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MANAGEMENT OF CONSTRUCTION AND DEMOLITION WASTE IN CITIES IN INDIA: DEVELOPING A FRAMEWORK

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ABSTRACT: The growth in construction sector particularly in and around mega-cities in India has provided impetus to newer challenge of managing construction and demolition (C&D) waste for such cities. Poor management of C&D waste results in loss of a potential resource and threat to environment through pollution of air and water bodies. In context of cities in India, literature indicates the need for a comprehensive approach for C&D waste management that this paper addresses through development ofa conceptual framework for metro cities. The methodological approach for developing the framework is based on the review of literature focused on key management and technology related barriers faced by cities in managing C&D waste; and through non-directive interviews with key sector experts (mainly architects and construction managers). The findings from literature indicate barriers and challenges relating to management of C&D waste in cities within India and outside. Outcome of interviews with architects and construction managers from the city-region of Delhi NCR affirm the barriers faced by construction industry and reflect on potential strategies that metro cities in India need to adopt in accordance with key stages of construction project cycle of medium and large-scale construction projects. This paper drawsattention forenhanced role of architects and managers of construction projects,for a comprehensive management of C&D waste in metro cities in India.

KEYWORDS: Construction and demolition waste; barriers, metro-cities, architects & contractors.

I. INTRODUCTION

During the decade 2001-2011in India, the urban population grew from 286.1 million in 2001 to 377.1 million in 2011 and several new towns emerged thus contributing to urbanisation (MoHUA, 2018). Construction industry had grown and consequentially the construction and demolition (C&D) waste has also been increasing, particularlyin Mega cities in India. The C&D waste constitutes of waste generated due to renovation, construction and demolition of buildings, roads and bridges. Material such as concrete, wood, metals, asphalt, gypsum, plastics and salvaged building components (BMTPC, 2018) often are part of the C&D wate. Market research (PwC, 2014) projected that construction industry in India shall grow at a rapid rate over the next decade. After the agriculture sector, construction sector contributes most to the economic activity in India. The C&D waste from construction sector however is poorly managed and faces several challenges. The gaps in efficient management of C&D waste contributes to several environmental impacts associated with the land, water and air pollution besides economic loss due to improper management of a potential resource.

There are lacunae and inconsistencies in the process and implementation of C&D wastemanagement. The process and implementation are also weak due to limited awareness and proactive engagement of various stakeholders involved, including the architects and construction managers. While there is literature focusing on specific thematics of the C&D waste sector in India, there is vital need for an inclusive approach that accounts for various dimensions relating to C&D waste management for cities in India. This paper attempts to address the need by outlining a conceptual framework for management of the C&D waste in Indian cities. Paper is structured into 4 sections. Section 2.0 briefly presents the 3-stage methodological approach adopted in the paper for development of a conceptual framework for C&D waste. Section 3.0 presents the results and analysis of outcomes of the 3 stages namely literature review, non-directive interviews, and development of the conceptual framework. The conclusions are drawn in Section 4.0.

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2.0 DEVELOPING the conceptual FRAMEWORK: METHODOLOGICAL approach

This research focuses on developing a conceptual framework for management of C&D waste for cities in India. Three stages of methodological approach adopted for framework development in this paper are explained below (Figure 1):

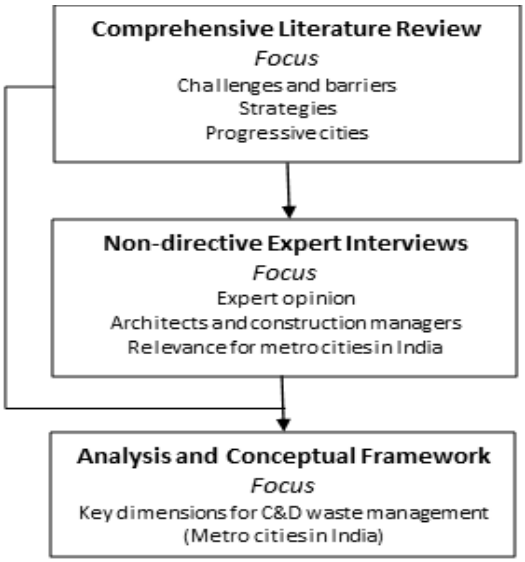

Figure 1: Methodological approach

Review of literature

A wide-ranging review of relevant literature was undertaken with objectives:

- to establish an inclusive understanding of key C&D waste management challenges and barriers and
- to take cognisance of different strategies being employed into construction projects by progressive cities to manage the C&D waste.

