggested by the Local body (Municipality), cannot mix the demolition waste with MSW (Municipal Solid Waste). Collection and storage of waste will avoid local disruption or pollution. (31)
2. **Utility service providers and their contractors:** Require approval from the municipal office before the structural demolition and also needs to submit a plan of action for waste management. paying for the collection and disposal of the demolition waste to the Local bodies. (31)
3. **Local Authority:** In the Urban region, all the activities were carried out by Local Authority which also can take help or suggestions from the state whenever required. It has the authority to make, fix and pass the rules or laws for CDW management and is also responsible for authorizing and approving management plans of generators. Sometimes third parties will join to look at the typical waste management plan and finalize the plan. It also has the authority to make fines for mistakes and collect the charges for services of collection, transportation and processing in contracts with private parties. Have to create incentives for the use of recycled products

including through preferential purchase agreements in municipal contracts. (31).

4. **State pollution control board/committee:** This monitors all the Local Authority activities in each state and corrects them. Which needs to study and observe the CDW processing & its facilities. Needs to submit the observed data with impacts on environmental, economic and social POV to CPCB (Central Pollution Control Board) for sustainability. (31)
5. **State Government:** Helps to identify the land to recycle the collected waste to the Local and Central bodies and facilitate procurement of recycled materials by all the states and create a market. It prepares a policy for waste management. (31)
6. **Central public commission board:** To provide guidelines for C&D waste management, it prepares an annual compliance report based on the data collected from the state committee and submits it to the central government. (31)
7. **Bureau of Indian Standards/Indian Roads Congress:** In order to utilize the materials produced from the waste after recycling, we need to standardize them to enable proper utilization of these products. (31)
8. **Central Government:** This facilitates compliance by the Ministry of Home and urban affairs and the Ministry of rural development and Implementation carried out by the Ministry of Environment, Forest and Climate Change. (31)

4.13 The Major Challenges of CE (Circular Economy) for CDW (Construction Demolition Waste) in India:

Any kind of system/topic/process will be going to face several challenges during or after adopting CE towards CDW.

4.13.1 Challenges in implementing government policies:

Land shortage – Treatment plants occupy a large area for storage and infrastructure and should install far from the residential, recreational and heritage areas. And also poorly designed infrastructure, because of highly populated land - scarcity is a big issue. In these cases, the government can't compromise with stakeholders on the location (32).

Funding shortages from the government: Since waste segregation and storage require a huge amount of area, modern equipment, and heavy-load capacity

vehicles for transportation, there is a lack of funding for construction and demolition waste management from the government (33).

Lack of monitoring capacity/resources – Due to shortages of personnel and resources among local governments and municipal agencies, obstructions occur in monitoring, collecting, and disposal of Waste. Also of public concern and a new CDW management system are the obligations for which they are unprepared (32).

Lack of capacity and experience in Demolition waste management – C&D waste management in India is a relatively new topic even though the work has been ongoing and increased before because of a lack of knowledge and still unfamiliar with the functional applications. This is where difficulties are found in waste estimation, waste management plans, PPP (Public – Private – Partnership) and other involved tasks by the Local governments and municipal bodies (32).

Funding shortages to get advice from the consultants but there is no cent per cent guarantee that they will provide satisfactory answers. Concern about finances and business case – stakeholders/entrepreneurs/government / municipal bodies are scared about the capital investment in novelties until if have theoretical and mathematical analysis and sometimes people do not have any interest even though it had analysis because of not much experience in using recycled products or no much knowledge about recycling and also because of a lot of commitments towards the social, environmental and ongoing budgetary constraints (33).

Policy interventions: Action plans or policies are needed against the ineffective Demolition waste management in India in the areas of respective fields given below: (32)

i. CDW (Construction Demolition Waste) assessment
ii. Application of RAC (Recycled Aggregate Concrete), RA (Recycled Aggregate) and derived products
iii. Small and large scale CDW collection system and its set-up
iv. logistics to the processing plant
v. Encouraging CDW recycled products utilization at Central, State and Urban local bodies (ULBs) levels
vi. Required Policy mediations from the Government of India / State government / ULBs for tax

vii. Standardization and Research Needs.

Therefore, in CDW management demolition and segregation plans should be rise and those will be part of all civil engineering infrastructural projects for better circularity and need to submit these policies/plans to the local body (municipality) at the time of building plan approval. To monitor and implement the efficacy waste management system, technical support such as a Web-based portal system is needed.

At ULB, District, state and national levels the materials from Demolition waste shall need encouragement for reuse and also for recycled material along with Rate schedules and Tender documents. In India, presently, the infrastructure for C&D Waste management plants is available only in metropolitan areas majorly (E.g: Delhi, Mumbai, Chennai, Bangalore) but it is found to be insufficient. So, in order to satisfy that state and central government should take responsibility and provide administrative, financial and other logistic support to the entrepreneurs and stakeholders. Some of the provisions are listed below: (32)

- Reduce the tax (GST) rate of 18% to 5% on C&D waste products
- Green tax exemption on empty vehicles (which are used for supplying/transporting the demolition waste from site to destination) while entering into the state after unloading or before loading
- Reductions in electricity charges or changes in the industrial rate in the C&D waste plant
- Need a clearance concerning environmental norms and regulations to install a C&D waste treatment & processing plant.

