Study of relationship between rework and labor productivity in Building Construction Projects

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Manuscript Code: 1449
Date of Acceptance/Reception: 24.12.2019/29.04.2019
DOI: 10.7764/RDLC.19.1.30-41

Abstract
The objectives of this study included: (1) identifying the factors affecting construction labor productivity, (2) identifying the causes of rework in building projects, (3) addressing the relationship between labor productivity and rework using regression analysis based on data collected from building projects implemented in Palestine. The following steps were used in this study: (1) Questionnaire survey – stage 1: a questionnaire survey was carried out to identify the main factors affecting labor productivity and the main causes of rework on construction sites, (2) Questionnaire survey – stage 2: after identifying the significant causes of rework using factor analysis, a questionnaire survey was conducted to address the impact of these significant causes on labor productivity, (3) Prediction models: Data collected from 40 building construction projects were used to establish the regression models that describe the relation between rework and labor productivity on construction sites. The study concluded that the top factors affecting labor productivity are: lack of labor experience, payments delay, rework due to labor mistakes, lack of supervisor's experience and materials shortage. The study also found that the top five rework causes in building projects are: lack of manpower skills, non-compliance with specifications, frequent change orders, inadequate job planning, and inadequate coordination and integration. Using regression analysis for data collected from 40 building construction projects, three predictive models were developed. The models indicated a significant relation between rework cost and labor productivity i.e the higher the rework cost the lower the construction productivity. This study is the first one that investigated the relationship between construction productivity and rework in Palestine, and that is why it is very important. Results would be helpful for researchers and construction professionals.

Keywords: Productivity, rework, regression, prediction, buildings.

Introduction

Construction industry is one of the largest industries contributing to about 10% of the gross national product (GNP) in industrialized countries (Navon, 2005). However, it is complex and associated with high level of risk that leads to failure in terms of time, cost and quality. According to Chandrusha and Basha (2017), rework is a major factor contributing to this failure. Chandrusha & Basha (2017) defined rework as "the unnecessary effort of redoing an activity that was inaccurately done the first time or the process by which an item is made to conform to the original requirement by completion or correction". They argued that rework seriously affect the performance and productivity aspects of construction projects and the problem of rework has been largely ignored by the construction industry. "Rework on construction sites" was concluded as a significant factor that influences the project performance in terms of time and cost (Mahamid, 2017; Enshassi et al., 2009; Kaming et al., 1997; Wasfy, 2010). However, "little is known about the background and consequently, rework remains an innate problem. The lack of attention to the root causes of rework seems to be a global phenomenon" (Chandrusha & Basha, 2017).

On the other hand, labors considered as significant ingredients for construction projects as their costs account for between 30 and 50% of a project's total cost. They play a critical role in project success (Liu & Ballard, 2008). Construction productivity is important because it influences time and cost objectives (Moselhi & Khan, 2012). Construction industry is mostly defined as a labor-intensive industry. Therefore, labor productivity is critical for financial success of construction projects (El-Gohary & Aziz, 2014). Due to the economic size of construction industry, an increase in labor productivity will improve the overall performance and increase the national income. Accordingly, attention should be paid to identify the factors affecting construction productivity to be able to improve it.

Previous research efforts had attempted to determine the factors that affecting construction productivity and rework. Yet, little or no attention has been directed towards the relationship between productivity and rework. Therefore, this paper is intended to address this important issue. Mainly, the objectives of this paper included: (1) identifying the factors affecting construction labor productivity, (2) identifying the causes of rework in building projects, (3) addressing the relationship between labor productivity and rework using regression analysis based on data collected from building projects implemented in Palestine. This study is the first one that investigated the relationship between

construction productivity and rework in Palestine, and that is why this study is very important and will be helpful for researchers and professionals as well.

