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Quantitative and Qualitative Estimation of Construction Waste Material in Punjab Province of Pakistan

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Abstract: Despite the fact that the construction industry is a major contributor for economic growth, it inflicts negative impacts to the environment and ecology. Further, source identification, classification and estimation of waste quantities are imperative for designing waste reduction strategies. This paper aims at assessing the wastage at construction sites to provide background and baseline information for construction waste management in cities of Province Punjab of Pakistan. The types of construction waste considered for this study include (i) cutting waste (ii) theft and vandalism waste (iii) transit wastes and, (iv) application waste. As many as 500 questionnaires of well-designed structured questionnaires were distributed among civil engineers, architects, quantity surveyors and contractors. Along with educational qualification and experience, the respondents were mainly asked to score their judgments about various categories and sub-categories on percentage of ten construction wastage classes: 00-05%, 5.1-10%, 10.1-15%, 15.1-20%, 20.1-25%, 25.1-30%, 30.1-35%, 35.1-40%, 40.1-45% and 45.1-50% and reasons of wastage. Finally, the data collected were statistically processed and analyzed. Theft and vandalism had the highest average wastage of 12.77% followed by cutting waste with 10.05% wastage. While, transit waste and application waste have least overall average wastage of 8.32% and 8.39%, respectively. However, total means wastage was calculated as 9.88%. Based upon the recommendations of construction professionals, the study recommends reducing wastage to as low as possible (5% or less) for saving billions in case of mega projects and millions in case of small or medium-sized construction projects.

Key words: Construction materials · Wastes · Quantification · Classification · Construction sites · Punjab · Pakistan

INTRODUCTION

The construction waste is the material wasted in any construction process [1], which may typically be defined as the difference between the materials ordered and applied in actual at a construction site. Construction waste is generated throughout the construction process and is a mixture of surplus materials: such as bricks or blocks, concrete or crushed stones, sand, cement, wood, metals and others [2].

Construction is believed to be an important activity in terms of infrastructure and economic development [3, 4]. But it is unfriendly as far as environment is concerned. A high amount of construction waste, up to 30%, is generated during construction activities [5-7].

As this waste is not managed properly in developing countries [8], it inflicts negative impact to the environment and ecology [2, 9-12] and causes serious environmental disruption and pollution [2, 8, 13, 14], both locally and globally [15].

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Quantity of Construction Waste: Quantity and composition of construction waste keep on changing due to dynamic nature of construction activities [15] and hence cannot be exactly measured with varying construction methods and practices and specificity and phases of the project [6]. However, various efforts have been made to determine the amount of waste generated during different projects and phases of construction.

Construction waste accounts for a substantial share of 25-30% of total solid waste generated worldwide [6, 7]. As per statistical data available, construction and demolition waste around the world frequently makes 10 to 30% of the waste at many landfill sites [7, 16].

The construction process in the European Union generates 530 million tones waste annually and produces about 33% of the total waste stream [7].

A study revealed approximately 136 million tons of building-related construction and demolition debris generation each year in the US [17]. In the Netherlands, depending on type of material, about 1-10% of the amount purchased is wasted for each building material. In UK, around 70 million tons of C&D materials and soil ended up every year [18]. The construction waste contributed 16-44 % of the total solid waste generated every year in Australia [19, 20]. In China, construction activities contribute for nearly 40% of the total municipal solid waste generated every year [21, 22]. According to another study, the construction activities generate solid waste 30-40% of the total solid waste generated per year in China. In Hong Kong, contribution of construction waste has been reported to be 38% [23]; while, in other studies, 30- 40% [24-25] have been stated. In 2007, total construction waste produced was reported to be 4,656,037 tons in 2007, which accounts for 61% of the total waste (7,669,097 tons) generated that year [26]. In two separate studies, the waste produced at construction sites in Brazil have been reported to be almost 28% [27] and 20-30% of the total weight of materials on site. These results fairly resembles with the results of the studies carried out in other countries- Netherlands, Germany, Australia, UK, China etc [28].

