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Relationship between delay and productivity in construction projects

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ABSTRACT

This study is conducted to recognize the major delay factors, the major construction productivity factors, and to establish the relationship between productivity and delay in construction projects in Saudi Arabia. A questionnaire survey is performed to achieve study objectives. Fourteen-time overrun factors and 13 construction productivity factors are listed in a questionnaire form. Fifty contractors consultants are asked to rank the identified factors according to their importance. The study also addresses the relationship between labor productivity and time overrun based on data collected from 34 building projects implemented in Saudi Arabia. Results conclude that the top factors affecting delay in construction projects are: poor labor productivity, poor coordination between construction parties, lack of adequate manpower, bid award for lowest price, and mistakes in design. It also indicates that the major labor productivity factors are: payments delay, lack of labor experience, frequent change orders, rework, and financial conditions of the contractor are ranked overall as the top 13 factors affecting labor productivity on construction sites. Regression analysis for data collected from 34 building projects indicates a strong correlation between the delay and labor productivity. It is hoped that the results of this study will be helpful for construction parties and researchers in Palestine and other developed and developing countries.

1. Introduction

The construction industry is one of the biggest dollar-generating segments of the economy in many countries in the world. It varies from houses to highways, schools, hospitals, plants, and many other constructions. It pushes many other related industries, such as concrete, lumber, steel, paint, furniture, mining, paving, and shipping among other industries. However, the construction industry is complicated and associated with high risks, and many factors influence the output of construction projects. Enshassi et al. (2003) stated that "the increasing complexity of infrastructure projects and the environment within which they are constructed place greater demand on construction managers to deliver projects on time, within the planned budget and with high quality." One of the main problems in construction projects is time overrun. It may be expressed as a "percent difference between the actual completion time and the estimated completion time, agreed by and between the client and the contractor during the signing of the contract" (Mahamid, 2017a). Ameh et al. (2010) indicated that the history of the construction industry is full of projects that were completed with critical delay. For instance, Omoregie and Radford (2006) found that the average time overrun in Nigerian construction projects is 188%. Assaf and Al-Hejji (2006) concluded that 70% of Saudi Arabian construction projects were completed with critical time overrun. In UAE, Faridi and El-Sayegh (2006) revealed that 50% of construction projects were completed with schedule delay. Mahamid et al. (2012) found that about 100% of highway construction projects in Palestine were completed with time overrun. Mahamid et al. (2012) concluded that time overrun has negative effects on construction projects in terms of cost increase, conflicts, disputes, quality problems, and mistrust between parties.

Productivity is simply defined as a ratio between an output value and an input value used to produce the output. It has its proven importance as a critical factor for project success. Mahamid (2018) linked labor productivity with a cost overrun; he concluded a strong relationship between. Mahamid (2020)

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found a high correlation between labor productivity and rework in building projects. Thus labor productivity plays a critical role in the financial success of a project (Liu and Ballard, 2008). However, some previous studies found that construction productivity variations are one of the most daunting problems faced by the construction industry, especially those in developing countries and it is one of the main factors affecting cost and time overrun (Mahamid et al., 2013; Liu and Ballard, 2008).

Literature review indicates that very few studies have investigated the relationship between labor productivity and time overrun in building projects. This study addresses the problems of labor productivity and time overrun in Saudi Arabia. Furthermore, it investigates the relationship between construction productivity and delays in construction projects. This paper aims at (1) identifying factors affecting labor productivity in construction projects, (2) identifying factors affecting delay, (3) establishing the relationship between delay and labor productivity.