4.13.2 Challenges in CDW management:

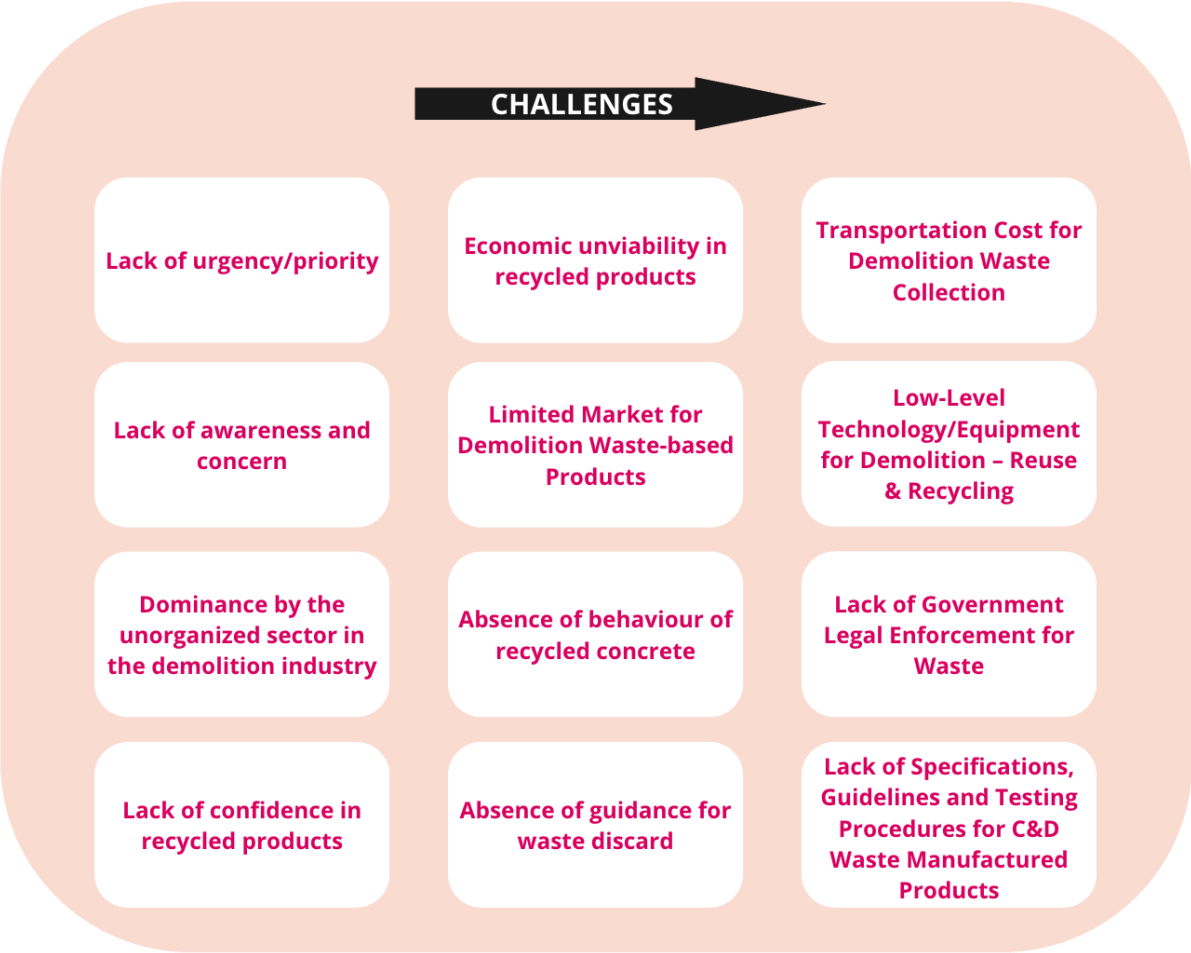

Figure 7. Challenges in CDW management

Lack of urgency/priority – Due to the insufficiency of required resources and unknown knowledge about the impacts that occur in future, less priority is given to Demolition waste and management. And disposals on roads suffer the public survival and made more attention towards the collection and disposal of waste (32).

Lack of awareness and concern – Negligence and Irresponsible towards the environment, only a few people are aware of waste management and its importance in reuse and recycling options except for refill (33)**.**

Dominance by the unorganized sector in the demolition industry – From the point the source (waste) is generated and transported to the destination (treatment plant/construction site), there are some operators who will organise the entire system and also controlled by some unorganised operators (unregistered officially) in a primary sector and they commit mistakes for the money by doing

illegal dumping's. This is where the specialists/officials/engineers face difficulties in supply and that affects CE (32).

Lack of confidence in recycled products – Even though the Bureau of Indian Standards (BIS - 383) confirmed and announced that recycled products (concrete aggregates, concrete blocks, tiles, etc) can be used in construction & other applications and also cheaper, some people in India still think that the products made from waste will be of poor quality and prefer traditional products because of not much variation in prices (34).

Economic unviability in recycled products – The tax rates for recycled products (18%) is way higher than the traditional products (5%) and customers think this is economically unviable and can't be affordable. Therefore GST (Goods and Service Tax) exemptions on C&D waste recycled products should be considered (10).

This could impact - the environment (by using natural resources), the economy (by not reusing waste in an effective way) and the public (by illegal dumping). Specific rules and regulations for the local and state bodies for waste management and disposal of demolition waste. And also removing the authority of unorganised urban agency involvement in the planning & execution (32).

Limited Market for Demolition Waste-based Products: There is a limited market for demolition waste-based products due to no labelling (eco/green) from the respective agencies to make sure that the waste-based products could use in the construction or other purposes which are referred, for that need a certification from the relative organizations of GRIHA (Green Rating for Integrated Habitat Assessment), IGBC (Indian Green Building Council) and promote them as green products (35).

Absence of behaviour of recycled concrete: recycled concrete products from demolition waste have higher absorption capacity than fresh concrete which leads to different curing times and will change concrete behaviour in the future (34).

The mortar on the recycled aggregates is less resistant (less compressive strength of concrete due to the heavy mortar adhesion there is a weak bond between the aggregate and the mortar in concrete) than natural aggregates (33).

Absence of guidance for waste discard: households and small demolition sites will throw the waste into municipal solid waste bins/on roadsides/public places /low-lying areas to save the transportation cost and this mix will degrade the quality of demolition waste material due to some chemical reactions and that require treatment to reuse the waste and it costs more. And if this kind of mixed waste shall give less energy recovery while the composting activity (35).

Transportation Cost for Demolition Waste Collection: In comparison, the cost of waste transported to the processing plant is higher than the landfills which change people's mind to go for the landfill option. Also, the transportation cost should be covered by the waste producer only (33)**.**

Low-Level Technology/Equipment for Demolition – Reuse & Recycling: There are still some issues regarding the quality of the products made from waste by recycling. In Delhi, there is a huge gap in the equipment for recycled materials to process and produce recycled materials with good/high quality. So that needs modern technology/machinery to achieve (35).

