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Impact of Change Orders on Construction Material Waste in Residential Buildings Projects

Impacto de las órdenes de cambio en el desperdicio de materiales de construcción en proyectos de edificios residenciales

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Abstract
The current study attempts to address the relationship between material waste and change orders in residential building projects implemented in the West Bank in Palestine. The main objectives include: (1) identify the main factors affecting change orders in residential projects, (2) identify the main factors affecting martial waste eon construction sites, (3) address the relationship between change orders and construction material waste, (4) develop prediction model that shows the impact of change orders on material waste. To achieve this, two methods are used: (1) questionnaire survey is conducted to identify the main factors affecting change orders and the major factors of material waste on construction sites. Fourteen (14) factors believed to affect change orders and 15 factors that might affect material waste are investigated in this study. (2) Case study is conducted to address the impact of change orders on material waste. Data collected from 40 residential building projects implemented in the West Bank in Palestine. Regression analysis is used to establish the predictive model that relates the change orders and material waste. Results indicate that the top five factors affecting change orders include: change of project scope by owner, shortage in equipment and materials, change in materials, design mistakes, and change of plans by owner. It also shows that the top five factors affecting material waste are: rework, lack of labors skills, design errors, purchasing materials not complying with specifications, and frequent design changes. The results revealed a strong relationship between number of change orders and construction material waste on site.

Keywords: *Change orders; material waste; wastage; residential building; regression, buildings.*

Resumen
El presente estudio intenta abordar la relación entre el desperdicio de materiales y las órdenes de cambio en proyectos de construcción residencial implementados en Cisjordania, Palestina. Los principales objetivos incluyen: (1) identificar los principales factores que afectan las órdenes de cambio en proyectos residenciales, (2) identificar los principales factores que afectan el desperdicio de material en los sitios de construcción, (3) abordar la relación entre las órdenes de cambio y el desperdicio de material de construcción, (4) Desarrollar un modelo de predicción que muestre el impacto de las órdenes de cambio en el desperdicio de material. Para lograr esto, se utilizan dos métodos: (1) se realiza una encuesta por cuestionario para identificar los principales factores que afectan las órdenes de cambio y los principales factores de desperdicio de material en los sitios de construcción. En este estudio se investigan catorce (14) factores que se cree que afectan las órdenes de cambio y 15 factores que podrían afectar el desperdicio de material. (2) Se realiza un estudio de caso para abordar el impacto de las órdenes de cambio en el desperdicio de material. Datos recopilados de 40 proyectos de construcción residencial implementados en Cisjordania, Palestina. El análisis de regresión se utiliza para establecer el modelo predictivo que relaciona las órdenes de cambio y el desperdicio de material. Los resultados indican que los cinco factores principales que afectan las órdenes de cambio incluyen: cambio del alcance del proyecto por parte del propietario, escasez de equipos y materiales, cambio de materiales, errores de diseño y cambio de planes por parte del propietario. También muestra que los cinco factores principales que afectan el desperdicio de material son: retrabajo, falta de habilidades laborales, errores de diseño, compra de materiales que no cumplen con las especificaciones y cambios frecuentes de diseño. Los resultados revelaron una fuerte relación entre el número de órdenes de cambio y el desperdicio de material de construcción en el sitio.

Palabras clave: Órdenes de cambio; desperdicio de materiales; pérdidas; edificación residencial; regresión; edificaciones.

