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Classification of Construction Waste Generation Attributes in Project Life Cycle

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***Abstract*- Waste generation is a major issue faced by construction projects. Construction waste has adverse effects the time, cost, productivity and economy of the industry. There are different causes of waste generation in different countries of the world. An extensive literature was carried out to identify the common factors of construction waste generation which resulted in identifying 59 common attributes. Through structured interview data was collected to classify the attributes on different stages of construction project lifecycle. A total of 15 experienced practitioners were interviewed classify the attributes into different phases of project life cycle. Frequency perception of the practitioner revealed that typical attributes are 25 in planning phases, during design phase 9 attributes occur, that during construction phase 53 attributes occur while at the final stage only 5 are encountered. From the findings it can be seen that construction stage is the critical stage in which 53 attributes are occurring. This study shows that the practitioners need to be very careful during construction phase for controlling construction waste generation.**

***Index Terms*—Construction waste, construction industry, Pakistan, Project life cycle**

I. INTRODUCTION

Construction waste is any loss resulted from the construction tasks which consume resources but does not increases the value of project [1-6]. Sometimes construction waste is by-product of construction works from the start of the project till its finishing [7-10]. Construction waste is classified into two types as waste generated from value added activities and waste generated from non-value added activities. Value added activities are those which are responsible for waste generation but also increase the value of project. Non-value added activities are those which produce waste but add no value to the project [11]. Other researcher classified waste as physical waste and non-physical waste. Physical waste involves wastage of materials in the construction activities. However, non-physical waste includes the waste of time and cost of project [12-15].

Construction waste has a direct effect on the time and cost of project. It also has a negative impact on the country's economy [14]. Construction waste is generally deposited in landfills but during recent years, in many countries waste is incinerated because of unavailability of enough spaces for landfills. Incinerators are very expensive and also require timely maintenance [16]. Even the waste disposed off to landfills is also very costly because local authorities demand high charges for transportation. If generated waste is left unattended then it would be dangerous to human health and other living beings [17].

Construction waste has an adverse impact on the environmental sustainability [18-20]. It involves environmental pollution, ecological damage and also effects the sustainable developments in any country. Construction waste is also causing shortage of land because of illegal dumping of waste and spoiling the beauty of environment [21-24].

II. LITERATURE REVIEW

The Volume of construction waste is increasing day by day because of the increasing population and living standards of people. Various researchers have notified the amount of the waste generation in the world.

- Bangladesh produces approximately 16015 tons of waste per day and it is estimated that it may grow up to 47000 tons per day in the year 2025.
- China produced 29% of the globe's total municipal solid waste and half of that is produced by construction waste.
- Egypt produces 89.03 million tons of solid waste, which includes 4 million of construction waste [8].
- Kuwait generates construction waste of 1.6 million tons per year from construction and demolition activities which includes waste of concrete, bricks, sand, steel and wood [9-10].
- Gulf Cooperation countries (GCC) generates a total waste of 80 million tons annually. Out of which 40 million tons is produced by the construction and demolition activities [12].
- Spain's construction industry produces 39.27 million tons of waste per year.

- The construction industry of United Kingdom generation a waste of more than 100 million tons out of which 16% are the materials which were not even used but only brought to site and then disposed of [13].

Construction waste is generated due to various factors which occur during different activities in different stage of project life cycle. A comprehensive literature review was conducted to identify the construction waste generating attributes. There are different factors of waste generation in different countries of the world. Numerous studies have highlighted the factors causing construction waste generation.

- Tam et.al in [14] conducted a study in Hong Kong reported that poor storage techniques, improper material handling, effects of weather, accidents and design changes are the causative attributes of waste generation. Moreover, findings of another study concluded that unclear design, in appropriate construction methods damage due to subsequent work are the main causes of waste generation.
- In Indonesia, A study concluded that the factors of waste generation are lack of waste management plan, design changes, poor coordination among staff, lake of trade skills, inappropriate construction methods, late material delivery and poor planning [15].
- An investigation carried out in Jordan mentioned that waste generating attributes are improper storage of materials, traditional construction methods, poor management, and unskilled labors and rework [16].
- Nazech et.al in [8] identified causative attributes of waste generation in construction industry of Saudi Arabia are poor material handling, lack of construction waste management plan, design changes, unskilled labor, low quality materials, shortage of resources delivery in loose form and theft and vandalism are the attributes of waste in Saudi Arab's construction industry.
- Bajjou & Chafi in [15-24] concluded that causative attributes of waste generation in the construction industry of Morocco are lack of waste management strategy, lack of communication among stakeholders, long duration project, poor material handling, unskilled labor, late payment and effects of ground condition.