Lack of Government Legal Enforcement for Waste: Even though there are some strict legal actions and policies towards C&D waste management, but still it is ineffective when coming to the urban local bodies. So, need regulations of fines for landfill and procedures to waste generators before transporting the demolition waste to dumping or treatment/recycling plants (33)**.**

Lack of Specifications, Guidelines and Testing Procedures for C&D Waste Manufactured Products: Due to having less attention towards demolition waste before, there are not many standards (codes) that talk about C&D waste. The recent provisions BIS 383:2016 and IRC 121:2017 speak about the specific uses of recycled products, limitations and concrete properties used as guidance during the preparation of concrete mix proportions just to overcome the challenges that are going to occur while the use of RCA due to adhered mortar on aggregates (which has high water absorption rate than natural aggregates) and can be eliminated by using different methods/treatments of chemical (acid treatment – pre-soaking) and mechanical (35).

4.14 The Major Barriers of CE (Circular Economy) for CDW (Construction Demolition Waste) in India:

Any kind of system/topic/process will be going to face several barriers during or after adopting CE towards CDW.

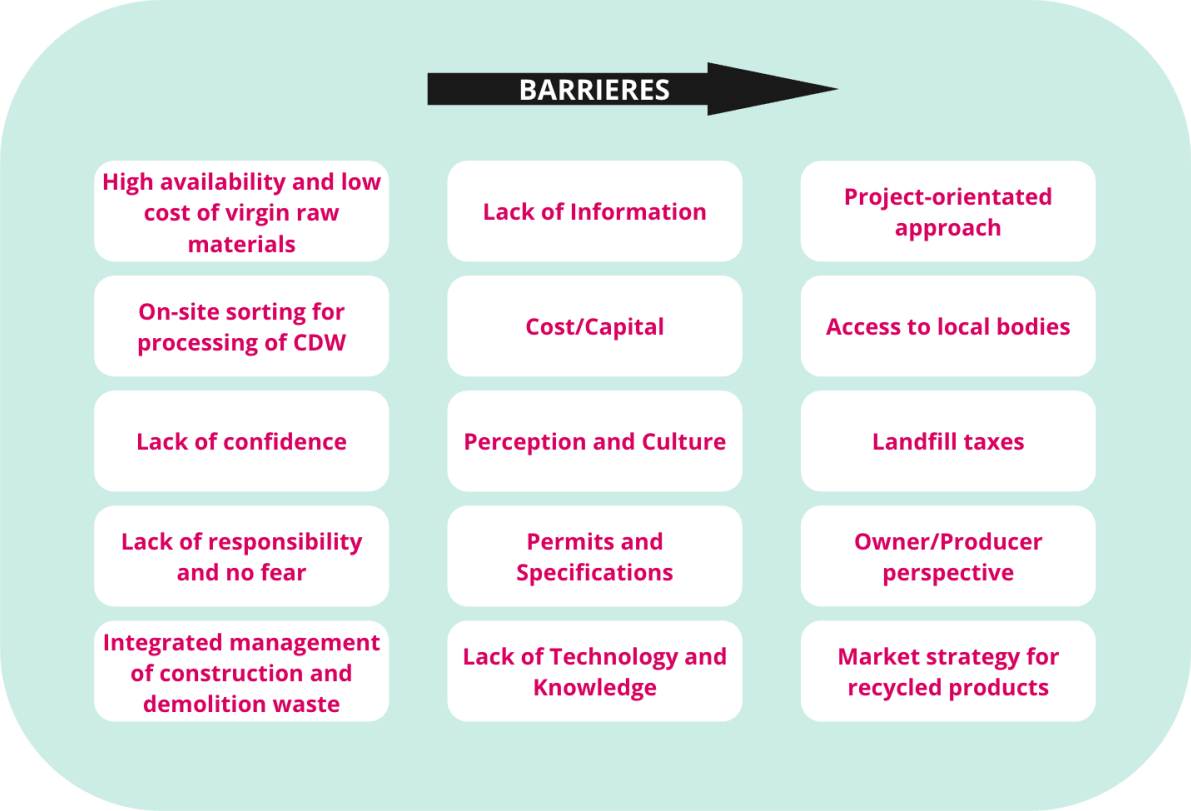

Figure 8. Barriers of CE

High availability and low cost of virgin raw materials: decrease in demand for recyclates due to the high availability and low cost of natural materials, leading to no interest in developing business in the recycling (31).

On-site sorting for processing of CDW: It has problems of space limitations, health and safety restrictions, added cost for equipment & sorting of CDW, management, stakeholder's attitude and interfering with other important construction activities (36).

Judgement: Even if waste-based products are cheaper in price, somewhere there is a negative attitude towards reused and recycled products perceived by many, as environmentally friendly but of lower quality (31).

Lack of confidence: In spite of the fact that people are aware of the demolition waste some clients still believe that recycled and reused products are transient and need maintenance earlier than the new products (partly correct only if there are errors in manufacture) (36).

Lack of responsibility and no fear: Although bylaws and regulations for demolition waste management are widely implemented and followed, there is room for negligence in demolition waste management and no fear to throw out the waste in public or private places without informing the municipality. This waste will be collected by the municipality and stored in dumping or municipal yards and transported to treatment plants (31).

Integrated management of construction and demolition waste: The C&D waste management & plant permits legislation will be taken care of under the Indian government by the central municipal legislation level (Indian government) and the Urban planning department is responsible for the building permits and developments, they do not look into the fidelity of the CDW plan and their functionality in person which creates a disturbance in supply and demand (31).

Lack of Information: There is a lack of information within the industry on the importance of recycling and the potential associated benefits (37).

Cost/Capital: The capital spent on recycling the material is higher than the material transported to the landfill (37).

Perception and Culture: construction practitioners should think about sustainable development in the construction area and need to use advanced/new technology in place of conventional methods (37).

Permits and Specifications: To use these recycled or reused materials in a project, one need permits and follow or give specifications regarding the material using ratios, purpose, application areas, etc. which take time for submission and approval and sometimes permission will be rejected which creates a negative impact (37).

