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Strategies for Effective Waste Management in Hydropower Construction Projects

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ABSTRACT

Construction materials employed in the sustainable design are commonly subjected to wide network of processing, extracting and transporting steps that are needed in creating the end products. Excess quantity and improper utilisation of the construction materials are the root-cause of the construction waste generation. These wastes probably contribute a major negative impact on the environmental sustainability. With regard to this, the present study investigates the construction waste generation and management practices in hydropower project. In order to work on the objective of the research, the study adapts quantitative research methodology. Data for the present research are collected from 195 experts working in the construction of hydropower project. Purposive sampling is employed in selecting the respondent population for the present research. Collected data are analysed using statistical tests such as one-way ANOVA, paired sample t test, bivariate and partial correlation analysis and regression analysis in SPSS tool. The overall results of the research disclose that metals such as iron and steel and plastics are observed to have major contribution in waste generation. These construction wastes are observed to have major impact on the environmental sustainability. Economic burdens are reported to be major issues faced during the waste management practices. Also, implementation of 3R strategies are observed to have neutral response from the respondent population. There is a significant relationship between proper and adequate storage of construction materials and waste generation level. Additionally, it underscores the importance of complying with regulations and implementing best practices to enhance the credibility and public backing of hydropower ventures. Ultimately, this study provides useful recommendations for waste management in the construction sector to assist policymakers and industry professionals. This promotes sustainability and aids hydropower projects in meeting clean energy goals with minimal ecological harm. In addition to this, corresponding discussion and policy recommendation have been proffered in subsequent sections.

Index-words: *Environmental sustainability, Hydropower project, Waste generation, Construction wastes.*

I. INTRODUCTION

For several decades, the construction sector is recognized as a significant contributor to environmental degradation due to the substantial amount of waste generated during demolition, construction, and associated restoration activities. In Malaysia, the construction industry plays a vital role in both economic and infrastructure development [1]. However, the prevalent "use and throw away" mentality has led to unsustainable practices that inhibit the efficient use of natural resources and contribute to rising pollution levels. Therefore, it is crucial to raise awareness and revise outdated practices within the construction sector. Waste generated from construction encompasses not only activities related to building, renovation, and demolition but also includes impacts from material delivery and land clearing operations. The waste typically comprises materials such as concrete, wood, bricks, packaging materials, plastics, cardboard, and paper [2]. Categorizing construction waste involves studying its quantity and composition, which aids in understanding the sources and causes of waste generation. Additional information can be gathered through assessments that include field surveys, waste quantification, and site observations. The definition of construction waste varies depending on the type of construction and practices involved in sampling [3]. Generally, construction waste is defined as solid waste specifically arising from construction activities, including demolition, renovations, and land clearing operations [4].

Recently, huge number of projects regarding housing have increased because of the financial support offered by the federal government. Due to the housing loan schemes, the accessibility to housing is observed to have considerably increased for the lower income groups due to the assistance offered by the housing loan schemes offered by the government [5]. This in turn, signified that generation of construction waste will be massively increased in the country in the upcoming epoch and will continue to grow. Around 28.34% waste generated in Malaysia is reported to generate due to the construction waste. Regarding this, minimisation of construction waste is regarded as the major issue in the city [6]. Many investigators emphasise that every residential project should adopt the organised construction waste management system to reduce and regular the construction waste generation in the construction sites. A proper set for an appropriate waste management system for the construction sector can be framed only when a set of data regarding the recent structure of the construction waste is generated [7]. In regions like Malaysia, very limited research is reported to be conducted on the problems regarding the construction waste. People who are employed in the construction sector should be educated regarding the waste generation from the constructions as well as in demolition. They should also be educated about the recycling and reuse of the construction waste [8].

This construction waste can be classified as handling, design, worker, condition of the site and management. These types of waste are observed to be derived from the data that are fetched from the existing researcher who is concerned with investigating various kinds of waste observed while executing each of these activities. Most of the construction projects utilise steel since they are employed as a structural integrity and reinforcement [9]. The main causes to consider steel as the major waste in the construction site are irresponsible cutting and associate fabrication issues. In addition to this, the worst sites commonly end up in being the ones which do not have enough amount of design information and standards that can result in waste because of the short bars that are incomplete due to inappropriate planning of the steel cuts [10].

Recently, several companies prefer to select preassembled steel reinforcement pieces. This would absolutely reduce the waste by farming out the bar cuttings to industries that prioritise the responsible utilisation of construction materials. Almost every guideline regarding the construction and demolition waste management adopts the waste management framework [11]. The waste management hierarchy model is observed to involve a set of alternatives to deal with the wastes that are sorted in a descending order of preference. The waste hierarchy is an internationally and nationally accepted domain that is employed to priorities and guide efforts in managing the waste. Under the notion of waste hierarchy, there is an implementation of 3R's which is commonly regarded as Reduce, Recycle and Reuse. Some countries implement different numbers of R's.

The concept of 4R's are used by the European Union that includes Recovery with other existing concepts for the reduction of the waste materials [12]. Certain other alternatives include energy recovery, disposal and prevention. There is a huge possibility to recycle several elements found in the construction wastes. Often roll-off containers are employed to transport the waste generated from the construction sites. These rubbles can be crushed and reutilised in the construction projects. Woods that are left as wastes can also be recycled and recovered. When there is no possibility to recycle, disposal of these construction wastes should be performed on the basis of the legislation of regulatory and relevant bodies. The penalties for inappropriate mechanism of disposal of the construction and hazardous waste include asbestos that can reach into tens of thousands of dollars for the individuals and business. More than 13% of municipal waste is reported to burn with the waste of energy facilities. The toxic fumes eliminated by the WTE plants possess hazardous chemical substances such as mercury and other heavy metals such as dioxins, carbon monoxide and sulphur dioxide.

