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ASSESSMENT OF CONSTRUCTION MATERIALS WASTAGE USING ARTIFICIAL NEURAL NETWORK MODEL

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ABSTRACT

Material wastage represents an important element of the total cost of any construction project. The expected percentage of such wastage should be accurately identified to arrive at a more reliable cost estimating process. The objective of this research is to provide an Artificial Neural Network (ANN) model for material waste assessment. Such model can accurately help to identify the expected percentage of cement and steel reinforcement waste. The main factors affecting material wastage were clearly identified. The different sequences of the model development were also discussed. The validity of the proposed model was tested.

KEY WORDS*:* Construction Materials Wastage, Neural Network.

ÉVALUATION DES MATÉRIAUX DE CONSTRUCTION DE PERTE UTILISATION ARTIFICIELLE MODELE DE RESEAU NEURONAL

RÉSUMÉ

Gaspillage de matériaux représente un élément important du coût total d'un projet de construction. Le pourcentage attendu de ce gaspillage doit être identifié avec précision pour arriver à un processus plus fiable d'estimation des coûts. L'objectif de cette recherche est de fournir un réseau de neurones artificiels (ANN) modèle pour l'évaluation des matières résiduelles. Un tel modèle peut aider à identifier avec précision le pourcentage attendu de ciment et d'acier d'armature des déchets. Les principaux facteurs affectant la perte de matériau ont été clairement identifiés. Les différentes séquences de l'élaboration du modèle ont également été discutées. La validité du modèle proposé a été testé.

MOTS CLÉS: le gaspillage de matériaux de construction, Neural Network.

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1 INTRODUCTION

Construction Materials represent a major portion of the total cost of any construction project. Consequently, a strict control over materials cost is of essential importance for project success. Materials wastage is one of the most important elements that have a serious effect on the total material cost. Waste in construction is defined as "the difference between the value of those materials delivered and accepted on site and those used properly as specified and accurately measured in the work, after deducting cost saving of substituted materials and those transferred elsewhere" , Polat (2003).

The subject of construction materials wastage was especially considered by many research papers. For instance, Urio and Brent (2006) stated that the average direct wastes of principal construction materials (as a percentage) on the selected Francistown city sites are: Cement is 10.30%, Sand is 13%, stone is 11%, Common bricks is 7.4%, Face bricks is 6.9%, Concrete (site mixed) is 5.7%, Mortar in brickwork is 7.2% and Mortar in plasterwork is 11%.

Ajayi et al. (2008) concluded that it is recommended that supervisors on site should be educated on how waste due to material handling should be minimized and also manufacturers should be made to develop basic standard for materials, so that invariably waste from material handling can be minimized **.**

Garas (2001) clearly demonstrated that some materials such as timber formwork with an average waste of 13% and sand with an average 9% reported the highest percentages of waste among all materials in Egypt. While other materials such as reinforcing steel with an average 5%, cement 5%, and concrete 4% were within the limits. Such acceptance limits are within 7% and 5% for steel and cement respectively.

In the next sections of this paper, the main factors affecting construction materials wastages will be identified. The process of the model development will be discussed. The validity of the proposed model will be evaluated and tested.

2 FACTORS AFFECTING CONSTRUCTION MATERIALS WASTAGE

Based on a comprehensive literature survey the following is a list of the different material waste factors that were considered in these studies , Urio and Brent (2006):

***First**: Design factors:*

1- Coordination of all parties during the design stage of a project.
2- Attention to the standard sizes of specified products during the design.
3- Quality of contract documentation.
4- Design changes related to designer.
5- Design changes related to owner.
6- Experience of designer's in method and sequence of construction.
7- Attention to alternatives available products related to designer.
8- Complexity of detailing in the design drawings.
9- Errors or availability of enough information of the design drawings.

Second: Procurement factors:

10- Material delivery procedures.
11- Order accuracy for indicate quantities.
12- Conditions of materials storage.
13- Supplier quality.
14- Purchased products compliance with specification**.**

***Third**: Material handling factors:*

15- Attention during transportation to the site.
16- Care during transportation in the site.
17- Materials supplied in loose form.
18- Use of whatever material which is close to working place.
19- Attitude of project team and laborers .

***Fourth**: Operating factors:*

20- Errors by tradesmen.
21- Equipment problems.
22- Inclement weather.
23- Damage by subsequent trade.
24- Use of incorrect material.
25- Accidents.
26- Conditions of site management.
27- Conditions of site supervision.
28- Degree of coordination of responsibilities between main contractor and sub-contractors.
29- Past experience of contractors.
30- Knowledge about construction.
31- Clearly identification of the required quantity.

***Fifth**: Residual factors:*

32- Waste from uneconomical shape.
33- Off cuts (small pieces).
34- Over mixing of material.
35- Waste from errors in the application process.