The quantum of construction waste generated in Malaysia is to the tune of about 175,000 tonnes annually in Kuching and almost 100,000 tonnes in Samarahan [29]. The solid waste generation in India is 48 million tonne per annum of which construction waste accounts for 25% i.e. around 12 million tonne per year [30]. Another study Hamassaki and Neto [31] concluded that 25% of construction materials are wasted during the construction operations.

A survey carried out by shows that the quantity of construction waste generated is 5.8 million tons annually in Mumbai, India. In Pakistan, as many as 30% of the total solid waste generated is estimated to be comprising of construction and demolition waste [32].

Types of Construction Waste: Construction is responsible for generating a variety of wastes. A study categorized construction waste into three major classes as material, labour and machinery waste [10]. Construction material waste can also be categorized as cutting waste, application waste, transit waste and theft and vandalism [33]. The waste can also be classified into construction, demolition, civil work and renovation work waste [34]. The European Waste Catalog (EWC) defines construction waste into eight categories such as tiles, bricks, concrete and ceramics; glass, wood and plastic; bituminous mixtures, coal tar and tarred products; dredging spoil, metals, soil and stones; insulation materials and asbestos-containing materials; etc. In Hong Kong, the construction waste is divided into inert and non-inert construction waste (non-ICW) [12]. In yet another classification, contractions waste have been divided into three major categories: (1) inert (soil, sand, rocks, concrete, aggregates, plaster, bricks, masonry blocks, glass and tiles), (2) non-inert (, wood, paper, drywall, gypsum, metals, plastic, cardboard, packaging) and (3) hazardous (flammable materials like paint and corrosive materials such as acids and bases, explosive materials that undergo violent or chemical reaction when exposed to air or water) [2].

Composition of Construction Waste: The construction is responsible for producing a number of waste components including papers, wood, metal, brick, material packaging, concrete, drywall, roofing, organic material, plastics, cardboard and others [5, 35, 36]. Wood, metals, concrete, drywall, roofing, brick and others are the typical components of construction waste [37, 38].

A study conducted on 30 construction sites reveals concrete (12.32%), metal (9.62%), brick (6.54%), plastic (0.43%), wood (69.10%) and others (2%) as the major waste generated [39]. In another study the concrete was estimated to be the largest part of the construction waste. Further, the concrete is the one of the major sources of construction waste at a construction project [25, 34]. Another survey reported rubbish (40-50%), wood waste (20-30%) and miscellaneous (20-30%) in the construction waste [15].

Reasons and Resources of Construction Waste: Waste production on construction sites have been reported owing to poor or multiple handling, inadequate storage and protection, over-ordering of materials, poor site control, lack of training, bad stock control and damage to materials during delivery [18, 40]. The building material surplus is the biggest contributor to construction waste generation [41]. Moreover, reasons and sources of waste are also found in faulty design, poor material handling, lack of planning, inappropriate procurement, mishandling and other processes.

Attitude and behavior of labour, material management and design coordination [42-44], region, structural and functional type, building above ground, height underground and total floor area [45] and project size, construction method, building type, human error, technical problem and material storage method, [46] are a few other factors that influence construction waste generation.

Furthermore, lack of experience and inadequate planning mistakes and errors in design [22], frequent design changes and inadequate monitoring and control are yet another reasons responsible for generation of construction waste [47].

Likewise, external factors like theft and vandalism and other key stakeholders such as vendors, developers, architects, owners, designers and contractors influence waste generation in their capacities.

Rationale of the Study: The construction waste, in fact, contributes a major part of waste in each country, but unfortunately, in under-developed and developing countries, awareness to construction waste, being not priority, is very poor [8]. Though, disposing of waste is not the right solution, construction waste in developed countries like the US, Australia, Germany and Finland, is disposed of by dumping at landfills [2, 47]. Many countries are facing the problem of scarcity of dumping yards and exhaust of landfill spaces forcing researchers to look for an alternate and efficient waste management system.