Dioxin is utilised as a waste oil in Times Beach located in Missouri [13]. Animals are observed to die after the introduction of chemicals to the community. Considering the massive damage caused by the chemical utilised during the construction process, the Time Beach has been relocated and advised Missouri to construct new incinerator in the affected land. Yet, they continued to burn around 265,000 tons of dioxin affected waste till the year 1997. The wastes generated from the construction sites are reported to be in great danger to the environment sustainability. This has considerably created pressures for the construction industries and also motivated them to create suitable techniques to safeguard the environment across all the industries. Quality

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and quantity of waste generate are reported to vary based on the projects and are also dependent on the circumstances and kinds of materials that are employed in the project. Thus, additional efforts should be put in designing the technology for recycling these construction wastes. For example, concrete waste should be crushed and utilised as recycled collections [14].

Wastes generated during the construction process is one of the controller solid wastes. 3R practices illustrate the concept of reduce, recycle and reuse. Here,

- **Reduce:** Reduction is regarded as the most effectual technique for managing the waste generated in the constructions. This not only reduces the waste generation, but it can also diminish the expense for the waste recycling, removal and transportation [15].

- **Reuse:** Reuse is commonly regarded as the favourite opinion since certain construction waste can be reutilised in other construction sites. Reuse is considered as the most advantageous contractors that can save money as the disposal involved expense. Reuse is the process of employing the similar materials more than once for the same function such as model in the construction works. Materials that cannot be reused or recycled are sent to the recycling centre [16].

- **Recycle:** When the reduction and reuse turn difficult, the recycling process is preferred. Certain new materials are generated through the recycling process. This process is categorised into two sections that include on-site and off-site. On-site recycling is regarded as the process of segregation of the construction waste for the ensuing utilisation as the materials in the construction process. Whereas off-site recycling is process of separating the construction waste that is later transported to other organisations or sites and the extracted waste is utilised with another set of raw materials for constructions. 3R practice has recently become more familiar as it is employed as the option and policy in other alternatives of the waste hierarchy domain on the basis of using the resources prior to the disposal process [17].

Significant efforts have been made to focus on 3R strategies with the objective of mitigating the solid wastes. Several developing countries were reported to face problems due to high waste generation during the construction process. Sustainable waste management is observed to remain as the least prioritised option among most of the contractors. Adoption of 3R strategies are also reported to be low which has considerably increased the waste generation during the construction projects. Most of the building contractors do not practice the concepts of segregation, reuse, recycling and reduction at the construction sites. These irresponsible practice of improper use of construction materials impacts the environmental sustainability and generates a huge amount of wastes that is typically hard to recycle and reuse [18]. Data regarding the waste generation process maintained by the local executives are observed to extensively varying and are also reported to be unstandardized. Most of the existing literatures make considerably efforts to investigate about the significant waste contributors and rate of waste generation during the construction process with different perspectives. Through extensive analysis, it is found that there are very few literatures that focus on all possible measures such as significant waste contributors, impact of these wastes on the environments as well as on the human health conditions and other possible associated factors [19]. Thus, with this perspective, the efforts and the contributions of the present research are unique among the existing literatures.

A. *Problem Statement*

Wastes of the construction sectors have high probability to create negative impact on the environment such as soil contamination, high energy and natural resources consumption, environmental degradation, air pollution and waste pollution. Less concerned attitude and efforts would be the problems that are left unspoken. Though, a lot of awareness programs are conducted and practiced, the necessary adoption of measures are ignored in most of the regions. Very few literatures illustrate the impacts and contributions of construction wastes. Keen research and observations will probably aid understanding the actual plight that will be created due to the massive generation of construction materials.

B. *Research Objectives*

The present research is constructed based on the following objectives:

- To identify and categorise sources of waste generation during the construction period in the Hydro power project.
- To analyse the environmental and economic impacts of waste generation during the Hydro power project construction.
- To evaluate the current practices followed by the management to minimize waste generation.
- To investigate the factors contributing to construction wastes (CW) generation in the power plant.
- To access the contribution of various construction activities to overall waste generation in hydropower projects.

C. *Paper Organisation*

With the aim of accomplishing the objectives, the present study is developed in such a way that section 1 commences with the introductory part, section 2 with literature review where the existing literatures are reviewed, section 3 includes the methodology of research, section 4 comes with the results and 5 with discussions, section 6 conveys the limitations of the present study and section 7 concludes the study with future recommendations. Section 8 proffers the policy recommendation in relevance to the formulated results of the study.

II. LITERATURE REVIEW

The concept of construction waste generation and management is one of the least prioritised problems in the present community. Several investigators work with the intention to research about the significant cause and measures that should be adopted to mitigate the waste generation. Certain existing literatures are showcased in this section. Demolition and construction wastes have a significant contribution to the industrial waste that is passed to the landfill. On the basis of this, [20] works with an intention to find the existing factors influencing the construction and demolition waste management in New South Wales, Australia. To work on the objectives of the study, semi-structured interviews are conducted with the 19 respondents who are in charge of construction and demolition waste management. Data collected through interview are analysed using Nvivo software. Certain identified key factors are identifying economic value of diverted material, knowledge, experience, online sorting and training of site operatives. In addition, factors such as a need for the dealer to include appropriate forecasting of waste management costs and verification of enhanced techniques of construction and demolition of waste management and disposal are highlighted. In the period of 2018-2019, Australia produced around 27Mt of construction and demolition waste which is equal to 44% of total waste. Though 76% of the identified wastes is sent for the recycling process, the observations report that there is about 61% of total increase in waste in the period 2006-2007. Thus, prioritising and mitigating the waste management are needed to construct a circular economy in the regions of Australia.

