ISSN: 0974-5823 Vol. 7 No. 2 February, 2022

International Journal of Mechanical Engineering

UNDERSTANDING THE ASPECTS OF SUSTAINABLE MANAGEMENT OF CONSTRUCTION AND DEMOLITION WASTE.

[1]Hardik Dhull
Research scholar, Civil engineering, ITM University, Gwalior
dhull.hdk19@gmail.com
[2]Mukesh Kumar Pandey
Professor, Civil Engineering, ITM University, Gwalior
mukesh.pandey.civil@itmunivercity.ac.in
[3]Deepak kumar
Assistant professor, Civil engineering, U.I.E.T., M.D.University, Rohtak
21deepakverma@gmail.com

Abstract

The construction industry produces an unacceptable amount of waste. In recent years, the construction industry has been increasingly conscious of the effects that debris from building and demolition have on the surrounding environment. The increase in C&DW has placed a strain on regional waste management systems and contributed to environmental degradation on a local and global scale. Some countries, such as India, have created new national C&DW plans (The CDWM Rules, 2016) and urged local and municipal organisations to implement and enforce further C&DW management policies. Among these countries is India. The C&D waste system, which encompasses a wide variety of building materials, is frequently divided into the following categories: waste resulting from the complete or partial demolition of buildings and/or civil infrastructure; waste resulting from the construction of buildings and/or civil infrastructure; social; rocks and vegetation resulting from site clearing; earth moving; civil works and/or excavations for foundations; and materials resulting from road construction. Each of these categories includes a subset of the overall C&D waste system. Due to the increased amount of C&D waste produced by construction activities, the industry is at risk of experiencing negative economic and environmental consequences as a result of a lack of waste management techniques. The reduction of waste from construction and demolition (C&D) provides financial and environmental benefits to the building sector. The inability to apply a sustainable strategy and develop an adequate management plan in order to lessen and/or prevent the construction waste stream is a key issue that must be addressed in order to reduce waste. Around the past few years, sustainable building has garnered attention all over the world. The creation of C&DW in Indian cities is measured with the use of a bottom-up material flow study in this article. Comparing the rates of C&DW generation across the cities of India was accomplished through the utilisation of a dynamic model. When estimating the amount of building and demolition in the various city classes, secondary literature was consulted. In 2016, urban areas in India generated more than 150 million tonnes of C&DW, with small to medium towns accounting for nearly 50% of the country's total. The study focuses on the elimination of material loops in Indian cities as well as C&DW recycling.

Keyword: *C&DW management, construction, waste and Environment.*

Introduction

It is estimated that the construction industry is responsible for the disposal of 35% of all of humanity's waste in landfills across the world (Ghaffar et al., 2020). The Environmental Protection Agency (EPA) of the United States defines construction and demolition waste, also known as C&D waste, as waste materials that consist of the debris created during the construction, renovation, and destruction of buildings, roads, and bridges. Construction and demolition waste is also commonly referred to as C&D waste. Construction and demolition (C&D) materials often contain a wide variety of components, including concrete, asphalt, wood, metals, gypsum, plastics, and reclaimed building components. Waste from construction and demolition is notoriously difficult to handle due to the fact that it is immobile, bulky, and lifeless. In addition to this, it is constructed out of a wide variety of various materials, each of which boasts its own individual set of characteristics. The capacity of the earth for self-renewal has been exceeded as a result of human activity related to the extraction of its natural resources (Ram et al., 2020). This has a considerable impact on the environment around the construction site, both on the site itself (during building activities) and outside the site in other locations (mining of source minerals, aggregates, iron ore, wood etc.). Activities associated to building, whether they take place on-site or off-site, have the potential to ultimately contribute to an increase in air pollution, which is responsible for a range of health issues as well as three million to four million deaths globally (Brown et al., 2018, Gautam et al., 2020). Therefore, there is no way to exclude the possibility of a more environmentally responsible expansion in the building construction sector. (Blaisi, 2019; Mathiyazhagan et al., 2018a). The adoption of environmentally friendly building methods makes it possible to lower pollution levels and minimises the dangers connected with traditional building methods (Li and Mathiyazhagan, 2017). Gro Brundtland advocated for the incorporation of ecological, economic, and social systems into the process of sustainable development in her article that was published in 1987 and titled Our Common Future (Brundtland Commission, 1987; Sinakou et al., 2019). However, the addition of sustainable goals does result in more challenging challenges for the worldwide actual implementation of the goals (Berglund et al., 2020). The annual amount of construction and demolition (C&D) waste in China is estimated to be 1130 Mt by Megaki and Damigos (2018). In comparison, the amount of C&D waste generated in Germany is 86 Mt, in Australia it is 20.4 Mt, in the Netherlands it is 22 Mt, in Italy it is 39 Mt, in Malaysia it is 8 Mt, and in France it is 65 Mt. (Aliferova and Ncube, 2017; Kabirifar et al., 2020). As a result of this, the results indicate that it is extremely important to develop alternative techniques and systems for the disposal of garbage in order to improve the existing status of the environment. Because of their prominent position in India's economy, the construction industries are also the country's most major contributors to environmental harm. This is due to the fact that building causes a lot of pollution (Mathiyazhagan et al., 2018b). The population of India has increased from 109 million in 1971 to 419 million in 2014, and it is anticipated to soar to around 600 million by the year 2030. As a result, India may experience a shortage of 10 million housing units as a result of this population growth. In 1971, the total number of people living in India was estimated to be 109 million. The initiative known as "Dwelling for All," which was started in June 2015, has established the year 2022 as the goal date for the construction of these dwelling units, which will contribute to an increase in the quantity of waste created by construction (BMTPC, 2018). Waste from construction and demolition is produced in significant amounts in cities that are expanding at a rapid rate, totaling 3000 Mt annually (Jain et al., 2020). The Indian Ministry of Housing and Urban Affairs initiated the Swachh Bharat Abhiyan, popularly known as the "Clean India Mission," in the year 2014. The mission's official name is "Clean India." Swachh Bharat Abhiyan is an effort that was established by the government of India in 2014 with the intention of improving the management of solid waste. It is a nation-wide programme. This undertaking is being undertaken with the intention of managing the combined wastes that are produced by commercial and residential sources. At the moment, the construction and demolition waste management sector is not as well-established as the household waste management industry. The municipal authorities require every construction project to draught and submit a site waste-management plan if the project creates more than 20 tonnes of rubbish in a single day or more than 300 tonnes of waste in a single month. This requirement applies to both daily and monthly totals (SWMP). However, this does not appear to be implemented on a national basis. For this reason, in order to enhance the state of WM as it exists right now, study into both the factors that contribute to the failure to execute SWMPs and the techniques that are applied in order to ensure compliance with them is required (Gautam et al., 2020). The upper management of construction enterprises in India has certain concerns concerning the use of materials that have been classified as construction and demolition waste (C&D rubbish) (Duan et al., 2020; Kolaventi et al., 2020). There is a lot of published material available on the topic of using construction and demolition debris (C&D debris) as a building material. On the other side, there is a substantial amount of opposition to the utilisation of recycled materials in construction projects (Evangelista and de Brito, 2007; Jin and Yuan, 2019). There is a prevalent misconception that the utilisation of recycled materials in the construction of buildings brings about a reduction in the performance of the aforementioned structures, namely in terms of their durability and tensile strength (Yuan, 2017).