2. Previous studies

2.1. Construction productivity on sites

Liu and Ballard (2008) stated that despite the advances in technology, the construction industry is still labor-intensive. Labors continue to account for between 30% and 50% of construction projects. Mahamid (2020) stated that labors are success key to any construction project and enhancing construction productivity is the main issue to increase profit and to complete projects on time. In his study, Mahamid (2020) found a strong relationship between labor productivity and rework in construction projects. He concluded that lack of manpower experience causes mistakes and misuse of resources that negatively affect productivity. Overall, he indicated that the main factors affecting labor productivity in building projects are: Lack of experience, rework, delay in payments, mistakes, and material shortages. Through a questionnaire survey, Mahamid (2018) found that the main factors affecting labor productivity in highway construction projects are: Material shortage, inaccurate specifications, and poor labor experience. Montaser et al. (2018) conducted a questionnaire survey to test the main productivity factors in concrete works. They concluded that design changes and equipment factors are the top affecting factors.

Sweis 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." In their study, they found that working overtime, quality requirements, and inaccurate specifications are key factors of manpower demotivation in residential projects. Among various factors affecting construction productivity shortage of materials, equipment problems, improper planning, lack of supervisor's experience, delay in inspections, rework, and payments delay topping the list. In Saudi Arabia, Mahamid et al. (2013) addressed the main productivity factors to be: Poor skills of labors, poor communication between parties, delay in payments, and bad working environment. Robles et al. (2014) revealed that the top factors affecting construction productivity in Spain are: Delay in material supply, inaccurate project documents, clear daily assignment, lack of equipment, and poor labor skills. Alaghbari et al. (2019) concluded that the top five factors affecting labor productivity in construction projects are: Lack of labor experience, shortage in materials on-site, poor site management, shortage in materials in the market, and political situation. Abdel-Hamid and Abdelhaleem (2020) concluded a strong relation between cost overrun and poor labor productivity. Nasirzadeh et al. (2020) investigated labor productivity factors in Australian multi-story building construction projects. They concluded that the top factors include: Lack of skilled and experienced labors, fatigue, poor supervision, award rates, and communication problem with foreign workers.

2.2. Factors affecting time overrun in residential projects

The construction industry is one of the most competitive industry and it involved a high level of risks due to the many resources and parties involved in the projects. Therefore, completing projects with limited time is one of the main issues that help in improving the industry. However, the history of construction projects is full of projects completed with time overrun (Kaliba et al., 2009; Mahamid, 2017b). Mahamid et al. (2012) defined time overrun as "the time difference between the actual completion time and the estimated completion time, agreed by and between the client and the contractor during the signing of the contract." Previous studies revealed time overrun in construction projects ranging from 30% to 188% (Omoregie and Radford, 2006; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Mahamid et al., 2012; Mahamid, 2017a). Gopang et al. (2020) concluded that the main time overrun factors in a building project in Saudi Arabia are: Late decisions by the client, changes in design, and delay in approvals. Some previous studies found a good relationship between site conditions and time overrun in building projects (Mahamid, 2017b; Memon et al., 2012). Mahamid's (2017a) study linked delay in a construction project with improper planning at the early stages of projects. In his study, Mahamid (2017a) revealed a relationship between time overrun and conflicts, disputes, and arbitration between construction parties.

Through a questionnaire survey in Saudi Arabia, Mahamid et al. (2015) found that the top delay

factors include: Bidding policy, inaccurate specifications, rework, lack of labors experience, poor productivity, and late changes.) The top time overrun factors in a construction project in Kenya according to Atibu (2015) are Payments delay by clients, improper planning, and weather effects.

In a study conducted by Mahamid et al. (2012) to identify, analyze and rank delay factors in highway projects in Palestine, contractors revealed that the top factors include: Political situation, delay in payments, delay in decision making, and poor productivity while consultants indicated that the top factors are: political situation, bidding strategy, equipment shortage and misuse of schedule. Zafar et al. (2019) conducted a study in Pakistan to investigate the time overrun risk factors in highway projects. They concluded that the top factors are: Stakeholder interference and insecurity threats, lack of contractors' experience in the line of work, lack of labor productivity, poor contract management, and shortages in materials. Johnson and Babu (2020) stated that time overrun is the main indicator of project success in the construction industry. They found that the top five causes for time overrun are: variations in design, tight schedules, unrealistic completion dates projected by clients, delay in government approvals, inaccurate time estimation by the consultants, and frequent change orders. Lindhard et al. (2020) stated that "for years, the construction industry has looked for ways to avoid time-overruns in construction. Despite previous research mapping the factors affecting time performance, site-managers have difficulties in reducing the time-overrun." They believed that time overrun factors are categorized under the following groups: (1) Construction design, (2) Connecting works, (3) External conditions, (4) Workforce, (5) Components and materials, (6) Space, (7) Equipment and machinery.