Previous studies

Construction labor productivity

Productivity is defined as ratio between input and output. Labor is the most important asset to a construction company. Despite many technological advances, construction industry continues to be a labor intensive. Labor costs account for between 30 and 50% of a project's total cost. Therefore, labors are key of project success (Liu & Ballard, 2008). Improving construction productivity is one of the main issues for construction parties to increase profit and to accomplish projects on time, cost and required quality. Thus, many previous studies were conducted to investigate the factors affecting construction labor productivity. Aynur et al. (2016) conducted a study to investigate the main factors affecting construction productivity from labors' perspective. Thirty-seven factors were identified and divided into four groups, namely: physical, economical, socio-physiological and organizational, factors. Nadia et al. (2017) reported that "residential construction involves labor-intensive tasks where workers are frequently confronted with problems that could lead to demotivation. Demotivation is caused not simply by a lack of motivators but the existence of certain situations that cause dissatisfaction and discourage individuals, therefore reducing overall productivity potential". Therefore, they did a field survey to determine the critical factors of manpower demotivation in residential construction projects in Jordan. The main factors are: working overtime and specifications and quality requirements.

Mahamid et al. (2014) addressed the main factors affecting labor productivity in public projects in Saudi Arabia. Lack of labor skills, poor communication between parties, payments delay, and bad working environment were among the top affecting factors. Robles et al. (2014) carried out a study to identify, analyze and rank factors affecting labor productivity in Spain. Findings revealed that the top five factors were: (1) late supply of materials, (2) poor project documents, (3) clear and daily task assignment; (4) shortage of equipment, (5) lack of labor skills. Montaser et al. (2018) found that the top factors affecting labor productivity in construction of pre-stressed concrete bridges were: design factor, equipment factor, execution and construction factor, external factor, financial factor, healthy and safety factor, labor factor, supervision factor, material factor, organization factor and other project factors.

Bekr (2016) indicated that the major factors affecting the labor productivity were: shortage of materials, shortage of equipment, inefficient equipment, poor planning, lack of supervisor's experience, inspection delay, rework due to workers mistakes and payments delay. Mahamid (2018) revealed that the most significant factors affecting labor productivity in road construction projects were: shortage of materials, inaccurate specifications and lack of labor experience. He also found a significant direct relationship between cost overrun and labor productivity in construction projects. Ghoddousi & Hosseini (2012) conducted a questionnaire survey to address the main factors affecting sub-contractors' productivity in Iran. The top factors included: shortage of materials and tools, poor planning, rework, poor supervision, weather and poor site conditions. Mahamid (2013) conducted a study to investigate the main factors affecting labor productivity in public projects. He found that the top five factors were: political situation, shortage in equipment, old equipment, lack of experience, and poor management on sites. Jarkas & Bitar (2012) found that the top five factors affecting construction productivity in Kuwait were: specifications clarity, frequent change orders, poor coordination between designers, poor supervision, and poor subcontractors.

Rework on construction sites

Rework is simply defined as the process when completed work does not conform to specifications (Oyewobi et al., 2011). McDonald (2013) defined rework as "work measures that have to be completed more than once". Love et al. (2000) identified rework as the ''unnecessary effort of redoing a process or activity that was incorrectly implemented the first time''. Enshassi et al. (2009) stated that rework is a critical problem in construction industry that leads to cost overrun, schedule delay and customer dissatisfaction. Oyewobi et al. (2011) revealed that the rework cost for new building is about 5.06% of their contract values. Barber et al. (2000) pointed that rework costs could be as high as 23% of the contract value. Many studies, which were investigated rework on construction sites, revealed that rework increased the cost of the different work elements between 3% to 30% and caused delays in the different work elements leading to the increase of their original durations from10% to 77%. In addition, rework caused clients' and contractors dissatisfaction (Wasfy, 2010). According to Love and Edwards (2004), the main causes of rework can be grouped into three different sources: 1) client-related, 2) design-related and 3) contractor-related factors. Palaneeswaran (2006) indicated that rework in building works is more predominate due to different interface-related management issues such as poor communication between construction parties during design phase and poor coordination between building contractors and building services. Enshassi et al. (2017) concluded that the main rework causes on construction sites in Gaza were: fraud, competitive pressure, ineffective management, schedule

pressure and the absence of job security. Hwang et al. (2009) showed that the main rework causes on construction sites included: owner change, design errors, constructor errors.

