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ANALYSIS OF CONSTRUCTION WASTE IN PUBLIC BUILDINGS USING REGRESSION METHOD: A CASE STUDY OF AMBO TOWN

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Abstract: The output of construction and demolition (C&D) waste in Ethiopia has been rapidly increasing in the past decades. The direct landfill of such construction and demolition waste without any treatment accounts for about 98%. Therefore, recycling and utilizing this waste is necessary. The prediction of the output of such waste is the basis for waste disposal and resource utilization. This study takes Ambo town as a case study, the current output of C&D waste is analyzed by regression method. The findings of the study indicated that the level of construction wastages on public buildings construction projects in Ambo town, the weighted average and ranking over-all factors of construction materials wastages for operations factors (0.399), design and documentation factors (0.3798), materials handling and storage factors (0.3797), site management and practices factors (0.334) and site supervision factors (0.316). Therefore, this study recommends improvement in the integration of public buildings construction materials wastages and the importance of evaluating construction materials wastage, serving for the intended purposes sustainably to the construction parties for public buildings construction projects starting from commencement up to its completion.
Keywords: construction and demolition waste; weighted average; public buildings, regression method

INTRODUCTION

Construction and demolition (C&D) waste is produced during the process of building construction, expansion, and demolition. Owing to the gradual progress of urbanization construction, the areas of buildings that have been completed and are still under construction, As a result, the production of C&D waste rapidly increases. The estimated annual production of C&D waste in Ethiopia is approximately 2 billion tons, which accounts for 80–90% of the total municipal waste. Demolition waste mainly consist of concretes, bricks, metals, timbers, plastics, gravels, ceramics, and glasses. Most of the compositions of such waste are reusable materials that are usually disposed in landfills and dumps, thereby causing serious environmental and land occupation issues . The disposal and utilization of C&D waste are common concerns of society. The government also lacks information about the production of C&D waste, which increases the difficulty of implementing comprehensive management for these waste. Quantitative waste prediction is crucial for waste management. Apart from estimation and prediction techniques, no method can be used to accurately and easily estimate the amount of waste produced by C&D projects. Estimation involves calculating the historical quantity of building waste and prediction determines the future production of construction waste on the basis of historical data.

The present study has been focused to conduct a detailed analysis of construction wastes in public buildings in Ambo town in Ethiopia country using regression method. The following are the specific objectives of the study:

- To identify and classify the leading major factors affecting the public building materials wastage in the construction sites.
- To develop a model to analyze the materials wastage using regression method.
- To suggest technique to reduce the impact of public buildings materials wastage

MATERIALS AND METHODS

This study's overall research approach includes the explanation in the choice of methods used to accomplish the objective of the study and review of literature was conducted on the basis of the research aim and a set of identified variables. Additionally, it gives information about the data collection method, research population, sample size, sampling technique and statistical tools (regression technique) used for data processing and results were interpreted.

— Study area description

The study area, Ambo Town, is located the Western Shoa part of Ethiopia, in Oromia National Regional State, at a distance of 110 km from Addis Ababa. Ambois located in the West side of Finfinnee City and located adjacent to the main road from Finfinnee to Wollega. It is situated at an altitude of 2110 meters above mean sea level.

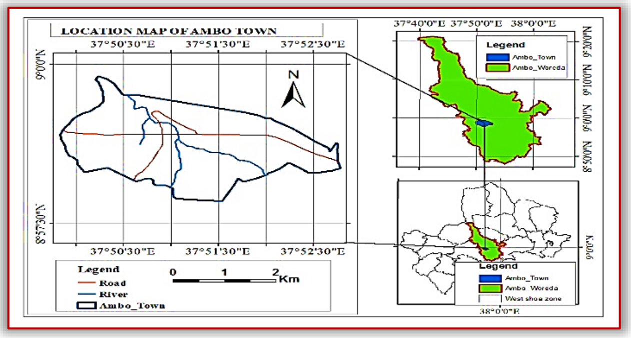
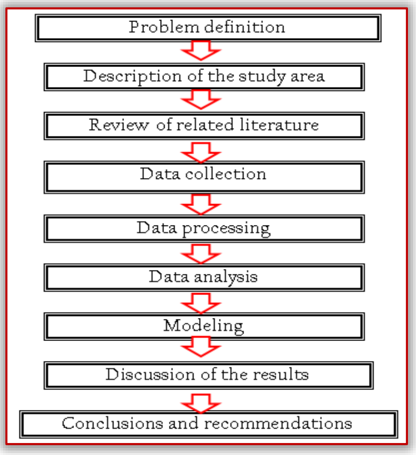