Through a review of globally relevant journal articles and reports, varied dimensions relating to the C&D waste management sector were identified.

Non-directive interviews with key sector experts

Non-directive/ unstructured interviews were conducted with 13 key experts namely architects and construction managers. The objective of interviews was to seek expert's opinion on the outcomes of literature review. Through interactions with experts, different important dimensions identified from literature were verified for their significance and relevance to C&D waste management for metro cities in India.

Conceptual framework development

Outcomes from literature review and non-directive interviews were analysed to finalise the key dimensions for C&D waste management that constitute the conceptual framework.

3.0 RESULTS and analysis

This section presents the results and analysis focusing on identifying barriers and strategies for C&D waste management through 3 stages. Firststageis based on the review of literature relating to the C&D waste management related developments in India and other countries. Second stage is focused on conducting and analysing non-directive interviews with experts to complement the findings from literature. Third stage is the development of a conceptual framework for C&D waste management based on assimilation of the outcomes from first and second stages.

Literature review:

Identifying barriers and strategies for C&D waste management in India: Construction sector employs around 35 million people in India. While the share of organized players is increasing however the industry remains largely fragmented. The urban housing in India is short of around 18.8 Million dwelling units and rural housing is short of around 47.4 Million units, as estimated in 2012. Theare inadequacies in urban infrastructure to meet demands of existing urban population. The re-generation of existing cities is much required alongside creating new, inclusive,sustainable and smart cities in order to meet the needs of rapidly increasing population and migration from rural catchments. Large amount of C&D waste is being generated due to re-development of infrastructure and housing and new construction for increasing demand (BMTPC, 2018). The academic and practice-based literature indicates that there are consequential negative impacts of poor management of C&D waste in cities in developing countries. The literature also highlights numerous challenges acting as barriers towards efficient C&D waste management including inaction by several stakeholders. These challenges range from limited political will and poor governance, lack of advanced technical knowhow and its application, and low awareness of construction managers, site engineers, architects and promoters/investors of various medium and large-scale construction projects. The lack of utilization of generated debris and large scale unorganised and illegal dumping results in air pollution and other risks of solid waste dumping in water bodies and *nallas* and mixes with municipal solid

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waste(BMTPC, 2018). It is expected that there will be serious threat to environment and to aspired sustainable movement of Indian construction industry, if initiatives to minimize and manage the C&D waste are not developed and efficiently adopted.

It is evident that the growth in built environment and infrastructure in and around mega cities has increased the potential of Construction and Demolition Waste generation. Many such cities are already exhausted with landfill capacities, thus restricting the disposal of C&D W under urban waste management mechanisms. As a resultant the unmanaged C&D waste reaches and chokes city drainage system, contributes to air pollution due to transportation of C&D waste thus leading to severe environmental and economic impacts. Disposal of C&D wastes is an ever increasing challenge as the waste is being improperly and illegally disposed to minimise transportation and other costs. Mostly the C&D waste is dumped in farm lands, within and just outside the city limits and in easily accessible low lying areas raising threats to air pollution and ground water contamination. The poor management of C&D waste can be attributed to several factors that are influenced by the stakeholders involved in building construction sector. The high-end stakeholders involved in construction process include developers, investors, architects, engineers, contractors, municipal authorities and suppliers etc. There is a need for process improvisation that can be accelerated through engagement of key stakeholders that can enhance sustainability in the construction industry. The behavioural and attitudinal aspects of stakeholders are critical in reduction and appropriate management of C&D waste.Two key stakeholders architects and contractors have a significant role in the construction industry and thus can also influence the management of C&D waste. Osmani et al (2006; 2008) raise the importance of the attitudes of architects and contractors towards minimisation of C&D waste. There is limited research on the C&D waste management in India with focus on key stakeholders.