Oyewobi et al. (2011) concluded that rework causes in building projects included: error in design, construction failure, frequent change orders, and poor coordination and communication between construction parties. Ye et al. (2014) carried out a questionnaire survey to investigate rework causes on construction sites in China. They concluded that the top rework causes were: poor construction materials, unclear project process management, and poor quality of construction technology. Toole (2005) indicated that excessive overtime has negative impact on productivity and quality and leads to rework on construction sites. Palaneeswaran (2006) concluded that rework has direct and indirect impacts on construction performance. According to Palaneeswaran et al. (2005), some of direct impacts include: (1) schedule delay, (2) cost overrun, (3) additional materials for rework and wastage, and (4) increase in labor cost to fix the defect. Some of indirect impacts are: poor moral, profit reduction, loss of future work, fatigue, stress, conflicts, end-user dissatisfaction, de-motivation, and absenteeism (Love, 2002). Mahamid (2016) conducted a study to identify the main rework causes in residential buildings. He concluded that the top causes were: poor communication and coordination between construction parties, material quality, and poor site management. Wasfy (2010) conducted a study in Saudi Arabia to address the main rework causes in construction projects. He found that the most severe factors included: poor supervisors, lack of supervisors, lack of labor experience, poor subcontractors, and improper work protection. Mahamid (2017) indicated that the main rework causes in highway projects were: non-conformance with specification, scope changes by owner, poor labor skills, improper subcontractor selection, and late changes.

In summary, many previous studies were conducted to identify factors affecting labor productivity and rework causes in construction projects. However, very limited or no literatures investigated the impact of rework on labor productivity. This study was conducted to address the relationship between labor productivity and rework on construction sites.

Methodology

The following methods were used in this study:

1) Questionnaire survey – stage 1: a questionnaire survey was carried out to identify the main factors affecting labor productivity and the main causes of rework on construction sites (more details in section 3.1)
2) Questionnaire survey – stage 2: Eigen values was used to identify the significant rework causes, then a questionnaire survey was conducted to address the impact of these causes on labor productivity (more details in section 3.3)
3) Data analysis: this section includes 3 subsections, they are: factors ranking, Spearman ran correlation, and prediction models. (more details in section 3.3).

Questionnaire survey

The questionnaire is divided into three main sections. The questionnaire sections were as follow: Section 1: this section asked for information about the respondent and the company (i.e. occupation, level, experience, staff, size). Section 2: it included the list of factors affecting labor productivity according to literature review and opinion of local experts. Section 3: it included rework causes as identified from literature review and opinions of local experts. 18 factors affecting labor productivity and 20 factors affecting rework are tabulated in the questionnaire. Respondents were asked to identify the impact level of each factor using an ordinal five-point scale as follow: 1 indicates very low impact, 2 indicates low impact, 3 indicates medium impact, 4 indicates high impact and 5 indicates very high impact.

A draft questionnaire was sent to some local construction experts to test the validity and suitability of the questions and to suggest any needed changes. Slight changes were done according to their feedback.

Study population

The target population included: 1) the total number of building contractors (grade 1, 2, and 3) who have valid registration in the Palestinian Contractors Union, 2) the total number of consultants who are involved in the building projects and have a valid membership in the Engineering Association in the West Bank and. The registered contractors are 212 and the registered consultants are 106. To compute the sample size that represents the total population, the following equation was used (Emory, 1980):

$$n = (ts/d)^2 / [1 + (ts/d)^2/N] \qquad \text{Equation (1)}$$

where,
n = sample size
N = sample of population
t = abscissa of the normal curve that cuts of an area of α = 0.01 at the tails (t = 2)
d = expected error in the estimate (d = 0.01)
s = max. standard deviation in proportion of estimation = P × q (at P = 0.5 and q = 1 – P = 0.5)

Equation 1 was used to compute the representative number of contractors and consultants (Table 1). Calculations stopped when the difference between n and n-1 is insignificant.

Table 1. Summary of sample size calculation trials. Source: Self-elaboration.