Figure 1: Location map of the study area

Table 1: Details of construction projects of case study area

S. No	Name of project	Location of the project	Current status
1	Ambo University Referral Hospital Public Building Project	Ambo town near to main campus	Under construction
2	Ambo Town, Bus Station Public Building Project	Ambo Town	Under construction
3	Ambo University, Awaro Campus Administration Building Project	Ambo town, Awaro campus	Completed
4	Ambo University, Building Project	Ambo town	Under Construction
5	Ambo University, Awaro Campus, Stadium Project	Ambo town	Under Construction

The framework of the study is presented as below.



— Data Collection Method

Various types and sources of data are identified and discussed for this research purpose. The primary task is gathering/collecting relevant information or data of the study area. Multiple evidences approach was used for data collection. These are questionnaire survey, site observations/field visit was made and case study by analyzing different documents. A questionnaire survey was selected as the research instrument owing to its suitability to the level of information required, cost and time limitations and the high number of participants.

— Sample Size and Sampling Technique

Sampling is the process of selecting representative units of a construction parties for the study in this research. The advantage of using a sample is that it is more practical and less costly than collecting data from the construction parties. The risk is that the selected sample might not adequately reflect the behaviors, traits, symptoms, or beliefs of the participate .

The investigation covered five selected public building construction projects. The researcher distributed fifty-six questionnaires for contractors, consultants and employees/engineers which are participated on public building construction projects in Ambo town.

To sample public construction parties (owner, contractor and consultant) in public buildings construction sites in Ambo town, reconnaissance survey was made and five public buildings were identified as project construction parties with project cost more than ten million (10 million) birr during this study. Therefore, this study paper considers these construction parties as sample representative. Therefore, the following equation is used to determine the sample size [3].

$$Ss = \frac{Z^2 * P * (1-P)}{C^2} \qquad (2.1)$$

where Ss = Sample size

Z = Z value (e.g. 1.96 for 95% confidence level)

P = percentage picking a choice, expressed as a decimal (0.50 used for sample size needed)

C = margin of error (9%)

$$Ss = \frac{1.96^2 * (0.05) * (1-0.05)}{0.09^2} = 118.57 \approx 119$$

For correction of finite sample:

$$Ss\ new = \frac{Ss}{1+\frac{Ss-1}{P\ op}} \qquad (2.2)$$

where total sampled of construction parties = 126 match the proposed contracting companies

$$Ss\ new = \frac{119}{1+\frac{119-1}{126}} = 55.94 \approx 56$$

Based on the sampling method and criteria cited above, the researcher selected fifty-six (56) construction parties which participated on public buildings projects in Ambo town.

— Data Processing and Analysis

The analysis was done by using Microsoft Excel and the responses which was assigned to each question by the respondents was entered and consequently is subjected to statistical analysis (regression) for further insight. The following statistical techniques which are grouped under various headings were employed to analyze the data which were collected from the survey.

Frequency tables and descriptive statistics were constructed to display results with respect to each of the questions of general information and effect of client material supplying. Whereas the contribution of each of the causes to material wastage generation and optimization strategies for each of the selected materials was examined and the ranking of the attributes in terms of their criticality as perceived by the respondents was done by the use of Relative Importance Index (RII). As a result, the analysis would have combined all groups of respondents (employers, consultants, contractors) in order to obtain significant results. Data were analyzed by calculating frequencies and Relative Importance Index (RII).

Table 2: Levels of responses indication

The levels of response are:		
E.S.	extremely important	[5]
V.S.	very important	[4]
M.S.	moderately important	[3]
S.S.	slightly important	[2]
N.S.	not important	[1]

Recognizing the difference in perceptions of the consultants and contractors, there is also the need to further ascertain if consultants' perception is statistically different from the contractors' perception. This leads to the use of regression methods. There are some regression methods namely linear and multiple regression methods. From this linear regression is selected because of it has an advantage of not requiring the assumption of normality and or homogeneity of variances.

— **Model Validation**

Model validation is a mandatory step in regression model development. Provided that not much data is commonly available for modelling, on one hand, all the available data should be used to build robust regression model. On the other hand, an external test set may be useful to evaluate the model predictive ability. This test set will be comprised of data that have never been used in model development and then the optimal way to select the test data is the random selection. Linear regression coefficient of determination (R2) value estimated from external test data set is used to measure the predictive ability of the regression model.