Because of its high density and inertness, it cannot be burnt in an incinerator, for example; as a result, choosing an alternative that is suited for disposal can be difficult.

OVERVIEW OF CONSTRUCTION AND DEMOLITION WASTE INDIA

Waste that was produced during the building, renovating, repairing, or demolishing of any civil structure is referred to as "construction and demolition garbage." These operations resulted in the creation of debris and rubble, in addition to building materials, which are included in this category of trash. Regardless of whether the trash was produced by a person, an organisation, or the authority, the regulations will apply to any waste that is generated as a consequence of the building, remodelling, repair, or destruction of any civil structure. These rules will apply to any waste that is generated. Rubble, debris, and other building materials are all types of trash that can be produced during the construction and demolition processes. Constructing new buildings is not an action that is in any way beneficial to the natural environment. At the present moment, the construction sector in India is increasing at a rate of 10% per year, and the accumulation of waste from building is also expanding at this rate. According to a study that was conducted by TIFAC in the year 2000, it was estimated that the entire quantity of garbage produced by the building sector was somewhere between 12 and 14.7 million tonnes each and every year. This estimate incorporated the cost of wasted concrete in addition to sand, gravel, bricks, brickwork, and bitumen. It is estimated that over 30,000 tonnes of construction and demolition waste are generated every single day in India, despite the fact that accurate data for the current situation are not yet accessible. The process of building anything results in the generation of a great deal of different kinds of garbage. It is projected that between 40 and 60 kg of waste will be produced for every square metre of space that is being constructed. In a similar vein, it is anticipated that the quantity of waste produced by building or remodelling work is between 40 and 50 kg per square metre. This figure is derived using the same methodology as the previous example. The activity that contributes the most to the creation of waste is the demolition of buildings, however there is no information that can be regarded acceptable or suitable for getting access to this topic. This is because in India the management of waste from building and demolition is included in the management of waste from municipal solid waste, despite the fact that India does not have a specific legislative framework for the management of waste from this type of construction and demolition in India. Because of this, it is becoming increasingly difficult to have access to the information and properly manage rubbish from building and demolition projects. The quantity of rubbish that is created in the country is estimated to be 0.53 million tonnes per day, which is according to a report that was published in 2008 by the Ministry of Environment and Forest.

LITERATURE REVIEW

A review study is not complete without a comprehensive analysis of the relevant prior literature. The following are some of the ways that trash from building and demolition may be used, recycled, and reused:

Wen-Ling Huang and her colleagues conducted research in the year 2002 on the method of recycling waste left over from building and demolition projects by employing a mechanical classification system. In this study, the authors perform an examination of a recycling programme for building and demolition debris with regard to a number of different factors, including those that are technical, economic, and institutional in nature. The primary focus of the investigation is a newly developed mechanical categorization method that has been configured with a variety of unit processes. These unit processes include bar detection, transfer, detection air classifier, disc detection and classification. The investigation is primarily an investigation to determine whether or not the method is applicable in real-world settings. tests and analyses carried out in the laboratory, including one involving sieving. In line with the predefined chemical and physical characteristics of the product flows, the brittleness test, the LA abrasion test, the organic content test, and the fineness test were carried out (A, B, and C). The findings of the survey indicate that it may be acceptable to use flow B of product to cover the solid waste in landfills if the foams can be reduced to an almost negligible amount; the findings also indicate that it may be possible to use flow A of product to construct streets because it contains fine particles; the findings also indicate that it may be acceptable to use flow B of product to cover the solid waste in landfills because it contains fine particles. If the level of impurities in product flow B can be reduced down to practically nothing, the finer components of that flow can also be employed as fillers in building projects. This is provided that the level of impurities can be brought down to almost nothing. If the product flow C can withstand the abrasion test conducted by LA, it has the potential to be utilised as a paving substrate or coarse aggregate in brand new construction. From the point of view of the long term, the rules, regulations, and procedures that are essential for the quality assurance and quality control of the collected waste, processed waste, and separated waste need to be careful for the adequacy and compliance of the recycled material and the market potential of the secondary material. Additionally, the rules, regulations, and procedures need to take into consideration the market potential of the secondary material.