	Population I (contractors)	Population II (consultants)
n_0	212	102
n_1	90	62
n_2	57	45
n_3	42	35
n_4	33	29
n_5	27	22
n_6	23	19
n_7	20	17
n_8	18	15

Results show that at least 20 contractors and 17 consultants should be involved in the questionnaire so that the sample size represents the total population. For instance, for more accurate results, the questionnaire was sent randomly to 40 consultants and 50 contractors. 38 contractors (out of 50; response rate = 76%) and 30 consultants (out of 40; response rate = 75%) completed the questionnaire. The respondents were experienced managers, engineers, and planners. The average experience of the respondents is greater than 10 years.

Data analysis

Factors ranking
After receiving the filled questionnaires (stage 1), Excel statistical tools were used to analyze the data. The identified factors were ranked using the weighted mean. Then, the most significant factors were identified using factor analysis such that: factors with Eigen value greater or equal to 1 (significant factors) were retained and factors with Eigen value less than 1 (insignificant factors) were dropped. After identifying the significant rework causes, a questionnaire survey (stage 2) was performed to address the impact of these causes on labor productivity.

Spearman rank correlation
This test is used to find the degree of agreement between contractors and consultants on the ranking of the factors affecting labor productivity and rework causes. A value of +1 means a perfect positive correlation between responses and a value of -1 indicates a perfect negative correlation. To calculate the values of Spearman rank correlation coefficient (r_s), Equation (2) was used (Harnett & Murphy, 1975):

$$r_s = 1 - [6 * \sum d^2/(n^3 - n)] \qquad \text{Equation (2)}$$

where; r_s = Spearman rank correlation coefficient.
d = difference between ranks on one variable and ranks on the other variable
n = number of causes

Prediction models
One of the study objectives was to address the relation between rework and labor productivity in building construction projects. To achieve this objective, data from 40 building construction projects. The data included records for rework cost and labor productivity of some finishing works (plastering, ceramic works, and brick works). The projects were implemented in the West Bank in Palestine between 2015 and 2018. The data were collected form contracting firms specialized in building construction.

Linear regression analysis was selected to develop the prediction models. Linear regression models were used to describe the linear combination between dependent and independent variables. The variables to be included in the models were defined as follow: “labor productivity” as dependent variable and “rework cost” as independent variable. (discussed in detail in section 4.5).

Results and Discussion

Ranking of factors affecting labor productivity

Table 2 presents the ranking of factors affecting labor productivity from contractors’ and consultants’ perspective. Eighteen (18) factors were identified through literature review and opinions of local experts. The identified factors were ranked by the respondents according to their negative impact on labor productivity. 5-points Likert scale (1-5) was used for ranking.

Results indicated that the top 5 factors affecting labor productivity from contractors’ point of view are: lack of labor experience, payments delay, rework due to labor mistakes, lack of supervisor’s experience and lack of coordination between construction parties. Consultants responses identified the following factors as top 5 factors: payments delay, rework due labor mistakes, lack of labor experience, materials shortage and low wages. Overall, results indicated that the top 5 factors are: lack of labor experience, payments delay, rework due to labor mistakes, lack of supervisor’s experience and materials shortage.

Results are in line with similar previous studies. For example, “lack of labor experience” concluded as a top factor affecting labor productivity by Mahamid et al. (2014), Mahamid (2018), and Robles et al. (2014). Mahamid et al. (2014) concluded that “payments delay” is one of the main factors affecting labor productivity. Bekr (2016) found that “rework due to labor mistakes”, “lack of supervisors experience” and “material shortage” are significant factors affecting construction productivity. Ghoddousi & Hosseini (2012), Robles et al. (2014), and Mahamid (2018) indicated that “material shortage” is one of the critical factors affecting labor productivity on construction sites.

Table 2. Ranking of factors affecting labor productivity in building projects. Source: self-elaboration.