With regard to this, [21] aims to determine the perception of the Australian construction sector regarding the existing waste minimisation. To work on the objective of the study, a semi-structured interview is organised among 50 industrial experts. The collected data are analysed with both quantitative and qualitative research methodology. The outcomes of the research emphasise that the initial contributor to the practice of personal realisation and implementation of waste management are significant. The results also signify that building information modelling are observed to have the potential to reduce the waste considerably. Similarly, [22] intends to research the mediating influence of policy associated features on the relationship among the practice of waste generation and sustainable waste minimisation process. A pilot test is performed for identifying the potential questionnaire adjustments. A survey is conducted among 220 construction professionals. Data are collected using Structural Equation modelling (SEM). The results of the study disclose that policy associated factors are observed to mediate the association among enhancing features and maintainable construction waste mitigation.

Conversely, they do not mediate the association between existing practices and maintainable construction waste management. [23] aims to interpret the associated challenges of construction and demolition waste management, exploring the opinions of waste regulation, schemes and policies and the contribution of the federal government. To work on the objectives, an online survey is performed in the year 2019 to understand the perceptions of the stakeholders. The outcomes of the research emphasise that the main challenges are tough acceptance, increased testing demands, lack of local market and over-regulation, poor education level. The key areas that need enhancement are to provide guidelines that aid in determining the level of contamination to reuse the construction and demolition waste, setting target that considerably aids in reducing the wastes, recycling and reusing the wastes.

Earlier research clearly illustrates that efficient mitigation of construction material wastes will possibly assist in controlling the environmental pollution that arises from the construction activities. Yet, it is observed that there is an inadequate knowledge regarding the contribution and role of architects in reducing the construction wastes particularly at the design phase. The ultimate purpose of [24] is to detect the methods, barriers and factors that drive the waste minimisation and to research the tactics used by the constructors at the design phase. To work on the objective of the research, a survey questionnaire is used for data collection from the architects. The outcomes of the research report that the major reason of the wastes is the last-minute changes made by the architects during the construction process. Major challenges faced during the construction process are adaptability, flexibility and lack of adequate training before the commencement of the work. Certain other driving factors are observed to be waste management policies and legislation and training.

The most important strategies were sharing proper details, coordination and market survey. Likewise, [25] investigates to identify the two factors of PEB (Pro-Environmental Behaviour) associated with construction waste management. To extend the further investigation, a survey is conducted to trace the determinants that predict the PEB associated with construction waste management. The overall results of the study disclose that environmental awareness, physical stress and tedious construction mechanisms are significant predictors of PEB. [26] attempts to carry out a holistic evaluation regarding the current waste management methods that are implemented in the construction projects of Nigeria. The data for the research are collected from both the primary and secondary sources. The primary data of the research are collected using survey questionnaires that are distributed through the mails of the targeted participants. The data collected are analysed using exploratory factor analysis. The results of the study report that the waste management methodologies are clubbed into three clusters, proper construction detailing and design, practical legal model and modular construction and defensible procurement and material optimisation.

[27] aims to assess the significance of plans regarding the waste management and their considerable impact on the production of the demolition and construction waste in Lebanon. To extensively research on the objective, a literature review is conducted. In addition to this, a questionnaire survey is developed. The overall results of the study are reported that site management and supervision associated factors are identified to be the main sources of demolition and construction waste management. The main challenges to apply 3R is the lack of awareness and knowledge. Along with this, the most successful factor is waste management regulations. [28] develops research to analyse the economic performance of the construction waste mitigation. The model is devised based on interrelationships of major elements that impact the economic performance of the construction wastes reduction.

This consists of three subsystems that enclose the waste generation disposal, assessment of the economic performance and waste reduction. Data for the study are collected from a residential building project and are utilised for the model simulation and validation. The results of the study reveal the four strategies that are efficient enough to support the economic performance of the construction waste reduction which include reducing illegal dumping, enhancing waste sorting, raising waste landfilling charge and promoting the behaviours of the government towards waste recycling. In addition to this, the simulation model report that combines different waste reduction methods would probably result in improved outcomes than single measures in terms of reducing construction wastes. [29] aims to understand the profits gained by two stakeholders in construction and demolition waste recycling under various market scenarios by considering the interactive decisions of stakeholders.

Game theory is used to research the interplay among waste recycler and producer in construction and demolition waste as well as to investigate the profits enjoyed by the stakeholders under two market conditions. The results of the study depict that both the recycling market conditions decrease the profit of the marketers in terms of the disposal rate of the waste, whereas the recycler is observed to gain more profits when the waste processing capability is observed to be inadequate to manage the produced from the demolition and construction waste. Recovery of resource through waste trading is reported to get blocked through the challenges for applying efficient waste trading practices construction and demolition industries. [30] intends to research about the challenges faced during the implementation in the Australian construction and demolition industries. To work on the objective, a triangulation method of qualitative and quantitative methods are utilised. The research adopts mixed approach that employs extensive literature review and survey using semi-structured interviews with the experts employing the construction industry. Certain barriers such as high cost related with the processing and arranging the on-site waste, reporting system during the project, inadequate security, lack of coordination and communication within the stakeholders, lack of user-friendly environment and lack of proper incentives from the government to motivate the development of the market.