Lack of Technology and Knowledge: Mostly, all the construction companies will use C&D Waste as input/substitute for original materials. To use them effectively certain technology and knowledge is necessary and make the circular economy. Due to a lack of knowledge/Education of workers/construction

practitioners, construction professionals couldn't make the project economical and sustainable and the whole responsibility should be taken care of him only. So, governments, regulatory authorities and companies should be responsible and conduct seminars, meetings, workshops, crash course programmes, etc to educate and give knowledge to the staff regarding material importance in reuse, recycling, recovery and their performance for better results in the industry (37).

Project-orientated approach: It is a Take-Make-Dispose pattern, which is not at all good for the environment (in terms of CO2 reduction, consumption of natural resources, etc). Instead, the ***system-thinking approach*** could use which helps in closing the loop in the circular economy and create an integration between the stakeholders. Because of the integration, stakeholders can communicate among themselves easily and share knowledge and gain information regarding the CDW and requirements. This is where people/stakeholders get the awareness towards the value chain and makes sustainable practices easier. Due to this construction sector has no need to depend on the material banks for the required material or used in recycling and breaks out from the poor quality & unsecured supply material (38).

Access to local bodies: To reduce the complications in accessing the waste material in the urban area, local bodies (municipalities) were created for easy processing but, to get economic benefits they were engaged with sub-contractors to inspect and manage the activities of the demolition waste in the respective area and this system dominated the supply of the waste to the companies and effected on recycling and reuse, for this local network system needed (38).

Landfill taxes: To control waste disposal in public and private places, Landfill or waste disposal taxes are introduced, but it creates another problem of Illegal dumping to save levies and transportation costs (39).

Owner/Producer perspective: It is one of the most important and common financial barriers from the Producer's POV (point of view), they think that the waste management procedure will increase project cost and time (40).

Market strategy for recycled products: Almost the government of India took action towards the recycled product market, which means it needs a strong marketing strategy to sustain the industry by selling the materials at the maximum prices without any comptonization in the material quality (40).

Demolition Waste Management Challenges in India and the way ahead: C&D waste management in India is hindered by several barriers such as the lack of infrastructure, varied construction types, the nature of the construction industry, and the current mindset of stakeholders. However, the C&D sector also promises opportunities for the economic and social development of the masses. Apart from preventing environmental degradation, C&D waste management interventions can lead to the development of novel business ideas, job creation, and social inclusion (41).

4.15 Strategies for CE in CDW:

4.15.1 Design for change and disassembly:

Some of the useful components in a product choose to be no reused and directly going for recycle "due to lack of knowledge" and "human negligence or errors in material sorting" - Need a design or step in a framework to disassemble or remove the useful or most effective components in the product, which is Reuse. For that technical & mechanical assistance would help to avoid errors and save time. **E.g.:** ***Material passport*** –provides data regarding the components in products value based on the characteristics, and that will help to know about which component/part of the demolished product can be reusable or recyclable (42).

Adoption of selective demolition to preserve the economic, qualitative and quantitative value of the demolition waste materials, save the consumption of original materials and reduce the waste treatment cost while recycling (38).

1) **The approaches for implementation of CE on CDW Management:** (41)

- In the ***design and planning stage***, there are 8 approaches listed – "optimization of materials", "effective design strategy", "develop a waste management plan", "estimating the number (amount) of materials (in volume) available for reuse or recycling through the adoption of BIM", "adoption of BIM to visualize the effects of materials on salvage performance of the building", "adoption of design for disassembly", "adoption of open-source design" and 'adoption of material passport as a design decision support tool".
- There are 8 approaches in the ***construction stage***, "apply an on-site waste management plan", "off-site manufacturing and prefabrication", "application of reusable and recyclable materials as primary construction

materials on-site", "set up waste collection point according to waste type", "evaluate the potential for salvage used products at the end of construction phase", "use of resins and renewable materials for substrates", "information on the location and connection method of the components be documented" and "application of 3D printing".

- For the ***operation stage,*** there are two significant approaches, "information of building keep up to date" and "design the building with easy access to any repairs and upgrades of a construction".
- At the ***end-of-life stage***, there are a total of 5 approaches that are considered significant, "reuse of building components", "selective deconstruction", "closed-loop and open-loop recycling", "redesign the building by reuse of the components" and "expand or contract the structure".

2) **Strategies for implementing CE in Demolition Waste Management:**

- **Strategies at the pre-demolition stage:** Once after the end of the design period of the building, either it should be demolished rather than remodelled. In this stage, Engineers will plan - how to utilise the waste, the type of demolition and the kind of processing like reuse or recycle or remanufacture or refurbish, etc. This stage will create more impact on the entire waste management system because of its direct relation with it. One small thing will save a lot of useful waste from the mix. Highlighting this point, Authors Benjamin Sanchez and Carl Haas developed an analysis called "Recursive Analysis" followed based on rules, which disassembles the building parts that are targeted in a systematic sequence and can be reusable with small changes (43). Especially in large-scale or volumetric structural projects, this kind of approach will help to increase the life span of the product while the reuse of demolished waste components in it gives better results (41)**.**
- **Strategies at the post-demolition stage:** Once the demolition happened, the immediate next step should be waste management but waste producers from households or small commercial builders can't follow the steps that are required for waste management due to several issues and they go for deposition or landfill options. Similarly, Authors W. Debacker and C. Hierarchy have stated 7 such choices that are called "paths", namely - landfilling, combustion, feedstock recycling, material recycling, reuse of components, renovation, and reuse of the building (44). So, there is an

efficient waste management strategy required for waste recovery and to satisfy the circularity in a loop and help to create a sustainability (41)**.** In the management process, there are some regulations and laws that need to follow and adopt to benefit from the penalties and get the reward in economic and environmental, a region-wise approach for waste management which discuss policies such as penalty, reward, fees, and supervision (45).

- **Current status of CDW management in India:** The existing tax regime (Goods and Service Tax) on recycled products (18%) is also not supportive of promoting recycled materials over virgin materials [213]. In such a scenario, the aim of the Indian government to increase the share of recycled products in total public procurement of construction by up to 30% by 2025 (MoEFCC, 2019) and recycle 50% of demolition waste by 2025 becomes more challenging (41).