	Contractor view		Consultant view		Overall	
Factor	Mean	Rank	Mean	Rank	Mean	Rank
Lack of labor experience	3.97	1	3.92	3	3.95	1
Payments delay	3.83	2	4.04	1	3.92	2
Rework due to labor mistakes	3.72	3	3.95	2	3.83	3
Lack of supervisor’s experience	3.51	4	3.57	6	3.54	4
Materials shortage	3.28	6	3.75	4	3.49	5
Lack of coordination between construction parties	3.41	5	3.49	7	3.45	6
Low wages	3.11	7	3.62	5	3.34	7
Misunderstanding between labors and superintendents	2.92	10	3.33	8	3.10	8
Equipment shortage	3.05	8	3.11	10	3.08	9
Unsuitable materials storage location	2.91	11	3.25	9	3.06	10
Lack of financial motivation system	2.97	9	2.98	11	2.98	11
Inspection delay	2.87	12	2.80	13	2.84	12
Bad relations between labors and management team	2.83	13	2.75	14	2.79	13
Labor personal problems	2.74	16	2.85	12	2.79	14
Labor absenteeism	2.69	17	2.65	15	2.67	15
Working within a confined space	2.78	15	2.52	17	2.66	16
Misuse of time schedule	2.82	14	2.44	18	2.65	17
Overmanning	2.67	18	2.58	16	2.63	18

Ranking of rework causes

Twenty (20) rework causes were identified from literature review and local experts' feedback. Respondents ranked these causes according to their impact level on rework. 5-points Likert scale was used to obtain the view of respondents. Results are shown in Table 3.

Contractors ranked the top 5 factors as follow: lack of manpower skills, non-compliance with specifications, inadequate coordination and integration, frequent change orders and inadequate job planning. Consultants input indicated that the top 5 rework causes are: inadequate coordination and integration, inadequate job planning, lack of manpower skills, non-compliance with specifications and errors and omissions. Overall view reveled that the top 5 rework causes are: lack of manpower skills, non-compliance with specifications, frequent change orders, inadequate job planning, and inadequate coordination and integration. The results agree with previous studies. For example, "lack of labor skills" is concluded by Wasfy (2010) and Mahamid (2017) as a top rework cause. "Non-compliance with specifications" concluded by Mahamid (2017) as a critical rework cause. Enshassi et al. (2017) found that "poor planning" is one of the top rework causes. "Late changes" is one of the significant rework causes as concluded by Hwang et al. (2009), Mahamid (2017), and Oyewobi et al. (2011).

Factor analysis was performed to address the most significant rework causes. Only causes with Eigen value ≥ 1.0 were retained. Results indicate four (4) key causes (Eigen value ranging from 1.008 for last one to 4.326 for top one). These causes are: namely: lack of manpower skills, non-compliance with specifications, frequent change orders, and inadequate job planning. The key causes accounted for a cumulative variance of 70.05%.

Table 3. Contractors' and consultants' perception of rework causes in building projects. Source: self-elaboration.

	Contractor		Consultant		Overall	
Cause	Mean	Rank	Mean	Rank	Mean	Rank
Lack of manpower skills	4.18	1	3.87	3	4.04	1
Non-compliance with specifications	4.13	2	3.76	4	3.96	2
Frequent change orders	3.82	4	4.06	1	3.93	3
Inadequate job planning	3.64	5	4.00	2	3.80	4
Inadequate coordination and integration	3.88	3	3.62	6	3.76	5
Errors and omissions	3.54	7	3.73	5	3.63	6
Improper contractor selection	3.60	6	3.46	9	3.54	7
Scope changes	3.37	9	3.57	7	3.46	8
Poor site management	3.33	10	3.48	8	3.40	9
Labors re-allocation to other projects	3.43	8	3.30	10	3.37	10
Unclear work specifications	3.15	13	3.16	11	3.16	11
Use of inefficient equipment	3.24	12	2.99	14	3.13	12
Late design changes	3.10	14	3.12	12	3.11	13
Inadequate supervision	3.29	11	2.85	15	3.10	14
Poor project document	2.96	15	3.08	13	3.01	15
Lack of employee motivation	2.90	16	2.72	17	2.82	16
Poor site conditions	2.77	18	2.74	16	2.76	17
Lack of supervisory skills	2.82	17	2.66	18	2.75	18
Excessive overtime	2.49	20	2.63	19	2.55	19
Errors due to inappropriate construction method	2.60	19	2.46	20	2.54	20

Spearman rank correlation

Equation (2) was used to test the agreement between contractors and consultants on the importance of the factors affecting labor productivity and rework causes on construction sites. The results show a good correlation between the respondents on the importance of labor productivity factors and rework causes with r_s value of 0.82 and 0.78, respectively. This result indicates that the study is reliable.