The prevailing study [31] explores improving the performance of small hydropower projects in Nepal by analyzing key performance indicators (KPIs). The study goal is to pinpoint and prioritize these KPIs, analyzing what factors impact them and suggesting ways to enhance them. Using quantitative methods, information is gathered from various parties such as developers, consultants, and contractors. The data are then examined with SPSS and Excel to display the results in tables and graphs. The findings show that cost-related factors are viewed as the most important KPI, with environmental management seen as less important. In addition, the research emphasizes notable variations in KPI rankings across various stakeholder groups, offering valuable information on areas that can benefit from specific enhancements in project management techniques. The preceding study [32] emphasizes the environmental effects and mitigation plans that aim to pinpoint primary environmental issues and suggest efficient management strategies. The approach includes a thorough examination of current EIA documents, consultations with stakeholders, and on-site investigations to evaluate ecological effects on nearby biodiversity and water systems. Discoveries show that there are serious environmental dangers linked to the project, such as habitat disturbance and changes in water flow, requiring strong mitigation steps like biodiversity action plans and community involvement tactics. The research highlights how crucial it is to incorporate environmental factors into hydropower planning in order to increase sustainability and reduce negative impacts on nearby ecosystems. The traditional study [33] delves into revolutionary developments in clean technology to move from pollution towards progress, seeking out inventive solutions to improve environmental sustainability. The approach includes a thorough examination of recent technological advancements and their impact on renewable energy by examining case studies and empirical evidence to evaluate their efficiency. Research shows that progress in renewable energy technologies, such as solar and wind, plays a major role in decreasing carbon emissions and encouraging sustainable practices in various industries. The research underscores the importance of ongoing funding in efficient technologies to reduce environmental effects and boost the economy, showcasing the opportunity for these advancements to revolutionize energy systems around the world.

A. *Research Gaps*

- The research [20] is limited to Australia, which may not account for the unique challenges and practices in other countries or regions with different regulatory frameworks and cultural attitudes towards waste management.
- The research [28] model reliance on specific datasets might limit its applicability across different regions or types of construction projects, as economic conditions and waste management practices can vary significantly.
- The study [29] focuses on interactive decisions within a specific context, which may not be generalizable to other regions or industries where different regulatory or market conditions exist.
- The study [30] identifies barriers to implementing waste trading practices, it may not provide sufficient actionable solutions or strategies for overcoming these barriers in practice.

III. RESEARCH METHODOLOGY

The present research aims to assess construction waste generation and management practice adopted in hydro-power project. In order to work on the objectives of the study, quantitative research methodology is adopted. The content briefing the selected methodology is depicted in this section.

A. Quantitative Research Methodology

Quantitative methods are used as it is strong at reviewing large sets of publics and creating generalities from the sample being considered to larger sets outside the sample [34]. Quantitative analysis uses statistical methods with the samples collected through structured questionnaire to justify the research objectives and framed hypothesis. Professionals who have vast experience in construction process of hydro-power project are selected as the target respondents for the research.

1. Research Design

As depicted in the prior section, the present research aims to investigate the construction waste generation and associated management practices implemented during the hydro-power projects. Quantitative research methodology is adopted to work on the objectives of the present research. The data for the study are collected from 195 professionals working in hydro-power projects. These respondents are selected using purposive sampling technique to get from the right target group to formulate the reliable results of the present study. A structured questionnaire is employed to get the data from the respondents. The collected data are analysed using SPSS (Statistical Package for Social Science) tool to test the hypothesis of the present study and certain statistical tests such as one-way ANOVA, Bivariate and partial correlation analysis and regression analysis are used. The research design of the present research is illustrated in figure 1.

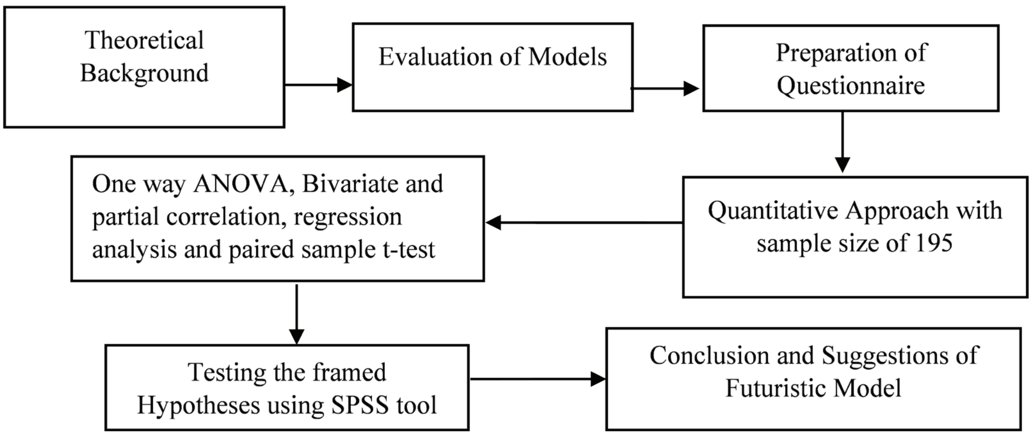

Fig. 1. Research design

2. Research Hypothesis

The research hypothesis of the present study is illustrated below.

H1: Significant sources of waste are generated during the construction period of hydro-power projects, and these sources can be effectively categorized.

H2: There exists impacts of construction wastes on environment and health status.

H3: There are certain factors that affect the waste generation and management practices during the hydro-power project.

3. Research Instruments

The Research Instrument is illustrated as an instrument that is employed to measure, analyze and fetch data on the basis of the proposed research interests. The proposed research uses a structured questionnaire as an efficient research tool that consists of close ended questions, pointing to three-point likert scale agree-1, Neutral-2, and disagree -3. The structured questionnaire research carried out in Accra metropolis, Ghana is surveyed from consumer populace, five selected sachet/bottle water and plastic packaging companies in the Accra Metropolis. An open-ended questionnaire is prepared to conduct interviews among the respondents from the Accra Metropolitan Assembly.