The proportion of total variation (SST) that is explained by the regression (SSR) is known as the Coefficient of Determination, and is often referred to as R.

$$R^2 = \frac{SSR}{SST} = \frac{SSR}{SSR+SSE} \qquad (2.3)$$

Where: SSR=The Sum of Squares Regression (SSR) is the sum of the squared differences between the prediction for each observation and the population mean.

SST= The Total Sum of Squares (SST) is equal to SSR + SSE

Mathematically,

SSR = Σ (y – y) 2 (measure of explained variation)

SSE = Σ (y – y) (measure of unexplained variation)

SST = SSR + SSE = Σ (y ^y)2(measure of total variation in y)

The value of R^2 can range between 0 and1, and the higher its value the more accurate the regression model is. It is often referred to as a percentage.

RESULTS AND DISCUSSIONS

Some techniques are suggested to minimize construction materials wastages on site prevention methods after construction waste analysis were done. Besides, the results that have been obtained from processing of fifty-six (56) respondents used excel and linear regression tool analysis.

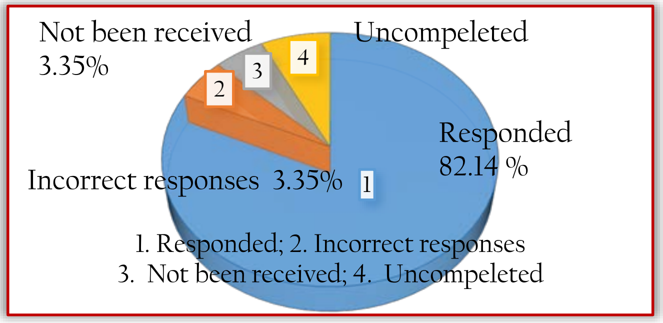


Figure 3: Questionnaires of general response rate

The results are prepared to present the information about the sample size, response rate and contracting company characteristics in Ethiopia especially in Ambo town. It also included the ranking of factors affecting the waste on construction projects based on their relative mean ranks, analysis of construction waste magnitude. In addition to the causes of waste and recommends construction waste minimization strategies after analyzing the present waste and the relative significant of construction waste sources.

Response Rate from 56 questionnaires distributed on the contracting companies, 46 responses were received with 82.14% return rate in this investigation. The other 10 questionnaires as follows: 3 (5.35%) have not been received, 4 (7.14%) are uncompleted and 3 (3.35%) are illogical or incorrect responses, indicated in Figure 3 shown below are the general response rate from questionnaires.

SOURCES AND FACTORS OF CONSTRUCTION MATERIALS WASTAGE ON PUBLIC BUILDING CONSTRUCTION PROJECTS

There are many factors, which contribute to construction materials waste generation on site. Construction materials wastage may occur due to one or combination of many causes. As discussed in literature review parts the sources of waste classified under five categories: Those are design and documentation, site management and practices, materials handling and storage, operation and site supervision.

— **Group 1. Design and Documentation Factors**

Table 3.1 below displayed that the Relative Importance Index of all the 8 (eight) causes of waste evaluated for the respondents (contractors, employees and consultants). This means that all the thirteen factors are considered as causes of waste arising from design and documentation.

Table 3.1: Ranks of construction materials wastage due to design and documentation factors

Factors	Contractors		Consultants		Clients		Weighted average (all groups)	
	RII	R	RII	R	RII	R	RII	R
Design changes and revisions	0.538	1	0.318	1	0.636	1	0.497	1
Designer's inexperience in method and sequence of construction	0.423	3	0.250	2	0.500	3	0.391	3
Lack of attention paid to standard sizes available on the market	0.404	4	0.239	3	0.477	4	0.373	4
Lack of information in the drawings	0.423	3	0.250	2	0.500	3	0.391	3
Ambiguities, mistakes, and changes in specifications	0.346	5	0.205	5	0.409	5	0.320	5
Rework that don't comply with drawings and specifications	0.327	7	0.193	6	0.386	6	0.302	6
Lack of knowledge about construction techniques during design activities	0.481	2	0.284	4	0.568	2	0.444	2
Poor communication leading to mistakes and errors	0.346	5	0.205	5	0.409	5	0.320	5

— **Group 2. Materials Handling and Storage Factors**

Table 3.2 shows that the Relative Importance Index of all the 11 causes of waste evaluated for the respondents (contractors, client and consultants).