Akash Raoa and his colleagues conducted a study on the utilisation of recycled waste aggregate from construction and demolition sources in concrete. The aim of the research was to better understand how this material may be used (2007). To find a solution to the challenge of utilising C&D waste from aggregate that was recycled in new concrete would be an inventive and creative method to solving the problem. The outcomes of the study that the concrete engineers have carried out suggest that they have found and indicated the potential of appropriately managing and utilising these wastes again as aggregates in the new concrete. This was identified and indicated by the concrete engineers. In their study, they examine the numerous facets of the issue, beginning with a concise review of the situation all over the world in terms of the quantity of garbage generated by C&D aggregates that have been reclaimed from C&D waste. After this comes a discussion of the various facets of the problem that have been identified. According to a survey on the manufacture and use of aggregate aggregates of recycled aggregates, as well as the properties of recycled aggregate and recycled aggregate concrete, which are discussed in the document, it is ideal that recycled concrete could be used in low-end concrete submissions. This is because recycled aggregate concrete possesses the properties of both recycled aggregate and recycled aggregate concrete. If the experimental work were done perfectly, recycled aggregates may be utilised to build regular structural concrete by combining them with condensed silica fume, fly ash, and other elements that are functionally equivalent. It is necessary to put in more effort to educate people and come up with appropriate criteria in order to more precisely define the areas in which recycled concrete can be utilised. It may be used without risk in any circumstance.

Research on the disposal of construction and demolition debris in Tehran was carried out by Babak Rouhi and colleagues (2016). The increase in the number of buildings being constructed gives rise to new concerns regarding the correct disposal of debris from construction and destruction (C&D trash). It has been recognised by the Environmental Protection Agency (EPA) that waste from construction and demolition (C&D) may be separated into the three categories of non-hazardous waste, hazardous waste, and semi-hazardous waste respectively. At current moment, Tehran creates about 50,000 tonnes of rubbish each and every day from building and demolition, of which more than 30,000 tonnes are put into landfills each and every day. According to the findings of their study, more than 57% of this rubbish is made up of non-hazardous waste and has the potential to be recycled or repurposed in some way. Their book provides a few different management options, some of which include methods for collecting and recycling construction waste in line with the requirements of the market in Iran at the present time. Their essay was created with the purpose of demonstrating that current C&Ds have a good possibility of being recycled and put to use in the foreseeable future. In addition, the findings of his research suggest that we should reduce, reuse, and recycle the waste left over from demolition and building projects in order to reduce the quantity of raw materials that we use and increase the amount of space that is available in landfills. In addition to that, it offers ideas for recycling and reusing the debris left behind from building and demolition projects. The findings are broken down into the following categories:

A research on a sustainable C&D technique that encompassed principles of zero waste was given by Sally M. Elgizawy and colleagues (2016). It is difficult to find a solution to the problems that are caused by improperly managing construction and demolition (C&D) trash because there is no definition of construction and demolition (C&D) waste that is universally accepted by everyone, and because the definition of C&D waste differs depending on the type of project and the location. The goals of his research are to acquire a more precise comprehension of the procedures for the separate collection of C and D garbage, as well as its constituents and treatment, when it has reached the end of its usefulness, and to evaluate the effectiveness of waste management using the zero-waste life cycle. One form that gives the possibility to change one's way of life and beliefs in order to achieve the ultimate goal of maintainable improvement over the extinction of waste materials and circulating in closed cycles is one that has zero waste or no waste at all. This form is known as a form that has zero waste or no waste at all. The term "zero waste or no waste" refers to this particular type. The management of trash will significantly improve as a consequence of the adoption of the notion of zero waste from building and destruction. This is because the idea promotes the reuse of resources, contributes to the preservation of the environment, and reflects a step in the direction of an environment that can be sustained. The reason for this is due to the fact that it helps to conserve the environment. At addition, recycling, which begins in a distant location and cannot be maintained, does not necessarily result in a profit and is typically evaluated as a downward cycle rather than an upward cycle of real product. This is because recycling begins far away and cannot be maintained. This is due to the fact that recycling begins at a considerable distance. As a consequence of this, the findings of their research highlight the necessity of C&D waste management that is predicated on the concept of producing no waste. The recycling of wastes from construction and demolition (C&D) is regarded to be the most serious problem by the zero waste technique, and it requires a substantial amount of inquiry and research work. On the other hand, recycling construction and demolition waste is incredibly beneficial since it encourages the circulation of materials inside a closed circuit, and it offers a substantial number of advantages both on a national and an international scale. The strategy that is used both during the building of a structure and afterwards, when its components are being removed or deconstructed, has an effect on the possibility for recycling all of the structure's components. Additionally, the wide variety of construction methods has a significant impact on recycling practises all over the world and on the likelihood that the final product will make use of recycled materials. This is due to the fact that the likelihood of the use of recycled materials increases with the variety of construction methods.

OBJECTIVE OF THE STUDY

1. To estimate C&DW generation in urban areas in India,
2. To analyses the impacts of existing C&DW management practices on the resource efficiency of cities and discuss recycling opportunities.

RESEARCH METHODOLOGY

In addition to that, the circumstances that led to the issue that now exists in waste management within the construction sector are going to be studied as part of this study. The findings of the study indicate that the designer, the contractor, the manufacturer, and the supplier are some of the most major contributors to the formation of construction and demolition debris (C&D waste). The C&D Waste Management Rules were operational in 2016, and its primary objective was to facilitate the centralised collection, storage, transportation, treatment/processing, and disposal of construction and demolition waste in India. Despite this, there was relatively little progress achieved during that time period in the more widespread use of C&D waste. According to the data provided by the Central Pollution Control Board of India, in the year 2017, the cities of Chennai and Mumbai each generated 2500 tonnes per day of waste from building and demolition activities. In addition, the strategies for the management of C&D waste that have been proposed by a variety of organisations encourage the use of "sustainable construction materials" and recycled C&D waste items, with the goal of constructing affordable housing units by the year 2022 in order to address serious housing shortages. This is done in order to address the serious housing shortages that are currently being experienced. Although there are standards in place, recycling has not yet achieved a level of popularity that is particularly noteworthy. This situation occurs because there is insufficient capacity at the factories, in addition to a lack of monitoring by the relevant authorities within the government. This research is relevant to policy makers, regulatory agencies, industry, and academics who examine or handle the rubbish and its recycling in building and demolition. Also relevant is anybody who handles the recycling of trash. The general public attaches a significant amount of importance to it as well. Renovation and demolition operations were estimated based on the lifespan distribution of structures because there was a lack of information available on earlier construction activity in Indian cities. This was done to make up for the fact that there was not enough information (i.e. buildings older than an age threshold are renovated or demolished). To calculate the overall quantity of waste produced during construction and demolition, multiply the amount of waste produced during building, renovation, and demolition projects by the rate at which each type of trash is produced.