On the other hand, in most of developing and underdeveloped countries, construction waste is a major issue in solid waste management plans. The construction waste not only creates hindrance in management of solid waste but also give ugly look, besides causing water and soil pollution [48] and threatening sustainable development in developed and developing states [1]. Evidence indicated that 50% of mineral resources from nature are consumed by the industry [49], in addition to contributing over 33% of global CO_2 [50]. Surplus construction material, which is one of the major causes of construction waste generation, also increases cost of the project significantly. Reducing construction waste by 5% could save up to £130 million in the UK [51].

The need for environmental protection led to the development of guidelines and regulations to improve the management of CW with the goal of reducing the amount of waste. In many nations, solid waste management plan is a legislative requirement for construction activities. In the UK, a legislative framework requires every project above £300,000 to produce SWMP before actual construction activities. Every maintenance, demolition, excavation, alteration, civil engineering project and decoration above the amount was required to produce SWMP before the regulation was repealed in December 2013 [51].

By devising such rules, regulations and policies, some countries have reported promising results. In Japan, the amount of construction waste dropped from 99 million tons to 77 million tons in a ten-year period (1995-2005), while the recycling rate increased from 58% to 92% in the same period [52]. The Netherlands, Denmark, Germany and the UK show construction waste recycling rates ranging between 50% and 90% [53].

Therefore, it has become essential to raise the awareness and design and implement plans for management and minimization of waste for a sustainable built environment [1]. The first step in designing and implementing such plans and programs is to categorize and estimate the quantity and composition of construction waste generated. In fact, information about quantification and classification provides the actual size of the waste and hence help in making the adequate decision for their minimization and sustainable management [54-55].

In nutshell, construction waste minimization and its management has become a serious and challenging environmental issue in the developing cities all over the world today and hence more and more research is needed in this area to combat the issue.

METHODOLOGY

Methodologies adopted for determining data for quantifying and classifying waste generation rates are diverse and usually include: direct observation by the researchers; analyzing records of contractors; survey *via* telephone and questionnaire; on-site weighing and sorting the waste materials; data acquiring through employees of construction companies; and tape measurement and truck load records. Most of the studies investigated WGRs by differentiating material waste, while others investigated waste by treating the waste stream as a whole. All the studies derived a general rate in terms of percentage (%), volume (m^3) or quantity (tons).This research study adopted (Howard, 1970 cited in Muhwezi et.al., 2012) [33] classification of construction materials waste, i.e. cutting waste, application waste, transit waste and theft and vandalism. Cutting waste includes reinforcement bars, roof carcass, roofing sheets, false ceiling, wires and cables and pipes; Theft and Vandalism waste includes cement, sand, clay, crushed stone, wood/timber, wires and cables, pipes, wood preservatives and reinforcement bars; Transit wastes includes blocks and bricks, window glazing, prefabricated windows, tiles and ceramic sanitary appliances; while Application waste includes paint, mortar, concrete and POP/POP ceiling.

For this study, data were collected through structured questionnaire distributed among civil engineers, architects, quantity surveyors and contractors, hailing from various districts of Punjab province of Pakistan. As many as 500 copies of the questionnaire were administered to construction professionals, contractors and other stakeholders involved at design and construction activities in the study area. A total of 411 copies collected were found suitable for the analysis. The data collected were presented in tables and analyzed using frequency distribution, summation, percentage and mean representations. Along with other details such as educational qualification and experience in the relevant field, the respondents were mainly asked to score their judgments about various categories and sub-categories on percentage of ten construction wastage classes as: 00-05%, 5.1-10%, 10.1-15%, 15.1-20%, 20.1-25%, 25.1-30%, 30.1-35%, 35.1-40%, 40.1-45% and 45.1-50%, besides reasons of wastages. The score of each class of wastage [frequency (f)] was multiplied by the mean (x) of each class and summation of fx was divided by the total numbers of responses (questionnaires) i.e. 411, to calculate mean (%) of each construction material in all four categories of wastes. Mean wastages (%) of all four types of wastes was calculated by taking mean of all constituents in each and every category of the waste. Similarly, reasons of wastage were determined by calculating percentages of responses. The same methodology was adopted by Babatunde and Olusola [4]. Moreover, respondents were also asked to give reason of each sub-category of the waste in the questionnaire.