Table 3.2: Ranks of construction materials wastage due to materials handling and storage factors

Factors	Contractors		Consultants		Clients		Weighted average (all groups)	
	RII	R	RII	R	RII	R	RII	R
Poorly schedule to procurement the materials	0.404	6	0.239	6	0.477	6	0.373	6
Over ordering or under ordering due to mistake in quantity surveys	0.327	8	0.193	8	0.386	8	0.302	8
Purchased materials that don't comply with specification	0.442	5	0.261	5	0.523	5	0.409	5
Damage materials on site/wrong handling of materials	0.404	6	0.239	6	0.477	6	0.373	6
Overproduction/ Production of a quantity greater than required or earlier than necessary	0.385	7	0.227	7	0.455	7	0.356	7
Lack of onsite materials control	0.269	9	0.159	9	0.318	9	0.249	9
Poor storage of materials	0.212	10	0.125	10	0.250	10	0.196	10
Damage during transportation	0.481	4	0.284	4	0.568	4	0.444	4
By bulk	0.5	3	0.295	3	0.591	3	0.462	3
By partial	0.538	2	0.318	2	0.636	2	0.497	2
On time delivery	0.558	1	0.330	1	0.659	1	0.516	1

— **Group 3. Operation (On site, equipment) factors**

The Relative Importance Index each of the sub-factors of the operation/on site group, which causes of construction material waste, is presented in Table 4.3 in a descending order.

Table 3.3: Ranks of construction materials wastage due to operation/ on site factors

Factors	Contractors		Consultants		Clients		Weighted average (all groups)	
	RII	R	RII	R	RII	R	RII	R
Rework due to workers' mistakes	0.385	6	0.227	7	0.455	6	0.356	6
Damage to work done caused by subsequent trades	0.519	2	0.307	2	0.614	2	0.480	2
Use of incorrect material, thus requiring replacement	0.462	3	0.273	6	0.545	3	0.427	3
Poor workmanship	0.308	7	0.182	8	0.364	7	0.285	7
Lack of workers or tradesmen or subcontractors' skill	0.404	5	0.239	5	0.477	5	0.373	5
Choice of wrong construction method	0.558	1	0.330	1	0.659	1	0.516	1
Lack of coordination among crews	0.404	5	0.239	5	0.477	5	0.373	5
Problems between the contractor and his subcontractors	0.404	5	0.239	5	0.477	5	0.373	5
Equipment frequently breakdown	0.462	3	0.273	3	0.545	3	0.427	3
Poor technology of equipment	0.404	5	0.239	5	0.477	5	0.373	5
Shortage of tools and equipment's required	0.442	4	0.261	4	0.523	4	0.409	4

— **Group 4. Site Management and Practices Factors**

The Relative Importance Index each of the sub-factors of the site management and practices group, which causes construction material waste, is presented in Table 3.4 in a descending order.

Table 3.4: Ranks of construction materials wastage due to site management and practices factors

Factors	Contractors		Consultants		Clients		Weighted average (all groups)	
	RII	R	RII	R	RII	R	RII	R
Lack of proper waste management plan and control	0.212	5	0.125	5	0.250	7	0.196	8
Poor project management	0.250	4	0.148	6	0.295	6	0.231	7
Lack of a quality management system aimed at waste optimization	0.308	3	0.182	5	0.364	5	0.285	5
Lack of team work	0.423	2	0.250	4	0.500	4	0.391	4
Poor site layout	0.442	2	0.261	3	0.523	3	0.409	3
Poor qualification of the contractor's technical staff assigned to the project	0.462	2	0.273	2	0.545	2	0.427	2
Poor coordination and communication between parties involved in the project	0.481	1	0.284	1	0.568	1	0.444	1
Poor management and distribution of labors, materials and equipment's	0.308	3	0.182	5	0.364	5	0.285	6

— **Group 5. Site Supervision Factors**

The Relative Importance Index of each of the sub-factors of the site supervisor group, which causes construction material waste, is presented in Table 3.5.

The questionnaires of this study considered 42 factors which cause material waste in construction, and those factors were distributed into five groups as mentioned above. Table 3.6 gives the results based on thea collected data from the questionnaire. Causes of construction materials waste, which illustrates the mean and ranking of each group.