***Sixth**: Others factors:*

36- Criminal waste due to damage and theft.
37- Guarding on site.
38- Change cause of stakeholders like: government.

3 DATA COLLECTION

A field survey was carried out to identify the most important material waste factors. The survey is based on a questionnaire through direct interviews or sending E-mails. Engineers opinions reflect their past experiences in construction projects and indicate the relative impact of each of the previously identified thirty eight factors on cement and steel reinforcement wastage. Those engineers work in different types of projects and companies in the industry. The total number of engineers surveyed is (60) engineers. The surveyed engineers have different period of past experience ranged from 5 to 40 years. The form of the questionnaire is divided into two parts; the first part shows the impact that each of the previously identified factors can have on the cement wastage as an impact indicator of low, medium or high impact. The surveyed engineer is asked to mark (√) in front of each factor that reflects his opinion regarding the impact of this factor on cement waste. The second part is similar to the first part and shows the impact on steel reinforcement. A sample of the questionnaire form is shown in Table 1.

4 IDENTIFICATION OF THE MOST IMPORTANT WASTE FACTORS

Some statistical analysis was carried out to the collected data to identify the most important factors. Such analysis is known as Pareto rules. Pareto rules include three steps:

Table 1: Questionnaire form.

		waste in CEMENT										waste in STEEL									
No.	Impact Indication	Low Impact			Medium Impact				High Impact			Low Impact			Medium Impact				High Impact		
	Impact Grade	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
	First: Design factors :																				
1	Design changes related to owner																				

First step: Insert all the data collected of the materials waste factors (38 factors) in a table.

Second step: Calculate the "Importance Index" for each factor that depends on 60 respondents using the following equation, Ali (1993):

$$\text{Importance index} = \frac{a*(n)}{\text{Max grade} * N}$$

Where: (a): Selected score 1,2,3,-----,10.
(n): Frequency of the selected score.
(N): No. of Respondents = 60.
(Max. grade): Maximum grade for impact grade = 10.

Third Step

1- Indicate the "importance index" rank of all factors according to the calculated Importance Index (from the largest to the smallest).
2- Choose the first ten factor which score high rank of the importance index.

Table 2 shows the third step of Pareto rule for the first ten factors which score high rank of the importance index for cement and steel reinforcement wastage.

Table 2: High ranks of importance's index of factors affecting cement and steel wastage.

Cement wastage				Steel wastage		
Factor No.	Importance Index	RANK		Factor No.	Importance Index	RANK
12	74.17%	1		35	68.00%	1
29	69.83%	2		29	66.00%	2
22	68.00%	3		33	66.00%	3
35	67.67%	4		6	65.83%	4
34	66.83%	5		30	65.00%	5
6	66.83%	6		31	63.83%	6
26	66.50%	7		27	63.67%	7
31	66.00%	8		26	62.50%	8
27	65.33%	9		32	62.50%	9
30	65.33%	10		12	62.00%	10

The combination between the first ten factors that have the highest score of the importance index for cement and steel reinforcement wastage results in the following twelve factors:

1- Conditions of materials storage.
2- Past experience of contractors.
3- Inclement weather (cement).
4- Waste from errors in the application process.
5- Over mixing of material (cement).
6- Experience of designer's in method and sequence of construction.
7- Conditions of site management.
8- Clearly identification of the required quantity unclear due to improper planning.
9- Conditions of site supervision.
10- Knowledge about construction.
11- Off cuts (small pieces, steel).
12- Waste from uneconomical shape(steel).

5 CEMENT AND STEEL REINFORCEMENT WASTE DATA

The most important waste factors were taken to prepare the cement and steel reinforcement waste data form. The actual percentage of cement and steel reinforcement waste of a suitable samples of different building projects in Egypt were collected to be used as a training material for the development of the proposed ANN material waste model. The total size of sample is fifty five projects for each of cement or steel reinforcement. The collected data described the project site and management conditions represented through the previously identified twelve factors. Such data also include the actual percentage of cement and steel reinforcement wastage.

6 MODEL DEVELOPMENT

The results of cement and steel reinforcement waste data form were taking to prepare two different ANN models, one for cement wastage and the other for steel reinforcement wastage. Neural Connection Program-Version 2.0- was using to prepare the application models. To prepare an ANN Model, the following steps must be followed:
Step1: Data were collected from cement and steel reinforcement waste forms; these include the conditions of each factor of the previously identified twelve factors. The conditions of each factor are presented according to three measures: excellent condition, good condition

and poor condition. Considering these conditions to prepare data collected file are as follows:

Consider: "Excellent" = 1 "Good" = 2 "Poor" = 3

Step2: Write the condition of the twelve factors and the percentage of actual waste for each sample in an Excel file like: 1,2,3,3,1,1,3,2,1,2,2,3,5.5

Where: (1): means excellent condition for the first factor of the twelve factors that affect cement or steel wastage.