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1. Introduction

Construction industry is an important sector for any country. It has a major role in national welfare as it provides people with residential buildings, office buildings, commercial buildings, infrastructure, and industrial plants. It also absorbs high percentage of labors. However, it is full of risks and uncertainties (Mahamid, 2020a). "It is fragmented, sensitive to changing variables such as political and environmental factors and has a significantly high rate of business failure" (Nega, 2008). Some of the main problems facing construction projects are material waste (Saidu and Shakantu, 2016a) and frequent change orders (Mahamid, 2017). (Bekr, 2014) revealed that about 15% of building materials end up as waste. In the Uk, (Osmani, 2011) concluded that more than 10% of construction materials delivered to the sites are accounted as wastes. In United States (US), about 40% of annual municipal solid waste are generated from construction waste. (Ameh and Itodo, 2013) found that more than 10% of materials delivered to construction sites end up as wastes. (Saidu and Shakantu, 2016b) found that material waste on sites is one of the main factors leading to cost overrun. In the same vein, (Ameh and Itodo, 2013) found that construction material waste accounts for an additional 15% to project cost in UK, 20-30% in Netherland and 11% in Hong Kong. They indicated that project managers pay little attention to material waste and its bad effects on project cost.

On the other hand, (Mahamid, 2017) concluded that "change orders" is one of the main factors affecting project performance on site. It leads to cost overrun, time overrun, conflicts and disputation between construction parties. (Msallam et al., 2015) stated that "Change order is one of the few tools that the project manager contractually has to accommodate for unplanned occurrences once the project is under construction. It is important for a project manager to understand the reasons behind such unexpected variations in a project and has to act accordingly so that the project can be accomplished successfully". In general, all construction parties agree that project without change orders will improve the smoothness of project workflow (Alaryan et al., 2014).

While numerous studies addressed the factors affecting change orders and material waste on construction sites, very little studies conducted to investigate the impact of change orders on construction material waste. However, the current study attempts to address the relationship between material waste and change orders in residential building projects implemented in the West Bank in Palestine. The main objectives include: (1) identify the main factors affecting change orders in residential projects, (2) identify the main factors affecting martial waste eon construction sites, (3) address the relationship between change orders and construction material waste, (4) develop prediction model that shows the impact of change orders on material waste.

2. Previous studies

2.1. Change orders in construction projects

Change order is defined as "any deviation from an agreed upon well-defined scope and schedule" (Osman et al., 2009). Change orders have direct negative impact on cost of the projects. It leads to increase the project cost. (Homaid et al., 2011) found that the project cost increases by 11.3% due to change orders. (Osman et al., 2009) carried out a questionnaire survey in Malaysia to find out the common effects of change orders on construction projects. He found that the main effects are: time overrun, cost overrun, rework and waste. (Enshassi et al., 2010) conducted a questionnaire survey to investigate the causes of change orders n Gaza strip. They concluded that the main causes of change orders are: shortage in equipment and materials, design mistakes, design changes, poor consultant knowledge in materials available in the market, poor contract documents, financial problems, variation in specifications and lack of communication between construction parties. (Alnuaimi et al., 2010) studied the causes and effects of change orders in public projects in Oman. They concluded that the factors affecting change orders are owners' modifications and lack of manuals and procedures. They also determined that the main effects of change orders are cost overrun, delays and disputes. (Olsen et al., 2012) concluded that mistakes in design is the main factor affecting change orders in construction projects. (Alaryan et al., 2014) conducted a questionnaire survey to investigate change orders in Kuwaiti construction projects. They found that owners are the most responsible participant who causes changes. They also concluded that the top factor of change orders is plans' changes by owner, and the main effect of change orders is cost overrun.

Through a questionnaire survey, (Msallam et al., 2015) found that the main factors of change orders in Jordanian construction projects include schedule changes, plan changes, mistakes in design, conflict between construction documents, poor coordination and communication between parties, financial problems. (Mahamid, 2017) linked the change orders in public projects with rework cost. He concluded a strong linear relation between change orders and rework cost. He also concluded that the main factors affecting change orders in public projects are changes in project scope, errors in design, financial problems, changes in materials, and poor coordination between construction parties.