In cities in India, C & D waste generation is mainly from activities such as - demolition of old dilapidated buildings; construction of new buildings (residential, commercial, hotel, institutional and other uses); renovation of existing buildings; reconstruction of roads; construction of bridges, etc.; renovation of city services; and from existing waste collection and disposal system (CBCB, 2017).Most of C&D wastes is generated form activities such as re-development of infrastructure and housing and new construction. A fundamental challenge relates to uncertainties in estimation of the quantum of C & D waste generation, due to reasons such as different methods adopted for estimation of quantum of C & D waste generated, differences in the pace of developmental activities across cities, and differences in the need for redevelopment across cities wheredemolition of buildings or parts are required.While the quantum and composition of C & D waste is construction project specific, however, it is estimated that C & D waste is around 25 - 30 percent of the total solid waste generated in India. There is ambiguity over the amount of C & D waste being generated in India, though estimations from different institutions indicate - approximately 25-30 million tonnes (MT) generated annually of which 5% is processed by MoUD; 12-15 MT by the Technology Information, Forecasting and Assessment Council (TIFAC) (in 2001); 10-12 MT by MoEF (in 2010); and 12 MT by CPCB. The range of C & D waste generation at the construction project level had been estimated by TIFAC as - 40-60 kg per sqm of new construction; 40-50 kg per sqm of building repair; and 300-500 kg per sqm for demolition of buildings, thus clearly indicating highest C & D waste generation from buildings demolition. One of the many estimations of C & D waste from demolition of old buildings is by BMTPC indicating that the composition includes bricks (26%), concretes (28%), masonry (32%),wood (3%), metal (6%) and others (5%). In general the construction and demolition waste constitutes of major component of bricks, cement concrete, cement plaster, roofing support systems, steel from RCC, rubble, stones, timber, doors & windows etc. and minor component of conduits, electrical fixtures, GI/Iron/Plastic pipes, glass and panels.

Associated with the generation of C & D waste, several challenges, especially in large cities are being experienced and the impacts are already being felt(GIZ, 2015). Such challenges include regulatory challenges for C&D waste management and building bye-laws do not specify the requirement for permits for demolition (GIZ, 2015). The records relating to consolidated estimate of waste generation is not maintained and most ULBs also don't maintain the landfill records. Dumping of waste in open and low-lying areas also distort any estimation of C & D waste generation. Such illegal dumping in cities is due to lack of effective regulatory framework and incentives to dump the waste in designated dump yards. The generators of C&D waste in cities find it viable financially to illegally dump waste over transporting waste to designated sites. Poor availability of skilled manpower is also a challenge that cities are facing. Due to the lack of codes and standards, the market for C&D waste based building materials such as paver blocks, aggregates and sand, is also very limited (GIZ, 2015). Additionally, there are limited technology service providers due to which the local authorities are unable to set up processing facilities in cities. So far mainly cities of Delhi and Ahmedabad have set up such facilities that are facing constraints. Other challenge includes the resource challenges relating to the constraint of land availability for disposal of waste since most city development authorities in India are unable to identify additional land for landfills. The technical understanding and capability of city authorities and other stakeholders is another constraint in managing the C&D waste appropriately.

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For C&D waste management in India, the 'ready reckoner' by BMTPC (BMTPC, 2018) identifies the key stakeholders and mentions their respective duties aimed at enhanced utilisation of recycled produce of C&D waste. The stakeholders include local bodies, SPCBs and Committees, State Governments and UT Administrator, CPCB, Bureau of Indian Standard and Indian Road Congress, Central Government, and C&D waste processing contractor and concessionaire.