DATA ANALYSIS AND RESULT

INDIAN CONSTRUCTION INDUSTRY

According to the 11th five year plan, the construction industry's contribution to the economy is only second to that of agriculture in terms of the magnitude of its impact. It is hypothesised that the building sector will have a substantial multiplier effect on the overall economy. An investigation of the forward and backward links that are found within the construction sector led to the formation of this conclusion. There were roughly 27,770 companies that were directly engaged in the activity of building in the year 2005. As a result, the construction sector is now one of the most important sources of employment in the nation. In addition, the construction sector is distinguished by the presence of a combination of both organised and unorganised enterprises. According to the statistics on employment, the number of people holding jobs has steadily increased from 14.6 million in 1995 to 31.46 million in 2005, which is more than double the previous amount. This figure takes into account both skilled and unskilled labourers, as well as engineers, technicians, foremen, and secretarial staff. As a consequence of the fact that a number of ambitious projects are expected to be carried out during the 11th Plan, the need for skilled labourers in the construction industry is likely to increase at a rate of at least 8%–9% on a constant basis. Because of this, the existing pool of construction workers will see an annual increase of nearly 2.5 million new faces.

The expansion of the nation's economy is sparked into motion by the construction sector. During the fiscal year 2004-2005, investments of over one hundred billion United States Dollars were invested in this business. Of these investments, the private sector was responsible for supplying 32.7% of them. It is anticipated that the real estate development industry will continue to experience a faster rate of expansion over the next several years as a direct result of the recent decision made by the Government of India (GOI) to permit 100 percent foreign direct investment in real estate development projects. This decision was taken as a result of the recent decision taken by the Government of India (GOI) to permit 100 percent foreign direct investment in real estate development projects. As shown in Figure 1, the contribution of the construction industry to the overall GDP has grown from 6.4% in 2000-01 to 7.2% in 2004-05. This represents an increase of 1.6%. According to the findings of a study that was carried out by the Technology Information, Forecasting and Assessment Council (TIFAC), the total value of all construction work that was carried out throughout the period of time spanning from 2006 to 2011 amounts to a total of $847 billion. On the basis of the facts that were shown before, the figures for the years 2008 to 2011 have been calculated with the premise that the rate of growth will remain the same.

Table 1: Billion-dollar building industry investments.

Year	2008	2009	2010	2011
Residential Construction				
	8.00	8.62	9.24	9.86
Non Residential Construction				
	5.19	5.33	5.45	5.58
Civil Eng. Construction				
	115.24	122.38	129.52	136.55
Total				
	128.43	136.33	144.21	151.99

COMPOSITION OF CONSTRUCTION WASTE GENERATED INDIA

In the construction business, the many various types of constructions each produce their own unique types of waste. For instance, the composition of the building will normally consist of concrete and steel if it is a bridge or a flyover that is being constructed. Whether the buildings in issue are houses or apartment complexes, the composition will take on a variety of various forms depending on the nature of the structures. It is composed of a wide range of components, such as concrete, steel, wood, tiles, bricks, polymers, and other such things.

Table 2. Composition of construction and demolition waste

Components of C & D waste	TIFAC (%)	MCD Survey	Survey IL & FS (%)
Soil/Sand, Gravel	36	43	41.5
Bitumen	2	-	-
Metals	5	-	0.4
Concrete	23	35	-
Wood	2	2	1.5
Other	1	1	7.6

Urban population and city classification

There were 26 million people living in India's cities in the year 1951, but by 2011 that number had increased to 377 million (Census of India 2001, 2011). By the year 2050, it is expected that there would be more than 800 million. (UN DESA 2018). The pattern of urbanisation that is taking place in India is seen in figure 2, which can be found here. In five- or ten-year increments at a time, the figures that were compiled by the census and the United Nations were made available to the public. The technique of linear interpolation was applied in order to transform this data into annual values.

The degree to which various regions of India have been impacted by urbanisation stands in stark contrast to one another. Only a few of cities are seeing a disproportionately high rate of urban population growth, but those places are seeing it happen faster than the others. According to the results of the 2011 Census in India, the top 10 cities in terms of population are responsible for accounting for 25% of the total population of the nation.

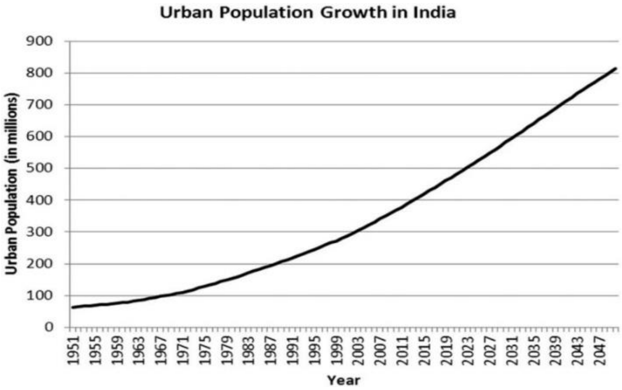

Figure 1. Trend of urban population in India.

the urban population of India, which has a total population that averages 9.3 million people. The following 90 cities, excluding the top 10 cities, each have an average population of 1 million people and account for 26% of the urban population. The top 10 cities account for the majority of the urban population. The remaining 49% of the urban population is distributed among the various towns and cities, each of which has an average population that is fewer than 25,000. (see Table 2).