2.2. Materials waste on construction site

Waste can be simply defined as "unwanted material" (Ikau et al., 2016). It causes cost increase (Mahamid and Badawi, 2014) and environmental problems (Rawshan et al., 2009). (Ameh and Itodo, 2013) linked material waste with cost increase in construction projects. They found that building material wastage contributes to about 30% of project cost overrun. In Jordan, (Bekr, 2014) concluded that building material wastes are accounted for by values between 15 and 21%. (Swinburne et al., 2010) concluded through a questionnaire survey that bad storage, handling problems, poor control on site, overordering of material, and transportation are the major factors affecting construction wastes on site. (Al-Hajj and Hamani, 2011) conducted a questionnaire survey to investigate material waste in construction projects in UAE. They concluded that the main factors affecting

material waste are poor design, change orders, and rework. (Nagapan et al., 2011) found that the top factors leading to material waste on construction sites include: changes in design, bad storage, variation orders, weather, and poor labor skills. (Muhwezi et al., 2012) classified the factors affecting construction material waste into 9 categories, they are: "materials handling", "materials storage", "operation", "environmental", "design and documentations", "site management", "procurement", "transportation" and "others".

(Ameh and Itodo, 2013) indicates that the major factors affecting building material wastes are poor material handling, rework, and poor supervision. (Agyekum et al., 2013) indicated that the materials with highest level of waste include: concrete, timber, bricks, and cement/mortar. They also concluded that the main factors of materials waste are: bad storage, late changes, poor management on site and poor materials. They recommended "recycling of some waste materials on site", "reusing of surplus materials" and "preventing the occurrence of waste" to minimize material waste on site. Material wastage in construction projects could be result of poor experience in construction waste, poor materials, bad storage, and rework (Ikau et al., 2016).

(Arshad e al., 2017) indicated that the most wasteful material in building projects are plaster from mortar, tiles, and bricks. They found that main factors of material wastes on site are: poor labors skills, poo management and poor supervision. Financial problems, specifications variation, lack of coordination and communications between construction parties, improper material handling, and lack in planning are the main factors of building material wastes in Pakistan (Mahamid, 2022). Through a questionnaire survey, (Luangcharoenrat et al., 2019) identified the main factors affecting construction materials waste in Thailand, namely: design changes, lack in planning and bad storage. (Mahamid, 2020b) conducted a questionnaire survey to identify the main factors of material waste. He revealed that the top factors include: lack of labors skills, rework, design changes, selecting the lowest bidder contractor, and design errors. In his study, he found a strong relation between material waste and rework on site.

3. Research methods

To achieve the study objectives, the following methods were used:
(1) Questionnaire survey to identify the main factors affecting change orders and the major factors of material waste on construction sites.
(2) Establishing the relationship between change orders and material waste using regression analysis.

3.1 Questionnaire surveys

After identifying factors that might affect change orders and material waste from literature and experts' opinions, a questionnaire was designed. The questionnaire was divided into three parts: part 1 which included general questions about the company and the respondent such as company name, experience, education, company size, …etc. part 2 includes list of factors that might affect change orders on construction site. Part 3 includes list of factors that might affect material waste in building projects. Fourteen (14) factors believed to affect change orders and 15 factors that might affect material waste were investigated in this study. Respondents are asked to identify the level of importance of each factor using an ordinal five-point scale as follow: very high (5), high (4), moderate (3), little (2) and very little (1). A chance is given to the respondents to add any related factors and to rate them using the same scale. Before distributing the questionnaire, a pilot study is conducted to be sure that the information collected from questionnaire survey will be suitable to achieve the study objective. So, the draft questionnaire is sent to 3 local experts to check its validity. The experts' recommendation indicated validity of the questionnaire.

The targeted population included the general contractors who registered in the Palestinian contractors Union and consultants who registered in Palestinian Engineers Association. 60 contractors and 40 consultants are selected randomly. 50 completed questionnaires returned from the contractors and 36 completed questionnaires returned from consultants (response rate of 83% and 72%, respectively). The respondents were engineers, planners, and managers. Most of the respondents have experience of more than 10 years in building projects.