Rework and labor productivity on construction sites

The impact of four key rework causes (causes with eigen value ≥ 1.0) on labor productivity was ranked according to respondents' point of view. Table 4 shows the impact of these causes in relative ranks. Results show that the factor with highest impact on labor productivity is "lack of manpower skills". 80% of responses rated this factor as a top affecting factor. This is followed by "non-compliance with specifications", "frequent change orders" and "inadequate job planning". These factors received response of 73%, 72% and 66% on account of high impact on labor productivity, respectively. The results reveal that the four key rework causes have high impact on labor productivity on construction sites. Therefore, attention should be paid to control these causes to improve project performance in terms of reducing rework cost and increasing labor productivity.

Lack of manpower experience leads to labor mistakes, misunderstanding of drawing and specification, misuse of available resources. This resulted in rework and loss in productivity. "non-compliance with specifications" comes from several reasons such as: labor mistakes, lack of understanding of contract documents, unclear specifications, lack of experience. Specifications should be written in clear and well from, such that it can be well understood. Training workshops should be performed for labors to increase their experience and site superintendents to have better understanding for contract documents. Inadequate job planning could be due to poor communication and coordination between construction parties during different phases of project, and this affect progress flow and lead to late changes that lead to rework and loss in productivity.

The results reveal that the four key rework causes have high impact on labor productivity on construction sites. Therefore, attention should be paid to control these causes to improve project performance in terms of reducing rework cost and increasing labor productivity.

Table 4. Relationship between rework and labor productivity in building projects. Source: self-elaboration.

Significant rework causes	Impact on labor productivity					
(Eigen values ≥ 1.0)	No impact	Low impact	Moderate impact	High impact	Extreme impact	Relative index
Lack of manpower skills	0	2.02	18.3	56.78	22.9	0.60
Non-compliance with specifications	0	3.57	23.2	59.73	13.5	0.57
Frequent change orders	0	4.1	22.55	60.75	12.6	0.56
Inadequate job planning	0	5.5	27.7	61.7	5.1	0.53

Predictive models describing the relation between rework and labor productivity

One of the study objectives was to address the relationship between rework and labor productivity in building construction projects. To achieve this objective, needed data were gathered from 40 building projects implemented in the West Bank in Palestine. Regression analysis was used to establish the required models. In the developed models, the dependent variable is labor productivity and the independent variable is rework cost. Equation 3 shows the standard form linear regression models:

$$Y = \alpha + \beta X \qquad \text{Equation (3)}$$

where:
Y = Rework cost (% of item contract price)
X= labor productivity
α = intercept
β = coefficient of rework cost

Three (3) predictive models were developed; each one described the relation between labor productivity and rework cost in a specified activity, namely: plastering, ceramic works, and block works. Details are shown in the following sections.

Model 1: predictive model of rework impact on labor productivity in plastering

To establish a mathematical model that relate rework and labor productivity in plastering works, data from 40 building projects was used. The data indicated that the average of rework cost in plastering is 5.11% and the average of labor productivity is 30.59m^2/day (productivity for 2 labors crew). Figure 1 shows the linear regression model that describe the impact of rework on labor productivity in plastering. Table 4 shows the results of regression analysis. The table shows that R^2 = 0.82, $F_{(1,39)}$ = 68.24, and p = 0.00; indicating that the model can well predict the impact of rework on labor productivity. The model indicate that labor productivity decreases by 2.02 for 1 unit increase in rework cost. The model is presented in Equation (4):

$$Y = 40.9 - 2.02X \qquad \text{Equation (4)}$$

Where; Y is labor productivity in plastering (m^2/day), X is rework cost in plastering (%).