3. Research methods

The objective of the study is to establish the relationship between delay and labor productivity in building projects implemented in Saudi Arabia. To achieve this, a structured questionnaire is used to collect primary data for the study. A questionnaire survey was used to elicit the attitude of contractors and consultants towards labor productivity factors and delay factors in construction projects. 13 factors that might affect labor productivity are considered in this study, while 14 factors believed to affect time overrun are identified. These factors are identified based on previous studies conducted in the same area and as recommended by local experts in residential projects. Each respondent, from the targeted contractors and consultants, is asked to state the level of importance of each factor using an ordinal 5-point scale as follow: 5 (very high), 4 (high), 3 (moderate), 2 (little), and 1 (very little). A chance is given for each respondent to add and rate other factors that are believed to affect either labor productivity or time overrun.

The target population is the total number of contractors the total number of consultants who have experience in construction projects.

The questionnaire is distributed to 50 contractors and 50 consultants. The contractors and consultants are selected from an available list. Eighty-four (84) questionnaires are received (84 %) as follow: 46 (92%) from contractors, and 38 (76%) from consultants. The targeted participants have an average experience of more than 10 years in building projects.

Fig. 1 shows the respondents' positions in their organizations. It shows that the respondents experienced office engineers are (13.6%), site engineers (26.5%), designers (16.3%), construction managers (18.2%), project managers (12.8%), and others (12.6%).

3.1. Data analysis

Excel statistical tools are used to analyze the information returned form the respondents. The suggested time overrun factors and labor productivity factors are ranked by the measurement of the importance index which is a formula used to rank the factors based on impact level as identified by the participants (Eq. 1).

$$\text{Importance Index (\%)} = \sum a\,(n/N) * 100/5 \quad (1)$$

where, a is the constant expressing weighting given to each response (ranges from 1 for very little up to 5 for very high); n is the frequency of the responses; N is total number of responses.

3.2. Spearman rank correlation

To measure the correlation between contractors and consultants on the importance of the identified factors, the Spearman rank correlation test is used. Judgment on the correlation is based on the value of Spearman correlation (r_s) such that: r_s value of (+1) shows a perfect positive correlation, r_s value of (-1) shows a perfect negative correlation, and values between (-1) and (+1) shows a correlation less than perfect. The value of r_s is computed using Eq. 2 (Harnett and Murphy, 1975):

$$r_s = 1 - [6 * \sum d^2/(n^3 - n)] \quad (2)$$

where, r_s=Spearman rank correlation coefficient (the agreement between contractors and consultants); d=difference between ranks on one variable and ranks on the other variable; n=number of factors.

4. Results and discussion

4.1. Ranking of factors affecting delay in construction projects

Literature review and feedback from local experts in residential buildings identified 14 delay factors as shown in Table 1. Using a 5-point Likert scale,

contractors and consultants rank the identified factors. The overall ranking shows that the top factors affecting time overrun in residential projects are poor labor productivity, poor coordination between construction parties, lack of adequate manpower, bid award for lowest price, and mistakes in design. These factors are recognized by both contractors and consultants as top factors, but in a different order as shown in Table 1.