(2): means good condition for the second factor of the twelve factors.

(3): means poor condition for the third factor of the twelve factors…etc.

(5.5): means the percentage of actual waste for cement or steel.

Write the actual data of each of the collected fifty five samples as explained in one row in Excel file to prepare a data file for cement and another one for steel. The twelve factors (Input factors in the model) and the percentage of the actual waste (Target output in the model) are shown in Table 3.

Table 3: Model Inputs and Output.

Input Factors	Target Output
1- Conditions of materials storage 2- Past experience of contractors 3- Inclement weather (cement). 4- Waste from errors in the application process. 5- Over mixing of material (cement). 6- Experience of designer's in method and sequence of construction 7- Conditions of site management 8- Clearly identification of the required quantity unclear due to improper planning 9- Conditions of site supervision 10-Knowledge about construction 11- Off cuts (small pieces, steel) 12- Waste from uneconomical shape(steel)	Percentage of waste for cement or steel reinforcement

Step3: Identify the best structure of the proposed model through 70 trials by changing number of hidden layers, number of nodes in each layer, and nodes activation function to obtain to lowest "RMS Error". A sample of such trials for both cement and steel reinforcement models are shown in Table 4.

Note: the node activation function for each of the hidden layers is “Sigmoid” in each trial for cement or steel model.

An investigation to Table 4 shows that the minimum value for "RMS Error" in cement model was 1.55 and absolute variance was 20.66%, trial No.37. Table 5 summarized the features of that best model.

The lowest “RMS Error” for the best steel waste model was 1.89 in trial No. 64 with absolute variance 16.49%. Table 6 summarized the features of that best model.

7 Validations of Cement and Steel Models

A number of data samples are set aside to be used for the validation of the two models. Five samples are used for the validation process. The results of such validation test are shown in Table 7 and Table 8 for the two best models respectively. According to Table 7 ,the difference between the actual and the predicted percentages of the cement wastage were between -15.78% and +24.33%. Based on the previously identified percentage of the absolute variance of the best model for cement (20.66%) , the results of such testing indicated an accuracy of 80% for the proposed model. This can be considered as a good indicator regarding the validity of such model. The difference between the actual and the predicted percentages of the steel reinforcement wastage were between -33.87% and -0.36%. Again, such differences are within the percentage of the absolute variance of the best model for steel (16.49%), except one. The results of such testing indicated an accuracy of 80% for the proposed model.

Table 4: Details of NN Experiments in Cement and Steel Models.

	Cement Model					Steel Reinforcement Model				
	Hidden Layers					Hidden Layers				
Trial No.	No. of layers	No. of nodes in first layer	No. of nodes in second layer	RMS Error	Absolute Variance (%)	No. of layers	No. of nodes in first layer	No. of nodes in second layer	RMS Error	Absolute Variance (%)
1	1	1	0	3.03	44.43	1	1	0	2.07	18.32
2	1	2	0	4.59	51.72	1	2	0	3.42	32.37
3	1	3	0	3.92	51.54	1	3	0	3.37	32.11
4	1	4	0	3.17	47.86	1	4	0	2.49	25.66
5	1	5	0	3.12	45.04	1	5	0	2.33	22.42
6	1	6	0	4.97	60.87	1	6	0	3.39	32.05
7	1	7	0	7.50	84.42	1	7	0	3.61	33.17
8	1	8	0	5.24	66.55	1	8	0	1.94	18.69
9	1	9	0	3.94	51.94	1	9	0	3.49	32.54
10	1	10	0	5.00	61.00	1	10	0	3.67	33.36
11	1	11	0	5.32	65.65	1	11	0	3.58	33.01
12	1	12	0	4.14	52.61	1	12	0	3.43	32.48
13	2	1	1	2.73	37.46	2	1	1	3.49	32.64
14	2	2	1	4.00	46.38	2	2	1	3.36	29.76
15	2	2	2	2.71	39.94	2	2	2	3.28	31.62
16	2	3	1	3.14	43.03	2	3	1	3.39	32.24
17	2	3	2	3.97	44.48	2	3	2	2.45	22.49
18	2	3	3	2.67	34.48	2	3	3	3.49	32.65
19	2	4	1	2.55	35.22	2	4	1	3.46	32.50