- The factors of waste generation occur from various activities at different stages of the project lifecycle. Project life cycle is a sequence of stages of project. Project life cycle is divided into four stages and the phases are planning, design, construction and finishing
- Planning stage: During this stage, the client explains the work requirements for the construction project. The activities include calculating the project's objectives, preliminary costs, and funding sources.
  Any issue regarding to the project is taken into consideration and the alternative solution is suggested.

- A research was carried out in New Zealand reported that cutting uneconomical shape, inappropriate storage of materials, damage during transportation, last minute client's requirements, improper material handling, order errors, accidents, effects of ground condition, equipment malfunction and vandalism are key causes of waste generation [11]
- The Oman construction industry generated a large amount of waste as a result of frequent design changes, incorrect material storage, poor site management amd lack of skilled workers [12].
- According to a Pakistani study, the factors causing waste generation are poor workforce performance, improper material handling & storage; and changes in design [13]. Another researcher mentioned that in Pakistan waste is generated due to poor site layout, lack of waste management plan, and inappropriate storage of materials, effects of ground condition, poor resource allocations and rework [14].
- Sri Lanka is also facing the issue of waste generation [23]. Waste generated due to poor planning, late information flow, poor management control and shortage of resources.
- Al-Hajj & Hamani in [17] carried out a study in United Arab Emirates to identify construction waste generation causes. Study identified the factors of waste generation including cutting uneconomical shape and size, poor quality materials, poor resource allocations, rework and poor material handling.
- In Vietnam, it was concluded that waste is generated because of too late supervision, poor Planning, equipment shortage, inappropriate construction methods, poor site layout, poor material handling, outdated equipment low quality materials and complicated information [18].

- Beside these, there numerous research studies carried out globally in identifying the factors which result in waste generation. An intensive literature review was carried out to identify the common factors which cause waste generation on construction sites as summarize in [18-22].

- Design stage: This phase plays very important role in the construction as all the execution works will follow the design instructions. In this phase, all the design specifications and the concerned drawing are prepared and then bid process is carried to select the appropriate contractor for converting design into actual physical works.
- Construction stage: The contractor is solely responsible for translating the client's requirements in the form of drawings into reality. They must adhere to the specifications provided when carrying out the construction work. A continuous monitoring process is

carried out throughout the period to ensure that all the activities are being carried out in accordance the with design and contract conditions.

- Finishing stage: This stage ensures that all the works assigned to contractor are completed as per requirement. Concerned team representing client and consultant inspects all the work done and then the project is handed over to the client.

III. RESEARCH METHODOLOGY

This study was conducted by qualitative mode of research using interviews. Interviews were conducted from the experts involved in the construction projects with the help of structured questionnaire form. Questionnaire form consisted of 2 sections where first section was aimed to gather demographic information while second part of the questionnaire was designed to perceive the perception of the practitioners regarding relevancy level of the factors with Pakistani construction environment. The respondents were provided with list of the factors to park in the relevant phase of construction project life cycle. The analysis of the collected responses was analysis based on frequency.

IV. RESULTS AND CONCLUSION

A total 15 practitioners working on construction sites were interviewed. The demographic information of the respondents was assessed and presented in table II.

Table II shows minimum experience of the respondents participating in interview session is 6 years and maximum experience is 24 years. Total experience of the 15 respondents is 209 years with average of 13.93 years. The respondents represent all three major stakeholders i.e. client, consultant and contractors with 5 respondents from each group respectively. The respondent are bear sound academic background where 11 respondents have completed bachelor degree while 2 respondents have obtained master degree and 2 respondents are diploma holders. These respondents are holding engineering and management positions in their respective organizations.

Based on table II, as shown in table III, there are 25 attributes in the planning stage, 9 attributes in the design stage, 53 attributes in the construction stage, and 5 attributes in the finishing stage.

Frequency analysis regarding parking the attributes of construction waste in different stages of the project lifecycle is shown in Table II.