4.15.2 Collection and Segregation:

"Improper regulations & laws in waste collection", "lack of awareness towards the value of waste", "Improper waste management", etc., will affect the circularity in terms of insufficient input for waste management and its applications - The waste collection points always preferable if on-site for easy transportation and need to utilise and collect simultaneously to save the land use by the generated waste material and can be separated into three types, i.e. normal waste collection, temporary waste collection and hazardous waste collection (42).

1) **Identification of local strategies and the involvement of stakeholders:** The authors Mario and Graca have defined these strategies to test the improvement of CDW management: (46)

- ***Local Strategy - 1 (LS1):*** Responsibility for waste storage will be taken by the municipality ("Preliminary storage")
- ***Local Strategy - 2 (LS2):*** Calculation of waste generation and supervision of the practices on construction sites are managed by micro and small construction companies ("Supervision onsite")
- ***Local Strategy - 3 (LS3):*** Works based on legal criteria and procedural controls towards construction ("Procedural control")

The "COM-B Model of Behaviour", established by the author Michie, which was explained behavioural change and were given below: (47)

- ***"capability",*** Physical – Capable to execute (E.g: Transportation of sorted Demolition Waste to the municipality by the referred staff); Mental – Knowledge to succeed (E.g: supervision of waste management by the experienced municipal technician).
- ***"motivation",*** Behavioural - Procedural understanding, if it is by the municipality (procedures implemented by municipal supervisors as a habit) or if it is a reflection of an action (the companies can look into this so, CDW treatment cost reduces).
- ***"opportunity",*** if the behavioural modification is dependent on the available physical resources (e.g. a municipal site for CDW preliminary storage); if motivated/ influenced by the external force (e.g. municipal technicians will put pressure on construction companies through communication about legal requirements and compliance).

4.15.3 Management sector:

A lot of waste will be deposited in water bodies and used for landfill, which will affect sustainability (Social, Economic & Environment) - Principles (Reduce, Reuse, Recycle, Recovery, etc) involved in the hierarchy should utilize the waste as a resource for new products in the construction sector. So, need precise and effective steps for a waste management plan (either on-site or off-site) in the framework to minimise waste disposal (42).

1) CDW management strategies towards circular construction:

- Due to the competition in the construction industry, contractors would choose recyclable and reusable materials from previous projects or demolition or mine which help to reduce the use of original material in the project that's where contractors can save the budget without compromising the quality, so that they can get the contract in the tender. This is the reason nowadays the construction industry has been investing in research to make sure that strong and simple strategies that can be useful in saving time, money and energy (48).
- And also, to implement and develop supply chain innovations for efficiency, resilience and resource use. By introducing technology like artificial intelligence for sorting and processing waste to reuse then contractors can compete with the competitors in the market (48).

- To reduce demolition waste, better use of Green buildings and Circular buildings which are designed, planned, built, operated, maintained, deconstructed, reuse and recycle in a consistent manner with circular economy principles (48).
- To change the stakeholder's and public mindset, practitioners in the construction industry should adopt simple, acceptable and effective decisions/strategies with examples and neat flow diagrams. Which should have Creative designs, Focused academic research, advanced technology, and internal & external industrial engagements and regulation (48).
- Using technology in CE, will extend product life, eliminate the extra waste and create a sustainable environment around. The extended life of construction materials can increase competition between stakeholders, resulting in decreased costs and an improved global economy (40).
- The CE and waste hierarchy have a common concept, i.e., trying to manage waste via rethinking, redesigning, and repurposing to improve a product's resource efficacy and reduce waste generation and negative impact (40).
- Raising awareness is critical and can be accomplished by incorporating all stakeholders and emphasizing local, national, regional, and international collaboration in building a global partnership (40).
- An Integrated Action Plan (**IAP**) can be used to achieve Stakeholder engagement and Knowledge enhancement on issues of circularity in CDW. And also helps to increase - awareness towards waste management, coordination/alignment between the different construction services and municipality regarding data collection & homogenization and also focus on training for workers, engineers and professionals on demolition type, techniques & frameworks for waste management (40).
- Green Public Procurement (**GPP**) allows the public authorities to choose environmentally friendly goods, services and works that will help in increasing the demand for recycled products and promotes new business models (40).

4.15.4 Strategies required to increase circularity on CDW in India:

- Law enforcement & Flexible regulation
- Increase competitiveness through creative designs
- Targets and achievement awards
- Innovative ideas required and possibilities in the current world (5).

4.16 Solutions to critical waste-related issues:

The possible solutions for waste-related issues in each category named organizational waste management, process waste management and people waste management have been notified through the previous literature reviews (13).