Figure 1. Rework cost vs labor productivity in plastering. Source: self-elaboration.

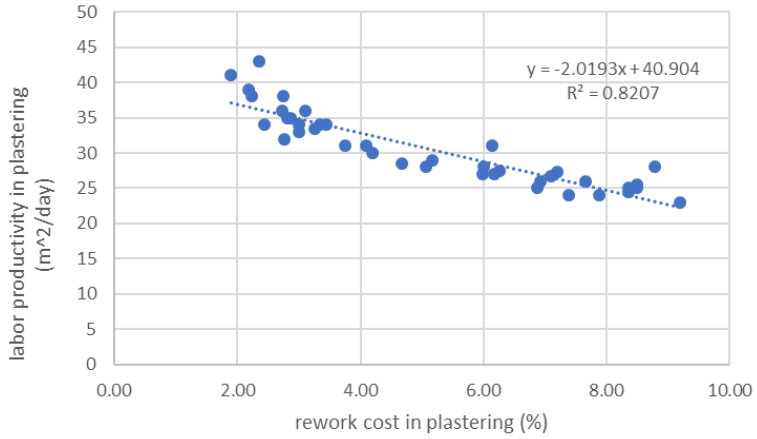


Table 4. Regression statistics for Equation 4. Source: elf-elaboration.

Regression Statistics			*Coefficients*	*t Stat*	*P-value*
R Square	0.82	Intercept	40.9	6.39	0.00
Observations	40	Rework cost in plastering (%)	-2.02	7.88	0.00
F	68.24				

Model 2: predictive model of rework impact on labor productivity in brick works

Figure 2 shows the relationship between rework cost and labor productivity in brick works. Figure 2 indicates inverse relationship between them: the higher rework cost the lower productivity. The results show that the percentage of average rework cost in brick works is 4.51 and the average labor productivity is 26.2m^2/day (for 2 labor crew). The developed model that describes the impact of rework cost on labor productivity in brick works is shown in Equation (3). Table 5 shows the statistical analysis for Equation (5): R^2 = 0.78, $F_{(1,39)}$ = 62.71, and p = 0.00; indicating good correlation between the dependent and independent variables. The model indicates that labor productivity decreases by 1.71 unit for 1 unit increase in rework cost.

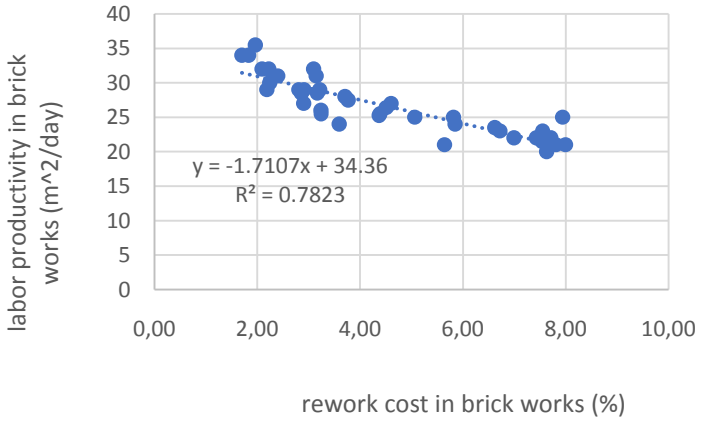
$$Y = 34.36 - 1.71X \qquad \text{Equation (5)}$$

were: Y is labor productivity in brick works (m^2/day), X is rework cost in brick works (%).

Table 5. Regression statistics for Equation 5. Source: self-elaboration.

Regression Statistics			*Coefficients*	*t Stat*	*P-value*
R Square	0.78	Intercept	34.36	7.11	0.00
Observations	40	Rework cost in brick works (%)	-1.71	6.44	0.00
F	62.71				

Figure 2. Rework cost vs labor productivity in brick works. Source: self-elaboration.