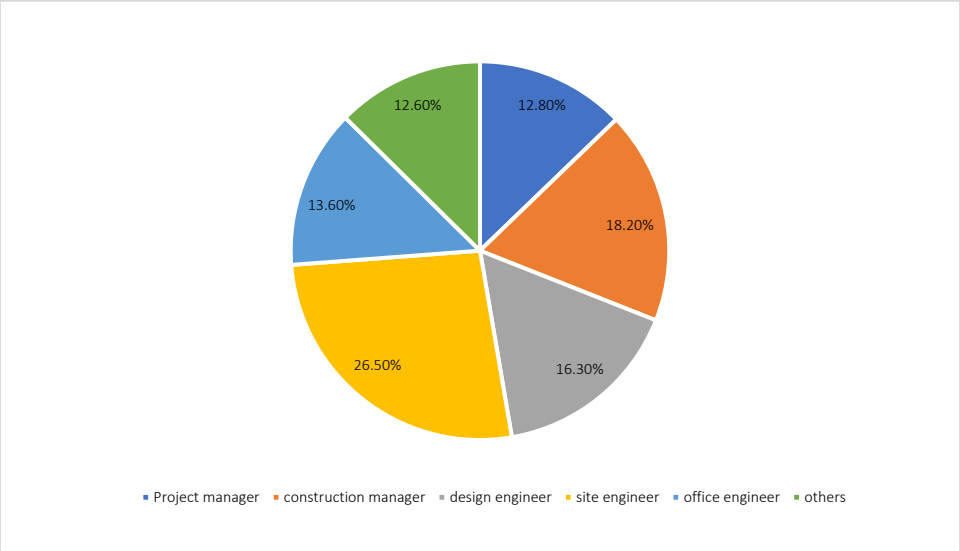

Fig. 1: Respondents' positions

"Poor labor productivity" implies that activity takes more time than planned. Poor productivity could be because of a series of factors such as payment delay, low wages, bad relations between labors, and poor skills. This result is in line with Mahamid (2017a). "Poor coordination between construction parties"; coordination between construction parties during all project stages is a success key, it helps in determining the project needs and to be ready on time. Inversely, poor coordination leads to interruptions and disputes between parties that cause time overrun. This result is in line with Mahamid et al. (2015). "Lack of adequate manpower" is a major problem in the Saudi construction market because of limitations and extra taxes implied by the government. This result agrees with Mahamid et al. (2015). "Bid award for lowest price" is the main problem that leads to time overrun. This is because a contractor with the lowest price normally is a contractor with low qualifications. "Mistakes in design" indicates that change orders and rework are needed which implies that more time and effort are required to complete the same activity. This result is in line with Mahamid et al. (2015), Kaliba et al. (2009), and Mahamid (2017a).

Table 1: Ranking of factors affecting delay in construction projects

Factor	Contractors		Consultants		Overall	
	IMP.I	Rank	IMP.I	Rank	IMP.I	Rank
Poor labor productivity	82.14	1	82.33	2	82.23	1
Poor coordination between construction parties	78.12	3	84.25	1	80.89	2
Lack of adequate manpower	81.36	2	80.07	3	80.78	3
Bid award for lowest price	77.50	4	77.63	5	77.56	4
Mistakes in design	73.00	5	79.49	4	75.94	5
Unreasonable project time frame	71.12	7	74.86	6	72.81	6
Late design work	72.89	6	69.92	8	71.55	7
Poor relationship between managers and labors	67.59	9	72.86	7	69.97	8
Lack of coordination between design and contractors	68.47	8	65.81	10	67.27	9
Lack of contractor experience	67.41	10	66.97	9	67.21	10
Disputes on site	64.76	11	63.66	12	64.26	11
Additional work	62.11	13	65.19	11	63.50	12
Poor resource management	62.99	12	59.17	14	61.26	13
Effects of weather	61.17	14	60.3	13	60.78	14

4.2. Ranking of factors affecting labor productivity

Thirteen (13) affecting labor productivity in residential projects are identified from literature and experts' feedback as presented in Table 2. Respondents are asked to identify the importance of the identified factors based on their influence on labor productivity. The result is presented in Table 2.