B. Data Collection

Data collection is the tool used to collect information from the respondents based on a particular research subject. With respect to the present study, the primary data are collected from the women participants, purposely from different sets of people satisfying the objectives.

1. Primary Source of Data Collection

The primary data refers to the fresh data collected from the respondents directly by using survey analysis. They are free to answer their views for the framed close-ended questions. As the primary data are acquired in actual time, it is more accurate and real in nature. The main advantage of using primary data collection is that the data gathered seem highly reliable since they are not collected from any of second-hand sources such as printed notes or books. Primary data collection is more like a raw substance gathering and it is collected through long time process, however the results and input data are worthy enough.

C. Sampling Strategy

1. Purposive Sampling

The sampling method basically refers to set of non-probability sampling approach, wherein the units are selected as they have the characteristics required for the research method or objectives [35]. It is usually used in this quantitative research to recognize and select the information-rich respondents appropriate to study about construction waste generation and management practices in the hydropower project. This sort of sampling approach is used in this quantitative study, for documentation and collection of individuals or groups of individuals that are capable and well-informed with the subject of interest.

D. Data Analysis

Research approach is the process typically used to manage the intricate steps in the assumptions and methods used in data collection, assessing the collected data through sampling method, and finally driving conclusions from the examined data (may be qualitative or quantitative). With the support of framed questionnaire, the data are collected from the particular set of sample respondents, and quantitative methodology is utilised for the data analysis. The data collection accomplished through survey assessment, wherein it is distributed to 195 participants who have adequate experience in working for the construction of hydropower projects. The respondents' data are recorded using excel sheet to commence the quantitative assessment. The software tool of IBM Statistical package of social sciences (SPSS) is used for the subsequent estimation stage to analyse the variables associated with research objectives. The test used by the researchers to test the research hypothesis are regression test, bivariate and partial correlation test, paired sample T test and One-Way ANOVA analysis. The collected data are enumerated with the usage of excel and SPSS software. Bivariate and partial correlation, Regression, one-way ANOVA and paired sample-T test are accomplished to evaluate the organized hypothesis. The data analysis is carried out including the below three steps

- MS-Excel is used to incline the demographic variables, dependent and independent variables.
- Exploratory data analysis is illustrated through the variable frequency distribution.
- Regression, paired Sample-T test, one way ANOVA and Bivariate and partial Correlation tests are employed to evaluate the research hypothesis and evidence the objectives.

E. Ethical Considerations of Research Study

Certain ethics are followed while conducting the research analysis. As the study is based on the evaluation of socio-psychological factors of women empowerment, the research handles out high confidentiality based responses. The following ethics are followed

- Before the researcher's survey assessment, information about their consent and participation are asked in prior basis.
- The respondents are not forced by any means to give their responses. Only willing respondents are selected for the interview.
- Only the responses to the questionnaire are asked to the respondents, their private reports are not forced for getting exposed.

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IV. RESULTS

The data collected from the respondents who took part in the survey are analysed using SPSS statistical tool. The results observed during the analysis part are depicted in this section.

A. Statistical Analysis

The outcomes recorded during the statistical analysis are depicted and interpreted with the intention to conclude whether the framed hypothesis is either accepted or rejected.

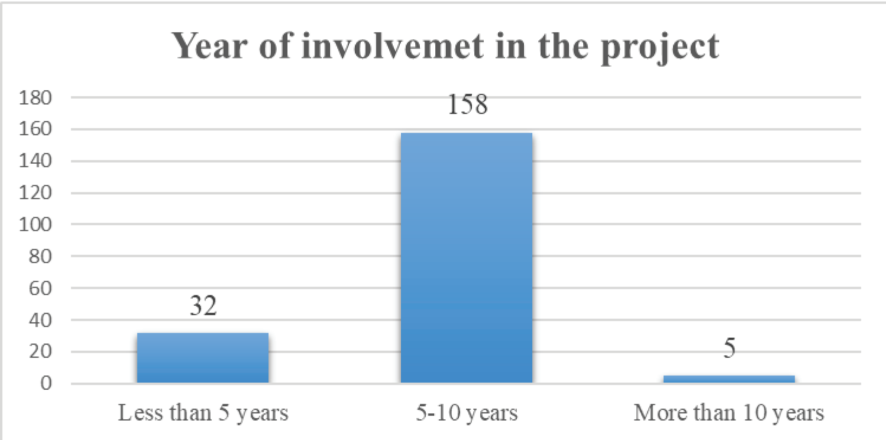

Fig. 2. Years of working in construction of hydro-power projects

The results represented in the figure 2 illustrate the participation of the respondents based on their years of experience in the construction of hydro-power projects. The overall results depict that around 158 respondents who take part in the survey are reported to have around 5-10 years of experience. In addition, 32 participants are reported to have less than 5 years of experience and 5 with more than 10 years of working experience in the construction project of hydro-power plants.