Model 3: predictive model of rework impact on labor productivity in ceramic works

Figure 3 shows the relationship between rework cost and labor productivity in ceramic works. It indicates inverse relationship between them: the higher rework cost the lower productivity. The results show that the percentage of average rework cost in ceramic works is 5.43 and the average labor productivity is 30.55m^2/day (for 2 labor crew). The developed model that describes the impact of rework cost on labor productivity in ceramic works is shown in Equation (4). Table 6 shows the statistical analysis for Equation (6): R^2 = 0.79, $F_{(1,39)}$ = 64.15, and p = 0.00; indicating good correlation between the dependent and independent variables. The model shows that labor productivity decreases by 2.58 unit for 1 unit increase in rework cost.

$$Y = 44.60 - 2.58X \qquad \text{Equation (6)}$$

where: Y is labor productivity in ceramic works (m^2/day), X is rework cost in ceramic works (%).

Figure 3. Rework cost vs. labor productivity in ceramic works. Source: self-elaboration.

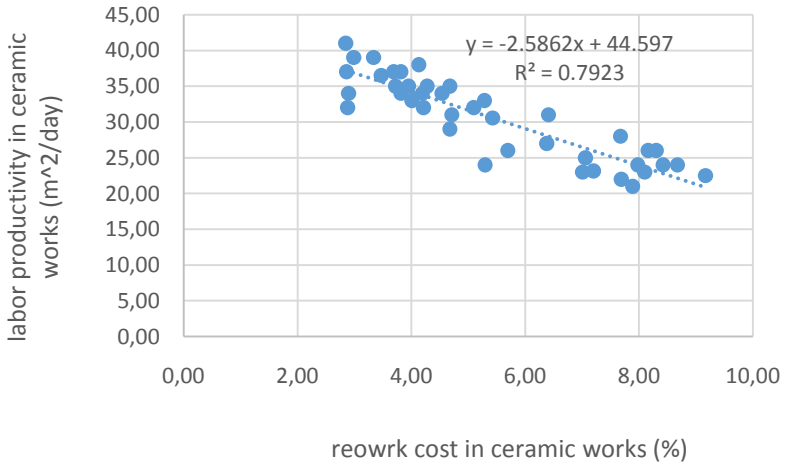


Table 4. Regression statistics for Equation 6. Source: self-elaboration.

Regression Statistics			*Coefficients*	*t Stat*	*P-value*
R Square	0.79	Intercept	44.60	5.89	0.00
Observations	40	Rework cost in ceramic works (%)	-2.58	6.02	0.00
F	64.15				

Conclusions

This study was conducted to address the relationship between rework cost and labor productivity in building construction projects in the West Bank in Palestine. The study concluded that the top five factors affecting labor productivity were: lack of labor experience, payments delay, rework due to labor mistakes, lack of supervisor's experience and materials shortage. The study also showed that the top five rework causes in building projects were: lack of manpower skills, non-compliance with specifications, frequent change orders, inadequate job planning, and inadequate coordination and integration. The results of Spearman rank correlation test indicated a good correlation between the respondents on the importance of labor productivity factors and rework causes with r_s value of 0.82 and 0.78, respectively. This implies that the study is reliable.

Based on data collected from 40 building construction projects implemented in Palestine, predictive models that described the relationship between rework and labor productivity were developed. Three (3) models were developed: rework versus labor productivity in plastering, rework versus labor productivity in brick works, and rework versus labor productivity in ceramic works. The results indicated that rework has a significant impact on labor productivity in building projects. Rework and labor productivity have an inverse relationship. i.e. the higher the rework cost the lower the labor productivity.

Based on the results of the study, the following points were recommended to minimize rework and improve labor productivity on construction sites: (1) labors should have workshops to improve their skills; technical skills and managerial skills as well, (2) specifications should be clear, well written, and carefully read during bidding phase to avoid conflicts during construction phase, (3) construction parties should have more communication and coordination during the early project phases to minimize late changes during construction, (4) payments should be paid on time to maintain the smooth progress of the project, (5) construction parties should prepare a well-defined plan for job doing.

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