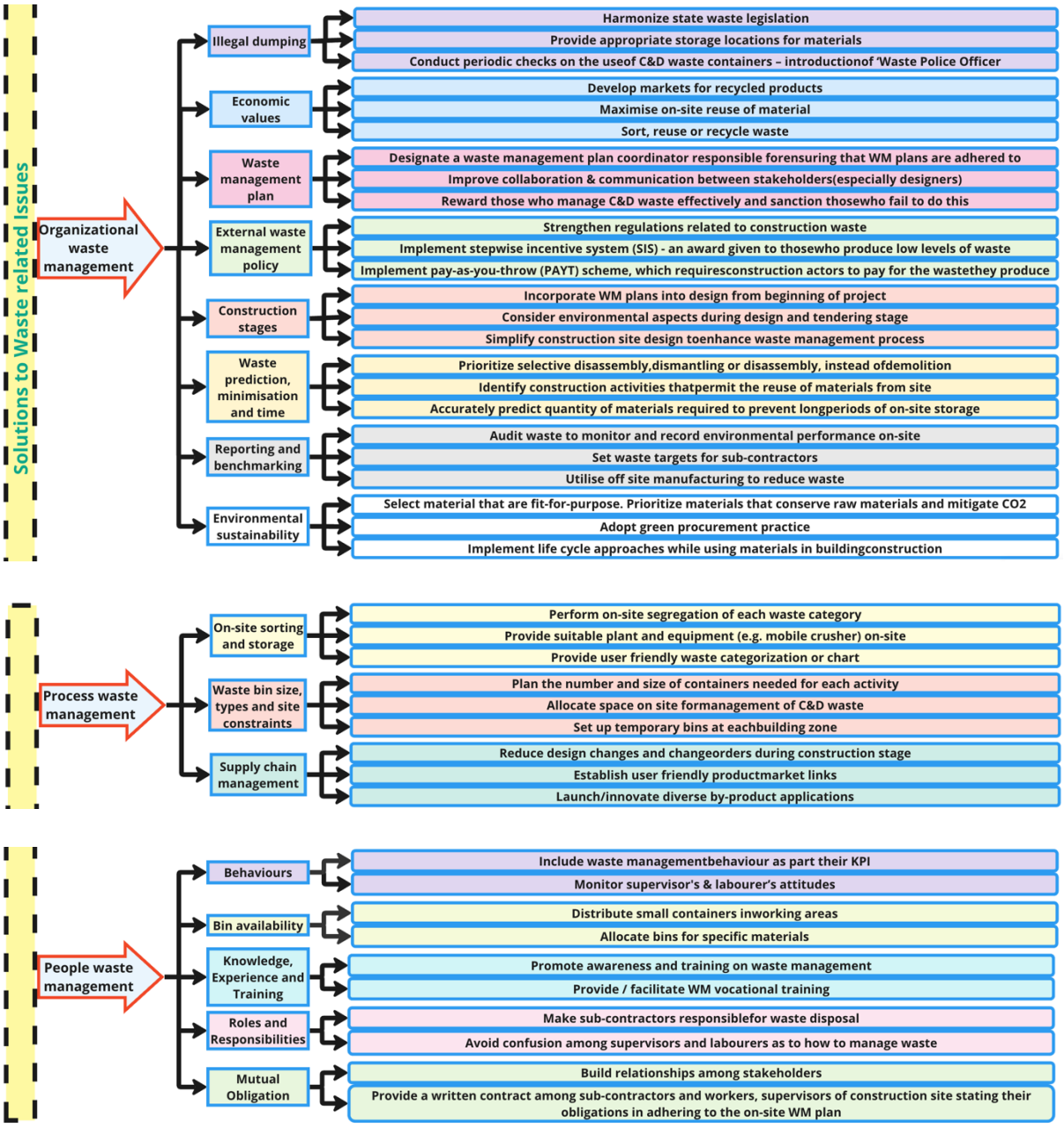

Chart 14. Solutions to critical waste-related issues

4.17 Information technology (IT) tools in Demolition waste management:

-> **BIM:** BIM stands for Building Information Modelling and is widely used nowadays in C&DW estimation, material selection and Planning. And it has huge data collected from multisource on materials from demolition, which helps

stakeholders to improve technologies and process end-of-life phase for the management and this collected data can be utilised to select decision-makers (50).

BIM implementation in India: Development in technology towards the construction sector across the globe many tools that can be introduced to minimize the workload, time and capital, among them BIM was the most important and widely used technology all over the world including India in the past 10 years. It helps to minimise waste generation during pre & post-activities of building or structure demolition, excess purchase of raw material, delay/errors in material handling and also managing the consumed resources in the building life cycle. The connections between lean thinking, the philosophy behind lean construction and CE have the potential to yield positive effects (13).

BIM in the construction industry will help to improve the concept of sustainability. And also can be used for Life Cycle Assessments in design modelling, plan changes and impact calculation due to changes and other designs. The application was incorporated in many places in the phases of the construction sector during the design, planning and maintenance of the built construction also it gives virtual and augmented outputs in future by the increasing Artificial Intelligence and BIM use becomes common and obligatory in the public sector and projects are like Airport of Bengaluru – Terminal 2, Personal Rapid Transit – Amritsar, Neggur and Delhi Metro rail projects (13).

-> **GIS:** Frameworks of GIS **(**Geographical Information System) used to estimate quantity and assess the economic value of C&DW recycling and also used to allocate land for recycling based on geographical feature requirements (49).

-> **Big Data:** The name itself gives the meaning of the work that we are looking for, which is used to store and analyze large data volumes with technology in C&DW. Waste generation rate is used as a key performance indicator to benchmark C&DW performance (49).

-> **RFID:** It works as a logbook but uses radio signals of different frequencies, which is technically called RFID (Radio Frequency Identification). Activities are to control, locate, tool identification, data transmission & store materials, and inspect high-degree material at the storage/collection point (49).

4.18 Linking the circular economy to Sustainability and Urban Resilience:

- The research done by researchers, engineers, students, policymakers, etc on a CE for Construction Demolition Waste management was widely explored to create urban resilience and sustainability by doing reuse, refurbishing, repairing and recycling the waste (51).
- And still, there is scope for researchers to implement this sustainability concept more towards environmental performance and material processing economically and also can satisfy the Sustainable Development Goals of SDG – 3 (good health and well-being), 6 (clean water and sanitation), 7 (affordable and clean energy), 8 (decent work and economic growth), 9 (industry, innovation and infrastructure), 11 (sustainable cities and communities), 12 (responsible consumption and production), 13 (climate action), 15 (life on land), and 17 (partnerships for the goals) (52).
- The SDGs mentioned were clean, resilient, inclusive and sustainable. Resilience – is the urban community's ability to recover from the risks of hazards. For this many initiatives, plans and activities are taken in all the metropolitan cities (urban and rural) and municipal towns. (**E.g**: Integrated management of CDW) The main factors that affect the sustainable culture are Politicians and the Public as well as the control mechanisms (51).

4.19 Demolition waste management from a sustainability perspective:

SUSTAINABLE CDW MANAGEMENT	CONTRIBUTING FACTORS
Environment 	Environmental (water, soil, air, and noise) pollution and degradation, global warming challenges, barriers to green development, greenhouse gas emission, fossil fuel emission, resource and raw materials depletion, impacts of illegal dumping on neighbourhood, etc.
Economic 	Cost of materials, energy, waster, labour and equipment, costs associated with waste transportation, costs associated with disposal, costs of valuable lands filled with C&DW, reuse and recycling costs, etc.
Social 	Short-term and long-term health and safety impacts of C&DW collection, sorting and disposal, project stakeholders' attitude towards C&DW management, public view and awareness alteration towards C&DW management, the role of incentive to prevent illegal C&DW dumping, aesthetic impacts of recycling plants and material stockpiled, etc.