TABLE I
DEMOGRAPHIC INFORMATION OF RESPONDENTS INTERVIEW

S.No.	Designation	Type of Organization	Qualification	Experience
1	Assistant Engineer	Client	B.E. (Civil Engineering)	24
2	Project Engineer	Consultant	B.E. (Civil Engineering)	23
3	Construction Manager	Contractor	B.E. (Project Management)	20
4	Executive Engineer	Client	B.E. (Civil Engineering)	19
5	Resident Engineer	Consultant	B.E. (Civil Engineering)	17
6	Deputy Director	Client	M.E. (Construction Management)	15
7	Project Director	Contractor	B.E. (Civil Engineering)	14
8	Assistant Engineer	Client	B.E. (Civil Engineering)	12
9	Project Manager	Contractor	B.E. (Civil Engineering)	12
10	Resident Engineer	Consultant	B.E. (Civil Engineering)	12
11	Resident Engineer	Consultant	B.E. (Civil Engineering)	11
12	Assistant Resident Engineer	Consultant	M.E. (Construction Management)	9
13	Sub Engineer	Client	B.E. (Civil Engineering)	8
14	Site Supervisor	Contractor	Diploma (Civil Engineering)	7
15	Site Supervisor	Contractor	Diploma (Civil Engineering)	6

TABLE III
FREQUENCY TABLE SUMMARY

S.NO.	Stages of Project Life Cycle	Number of Attributes
1	Planning Stage	25
2	Design Stage	9
3	Construction Stage	53
4	Finishing Stage	5

TABLE II
FREQUENCY TABLE OF WASTE GENERATING ATTRIBUTES

S.NO	Construction Waste Generation Attributes	Planning	Designing	Construction	Finishi
1	Accidents	4		12	3
2	Communication problems	9	6	7	
3	Damage caused by workers	1	2	12	4
4	Damage during transportation	7		10	1
5	Delay during delivery	8	1	5	3
6	Design and detailing error	4	13	3	2
7	Difficulties in excessing construction site	7	3	10	1
8	Effect of weather	3		13	7
9	Equipment failure	3	3	13	1
10	Error in contract documentation	12	3	5	5
11	Frequent design changes	4	9	8	2
12	Inappropriate construction methods	5	2	11	1
13	Inappropriate resource allocation	9	2	10	
14	Inappropriate use of materials	4	2	11	3
15	Incompetent workers	3		11	6
16	Insufficient methods of loading	6	3	9	1
17	Insufficient training for workers	5		12	4
18	Interaction between various specialists	8	6	7	2
19	Interference of other crew at site	2		13	2
20	Inventory of materials not well documented	10	3	6	
21	Items not in compliance with specification		2	11	5
22	Lack of awareness among the workers	2	3	10	4
23	Lack of coordination among parties	10	7	8	2
24	Lack of design information	4	12	4	1
25	Lack of environmental awareness	7	4	7	4
26	Lack of experience	6	3	9	4
27	Lack of influence of contractors	6	6	10	4
28	Lack of legislative enforcement	9	1	6	4
29	Lack of knowledge about construction	3	5	10	2
30	Lack of waste management plans	7	1	6	5
31	Last minute client requirements	5	1	8	4
32	Late information flow among parties	6	4	10	
33	Left over material on site	3		8	7
34	Long project duration	10	1	5	5

S.NO	Construction Waste Generation Attributes	Planning	Designing	Construction	Finishing
35	Material supplied in loose form	5		13	1
36	Ordering errors	11	3	6	
37	Outdates equipment	4		10	4
38	Poor attitudes of workers	1	1	14	3
39	Poor controlling	2	2	11	2
40	Poor design quality	2	8	7	4
41	Poor information quality	6	7	7	2
42	Poor material handling	1	1	14	3
43	Poor planning	12	2	5	1
44	Poor quality of materials	1	2	13	4
45	Poor site conditions	5	1	12	2
46	Poor site management	7	1	10	2
47	Poor supervision	3	2	12	3
48	Poor workmanship	2	2	12	4
49	Rework	2	2	10	7
50	Scarcity of equipment	3	1	12	2
51	Supplier error	7	1	10	2
52	Shortage of skilled workers	3	1	14	3
53	Theft and vandalism	4	1	10	6
54	Unforeseen ground conditions	8	3	7	1
55	Waiting periods	9	3	8	
56	Wastage due to cutting	1	4	13	1
57	Waste resulting from packaging	3	2	11	1
58	Worker's mistake during construction	2	1	11	4
59	Wrong material storage	10	1	6	3

V. CONCLUSION

This study was conducted to identify and classify the construction waste generation attributes. Review of literature resulted in identifying 59 common attributes of construction waste generation globally. 15 experience practitioners were interviewed to confirm the attributes and park in to various phases of project life cycle to categorize the factors. Frequency analysis of the data collection in interview session revealed that construction stage is the critical stage where 53 attributes occur while in planning stage 25 attributes occur. In design stage only 9 attributes occur while in finishing stage 5 attributes are faced. This study would be helpful for the practitioners to understand the problem of construction waste.

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