In this article, estimates of the rates of C&DW generation were supplied for many different types of cities and their respective categories. The top ten cities in India in terms of population were given the designation of "mega," the next ninety cities were given the designation of "million," and the remaining cities were given the designation of "town." These population rankings were determined based on the average population of the cities included in each class. In addition, for the sake of making accurate projections for the future, it was assumed that the percentage of people living in each classification of city would remain the same (Swerts, Pumain, and Denis 2014). The projections of population growth shown in Figure 2 cover a range of different types of cities and span the years 2011 to 2050.

Construction activities in cities

The requirement for residential and commercial structures that has arisen as a consequence of population growth and economic expansion is what drives construction activity in metropolitan regions. This need has arisen as a result of both population growth and economic expansion. In India, there are not a great deal of data sets accessible at the city level for use in building and demolition activities. There are no published government estimates for the total amount of building that is finished in each year across all of the different cities. In the absence of data that has been painstakingly documented, one alternative method for assessing the rate of growth in metropolitan areas is to compute the expansion of overall floor space. This may be done by dividing the total amount of floor space by its initial amount (H. Wu et al. 2016; Z.2014). The National Sample Survey Organisation carried conducted a number of housing and building surveys in order to acquire a better knowledge of the circumstances of houses in both urban and rural settings. The surveys were carried out in order to compare the conditions of urban and rural homes. According to the findings of the survey, the typical size of a home in a metropolitan region was between 37 and 41 square metres, with an average size of 37 square metres, during the period between 1993 and 2005.

Table 3. Urban population distribution across the various types of cities examined in this study.

City classification 2011	Mega	Million	Town
Number of cities	10	90	~7,800
Population (in million)	93	97	216
Share	25%	26%	49%
Avg. population per city (in million)	9.3	1	0.024
Source: based on Census of India (2011).			

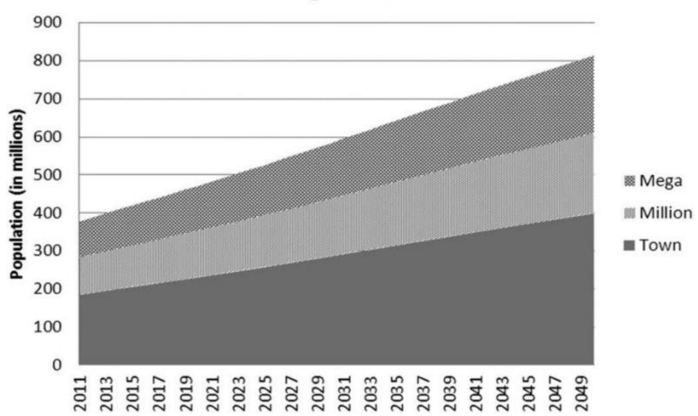

Figure 2. Urban population projections for different classes of cities.

Table 4. Per capita floor space in different metropolitan cities around the world.

City	Population – 2011 (in millions)	GDP – 2011 (in US dollars)	PCFA – residential (m2)	PCFA – commercial (m2)	PCFA – total (m2)	Ratio of commercial to total
London	8	47,333	18	10	28	35%
Paris	12	56,943	30	51	80	63%
Los Angeles	10	74,045	41	29	70	42%
Manila	12	11,788	17	13	30	44%
Karachi	15	5161	18	7	26	29%
Guangzhou	13	23,197	16	13	29	43%
Shanghai	23	19,470	23	18	42	44%
Beijing	20	19,169	22	18	40	46%

Numbers have been rounded off to nearest integer.

Source: Kennedy et al. (2015).

About 39 square metres in total (NSSO 1993, 2012). (NSSO 1993, 2012). In metropolitan regions, the household PCFA was measured at 9.45 square metres (NSSO 2008). However, the only levels of government that have access to these data are the state and the federal levels. There is no information available for individual cities or for distinct types of urban areas. It was consequently expected that the PCFA-residential value would remain the same regardless of the class of the city.

There were no estimates available for the floor space of India's urban business establishments. The overall floor area of residential buildings in metropolitan areas of countries like India and China is on average four times greater than the total floor area of commercial buildings in these same areas (Chaturvedi et al. 2014; Huang et al. 2013). It appears that residential space accounts for around 80% of all building space, whereas commercial space accounts for approximately 20% of all building space. In a few of the world's largest cities, the proportion of total floor space used by commercial space is significantly higher than in other types of buildings (see Table 3). This makes perfect sense when taking into account the fact that megacities are the driving force behind the economy of many nations (Swerts and Denis 2015), and megacities should also have a bigger overall commercial floor space per capita. In a manner comparable to this, there is not a great deal of commercial activity in relatively little towns. It only makes logical that as populations increase and cities become more prosperous, the proportion of floor area devoted to commercial use would increase relative to that devoted to residential use. According to study that was conducted by Chaturvedi and colleagues (2014), the amount of residential and commercial floor space that will be available per person in metropolitan India would expand by three and five times, respectively, between the years 2005 and 2050. This indicates that between now and 2050, the amount of floor space devoted to residential and commercial uses will expand at compound annual growth rates of 2.5% and 3.6% respectively. Table 4 presents the total floor areas and the assumptions that underpinned those totals for the various types of cities that were used in this research.

C&D waste handling

In India, contractors play an extremely important role in the process of trash management. The contractor is responsible for paying to have the debris from the demolition project disposed of, as stated in the contractual terms. The demolition of pre-existing buildings and structures is the principal driver of trash generation in the construction industry. This is in contrast to new building construction, building renovation, or building repair, all of which contribute to the generation of garbage. Demolition contractors are brought in if an older building in India has to be taken down. This may be necessary due to the building's deterioration or because more space is required for the construction of a new structure. based on the findings of a TIFAC research.

- The market is flooded with recovered materials from demolition projects, all of which are sold at prices that are far cheaper than those of similar new products.
- Landfills are used for the disposal of materials that are incapable of being repurposed.
- While some municipal corporations make an effort to lessen the amount of construction and demolition waste they produce, others continue to make landfill space available for it.
- Prior to disposal, the various components of garbage are not sorted out individually.
- It is the responsibility of the builders and owners to pay the transportation fees, which at the present time range from $6 to US$13 each truckload depending on how close the landfill is to the demolition site.