RESULTS AND DISCUSSION

The average years of professional experience of respondents were approximately five years. So, it can be concluded that the respondents were suitable and have acquired adequate relevant experience of the construction industry. Therefore, based on this ascertain, the information provided by these respondents was considered reliable and dependable.

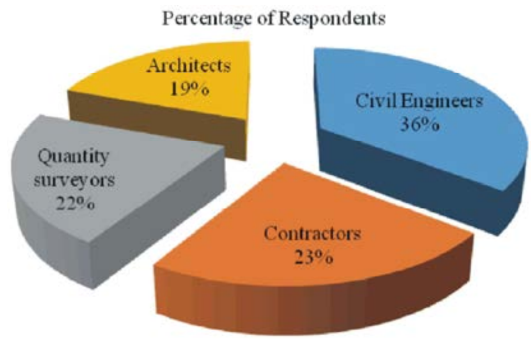

Fig. 1: Percentage of respondents in the survey

The percentage designations of respondents indicated that 35.52% were civil engineers, 23.36% were architects, 21.65% were quantity surveyors and 19.46 % were contractors. Based on this information, it can be stated that civil engineers, followed by contractors, played a major role in this study. As far as academic qualification of respondents is concerned, 56.45% were bachelors and 18.49% was masters' degree holders. Hence, it can be deduced that most of the respondents were highly educated and were information provided by them were reliable.

Table 1 exhibits the quantitative assessment of cutting waste generated on construction sites. Table 1 also shows that pipes had highest percentage of wastages (12%), followed by false ceiling (11.44%). On the other hand, wires and cables and roofing sheets have the least percentage wastages (7.67% and 8.73). Table 6 shows that error in calculation/cutting and poor material handling/operations are the main reasons behind this high percentage. However, in another study in Nigeria, wastage of reinforcement bars was found to be highest (19.03%), followed by wires and cables (17.26%) and roofing sheets and pipes (both 15.70%). Poor and multiple handling of tools and inadequate training of the construction workers to handle sophisticated equipment were stated to be reason of wastage [4]. Almost same wastage due to cutting (10%) was reported by Katz and Baum [57].

Table 1: Quantitative Assessment of Cutting Waste at Construction Sites

		No of responses against each types of cutting waste [Frequency (f)]					
Class Intervals	Means (x)	Reinforcement bars	Roof carcass	Roofing sheets	False ceiling	Wires and cables	Pipes
00-05%	2.5	137	103	135	90	119	51
5.1-10%	7.5	109	133	123	121	190	90
10.1-15%	12.5	46	80	71	85	75	153
15.1-20%	17.5	75	55	81	51	23	85
20.1-25%	22.5	23	26	1	38	4	30
25.1-30%	27.5	10	11	0	17	0	2
30.1-35%	32.5	9	2	0	9	0	0
35.1-40%	37.5	2	1	0	0	0	0
SUM fx		4207.50	4207.50	3587.50	4702.50	3152.50	4932.50
Mean (%)		10.24	10.24	8.73	11.44	7.67	12.00

Table 2 shows quantitative assessment of Theft and Vandalism (T&V) during construction. Data in Table 2 indicated that Wood/Timber have highest percentage of wastages of 16.78 %, followed by sand and cement with percentage of 16.03 and 13.80%, respectively; while wood preservatives and pipes have the least percentage wastages of 8.90% and 10.65%, respectively. The main reason for this wastage was found to be improper storage as indicated in Table 6. Contrary to this, Babatunde and Olusola [4] reported that reinforcement bars, timber and cement had the highest percentage of wastages (18.64%, 18.64% and 18.44%, respectively), due to workers' poor or no educational level and poverty in Nigeria.