Table 4 Continue

31	2	6	4	2.84	38.94	2	6	4	3.45	31.57
32	2	6	5	3.32	40.52	2	6	5	2.07	18.32
33	2	6	6	2.71	35.50	2	6	9	2.60	37.16
34	2	7	1	2.71	36.17	2	7	1	1.93	16.89
35	2	7	2	2.63	34.85	2	7	2	2.97	41.00
36	2	7	3	3.30	47.59	2	7	3	2.74	39.42
37	2	7	4	1.55	20.66	2	7	4	2.78	38.42
38	2	7	5	5.07	55.93	2	7	5	2.59	37.07
39	2	7	6	4.91	63.59	2	7	6	2.63	37.47
40	2	7	7	7.61	88.75	2	7	7	2.59	37.09
41	2	8	1	2.50	35.91	2	8	1	2.74	38.14

Table 4 Continue

57	2	9	9	4.90	60.71	2	9	9	3.14	28.26
58	2	10	1	6.65	63.56	2	10	1	3.55	32.93
59	2	10	2	5.41	58.61	2	10	2	3.39	32.23
60	2	10	3	3.17	44.46	2	10	3	2.58	24.92
61	2	10	4	5.15	56.78	2	10	4	3.14	29.47
62	2	10	5	1.71	22.14	2	10	5	2.57	25.53
63	2	10	6	2.32	34.11	2	10	6	3.35	31.99
64	2	10	7	3.94	46.76	2	10	7	1.89	16.49
65	2	10	8	3.89	50.95	2	10	8	2.01	20.88
66	2	10	9	4.53	51.53	2	10	9	3.54	32.85
67	2	10	10	4.52	54.10	2	10	10	2.73	25.34
68	2	11	1	3.99	53.26	2	11	1	3.42	30.80
69	2	11	2	6.10	72.60	2	11	2	3.47	30.98
70	2	11	3	2.91	42.52	2	11	3	1.95	16.56

Table 5: Features of the Best Structure of the Cement Model.

Trial No.	Input (No. of nodes)	Output (No. of nodes)	Hidden Layers				RMS Error	Absolute Variance (%)
			No. of layers	No. of nodes in first layer	No. of nodes in second layer	Function		
37	12	1	2	7	4	sigmoid	1.55	20.66

Table 6: Features of the Best Structure of Steel Reinforcement Model.

Trial No.	Input (No. of nodes)	Output (No. of nodes)	Hidden Layers				RMS Error	Absolute Variance (%)
			No. of layers	No. of nodes in first layer	No. of nodes in second layer	Function		
64	12	1	2	10	7	sigmoid	1.89	16.49

Table 7: The actual and predicted results for testing the Cement Model.

Sample No.	Actual (%)	Predicted Value (%)	Different (%)	Comment
1	6.00%	6.49%	+8.17%	Correct
2	6.00%	7.46%	+24.33%	Wrong
3	12.50%	11.13%	-10.96%	Correct
4	8.30%	6.99%	-15.78%	Correct
5	4.30%	4.24%	-1.40%	Correct

Table 8: The actual and predicted results for testing the Steel Model.

Sample No.	Actual (%)	Predicted decision (%)	Different (%)	Comment
1	11.1%	9.99%	-10.00%	Correct
2	10.5%	10.25%	-2.38%	Correct
3	15.0%	9.92%	-33.87%	Wrong
4	8.3%	8.27%	-0.36%	Correct
5	4.3%	4.21%	-2.09%	Correct

8 SUMMARY AND CONCLUSION

This study aims to develop an ANN model that can be used to assess the expected waste values of the cement and steel reinforcement. This can help to arrive at a more reliable cost estimating process. Such model considers the effects of the different relevant factors. The following points represent the main conclusions of this study:

1- Twelve factors affecting cement and steel reinforcement wastage in the building construction projects were identified to be:
   1- Conditions of materials storage.
   2- Past experience of contractors.
   3- Inclement weather (cement).
   4- Waste from errors in the application process.
   5- Over mixing of material (cement).

6- Experience of designer's in method and sequence of construction.
7- Conditions of site management.
8- Clearly identification of the required quantity unclear due to improper planning.
9- Conditions of site supervision.
10- Knowledge about construction.
11- Off cuts (small pieces, steel).
12- Waste from uneconomical shape(steel).

A suitable sample of different building projects in Egypt were used to prepare two different neural network models, one for cement wastage and the other for steel reinforcement wastage. The inputs data are the factors affecting cement and steel reinforcement wastage and the output is the percentage of actual waste for cement and steel reinforcement. The best structure of the two models was identified through 70 trials. Number of hidden layers was two, number of nodes in the first hidden layer was 7 and 10 for cement and steel models respectively, number of nodes in the second hidden layer was 4 and 7. The node activation function for each layer is “Sigmoid”.

2- Testing the validity of the two proposed models with 5 samples that were still unseen by the network was performed. The results of testing indicated an accuracy of (80%) for each of the cement and the steel reinforcement model. This can be considered as a good indicator for the validity of the proposed models.
3- The proposed models should be augmented to take into consideration the other different types of construction projects such as heavy construction projects and industrial projects.

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