Based on the responses received from the participants, the factors were ranked according to their weighted arithmetic means. Then, factor analysis technique was used to identify the significant change orders factors. Consequently, only factors with Eigen values ≥ 1.0 are retained, meaning that the factors are significant to the study. After reducing the number of change order factors to the significant factors, respondents were asked again to identify the impact of these factors on material waste on construction site through a questionnaire survey.

3.2 regression models

To establish the relationship between material waste and change orders in building projects, historical data is collected. First, the dependent and independent variables were identified (material waste is decided to be a dependent variable and number of change orders used as independent variable), Linear regression analysis is decided to be used as a tool to establish the prediction models that relate material waste with change orders. The data comprised of 40 residential projects which was collected from records available in contracting firms who implemented those projects (more details are in section 4.4).

4. Results and discussion

4.1 Ranking of change orders factors

Fourteen (14) factors that might affect change orders in building projects were identified from literature and experts' opinions. The targeted population are requested to rank the identified factors according to their impact on change orders on construction site. The

respondents used a 5-point Likert scale ranging from very high impact (5) to very low impact (1). Results are shown in (Table 1). Contractors

input revealed that the top five affecting factors are: change of project scope by owner, change in materials, shortage in equipment and materials, design mistakes, and change of plans by owner. In turn, the consultants showed that the top 5 factors affecting change orders in building projects include: shortage in equipment and materials, change of project scope by owner, change in materials, design mistakes, and Lack of coordination between construction parties. The overall results indicated that change of project scope by owner, shortage in equipment and materials, change in materials, design mistakes, and change of plans by owner are the top five factors among the 14 identified factors that affecting change orders on construction sites.

Factor analysis techniques is used to identify the significant factors affecting change orders. Results indicate 4 significant factors, namely: change of project scope by owner, shortage in equipment and materials, change in materials and design mistakes. They accounted for cumulative variance of value 73.26% and Eigen values ranging between 1.338 and 4.892. Results are in line with the previous studies that conducted to identify factors of change orders on construction sites. For example, (Alnuaimi et al., 2010), (Msallam et al., 2015) and (Mahamid, 2018) found that "change of project scope by the owner" is a main factor of change orders. (Enshaasi et al., 2010), (Msallam et al., 2015) and (Mahamid, 2017) concluded that "lack of coordination between construction parties" is one of the top change order factors. "design mistakes" is concluded as a severe factor of change orders on construction sites (Alnuaimi et al., 2010); (Enshaasi et al., 2010); (Olsenet al., 2012); (Mahamid (2017) and (Enshaasi et al., 2010) revealed that "shortage in equipment and materials" and "Change in materials" are top factors of change orders. (Alaryan et al., 2014) indicated that "change of plans by owner" is a top factor affecting change orders in building projects.

Table 1. *Contractors' and consultants' perception of change order factors in residential projects*

Factors	Contractor		Consultant		Overall	
	Mean	Rank	Mean	Rank	Mean	Rank
Change of project scope by owner	4.21	1	4.16	2	4.19	1
Shortage in equipment and materials	4.03	3	4.22	1	4.11	2
Change in materials	4.16	2	3.93	3	4.06	3
Design mistakes	3.92	4	3.87	4	3.90	4
Change of plans by owner	3.82	5	3.65	6	3.78	5
Lack of coordination between construction parties	3.79	6	3.66	5	3.72	6
Change in design	3.75	7	3.43	10	3.61	7
Unavailability of required labor skills	3.66	8	3.50	8	3.59	8
Problems on site	3.65	9	3.49	9	3.58	9
Defective workmanship	3.49	10	3.60	7	3.54	10
Owner's change of schedule	3.36	11	3.18	12	3.29	11
Conflict between contract documents	3.20	12	3.31	11	3.25	12
Weather	3.07	13	2.99	14	3.04	13
New government regulations	2.89	14	3.12	13	2.99	14