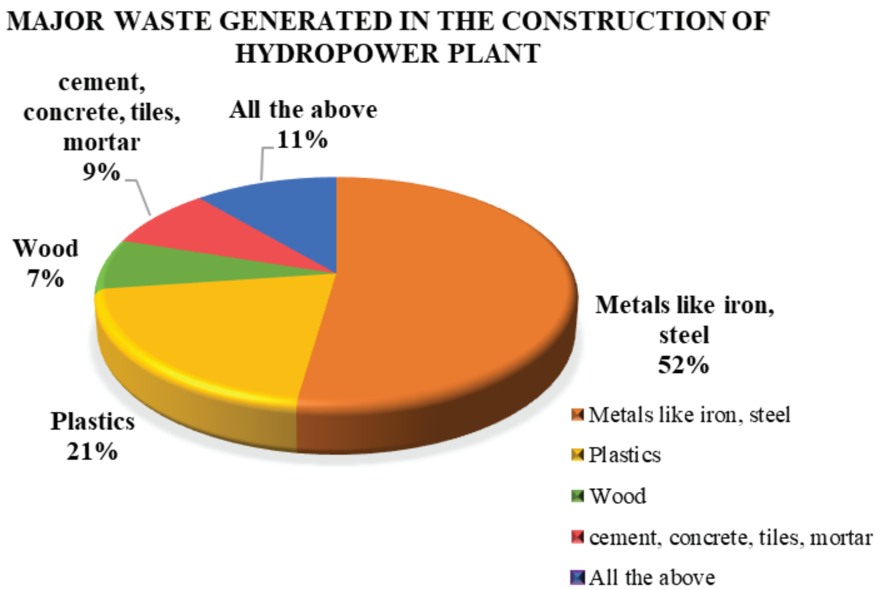

Fig. 3. Major Waste generated in the construction of hydro-power plant

The outcomes depicted in figure 3 above illustrate the major sources of waste generation in construction of hydro-power plant. The results claim that metals such as iron and steel (52%) are observed to have a major contribution to the waste generation during the construction of hydro-power plant. In addition, plastics have around 21%, cement, concrete tiles and mortar have 9%, wood has 7% of contribution in waste generation during the construction process of hydro-power plants.

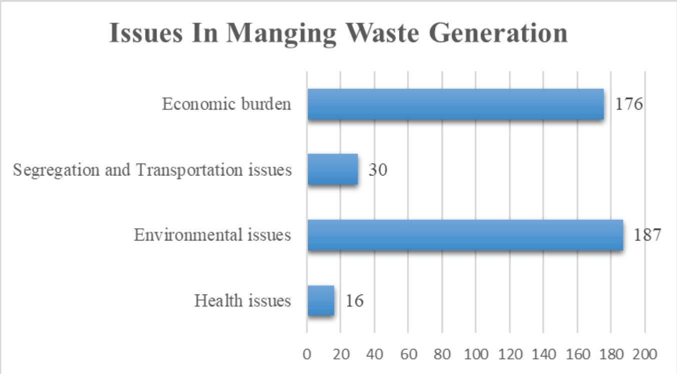

Fig. 4. Issues in managing the waste generation in hydro-power plants

The results represented in the graph of figure 4 demonstrate the issues faced by the participants in handling the waste generation of hydro-power plants and reveal that environmental issues (scoring 187) and economic burdens (scoring 176) are the primary challenges faced in waste management, indicating that these factors significantly influence operational effectiveness. Environmental concerns likely encompass pollution, ecosystem disruption, and water contamination resulting from improper waste disposal. The economic burden reflects the financial demands associated with waste treatment, disposal, and investments in technology to mitigate waste impacts. In contrast, segregation and transportation issues (scoring 30) are less critical, suggesting that while sorting and transporting waste remains a concern, it does not pose as significant a challenge as environmental or economic factors. Health issues (scoring 16) are the least pressing, indicating minimal health risks compared to other challenges. Overall, the chart emphasizes the need for future waste management policies to focus on sustainable practices and cost-effective solutions that address the dominant environmental and economic challenges while acknowledging the lesser operational concerns.

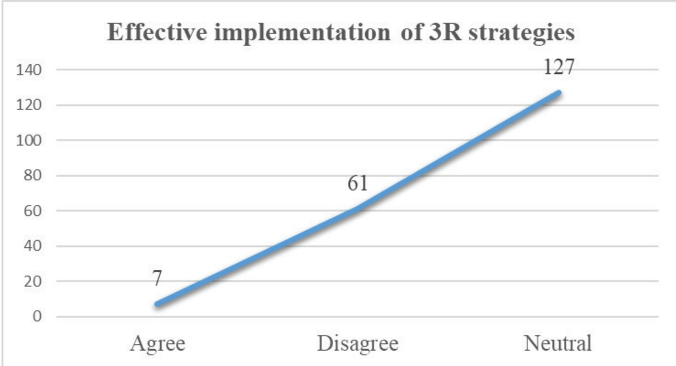

Fig. 5. Perception regarding the implementation of the 3R strategies

The graph depicted in the figure 5 illustrates the perception of population regarding the application of the 3R strategies in waste management during the construction of hydro-power project. From the recorded outcomes, it is obvious that around 127 respondents submit a neutral response regarding the effective application of the 3R strategies, and around 61 respondents disagree regarding the efficient implementation and around 7 participants report a positive response regarding the effective implementation of the 3R strategies.

B. *ANOVA Analysis*

Analysis of Variance (ANOVA) estimates the means of two or more independent variables to find whether there is an existence of statistical evidence that correlated means of the population are statistically differing.

TABLE I
ANOVA.

		Sum of Squares	df	Mean Square	F	Sig.
Impact on health issues	Between Groups	.600	2	.300	.991	.373
	Within Groups	58.149	192	.303		
	Total	58.749	194			
Impact of waste on environment	Between Groups	1.186	2	.593	3.476	.033
	Within Groups	32.762	192	.171		
	Total	33.949	194			

Results recorded in ANOVA test ate illustrated in Table I. The analysis considers variables representing the impact of waste generation on health and environment as dependent variables and level of waste generation as the independent variable. Since the significant value of the variable representing the impact of waste generation on environment is 0.033, which is less than the p value 0.05, this indicates that there is a significant impact of the waste generation during the construction process on the environment. Whereas the significant value for the variable representing the impact of waste generation on health issues is 0.373, which is obviously greater than the p value (0.05), and this signifies that there is no considerable impact of the waste generation of the construction process of hydro-power plants on the health issues of the people residing in the surrounding regions. Thus, the results of the ANOVA indicate that there is a significant impact of waste generation on the environmental issues during the construction process.