Identifying barriers and strategies for C&D waste management in other countries: The literature also informs on various strategies being employed by cities in developed and developing countries. It is evident that the developed economies such as the UK (Osmani et al, 2006) and other European countries, US and a few countries from Asia also are in advance level ofprocesses and its implementation in practice and are relatively bettermanaging their C&D waste. The level of awareness is higher among various stakeholders.Several countries have developed Mature regulatory frameworks and policies for C&D waste management have been developed by several countries such as the Waste Framework Directive 2008/98/EC of the European Union that directs quantitative targets for reusing the C&D waste (GIZ, 2015). Countries such as Germany have been using an effective waste management practice of controlled deconstruction in which a detailed planning for controlled demolition, disposal and recovery is performed before controlled demolition is carried out. In countries as Australia, Germany and United Kingdom the use of materials from C&D waste had been popularised through the green building ratings such as the Leadership in Energy & Environmental Design (LEED).

In the United States, in 2017, 569 million tons of C&D waste was generated, which was more than twice the amount of municipal solid waste.Demolition represents more than 90% while construction represents less than 10 percentof total C&D waste generation(USEPA, 2020).The New York Department of Design and Construction (NYDDC) developed'High Performance Building Guideline,1999' to maximise waste reduction and recycling. The LEED rating was targeted that requires 50% or 75% waste recovery based on rating level. In 2002 NYDDC introduced specifications for using recycled building materials in all its projects. DDC encouraged following a mechanism to track results, document best practices and highlight areas that required more efforts. Combination of 3 R i.e. reduction, reuse and recycling along with disposal of non-recyclable material were identified as making up a comprehensive waste management plan that required collaboration and understanding of C&D waste recycling by all key stakeholders (including architects, engineers, consultants, etc.). The training of team, encouragement of the use of recycled materials, and increase in recycling rate by segregation of recyclable material at source, and documentation of all details of recycling, were recommended. The Institution Recycling Network developed a guide for architects and contractors related to Recycling Construction and Demolition waste in 2005.The guide included a detailed description of basics of C&D waste recycling, barriers and responses, waste management plan, case studies and examples. Furthermore, in the US, site management is also included as a part of C&DW handling legislation. Ordinance no 27-06, that came into effect in July 2006, requires all projects to complete a Demolition Debris Recovery Plan (DDRP) requiring to achieve a minimum reduction of 65% of waste to landfill. Transportation of C&D waste to landfill is illegal and is transported only through vehicles registered to transport C&DW. There is penalty in case a person violates this rule (SF environment, 2020).

In Europe, C&D waste accounts to almost 1/3rd of the total waste generated in Europe. Proper handling and management are important factors in sustainability, improving life quality and also boost recycling industry (Ecorys, 2016). Waste management, prevention and management was defined and prioritised according to the waste hierarchy. Europe has a target of recycling 70% C&D waste by 2020 which is being supported by the protocol of Construction 2020 strategy (European Commission, 2012), resource efficiency in building sector (COM, 2014), circular economy packageand Waste framework Directive (EU, 2008). InGermanya cradle to cradle approach had been adopted to reduce the C&D waste.The reusable as well as non-reusable materials generated from C&D operations in Australia and Germany, are categorized differently between the recycling systems instead of being disposed directly atlandfills(Brennan et al, 2014).

There are strict waste disposal laws and disposal fees which further encourage recycling C&D waste (Deloitte, 2015). About 90% is recycled and reutilised, but very little is utilised for structural applications (detailed standards and protocols have been developed) (Dittrich et al, 2015). Simple technologies like crushing and sorting are utilised. Thus economic and regulatory components along with recycling techniques enable Germany to effectively use C&D waste as a resource. In the UK, Osmani et al (2006; 2008) andKhairulzan (2006) highlight the significance of proper design that is very helpful in reducing C&D waste generation. UK architects observed that majority of waste is generated at construction stage but the findings revealed that about one third of the C&D waste could be reduced at design stage only. In the Netherlands, the country has consistently high diversion rates of above 90% of C&D waste. The market conditions and legislation further encourage use of C&D materials. These products are cheaper as compared to non C&D waste processed materials. Certification

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from recycling companies ensure quality guarantee. A fee is applied for putting the waste in landfill or incineration. End of waste guidelines have also been issued which provides material conformity related information (Deloitte, 2015).