- Municipal agencies are required to pay between $1.50 and $2 per tonne of waste, but they are not required to collect taxes from owners or builders at this time.
- Even though there are regulations for how rubbish should be disposed of in landfills, there is very little to no consequence for those who violate these instructions.

C&D waste estimation

Estimates of the amount of C&D waste in India have been derived from a number of different research. 14.5 million tonnes of C&D trash are produced each year in India, according to Pappu, Saxena, and their colleagues. The Central Pollution Control Board (CPCB) estimated that the amount of solid waste generated in India was around 48 million tonnes per year for the year 2000. Of this total, the garbage produced by the construction sector accounted for approximately 12 to 14.7 million tonnes. Figure 4 presents the findings that Singhal and Pandey obtained about the increase in municipal solid garbage in India. Based on the premise that construction and demolition trash makes up between 25 and 30 percent of municipal solid garbage, this graph may be used to create a ballpark estimate of C&D waste.

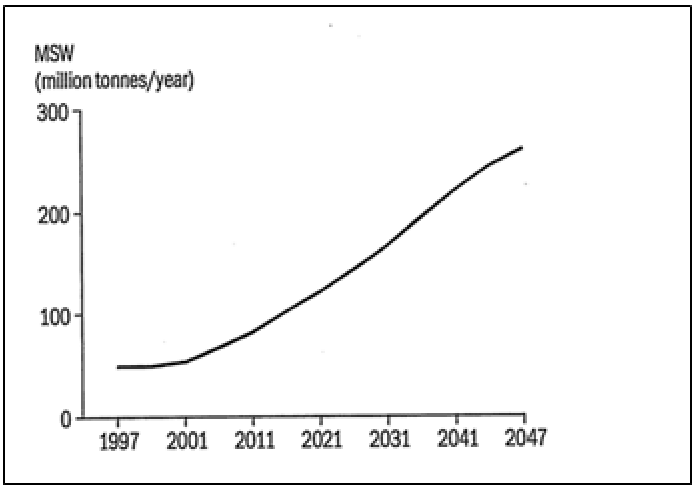

Figure 3: Municipal solid waste generation in India.

As a consequence of this, the total quantity of construction and demolition waste that was produced in the year 2000 was around 13-15 million tonnes, as indicated in Figure 3. For the objective of determining how much C&D waste there is, TIFAC conducted a comprehensive examination. According to the findings of this study, the following information on C&D waste in India for the year 2000:

- The quantity of waste generated by construction and demolition was anticipated to be 14.69 million tonnes.
- The quantity of waste created during construction, remodelling, or repair work varied from 40 to 60 kg/m2 and, consequently, 40 to 50 kg/m2, respectively.
- The demolition of structures was the single most important contributor to the accumulation of waste, which, on an area basis, resulted in an average accumulation of 425 kg of debris per square metre.

Table 5 India C&D waste comparison(2000) CIB TG 39 reports provided US statistics..

	Description	India	USA
1.	Year	2000	2000
2.	C&D waste generation		
	a) New Construction	50 kg/m^2	41 kg/m^2
	b) Renovation /Repair	45 kg/m^2	118 kg/m^2
	c) Demolition	425 kg/m^2	515 kg/m^2

Renovation and demolition activities

Construction, remodelling, and even total demolition are all part of city life. Demolition of a building is the result of actions related to its end of life or renovation. The use of indirect information was necessary given the lack of official statistics on the subject of city demolitions in India. The Indian government views as obsolete any homes that are more than 80 years old as well as any structures that are between 40 and 80 years old and in bad condition (MoUHPA 2012). 1.39 percent of homes have been around for more than 80 years, while 1.43 percent of dwellings are between 40 and 80 years old and are in bad shape (MoUHPA 2012). 2.82 percent of dwellings have become obsolete. There are a few old buildings that are left standing. There are quaint homes that are 80 years old and rundown shacks that are 1-40 years old (Mo UHPA 2012). It was anticipated that structures between 1 and 40 years old that were in bad condition would be renovated every year, while those older than 40 years would be razed every year due to the fact that fresher buildings may be restored without having to be completely demolished. 6.7% of housing units that are less than 40 years old are in a bad state, whereas just 1.6% of housing units that are older than 40 years are **(MoUHPA 2012)**. The ratios of the commercial buildings were the same.

Intensities Waste is generated during construction and demolition activities. Glass, entire bricks, and metals may be salvaged in India; nevertheless, most construction and demolition waste consists of mortar, concrete, soil, sand, and gravel (Development Alternatives 2015; TIFAC 2001). The construction industry produces less waste than the demolition industry. Construction and demolition each produce 40–60, respectively, and restoration and demolition each produce 500 kg/m2 of waste (TIFAC 2001). According to research conducted by Ram and Kalidindi (2017) in an Indian metropolitan area, demolition results in the generation of 1300 kg/m2 of rubbish, which is 2.5 times higher than the estimations provided by TIFAC (2001). The weight of debris after demolition in one Chinese city was 1,360 kilogrammes per square metre (H. Wu et al. 2016). This evaluation made the assumption that the density of demolition trash was 1,300 kg/m2, based on earlier studies.

Table 6. Per capita floor area values used in this study for India.

	Per capita floor area values (PCFA)			Compound annual growth rate of total [c]	
City class	Residential[a] (in m2)	Commercial[b] (in m2)	Total (in m2)	Residential	Commercial
Mega	9.45	2.36	11.80	2.5%	3.6%
Million	9.45	1.89	11.34		
Town	9.45	1.42	10.90		

Based on NSSO (2008).

If we assume that the percentage of residential area to commercial area is comparable to 15%, 20%, and 25% correspondingly for mega, million, and town classes, below are some possible outcomes. According to the results of the study that was conducted by Chaturvedi and colleagues together with other researchers (2014).