C. *Regression Analysis*

Regression analysis aids to investigate the strength of correlation between one dependent and independent variables. This analysis aids in forecasting the value of a dependent variable from one or more independent variables.

TABLE II
MODEL SUMMERY.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.467[a]	.218	.206	1.322
a. Predictors: (Constant), Impact of waste on environment, economic issues during waste management and disposal, and issues faced in waste segregation and transportation				

The results of the model summary corresponding to the regression analysis are depicted in the Table II. The test considers variables representing impact of waste generation on the environment, economic issues while disposing and managing the waste and issues faced while transporting and segregating the waste as predictor variables and waste generation during the construction process are selected as the dependent variables. The value of R square value is multiplied by 100, to calculate the degree of influence of the dependent variable on the predictor variables. The value of r square 0.218 is multiplied by 100, which signifies that there is around 21% of probability of impact among the predictor and dependent variables.

TABLE III
ANOVA[a].

Model		Sum of Squares	df	Mean Square	F	Significant value.
1	Regression	93.082	3	31.027	17.762	.000[b]
	Residual	333.656	191	1.747		
	Total	426.738	194			
a. Dependent Variable: Major wastes generated during the construction process						
b. Predictors: (Constant), impact of waste on environment, economic issue during waste management and disposal, issues faced in waste segregation and transportation						

The results of ANOVA corresponding to the outcomes of regression analysis are depicted in Table III. The significant value 0.00 shows that the considered model is statistically significant.

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TABLE IV
COEFFICIENTS.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.966	.379		2.551	.012
	Issues faced in waste segregation and transportation	-.333	.153	-.141	-2.171	.031
	Economic issue during waste management and disposal	1.268	.179	.457	7.081	.000
	Impact of waste on environment	.439	.230	.124	1.908	.058

a. **Dependent Variable:** Major wastes generated during the construction process

The recorded outcomes of coefficient table are depicted in Table IV. The significant values of the considered variables are 0.012, 0.031, 0.00 and 0.058, which are considerably less than and equal to 0.05. These values signify that there is a considerably significant impact of the predictor variables and dependent variables.

D. Correlation Analysis

Correlation test is a statistical technique that is employed to assess the strength of the correlation between the considered parameters or variables. These correlation are calculated using Pearson correlation coefficient. The outcomes of bivariate correlation analysis are listed in Table V.

TABLE V
CORRELATIONS.

		Appropriate storage area for construction material	Proper planning of entire construction waste
Appropriate storage area for construction material	Pearson Correlation	1	.162*
	Sig. (2-tailed)		.024
	N	195	195
Proper planning of entire construction waste	Pearson Correlation	.162*	1
	Sig. (2-tailed)	.024	
	N	195	195

*. Correlation is significant at the 0.05 level (2-tailed).

The Pearson correlation analysis depicted in the Table V considers variables representing storage capability for the construction process, planning procedure of the construction waste. The Pearson correlation coefficient for both considered variables is 0.162, which highlights that there is a positive association between the variables representing storage capability of the construction material and the planning of the entire construction waste. Also, the significant value of the relationship is 0.024, which is comparatively less than 0.05, and this illustrates that the model is said to be statistically significant.

TABLE VI
CORRELATIONS.

		Economic issue during waste management and disposal	Issues faced in waste segregation and transportation	Level of waste generation during the construction
Economic issue during waste management and disposal	Pearson Correlation	1	.194	.213
	Sig. (2-tailed)		.019	.052
	N	195	195	195
Issues faced in waste segregation and transportation	Pearson Correlation	.194	1	.005
	Sig. (2-tailed)	.019		.945
	N	195	195	195
Level of waste generation during the construction	Pearson Correlation	.213	.005	1
	Sig. (2-tailed)	.052	.945	
	N	195	195	195

The outcomes of the Pearson correlation are depicted in Table VI. The test considers variables representing economic issues during waste management and disposal, issues faced during the process of segregation and transportation and the level waste generated during the construction process of hydro-power projects. The Pearson correlation coefficient of the variables representing economic issue while managing and disposing waste and level of waste generation during the construction process is 0.213, which depicts the positive relationship between the economic issues and level of waste generation during the construction process of hydro-power plant. The significant value of the relationship is 0.052 that is less than the significant value 0.05, which signifies that the relationship is statistically significant. Similarly, the variables representing issues faced during the transportation and segregation and the level of waste generation during the construction process have the Pearson correlation coefficient value of 0.194, which indicates the existence of positive relationship between the considered variables. In addition, the significant value of the model is 0.019 that is obviously less than 0.05, which illustrates that the model and the relationship are observed to be statistically significant.

E. Paired Sample T Test

Paired sample T test is also referred to as dependent sample T test which is a statistical technique that is utilised to find whether the mean values of the considered variables are statistically and significantly different.

TABLE VII
PAIRED SAMPLES STATISTICS.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Segregation of waste and their disposal	1.87	195	.430	.031
	Adoption of waste generation in the plant	1.58	195	.494	.035

The Paired sample T test considers variables representing segregation of waste and the disposal of construction wastes and adoption of waste generation in the hydro-power project. The mean values of the variables are 1.87 and 1.58 illustrating the mean of the responses of the participants.

TABLE VIII
PAIRED SAMPLES CORRELATIONS.