In other developed countries such as Australia, the construction industry participants signed a'Wastewise construction agreement' with the federal government, demonstrating a commitment towards reducing C&D waste. Australia has developed a waste hierarchy as key framework in waste management policy, which ranks the ways of dealing with waste in order of preferences (Commonwealth of Australia, 2018). The hierarchical framework states actions ranging from most preferred (starting from avoid and reduce waste, to reuse waste, to recycle waste, to recover waste, to treat waste) to least preferred (dispose waste). In South Australia, legislations ensure that specifications of C&D processed materials are met and C&D waste supply chain data is reported annually to EPA. In Japan, the country recycled and used advanced recovery process and recorded high recovery rates of crushed concrete. Different standards exist for different grade (such as C and F) of recycled aggregates categorised by Japan and a different set of standards exist for classes of intended applications of these aggregates (such as H, L and M), detailing the specifications (Harris, 2017).

In a few other countries such as UAE, as construction industry rapidly progressed, the need of including awareness towards waste generated and recycled was felt. About 47% of waste generated is C&DW in UAE. Reuse at source and recycling are two important components considered in waste management. The country has included rating systems like LEED, Pearl Rating System for Estidama and EHS Trakhees certification and other government initiative that regulate building design and construction activities further resulting in minimised C&D waste generated. These rating systems include waste management plan preparation, reuse of materials, diverting waste from landfills to other alternatives like recycling (Hamani, 2011; Eco MENA, 2018). In Malaysia, the government include National Strategic Plan on solid waste management2005, National Solid Waste Management Policy 2006and Solid Waste and Public Cleansing Management Act 672. An approach of 3Rs ('reduce, reuse and recycle') waste had been introduced in Malaysia. Institutions were established to implement the plans and policies on ground. Construction Industry Master Plan 2006-2015, was also introduced in 2006 to improve construction industry performance. Construction Industry Transformation Programme 2016-2020 was also launched by the Construction Industry Development Board in 2015 to ensure implementation of 11th Malaysian Plan. Despite of such initiatives, Malaysia is still facing challenges in effective waste management, it require support from government along with the stakeholders and should use waste management hierarchy for better results (Nagapan et al, 2012). In Bangkok, the C&D waste industry is still developing and Is faced with high cost of project implementation as one of the major issues.A system dynamics modelling technique is being developed as a C&DW recycling model. The cost model, labor and machine productivity model and leftover model provide the details of sector in such dynamics modelling technique (Doan and Chinda, 2016). Bangkok recycling program (BRP) is an initiative to improve recycling as a part of waste management plan (Sukholthaman, 2012).

Outcome of literature review: The review of international examples and developments in Indiahighlight a few important aspectsindicating strategies and barriers as explained below:

- C&D W considered critical issue by all the stakeholders ranging from government to general public. There is a fee levied to dump the waste in landfill or incinerate it in some countries. Also, the processed products may be more expensive than conventional materials making it difficult for contractors/builders to opt them thus their usage is low. C&DW management and recycling requires a connected framework to ensure better results.
- Ambitious targets for recycle, reuse and disposal in a country encourage others to move towards these targets with greater enthusiasm. E.g. recycling index of 90% in Denmark, Netherlands and Estonia.
- Appropriate regulations and policies in place at national and city level- Compiled policies and regulations for various levels from national to city level may result in better management of of waste. Standards and quality assurance are also easy in case there is a linked policy and regulation framework available.
- Behavioural and attitudinal aspects critical in C&D W reduction and management is very essential. The contractors, engineers, architects and owner of project play a large role in reducing the waste generated. The stakeholders feel that C&D waste processing is costly but once the equipment is set and the C&D waste is processed then the quantity of procuring conventional materials is reduced thereby reducing the cost also.
- Ensuring quality of C&D waste to be recycled through policies, regulation or benchmarks is essential. In some countries C&D waste processed materials are not used for structural components but if the quality is ensured then materials may be utilised better.