Table 3.5: Ranks of construction materials wastage due to site supervisor factors

Factors	Contractors		Consultants		Clients		Weighted average (all groups)	
	RII	R	RII	R	RII	R	RII	R
Lack of supervision and delay of Inspections	0.269	4	0.159	4	0.318	4	0.249	4
Poor qualification of contractors'	0.385	1	0.227	1	0.455	1	0.356	1
Poor coordination and communication between the consultant engineer, contactor and client	0.365	2	0.216	2	0.432	2	0.338	2
Change orders by owner	0.346	3	0.205	3	0.409	3	0.320	3

Table 3.6: Weighted average and ranking over-all causes of construction wastage

Group Numbers	Main Groups	All Groups (Weighted Average)	Rank
Group 3	Operations factors	0.399	1
Group 1	Design and documentation factors	0.37975	2
Group 2	Materials handling and storage factors	0.37973	3
Group 4	Site management and practices factors	0.334	4
Group 5	Site supervision factors	0.316	5

— Modeling by Linear Regression

≡ Statistical Analysis

Figures below showed the statistical summary of the comparison between design and construction of public building from consultant/contractor/employer for the calibration period. Then, as it was mentioned above, the correlation coefficient (R2) was used to check the results. The construction of materials wastage or construction wastage from design and documentation factors includes:- design changes and revisions, designer's inexperience in method and sequence of construction, lack of attention paid to standard sizes available on the market, lack of information in the drawings, ambiguities, mistakes, and changes in specifications, rework that don't comply with drawings and specifications, lack of knowledge about construction techniques during design activities and poor communication leading to mistakes and errors. The value of correlation coefficient (R2) is calculated from excel sheet as below.

R2=1 (ok) because the value of R2 range is in between of 0 and 1. It is shown on figure 4, above. Cause of Construction materials waste the following factors: procurement poorly schedule to procurement the materials, over ordering or under ordering due to mistake in quantity surveys, purchased materials that don't comply with specification, onsite damage materials on site/wrong handling of materials, overproduction/production of a quantity greater than required or earlier than necessary, lack of onsite materials control, poor storage of materials, materials transport/shifting damage during transportation, by bulk, by partial and on time delivery.

Table 3.7: Sample excel sheet calculation taken

Design and Documentation	
X	Y
0.1932	0.3269
0.2045	0.3462
0.2045	0.3462
0.2386	0.4038
0.2500	0.4231
0.2500	0.4231
0.2841	0.4808
0.3182	0.5385

Regression Statistics	
Multiple R	1
R Square (R2)	1
Adjusted R Square	1
Standard Error	3.02E-17
Observations	10

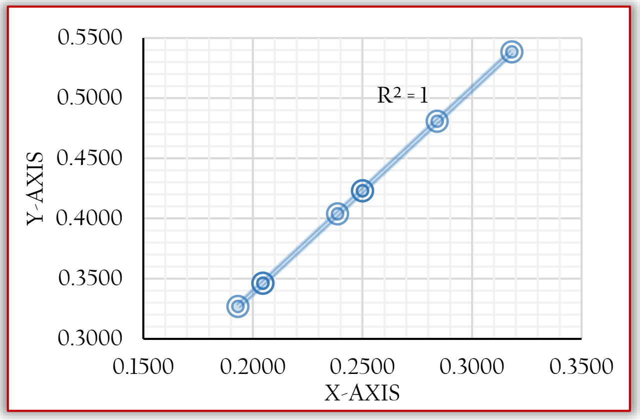


Figure 4: Construction materials wastage due to design and documentation factors comparison

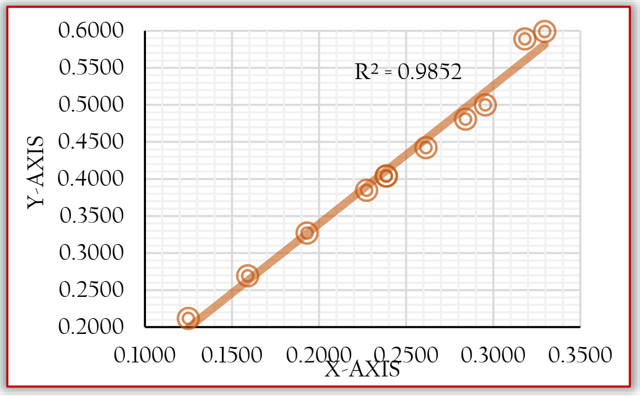


Figure 5: Construction materials wastage due to procurement and handling factors

R2=0.9852 (ok) because the value of R2 range is in between of 0 and 1. It is shown on figure 5 above.

The followings are Causes of construction materials wastage due to operation:- rework due to workers' mistakes, damage to work done caused by subsequent trades, use of incorrect material, thus requiring replacement, poor workmanship, lack of workers or tradesmen or subcontractors' skill, choice of wrong construction method, lack of coordination among crews, problems between the contractor and his subcontractors, equipment frequently breakdown, poor technology of equipment and shortage of tools and equipment's required.