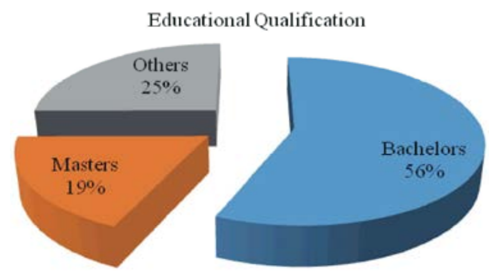

Fig 2: Percentage of educational qualification of the respondents

Table 3 reveals that blocks & bricks, tiles and window glazing have the highest percentage of wastages of 13.61%, 10.19% and 6.79%, respectively, in the category of Theft and Vandalism waste.

Table 2: Quantitative Assessment of Theft and Vandalism (T&V) Waste at Construction Sites

		No of responses against each types of T&V waste [Frequency (f)]								
Class Intervals	Means (x)	Cement	Sand	Clay	Crushed stone	Wood or Timber	Wires & Cables	Pipes	Wood preservatives	Reinforcement bars
00-05%	2.5	53	34	48	66	55	67	100	88	73
5.1-10%	7.5	86	63	100	110	50	103	80	203	146
10.1-15%	12.5	69	56	169	92	61	84	149	37	92
15.1-20%	17.5	139	127	36	36	107	85	55	83	49
20.1-25%	22.5	39	101	57	66	67	70	13	0	31
25.1-30%	27.5	18	28	1	28	33	2	9	0	17
30.1-35%	32.5	7	2	0	12	18	0	5	0	2
35.1-40%	37.5	0	0	0	1	20	0	0	0	1
SUM fx		5672.50	6587.50	4922.50	5452.50	6897.50	5107.50	4377.50	3657.50	4552.50
Mean (%)		13.80	16.03	11.98	13.27	16.78	12.43	10.65	8.90	11.08

Table 3: Quantitative Assessment of Transit Waste at Construction Sites

Class Intervals	Means (x)	No of responses against each types of transit waste [Frequency (f)] Blocks & Bricks	Window glazing	Prefabricated windows	Tiles	Ceramic sanitary appliances
00-05%	2.5	70	115	211	53	219
5.1-10%	7.5	93	208	151	128	146
10.1-15%	12.5	81	30	43	187	45
15.1-20%	17.5	83	30	4	42	1
20.1-25%	22.5	27	2	2	1	0
25.1-30%	27.5	42	0	0	0	0
30.1-35%	32.5	14	0	0	0	0
35.1-40%	37.5	1	0	0	0	0
SUM fx		5592.50	2792.50	2312.50	4187.50	2222.50
Mean (%)		13.61	6.79	5.63	10.19	5.41

Table 4: Quantitative Assessment of Applications Waste at Construction Sites

Class Intervals	Means (x)	No of responses against each types of applications waste [Frequency (f)] Paint	Morter (cement+sand)	Concrete (mortar+stone)	POP/POP ceiling
00-05%	2.5	100	60	83	140
5.1-10%	7.5	178	207	211	171
10.1-15%	12.5	95	67	92	86
15.1-20%	17.5	38	60	22	13
20.1-25%	22.5	0	13	3	1
25.1-30%	27.5	0	3	0	0
30.1-35%	32.5	0	1	0	0
35.1-40%	37.5	0	0	0	0
SUM fx		3437.50	3997.50	3392.50	2957.50
Mean (%)		8.36	9.73	8.25	7.20

Table 5: Quantitative Assessment of Waste Types on Construction Sites

Waste Types	Mean Wastage (%)
Cutting waste	10.05
T & V Waste	12.77
Transit waste	8.32
Application Waste	7.39
Total Waste	9.88

While ceramic sanitary appliances and prefabricated windows have the least percentage of wastages with 5.41% and 5.63%. As against this study, a survey indicated tiles, window glazing and ceramic sanitary with highest wastage of 21.38%, 14.73% and 14.72%, respectively [4], while prefabricated windows and blocks/bricks with least percentage wastages of 11.58% and14.15%, respectively. The reason was reported to be deplorable road network in Nigeria.