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- The C&D waste management related challenges and barriers of high generation, limited awareness among key stakeholders, design challenges and contractors poor response, neglection of environmental dimension, and limited documentation are also indicated through international examples.

Non-directive interviews

To complement the findings from literature focusing on domestic and international examples, a few non-directive interviews were conducted with key experts engaged with the construction sector. To conduct non-directive interviews, 22 key experts (architects and construction managers) were identified out of which final interviews could be conducted with 7 architects and 6 construction managers that were involved with medium and large-scale construction projects. Out of various stakeholders, architects and construction managers were chosen as they indicate high potential to play a vital role in appropriate management of C&D waste across all stages of construction cycle of a large and medium scale project. The non-directive interviews were undertaken through a questionnaire with a set of open-ended questions. A fewexamples of questions/aspects on which experts elicited their opinion include:

- barriers in reduction management of C&D waste that require attention on priority basis.
- role of city authorities, corporations and parastatals (that deliver urban services), institutions and professional bodies, towards appropriate management of C&D waste.
- specific existing and new planning and management approaches and strategies, can contribute towards better C&D waste management.
- effective mechanisms to enhance awareness and active participation of architects and contractors towards good management practices for C&D waste in construction projects.

Outcome of Non-directive interviews: An important aspect of interaction were the stages relating to design and implementation; construction on site; commissioning, occupying and maintenance of the building; and finally retrofitting or redevelopment of the project when necessary. The experts provided insight on various challenges faced in managing C&D waste relating to these stages of a construction project. In particular financial, priority and awareness, governance and technology related challenges were emphasised by the expert respondents. Analysing various stages of the construction project cycle, the experts reflected upon different management solutions and strategies relating to beter management of C&D waste in metro cities. The experts indicate that to adopt a comprehensive approach for longer-term benefits to metro citiessuch as Delhi, strategies need to be developed and implemented focusing on the key stages of - planning and design; in-situ construction;commissioning and operation & maintenance; and retrofitting in the building. The experts highlighted the need for enhanced awareness and greater role of architects and construction managers alongside other stakeholders, in effective management of C&D waste in metro cities in India.

Conceptual framework

Through the analysis of outcomes from the review of literature including various dimensions of C&D waste management practices in India and other countries and outcomes of non-directive interviews with 13 sector experts, a conceptual framework for C&D waste managementhas been developed. The conceptual framework takes cognisance of the key barriers faced by cities in different countries and the strategies they have been employing to address the barriers. The responses from architects and construction managers as sector experts involved with medium and large scale projects,have facilitated adaptation of the framework with focus on C&D waste management for cities in India.

The conceptual framework, presented in Figure 2, lists the key barriers and highlights the need for focused strategies. The 5 key barriers include - institutional,technological, regulatory, financial and implementation related challenges that negatively influence the management of C&D waste in mega-cities in India. Example of various relevant strategies, necessary for efficient management of C&D waste are also presented through the conceptual framework.