4.2 Ranking of change orders factors

Fifteen (15) material waste factors were identified through review of literature and feedback from local experts in construction industry. Both targeted contractors and consultants were asked to provide their views regarding the importance of the identified factors in material waste in building projects. The factors are ranked using a 5-point Likert scale ranging from very high important (5) to very low important (1). (Table 2) shows the results of the survey. Contractors' input revealed that the top five factors affecting material waste were: lack of labors skills, rework, design errors, purchasing materials not complying with specifications, and frequent design changes. Consultants' input indicated the same top 5 factors as revealed by the contractors, but in different order as shown in (Table 2). Overall view showed that the top five factors were: rework, lack of labors skills, design errors, purchasing materials not complying with specifications, and frequent design changes.

"Design errors", "frequent design changes" and "purchasing materials not complying with specifications" mainly lead to which generates wastages on site. Labors with low skills might perform their jobs in bad shape which leads to rework and causes material waste. Thus, construction parties should pay high attention and give enough time for design and reviewing design documents to minimize changes during execution phase. Contractors should assign high skilled labors and should conduct training workshops for those of low skills. High skilled labors play critical role in minimizing material waste on site.

The results agree with the previous studies conducted for the same purpose. For example, (Ikau et al., 2016) and (Al-Hajj and Hamani, 2011) concluded that "lack of labor experience" and "rework" are main factors of material waste in building projects. material waste on sites. (Nagapan et al., 2011), (Luangcharoenrat et al., 2019) and (Mahamid, 2020b) found that "design changes" is one of the critical factors affecting metrical waste on construction sites.

Table 2. *Contractors and consultants' perception of factors affecting material waste in residential projects*

Factors	Contractor		Consultant		Overall	
	Mean	Rank	Mean	Rank	Mean	Rank
Rework	4.03	2	4.30	1	4.14	1
Lack of labors skills	4.17	1	4.09	3	4.13	2
Design errors	3.95	3	4.16	2	4.04	3
Purchasing materials not complying with specifications	3.76	4	3.83	5	3.79	4
Frequent design changes	3.63	5	3.96	4	3.77	5
bad materials storage	3.60	6	3.74	6	3.66	6
Poor quality of materials	3.39	8	3.55	7	3.46	7
Lack of coordination between construction parties	3.42	7	3.37	8	3.40	8
Improper site management	3.30	9	3.34	9	3.32	9
Improper handling	3.09	10	3.21	10	3.14	10
Poor site supervision	2.80	12	3.10	11	2.92	11
Lack of tools	2.93	11	2.82	13	2.88	12
Wrong orders	2.65	14	2.91	12	2.76	13
Improper methods of unloading	2.77	13	2.72	15	2.75	14
Weather	2.52	15	2.77	14	2.63	15

4.3 Change orders and material waste in residential building projects

The significant 4 factors (factors with Eigen value > 1) that affect change orders on construction sites are selected to investigate their impact on material waste. Results are shown in (Table 3) which reveals the impact of the significant change orders factors on material waste on construction sites in relative ranks. Results show that "design mistakes" is the factors with highest impact on material waste; 78% of the respondents rated it as a top material waste factor in building projects. Mistakes in design lead to change orders that might be ordered after completion the works on site which required redoing the work and resulted in wastages.

This factor is followed by "Change of project scope by owner", which about 78% of responses confirmed its high impact on material waste. In the same vein, "change in materials" received 70% response on account of high impact on material waste. "shortage in equipment and materials" received 66% of respondents confirmed its high impact on material waste on construction sites. As these factors are identified as significant factors on both change orders and material waste on construction sites, construction parties should pay more attention to these factors to minimize change orders and material waste and to enhance the overall project performance.