Table 1. Contributing factors for Sustainable CDW management

- There are huge problems that occur because of no proper demolition waste management and that also effect the sustainability in respective areas. The activity of landfilling will occupy land space in a huge volume and starts effect on the environment, economy and social/human health. The costs of disposal or landfill is lower than the transportation and processing of waste but it will effect on human health, the environment and the economy for this, new technologies and artificial intelligence can be involved to reduce the capital investment and emissions to the atmosphere (53).
- The effects are severe like *losing fertility of the soil* gradually can lead to the deterioration of vegetables, in order to rectify this loss farmers will add fertilizers (Nitrate augmentation) which will effect *human health*. Solvents like paints and cement/concrete dust particles would penetrate through the soil pores and enter the underground aquifers which will *pollute the water*. Waste decomposition/landfilling in sites over a period of time can release methane gas into the atmosphere because of their CO2 composition and that leads to an increase the *global warming.* (in terms of global warming impact, methane is 21 times more harmful than carbon dioxide) (53).
- According to a Chinese researcher's experiment (Ding et al.,2016; Qin, 2012) 1000 m^2 of construction demolition waste going to landfill is equal to losing 1500 tons of groundwater and causes a loss of soil fertility of 52.5 kg every year. To rectify this nonsense circular economy and its principles were identified and will help to increase the sustainability (54).
- Social impact is explained as the procedure of analysing, controlling and managing the social effects from planned and unplanned ways, both negative and positive, of planned involvements (plans, programs, projects, and policies) and any processes of social change applied by those involvements. The commitment and participation of construction stakeholders are considered important drivers of C&DW management from a social perspective. Human capital deals with employees' skills and loyalty and social capital encompasses the quality of life and cultural components that are innate in each society (55).
- Dyllick and Hockerts (2002) pointed out the complexity of addressing the anticipation of various stakeholders simultaneously and trade-offs must constantly be made. And also stated "Communities gain values through sustainability carried out socially by developing the human resource and advancing the social capital among the people. It is essential to manage

social capital so that the stakeholders understand the motivations and accept the organization's value to the system" (53).

- The below-given table shall address the contributing factors to the sustainable management of CDW:

5. DISCUSSION:

5.1 Recommendations:

- Government involvement is necessary to measure the reduction of subsidies for linear goods and obstacles that occur in circularity [E.g: taxes – increasing the circularity by reducing the VAT (Value Added Tax) and GST (Goods and Service Tax) on materials], which provides energy to increase the CE (56).
- The possibilities of economic and social dimensions of circular construction are significantly less explored in the Indian context (56).
- Exploration in material value measurement dimensions & criteria in circular constructions and performance checks are not made in India. Circular construction needs to be explored in terms of an entire building rather than the material level (56).
- There are no specific targets that have been made by the government for stakeholders in the circular construction, which need an innovative (56).
- The irregular deposition of CDW in restricted or habitat areas will be identified with the help of technology GIS (Geographical Information System - to quantify the CDW generation) and GSM (Geo Statical Modelling). This approach could be useful for the authority of environmental law enforcement in inspecting the sites and saving resources by acting more efficiently against offenders (57).
- Integration of GIS with GPS will also help to manage the CDW – CDW generation rate reduced (57).
- Integration of GIS with MCDA (Multi-Criteria Decision Analysis) to determine the amount of generated CDW and management, propose areas for the recycling of the waste with the least possible movement of the material & management, performance evaluation of CDW installed recycling plants (57).

5.2 Comprehensive Action Plans for CDW Circularity:

The following table has a category of "Interests", "Activities" and "Authority" – the Interest has the circular activities in the CE on CDW, Activities discuss the

work and theme of each Interest and last, Authority will regulates the Activities and take responsibility for Interests (58).

No	Interests	Activities	Authority
1	Quantification of CDW generation and utilization of CDW based products	• Web-Portal creation/updation: to capture the C&D Waste generation data on regular basis by creating the baseline data through "Material passport" concept. Also used to monitor the effectiveness of the CDW (Construction Demolition Waste) management • Quantification of C&D waste - by doing survey or sampling in each populated areas (cities, town, villages, streets) individually • To utilize the CDW-based products, require enough material	State/ ULBs
2	Collection of low volume CDW at Collection points and its outbound logistics to the processing plant	• The no.of collection points depends on the number of waste collection & storage points, population area and the waste generation rate • If the generated waste by the producer will be small, they are allowed to manage the waste by their own arrangements for the collection and transportation of the waste on the approval of the ULB or Municipality through call or mail • The CDW outbound from collection points to processing plant shall manage by the plant company The terms & conditions and other formalities shall be arranged by ULB's with the processing plant for the collection and transportation of waste	ULBs

3	Collection of Bulk volume CDW and its outbound logistics to the processing plant	• More than 20 tons/more in one day (or) 300 tons per month in a project will considered it "Bulk generation" • The Agreement between the ULB's, bulk CDW generators and processing plant shall be necessary to outbound the CDW and to finalize the terms & conditions and other formalities for the collection and transportation of CDW to the processing plant	ULBs
4	Processing plant	• The minimum of 2-acre land is required to set-up the C&D waste processing plant (wet process based) with a capacity of 50-100 TPD waste (Ton Per Day) • If the CDW generation is less than 50 TPD, Mobile crusher unit (dry process based) may be used • In order to set-up and manage the waste processing plant of different models, need an encourage from different bodies - ULB, District, State & Central administration, Public-Private Partnership (PPP), Small business groups etc	ULBs

7	Research needs and Standardization	• Need separate BIS/IRC Guidelines for the utilization of recycled products made from the CDW. • Necessity of research work - to promote and create awareness on using CDW products in various applications. • IS 383 (latest revision) - use of recycled concrete coarse aggregate has been permitted as replacement of virgin coarse aggregates up to 25% in plain concrete works, up to 20% in reinforced concrete works (up to M25 grade) and up to 100% in case of lean concrete works. Usage of recycled fine aggregates for masonry and plaster works applications should be included in BIS / IRC Guidelines	NCCBM, CRRI and other R&D institutions, BIS, IRC