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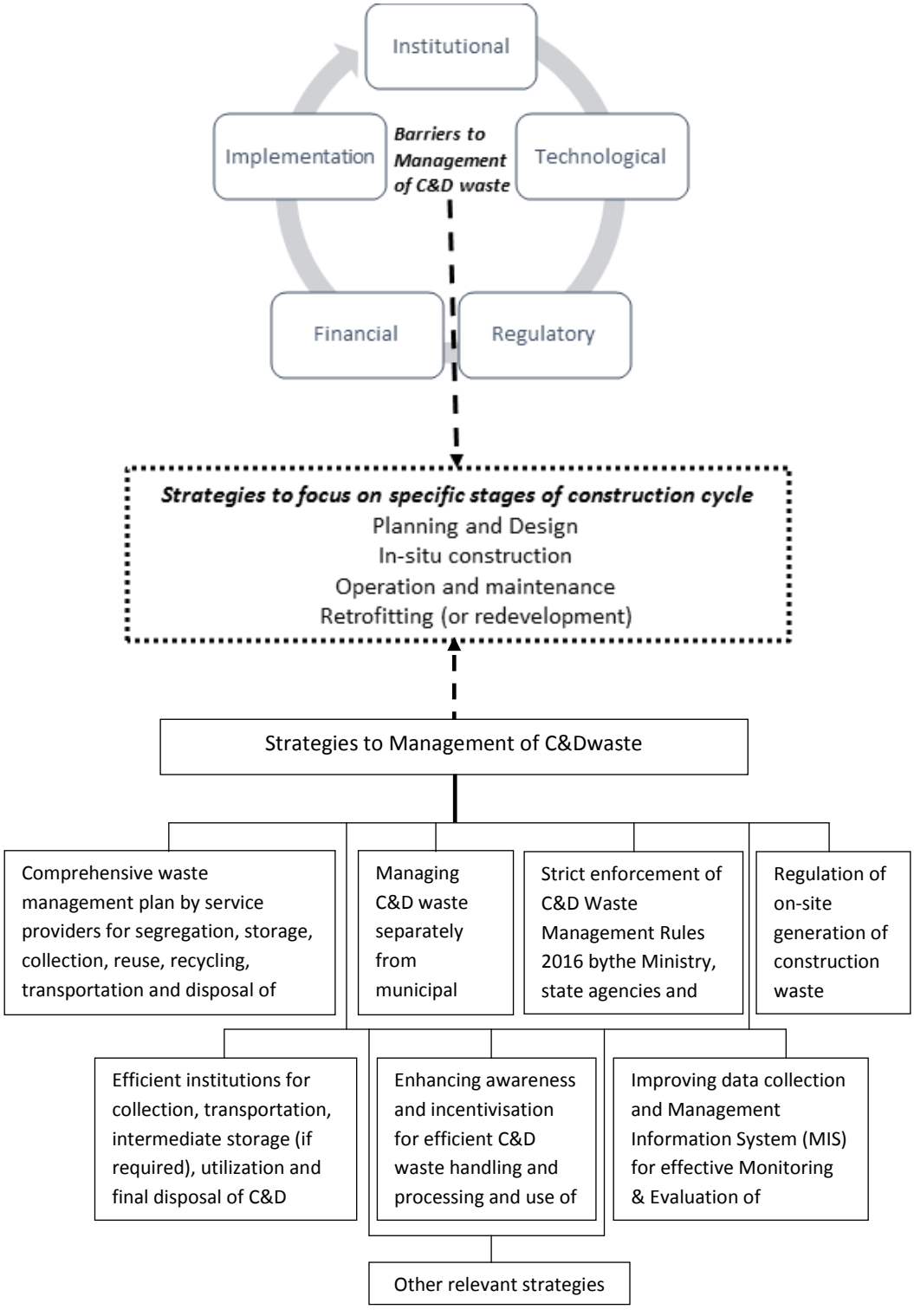

Figure 2: Conceptual framework for C&D waste management

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4.0 Conclusion

This paper addresses the concerns relating to the management of construction and demolition waste in cities in India. There is wide gap in maturity of practices for managing C&D waste in the cities in developed countries relative to developing countries. The focus of this paper is on management of C&D waste in metro cities such as Delhi, in India. The adopted methodological approach through review of literature and non-directive interviews with architects and construction managers in this paper creates an opportunity to relate theory and practice for development of the conceptual framework. This paper through the development of a framework, raises significance of institutional, technological, regulatory, financial and implementation related barriers that have negatively influenced the management of C&D waste in metro-cities. The importance of a structured approach through key stages of planning and design; in-situ construction; commissioning and operation &maintenance; and retrofitting in the buildings is highlighted in context of implementing various strategies. An important contribution of the paper is drawing attention towards greater role of architects and managers of construction projects for a comprehensive management of C&D waste in metro cities. Thispaper emphasises on need for focused strategies that relate to various stages of construction cycle.

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