Table 4 describes that mortar has the highest percentage of wastage of 9.73%, followed by paint with wastage of 8.36%, whereas, application of POP/POP ceiling and concrete has the least percentage of wastages of 7.20% and 8.25%, respectively, among the application waste. Reason behind this wastage was found to be over ordering and improper storage as shown in Table 6. Whereas, in another study conducted in Nigeria, wastage of the POP ceiling was reported as highest (15.70%),

Table 6: Reasons and source identification for each kind of waste

Sources/reasons of wastage	Cutting waste (%)	T&V waste (%)	Transit waste (%)	Application waste (%)
Faulty or fancy design	13.14	-	-	-
Improper storage	-	69.34	-	14.36
Over ordering	-	24.57	14.84	60.58
Error in calculations/cutting	62.77	-	-	-
Poor material handling/operations	24.09	6.08	-	10.95
Poor planning	-	-	6.81	14.11
Transportation	-	-	78.35	-

followed by wastage of mortar (14.91%), concrete (14.13%) and paint (12.95%), respectively. The reason was stated as multiple handling of tools and inadequate training of the workers to handle sophisticated equipment [4].

Table 5 represents the overall mean percentage of waste categories on construction sites. Data in Table 5 demonstrated that theft and vandalism has the highest average wastage of 12.77% followed by cutting waste with 10.05 % wastage. Transit waste and application waste have least overall average wastage of 8.32% and 8.39%, respectively. All the respondents were of the view that overall mean percentage of waste at any construction project should not be more than five percent.

Earlier, a study conducted in Nigeria, concluded that theft and vandalism waste had the highest average level of 16.58% followed by cutting waste with 15.44%. Application waste and transit waste had the least overall average wastage of 14.16 % and 14.89% respectively [4].

In this study, the total means wastage was calculated as 9.88%, which is in accordance with the findings of previous study, Shen *et al.* [58], which reported wastage rate as equivalent to 1-10% of the purchased construction materials and much less than the reported by Yahya and Boussabaine [59], who found out wastage of about 25% of construction materials during construction activities. The wastage rate in Nigerian and the UK construction industry were reported as high as 15.32% [4] and 10-15% [60], respectively. In another study, surprisingly, 30% of the weight of total construction materials on site has been reported in the UK.

From business and financial viewpoint, the cost of construction waste revealed in this study is too high. Reducing wastage to 5% or less may certainly help in saving billions in case of mega projects and millions in case of small or medium sized construction projects.

Table 6 shows that 62.77% respondents believe that the reason for cutting waste is error in calculations and cutting while 24.09% were of the view that poor material handling/operations are the main reasons. Improper storage was declared as the major source of theft and vandalism waste by 69.34% respondents.

Similarly 78.35% construction stakeholders opined transportation as main cause of transit waste. Therefore, it can be concluded that careful calculations and proper material handling can lead to reduction is cutting waste. Similarly, theft and vandalism waste can be reduced by proper storage of the construction material.

However, respondents indicated multiple reasons for wastage of application waste including over ordering (60.58%), improper storage (14.36%), poor planning (14.11%) and poor material handling/operations (10.95%)

In general, it may be deduced that all the construction materials have higher percentage wastages due to poor and multiple handling of tools and inadequate training of the construction workers to handle sophisticated equipment. Theft and vandalism was supposed to be very common among poor, unskilled and uneducated workers.

CONCLUSION

This study identified four major types of construction materials, which includes cutting, theft and vandalism, transit and application wastes. The study finally concluded that construction materials wastage accounted for an average of 9.88% at the construction sites in Punjab province of Pakistan. The main reasons behind wastage were found to be poor transportation/network of transportation, error in calculations/cutting, improper storage, over ordering and poor material handling. This wastage increases the cost of project to billions in case of mega and millions in case of micro projects. Therefore, the study recommends reducing wastage to as low as possible (5% or less) by overcoming the reasons of wastage to minimize environmental hazards and reduce the costs of projects and make solid waste management systems manageable.

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