5	Promoting utilization of CDW recycled products	• By using of maximum amounts of waste in the several projects by the construction companies and real -estate agents, the utilization of CDW or secondary materials or products happens successfully and can also do promotion of CDW materials by creating awareness to PPP by using of these materials in their own projects • Government should also involve in the promotion and utilization because the regulations and control over all the constructional works will be managed by City, District, State and Central level authorities based on with in their limited jurisdiction • And some of the agencies that look over in India are At National level, MoHUA/ CPCB should engage with agencies like CPWD, MoRTH, NHAI, NRRDA etc. for the promotion of C&D waste products	To engage with various stakeholders such as CPWD/PWDs, BIS, GRIHA/IGBC, BMTPC, etc.
6	Policy interventions	• GST on C&D waste products-reduced from 18% to 5% • Green tax (transportation of C&D waste products) - should be waived off • Electricity load in C&D waste processing plant charged at industrial rate shall be reduced suitably • Suggesting of having a single window environmental clearance to set-up a C&D waste processing plant	Government of India/ State government/ ULBs

Table 2. Comprehensive Action Plans for CDW Circularity

5.3 Possible opportunities for a better-built environment:

Technologies such as 3D printing, Modular construction, Industrial opportunities, District cooling, etc were been adopted by keeping in mind future requirements and innovations in the planning & funding of construction projects and these energy-efficient structures would help to move the construction industry towards circularity (Akadiri et al., 2012). Optimising the utilisation of land by urban planning, sharing building space and refurbishing existing buildings are some ways to embrace CE in construction. The figure given below shows various opportunities towards circularity that can be adopted in the built environment (13).

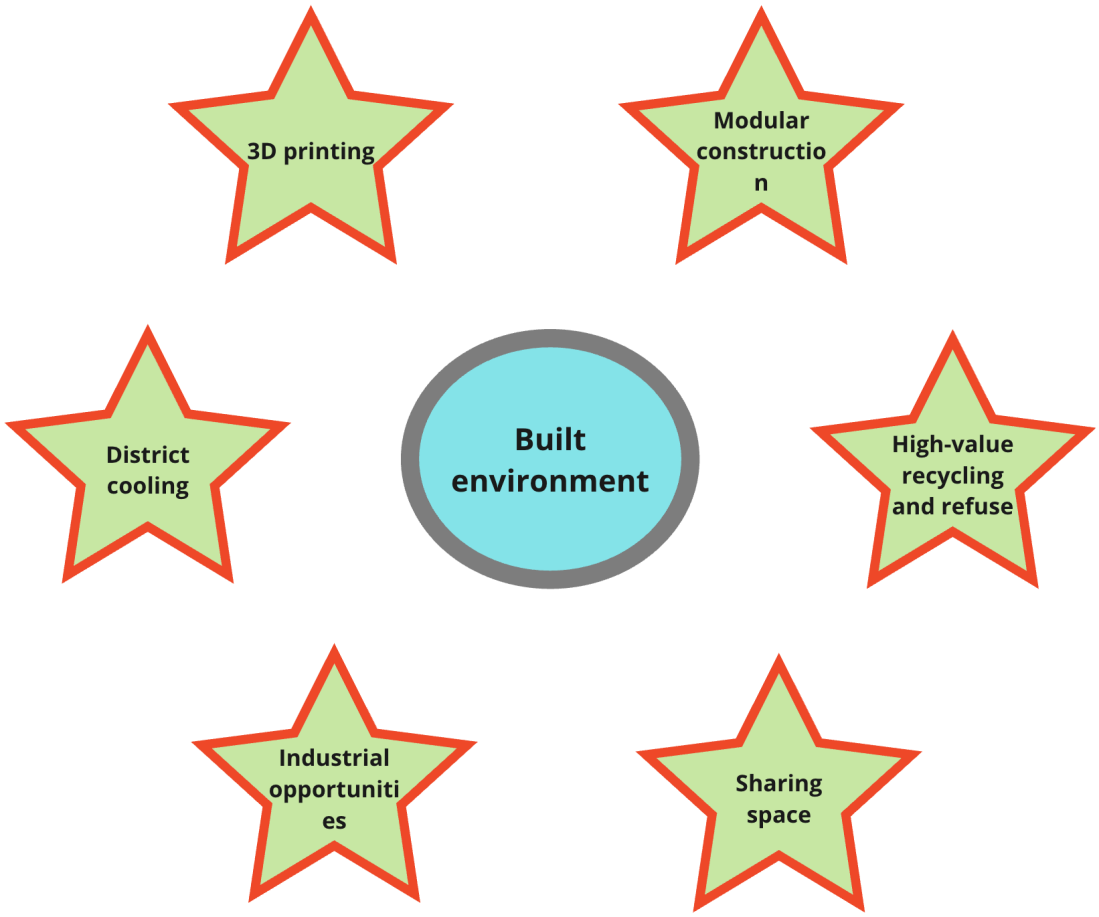

Figure 9. Possible opportunities for a better-built environment

6. CONCLUSION:

CDW material Recovery & Production in the CE would help the system economically and environmentally. Reuse & Recycling of CDW could save - energy, landfill, reduce greenhouse gas emissions and achieve environmental and economic sustainability. The frameworks would effectively lead to extending product/material value, providing long life to the material, and extending the resource value of CDW.

Material reuse either directly or by repair/refurbishment as published promotes CE by ensuring CDW is reused within the construction industry. This approach minimizes leakages in the sustainable reusing of CDW.

Even though technology, policy regulations and human resource knowledge on CDW management have been increased still there are some problems regarding management and sustainability are there, especially in developing countries like India.

Interventions for promoting reuse:

- Adaptive reuse – in this, the whole or part of a structure is reused when the structure is redundant.
- Deconstruction - is the careful dismantling to maximize the recovery of components to be reused.
- Design for deconstruction – closing the construction component loops by designing.
- Design for reuse – take in the use of reclaimed components in the new structures with design.

An effective framework in the CE:

- Narrowing resource loops – reduce waste generation by using fewer resources after the end of the life of the structure.
- Slowing loops - lengthening the use phase of materials by maintaining durability and quality in the material production.
- Closing resource loops - possible by the process of recycling materials.

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