Well defined scope and specification in the early stages of projects guarantees good project performance and helps in minimizing change orders and material wastage during construction. Shortage in equipment and materials in the Palestinian markets is crucial. This shortage might be due to limitations on the entering required equipment and materials into the Palestinian market by Israeli side. Therefore, more attention should be paid by the government to support producing local construction materials to minimize negative effects of movement's limitation.

Table 3. *Relationship between change orders and material waste in residential building projects*

Change orders factors	Impact on material waste					
	No impact	low impact	moderate impact	high impact	extreme impact	Relative index
Design mistakes	0	1.8	19.2	70.25	8.8	0.57
Change of project scope by owner	0	9.24	20.45	53.23	17.1	0.56
Change in materials	0	13.1	15.8	60.26	10.8	0.54
Shortage in equipment and materials	0	6.6	26.80	58.8	7.8	0.53

4.4 Predictive model of change orders impact on material waste in residential buildings

This study aims at establishing the relationship between change orders and material waste in residential projects. Therefore, a case study is conducted to achieve this objective. Ceramic work is considered in this case study. First, the required data are collected from 40 residential building projects that implemented in the West Bank in Palestine. Projects are residential buildings with 2-4 floors and total area from 350m2 and 800m2, executed between 2015 and 2020. Second, the data analyzed using regression analysis: "The number of change orders" used as independent variable (X) and "material waste in ceramic work (%)" used as dependent variable (Y). It is worthy to be noted that linear regression analysis is widely used to establish the relation between two variables because of its simplicity (Mahamid, 2018).

Results shown in (Table 4) and (Figure 1) indicate a good linear relation between change orders and material waste (R2 = 0.75, F(1, 39) = 78.12, p < 0.05). The developed model is shown in (Equation 1). The coefficient of change orders shows the variation in material waste due to variation in change orders that is 1.61. This means that a unit increase in number of change orders results in 1.61 units increase in material waste. The intercept is (-1.67).

$$Y = 1.61x - 1.67 \quad \textbf{(1)}$$

Where; y = material waste in ceramic work in per cent, x = number of change orders.

Figure 1. *Linear relation between change orders and material waste in ceramic works in residential buildings*

Table 4. *Regression statistics for model in (Equation 1)*

Regression Statistics				*Coefficients*	*t Stat*	*P-value*
Multiple R	0.86		Intercept	1.61	4.54	0.00
R Square	0.75		number of change orders	-1.67	6.23	0.00
Adjusted R Square	0.73					
Observations	40					
F	78.12					

5. Conclusion

Numerous studies addressed the causes of change orders and material waste on construction sites. However, little or no research has been undertaken to investigate the relationship between change orders and material waste in residential building projects. However, this study aims at establishing the relationship between change orders and material waste in residential projects based on questionnaire survey and a case study.

It was concluded that the changes ordered in construction projects are affected by the following five factors: change of project scope by owner, shortage in equipment and materials, change in materials, design mistakes, and change of plans. It also concluded that

the top five factors affecting material waste are: rework, lack of labor skills, design errors, purchasing materials not complying with specifications, and frequent design changes.

Linear regression analysis is used to address the relationship between change orders and material waste. The developed model indicates a good linear relation between them. The nature of relation is direct proportional such as the higher the number of change orders the higher the material waste. The finding from this study would be helpful for building construction professionals in assessing change orders and material waste. Furthermore, the study would also help them in taking proactive measures for eliminating or minimizing the effects of change orders and material waste n construction sites.

Based on study results, the following points are suggested to reduce change orders and material waste on construction sites: a) contractors are recommended to assign skilled labor and to conduct workshops to train the low skilled labors. This will help in minimizing mistakes and rework and improve the performance, b) designers should have enough time to prepare and review design documents. This will minimize design errors and enhance design quality and reduce late changes and wastage, c) consultants are recommended to provide the owners with comprehensive information about the project during the early stages of project. This will minimize the late changes made by the owners during the execution phase which minimizes material wastage.

6. Data availability statement

All data, models, and code generated or used during the study appear in the submitted article.

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