R2=0.999 (ok) because the value of R2range is in between of 0 and 1. It is shown on figure 6 above. The followings are causes of construction materials wastage due to site management and practices: lack of proper waste management plan and control, lack of a quality management system aimed at waste optimization, lack of team work, poor site layout, poor qualification of the contractor's, technical staff assigned to the project, poor coordination and communication between parties involved in the project, poor management and distribution of labors, materials and equipment's.

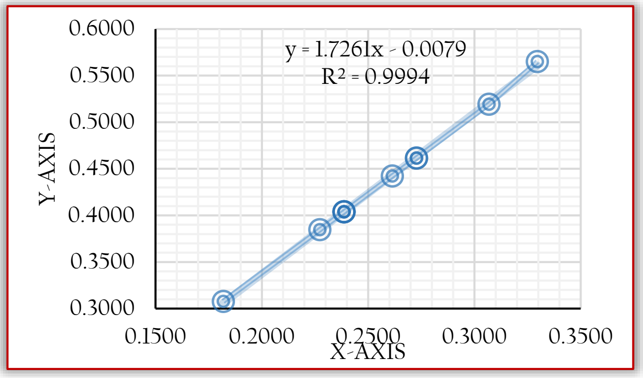


Figure 6: Construction materials wastage due to operation comparison

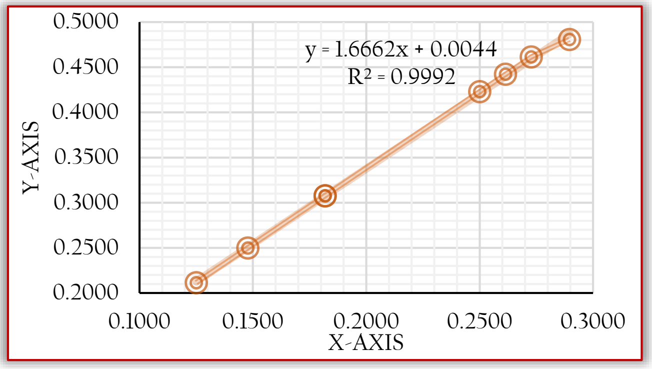


Figure 7: Construction materials wastage due to site management and practices factors

R2 = 0.999 (ok) because the value of R2 range is in between of 0 and 1. It is shown on figure 7 above.

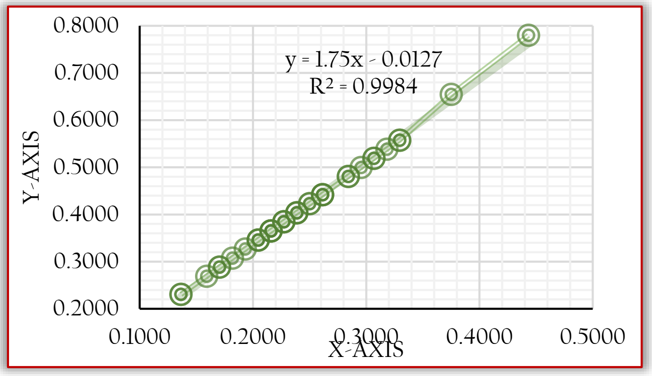


Figure 8: Construction materials wastage due to lack of proper site supervision factors

R2=0.998 (ok) because the value of R2range is in between of 0 and 1. It is shown on figure 8 above.

CONCLUSSION

Construction waste corresponds to a significant portion of the total waste produced by the society. Solutions that reduce construction waste generation are a challenge in the construction industry. This study contributes to the understanding of waste generation at construction sites through statistical modelling. A method for waste measurement was developed, and data were obtained from selected building sites. The proposed regression models had a satisfactory statistical performance and thus may be acceptable for estimating generated wastes to guide management plans. The models propose a comprehensive relationship between waste and building characteristics. The model to estimate total Waste had a simple yet effective linear format and was based on building characteristics, data for which may be collected directly from the project sites. The second model considered Time, and it indicated a link between waste generation and building schedules. This model suggested a small nonlinear influence of the Time attributes on Waste, through an S-shaped curve.

In summary, the models based on regression analysis could contribute to waste generation understanding by showing the most relevant attributes and their weights. Under these circumstances, they can be used to predict waste generation in projects with similar characteristics. The models can preview waste before construction commences and help builders improve onsite waste management. Therefore, this approach could be used to reduce cost and waste in new projects

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