Table 7. Summary of modelling data and main assumptions.

Parameters	Brief description
Urban population and city classification	377 million in 2011 living in three classes of cities; share of population in each class remains same until 2050
Per capita floor area (construction activities	Per capita residential floor area assumed to be same in each class, which grows until 2050; per capita commercial floor is certain percentage of residential floor space and assumed to be higher for mega cities
Renovation and demolition activities	Buildings due for renovations i.e. buildings in bad conditions and under 40 years old is 6.7% of total housing units; buildings due for demolition i.e. in bad conditions and over 40 years old is 1.67% of total housing units
Construction and demolition waste intensities	1300 kg/m^2; C&DW comprises concrete, broken bricks and mortar; other materials such as metals, glass, wooden frames have been excluded

Results

The yearly C&DW generation rates for different types of cities were anticipated for the period of 2012–2050 by making use of the modelling equations (Equations (1)–(7)) presented in Section 3.2 and the data given in Section 3.3. A condensed version of all of the information and

Table 8. Annual C&DW generation in different classes of cities and per city in those classes.

Year city class		2012 (millions tonnes)	2050 (millions tonnes)
Mega	Total Per city	35 3.5	203 20.3
Million	Total Per city	34 0.4	198 2.2
Town	Total Per city	64 0.008	353 0.045
Total	All cities	133	754

Table 8 contains the modelling assumptions that were used.

According to the results of the modelling that was presented, India generated around 130 million tonnes of C&DW in 2012. It is expected that this amount would increase to more than 750 million tonnes per year by the year 2050. The rates of total rubbish formation in mega-class and town-class towns were much higher when contrasted with those of million-class cities, which had the highest rates. This is due to the fact that town-level cities have a bigger proportion of commercial floor space than megalopolis-level cities do. On the other hand, megalopolis-level cities have a greater proportion of people living in them.

In addition to this, we figured out the average amount of C&DW trash generated by each class throughout all of the cities. According to the data, mega-class and million-class cities, which together make up the top 100 cities in terms of population, are the only ones where waste generation on a per-city basis was large. These cities make up the top 100 cities in terms of population. In towns that were classified as town-class, the amount of rubbish that was produced per city was not very high. The amount of garbage produced by each city in the town class was significantly lower than that of cities in the mega-class and the million-class, coming in at approximately 5000 tonnes per year, which is equivalent to 22 tonnes per day. This was in comparison to the amount of garbage produced by cities in the mega-class and the million-class. In spite of this, India's town-class cities were accountable for almost half of the country's C&DW when seen as a whole.

DISCUSSION

Consequences for the continued viability of the urban environment from an ecological perspective

The inefficient management of C&DW has a number of consequences, not just for the natural world but also for the resources found within it. In the metropolitan regions of India, for instance, land is a resource that fetches a very high price due to its scarcity. In the majority of the cities in India, a considerable amount of C&DW is disposed of in a manner that is outside the law or is buried in landfills. C&DW

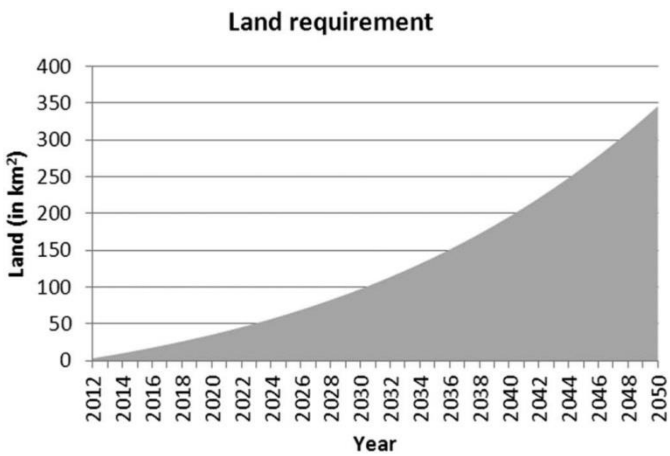

Figure 4. Cumulative land requirement for landfilling C&DW.

is difficult to move around and consumes a substantial amount of space in the garbage dump. The Central Public Health and Environmental Engineering Organization has devised a method for calculating the needed number of acres for the storage of municipal solid waste, and it has provided this method (CPHEEO). If we assume that the highest height that may be authorised for a rectangular landfill is 20 metres (CPHEEO, 2000) and that the density of C&DW is 2.1 tonnes/m3 (Ram and Kalidindi 2017), then we can store 42 million tonnes of C&DW on one kilometre square of land. This is based on the assumption that the maximum height that may be authorised for a rectangular landfill is 20 metres (CPHEEO, 2000). As a consequence of applying these statistics as well as the total annual C&DW that was estimated in the section preceding this one, a cumulative landfill space required was computed using Equation (8), and the results are presented in Figure 5 below.

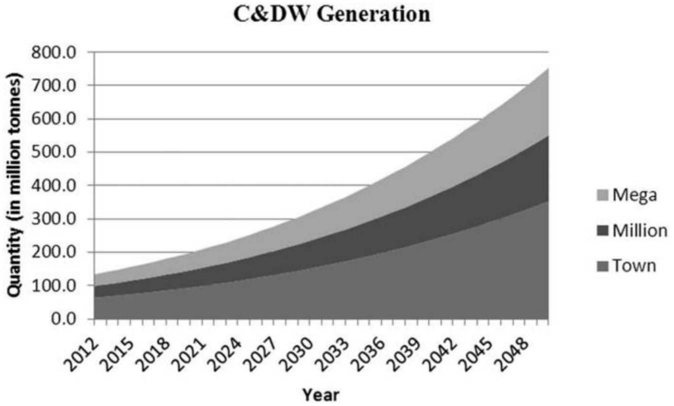

Figure 5. Projections of C&DW generation in Indian cities.