		N	Correlation	Sig.
Pair 1	Segregation of waste and their disposal & Adoption of waste generation in the plant	195	.136	.057

The observation of results corresponding to the paired sample correlation is demonstrated in table VIII. Here, N represents the overall sample of the model. The correlation coefficient 0.136 illustrates the existence of association between the considered variables. Also, the value of significance 0.057 depicts the statistical significance of the model.

TABLE IX
PAIRED SAMPLES TEST.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Segregation of waste and their disposal – Adoption of waste generation in the plant	.287	.609	.044	.201	.373	6.586	194	.000

The results of paired sample test are depicted Table IX. Here, the mean value of the considered pairs representing segregation and disposal of waste and adoption of waste generation in the hydro-power plant is 0.287 and the standard deviation is 0.609. Notably, the significant value of the pair is 0.00 which is considerably less than 0.05, which indicates that the considered sample average pair is not equal to 0.

TABLE X
PARTIAL CORRELATIONS.

Control Variables			Adoption of waste generation in the plant	Segregation of waste and their disposal
Level of implementing 3R strategies	Adoption of waste generation in the plant	Correlation	1.000	.155
		Significance (2-tailed)	.	.031
		df	0	192
	Segregation of waste and their disposal	Correlation	.155	1.000
		Significance (2-tailed)	.031	.
		df	192	0

The outcomes recorded while computing partial correlation analysis are listed in Table X. Here, the partial correlation considers variables representing adoption of waste generation and segregation and disposal of waste generated in the hydro-power project plant. The control variable of the model is the level of implementing 3R strategies. The correlation coefficient represents the existence of positive association between the considered variables and the significant value 0.031 indicates the strength of relationship between the two control variables.

V. *DISCUSSION*

Waste generated during the construction projects and the significant impacts of these wastes would obviously be massive and destructive to the environmental sustainability. This does not end here but also they are observed to have unavoidable influence on the human health. Considering this, the present research makes genuine efforts to investigate about the waste generated during the construction of hydro-power projects. The results of the study emphasise that most of the respondents involved in the survey have around 5-10 years of experience in project involvement. Metals such as iron and steel are reported to contribute for the major waste generation.

The waste generation during the waste construction process is observed to have significant impact on the environment. Also, most of the respondents have neutral response regarding the effective implementation of the 3R strategies. Results of ANOVA report that waste generated is observed to impact the environment more when compared with the health issues of the human beings. Outcomes of the correlation analysis report that there is a significant relationship between the proper storage of construction materials and appropriate adoption of waste management. Also, the outcomes of the test report that there is relationship between the issues in terms of waste management and waste generation, with the level of waste accumulation in waste generation during the construction process of hydro-power project. Similar to the results of the present research, [36] aims to investigate the techniques within the construction firms in order estimate whether there is a relationship between their implementation practices for waste disposal. The outcomes of the study report that landfilling is the most common technique of waste disposal which is followed by the recycling method. Likewise [37] is formulated with the objective to quantify the inventory of the E-waste and also to assess the processing and recycling techniques adopted in Pakistan. The results of the study disclose that processing of E-waste in Pakistan is done through the crude technique without any other safety gears.

Similarly, [38] tries to determine the significant wastes produced during the construction phase in the entire assessment. The outcomes of the concrete block and cement waste are observed to account for 70% of the contribution to all the environmental impact categories except for the resource depletion. Around 1% of the waste is generated by the insulation material, but these insulation materials are observed to have impact on the environment sustainability.

Though several researchers contribute their notions regarding the waste generation and management practice, very few investigators have considered every possible determinant such as waste generation sources, significant impacts and associated factors all together in a single work, thus in this perspective the contribution of the present study is enormous and informative when compared to the other existing literature.

VI. LIMITATIONS OF THE STUDY

Though the results of the present research are consistent and reliable, the present research suffers from certain limitations. Firstly, the present study does not formulate solutions in terms of waste management for any particular region, thus the results are very general. This is because the waste generation and management would probably differ in every region. The present research employs a quantitative research methodology, which may not have provided actual space for the respondents to present and discuss their opinion regarding the waste management like the adoption of qualitative research methodology. In addition, the data for the research are collected from the experts in the construction sector but do not consider collecting it from the public which would have talked about the actual problems faced due to the construction waste generation.

VII. CONCLUSION

Demolition and construction waste is produced when there are any activities that are related to the demolition and construction which occurs in places like bridges, building roads, subway and remodelling. This waste is mostly made up of non-biodegradable and inert materials like plaster, wood, concrete, plastic, etc. The present research investigates construction waste generation and management practices in hydropower projects, revealing that metal materials such as steel and iron significantly contribute to construction waste, which poses substantial environmental impacts. Respondents indicate a neutral stance on the effectiveness of the 3R (Reduce, Reuse, Recycle) strategies in managing this waste, suggesting that these practices are not adequately implemented. Correlation analysis demonstrates a significant relationship between the adequate storage of construction materials and effective waste management practices. Based on these findings, future research should focus on developing comprehensive waste management plans tailored to hydropower projects, implementing advanced recycling techniques to enhance material recovery, and establishing training programs for workers to promote best practices in waste management. Additionally, longitudinal studies are recommended to evaluate the long-term effectiveness of these strategies, alongside advocating for stricter policies on construction waste management. Engaging local communities in discussions about sustainable practices can further enhance the practical application of these findings, contributing to more effective waste management and environmental sustainability in future hydropower developments.

VIII. POLICY RECOMMENDATIONS

- Constructors should be cautious enough in selecting construction materials that have the least impact on the environmental and human health.
- Government should implement policies and procedures that would assist the construction sectors in managing and recycling the construction waste materials.
- Proper and relevant education should be proffered to the professionals and public regarding the construction waste generation and management in the hydro-power projects.

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