As shown in Table 2, payments delay, lack of labor experience, frequent change orders, rework, and financial conditions of the contractor are ranked overall as the top 13 factors affecting labor productivity in residential projects. The same factors are identified by both contractors and consultants as the top factors but in a different order. "Payments delay by the client" is ranked as the top factor affecting labor productivity. It affects the ability of

the contractor to pay for his labors, which negatively affects their moral, loyalty, and motivation. "Lack of labor experience"; is an "established fact from learning effect that if the same task or project is repeated more than one time, it will be controlled better with less time and less cost" (Mahamid et al., 2012). This leads to many problems on construction sites such as mistakes, rework, and poor productivity. "Frequent change orders" and "rework" indicate that more time and effort are required to redo the same activity. These results are in line with Kaliba et al. (2009), Mahamid et al. (2015), and Mahamid (2017a).

Table 2: Ranking of labor productivity factors in construction projects

Factor	Contractors		Consultants		Overall	
	IMP.I	Rank	IMP.I	Rank	IMP.I	Rank
Payments delay by the client	78.90	3	82.25	1	80.42	1
Lack of labor experience	81.50	1	77.18	5	79.55	2
Frequent change orders	79.36	2	78.26	4	78.86	3
Rework	77.21	4	80.13	2	78.53	4
Financial conditions of contractor	76.47	5	79.15	3	77.68	5
Low wages	75.25	6	76.89	6	75.99	6
Material shortages	72.51	8	74.55	8	73.43	7
Poor site management	73.39	7	73.13	9	73.27	8
Low quality of raw materials	68.50	10	74.69	7	71.30	9
Equipment's shortages	69.28	9	72.16	10	70.59	10
Lack of supervisor's experience	68.40	11	68.23	13	68.32	11
Project size	63.56	12	71.09	11	66.97	12
Bad labor relations	57.27	13	70.12	12	63.08	13

4.3. Spearman rank correlation

The correlation between contractors and consultants on the importance of delay factors and labor productivity factors is tested using Eq. 2. Results indicate a good correlation between contractors and consultants on the importance of delay factors (r_s=0.85) and labor productivity factors (r_s=0.82). The results of Correlation values show that the study is reliable.

4.4. Predictive models of labor productivity impact on delay on construction sites

One of the main objectives of this study is to establish the relationship between labor productivity and delay. To achieve this objective, data from 34 building projects implemented in Saudi Arabia over the years 2018-2020 (during the last 3 years) are gathered. Records from the targeted contracting firms are used to gather the required data. Then the data have been checked to ensure none double-counted and all are clearly defined. The collected data included information about the time overrun and labor productivity in ceramic works and bricks works. Some considerations are taken to when the data is collected such as Number of floors (2 floors (31%), 3 floors (37%), and 4 floors (32%)), a number of projects per year (2018 (35%), 2019 (35%), 2020 (30%), and all projects are residential buildings. After that, regression linear analysis is used to test the relation between the considered variables. According to Mahamid (2020), linear regression analysis is a widely used and well-defined approach to describe the relationship between variables (dependent and independent).

In the developed models, the dependent variable is time overrun and the independent variable is labor productivity. Eq. 3 shows the standard form of linear regression:

$$Y=\alpha + \beta X \quad (3)$$

where: Y=delay (% of planned duration); X=labor productivity; α=intercept; β=coefficient of labor productivity.

4.5. Predictive model of labor productivity impact on delay in ceramic works

Fig. 2 shows the relationship between delay and labor productivity in ceramic works. It shows an inverse relationship between them: The higher productivity the lower delays and vice versa. The results show that the average delay in ceramic works is 49.73 and the average labor productivity is 31.84m^2/day (for 2 labors crew). Model 1 describes the impact of labor productivity on delays in ceramic works. It is observed that the mathematical model expressed in model 1 can well predict the impact of labor productivity on delay. Therefore R^2=0.75, F(1,33)=152.31, p=0.000 (Table 3). The coefficient of labor productivity gives the magnitude of change in time overrun due to change in labor productivity which in this case is 2.91. This indicates that a unit increase in 'labor productivity' results in about a 2.91 unit decrease in time overrun and vice versa, while the intercept (constant) is 142.53. The prediction model is presented in the following Equation:

$$Y = 142.53 - 2.91X \quad \text{Model(1)}$$

where; Y is delay in ceramic works (%), X is labor productivity in ceramic works (m^2/day).