If existing disposal methods are kept, the total amount of landfill space that will be required for the management of C&DW in urban areas will reach 350 km2 by the year 2050. This projection is based on the assumption that current disposal methods will be maintained. Already operating at or very close to their maximum capacity, the landfills that service India's cities are seeing an increasing amount of waste. The only thing that will be accomplished by making an effort to find additional space for ever-increasing amounts of C&DW is that the overall management of solid waste will become more difficult. If alternative methods for the management of C&DW waste are not developed, it will be harder for cities to locate additional landfill space for their garbage.

Circular flow of materials

Per capita consumption of construction minerals in India, such as sand and aggregates, has increased 300 percent during the 1980s, at a growth rate that is comparable to the country's gross domestic product growth rate (S. J. Singh et al. 2012). As a result of comparable development trends in the economies and populations of other countries (such as the BRIC nations), the consumption of building materials in urban India will continue to climb for decades (Fernández 2007; R. Wu, Geng, and Liu 2017). This will have a wide range of effects on the environment as well as on the resources available, such as an excessive amount of sand mining (Padmalal and Maya 2014). As can be seen in Figure 6, the existing C&DW management techniques in Indian cities follow a linear pattern. This leads to the consumption of resources that are not only costly on the environment but are also non-renewable.

Circular material flow can lessen nonrenewable resource exploitation and environmental repercussions. Three C&DW recycling plants are located in New Delhi, with one additional unit located in Ahmedabad (BMTPC 2016). Both the Burari and Shastri Park C&DW processing plants in New Delhi have the capacity to handle 2500 tonnes of waste per day (BMTPC 2016). The National Building Construction Corporation established a C&DW recycling facility in Delhi with the capacity to process 150 tonnes of waste per day as a component of the government's massive rebuilding project (BMTPC 2016). Within the next two years, the government of India requires that every city in India with a population of more than one million people set up a C&DW recycling plant (MoEFCC 2016). It is anticipated that during the next several years, C&DW recycling facilities would soon be established in each of the nation's main cities. The infrastructure for recycling C&DW in India is significantly lacking and is mostly concentrated in the country's major cities. By concentrating on large cities, one overlooks town-class cities, which are responsible for 48 percent of India's C&DW (see Figure 6). There are not many curbside and drop-off waste recycling programmes in India's smaller and medium-sized cities.

Re-development under on-site C&DW recycling and the smart cities mission (SCM)

It may be possible to recycle and reuse significant quantities of C&DW on-site. The capital city of New Delhi issued directives to several government bodies ordering them to install C&DW recycling equipment in rehabilitation projects costing more than 500 million rupees (DSIIDC 2015). The rebuilding of Kidwai Nagar demonstrates how regulations from the government may encourage C&DW recycling on-site. The rebuilding project in Kidwai Nagar involves tearing down 2500 older homes and building 2500 new residences in their place. Recycling on-site of debris from demolition into bricks for use in the same project. Recycling municipal solid waste and construction and demolition debris (C&DW) reduced the demand for natural resources and landfill space.

The Indian government initiated the SCM in 2014 with the goal of improving the housing and infrastructure of one hundred cities during the next ten years. One approach for SCM is the redevelopment of metropolitan areas. In order to strengthen their infrastructure and amenities, several SCM cities are planning to remodel parts of their built environments. In the not-too-distant future, C&DW output will increase in a lot of cities thanks to active government initiatives like SCM. Recycling of C&DW generated onsite should be promoted as part of any SCM programmes.

CONCLUSION

This page provides estimates and comparisons on the amount of C&DW generation in Indian cities. India produced 150 million tonnes of C&DW in 2016, which is far more than the official estimates. The method used was dynamic MFA. We suggest conducting research on the differences in resource efficiency between large, medium, and small cities.

The amount of construction and demolition waste produced in India is expected to climb. It is possible that both the ecology and the long-term viability of the country would be jeopardised if measures to reduce and handle construction and demolition trash are not developed and adopted. The capacity of landfills is decreasing, and there is an increasing amount of rubbish from demolition, thus it is vital to reduce and manage construction and demolition waste. In that case, there can be difficulties in processing the rubbish and finding room for its disposal. This would be a strain on existing plans for solid waste management, which are already looking for novel ways to counteract the increase in municipal solid rubbish as a result of urbanisation and growth. C&D waste management should be made mandatory for all construction activities, and reforming government policies and regulations should accomplish this. We want data that is both more specific and more in-depth about the generation and management of C&D waste in India. Implementing the 3Rs policy and using waste-minimizing technology, such as designing for deconstruction and reuse, are two effective ways to reduce the amount of C&D waste. It is possible that recycling building and demolition waste into aggregate can conserve space in landfills and minimise the exploitation of natural raw materials for use in new construction, so supporting sustainable growth. The findings of the research are:

1. The reusing and recycling of waste products from construction and demolition projects in order to expand the capacity of landfills and decrease the demand for raw materials 2.
2. Carry out an investigation on a programme that recycles waste from building and demolition in relation to institutional, financial, and technological factors.
3. The recycling that has been going on for a long time cannot be maintained, which indicates that it may not be profitable the majority of the time and is occasionally considered an inactive cycle rather than an upward cycle of the actual product. 4. The recycling that has been going on for a long time cannot be maintained. As a consequence of this finding, the research in question focuses a significant amount of attention on the management of rubbish that is produced throughout the process of demolition and building by employing techniques that are centred on the eradication of waste.
4. Trash left behind from construction and demolition is considered to pose a minor risk despite its enormous volume. The practise of recycling the materials that are left behind after the destruction of buildings is one that has grown increasingly popular over the past several years as both the pace of garbage creation and public awareness of environmental concerns have increased.
5. The approach of systems dynamics should be employed in order to model the various cost-benefit ratios that are linked with construction projects. Surprisingly, as a component of the increased waste collection programme, members of the general public are expected to carry a bigger portion of the environmental cost that is produced by the unlawful dumping of rubbish.
6. Debris from construction and demolition projects are characterised not only by their physical attributes but also by a wide variety of different compositions.

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