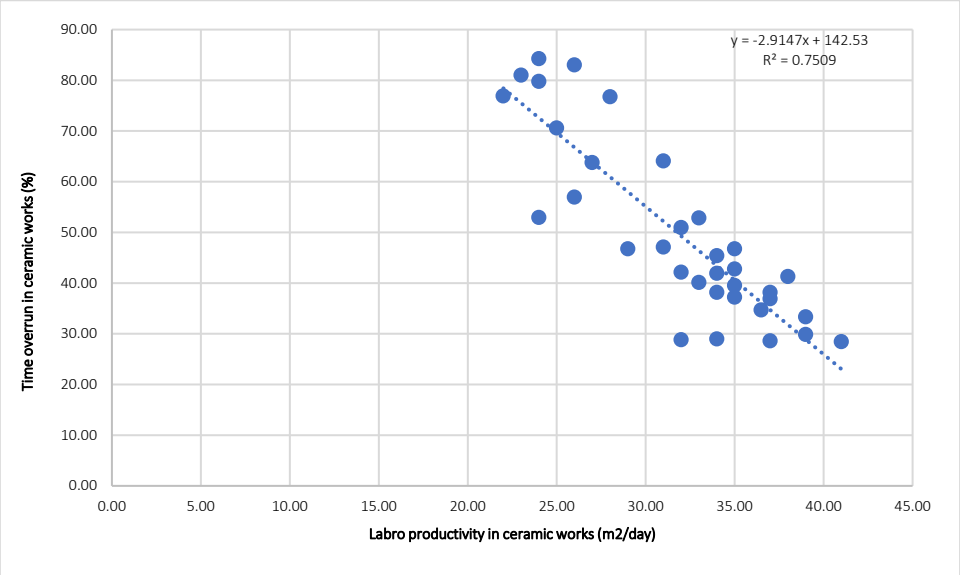

Fig. 2: Delay vs labor productivity in ceramic works

Table 3: Regression statistics of model 1

Regression Statistics			Coefficients	t Stat	P-value
R Square	0.75	Intercept	142.53	5.21	0.00
Observations	34	Labor productivity in ceramic works (m^2/day)	-2.91	5.98	0.00
F	152.31				

5. Summary and conclusion

This study is conducted to identify the major delay factors, the major labor productivity factors, and to establish the relationship between labor productivity and delay in construction projects. It concludes that the top factors affecting delay in construction projects are: Poor labor productivity, poor coordination between construction parties, lack of adequate manpower, bid award for lowest price, and mistakes in design. It also indicates that the major labor productivity factors are: Payments delay, lack of labor experience, frequent change orders, rework, and financial conditions of the contractor are ranked overall as the top 13 factors affecting labor productivity in construction projects. Spearman rank correlation test shows a good agreement between contractors and consultants on the importance of delay factors (r_s=0.85) and labor productivity (r_s=0.72). Therefore, the study is reliable.

To establish the regression models that describe the relationship between delay and labor productivity, data from 34 building projects implemented in Saudi Arabia are gathered. Delay is considered as the dependent variable while labor productivity is the independent variable. The predictive model reveals a significant relationship between delay and labor productivity. Equally, the nature of the relationship is inversely proportional i.e. the higher the labor productivity the lower the delay, and vice versa.

The following points are recommended to improve construction productivity on sites and to minimize delay: (1) Continuous training programs should be conducted to develop labor skills and managerial skills of construction participants, (2) Owners should pay progress payments on time, so the contractors could pay for labors and other resources on time, (3) Owner should check for contractor's qualifications before awarding the contract. Bidding on the lowest price basis should be improved.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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