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Impact of Weather Conditions on Construction Labor Productivity in Qatar

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Abstract
The construction projects in Qatar frequently encounter significant delays. One of the major sources of these delays is Qatar's extreme weather conditions. Hence, the paper studies the impact of weather components of temperature, humidity, and wind on labor productivity in Qatar for four construction trades, namely, formwork, masonry, plaster, and ceramic tiles. These trades were chosen because they are time consuming and commonly found in all types of construction. The weather data and trade labor productivities were recorded for a period of 8 months between July 2013 and February 2014. The results showed that the weather had a high impact on trade labor productivities. The labor productivity in the summer could be as low as half of that in the winter. Linear regression models were developed to predict trade productivities for given weather conditions.

Keywords
Extreme weather, weather impact, labor productivity, linear regression, construction delays

1. Introduction

The State of Qatar is currently experiencing a very high rate of economic growth and urban development. This situation has recently raised many concerns about the construction industry performance problems. Construction projects in Qatar usually encounter significant problems in term of delays and time completion. One of the major causes of construction delays in Qatar is the extreme weather conditions in the summer months. Extreme weather conditions tremendously decreases workers' productivity. Moreover, workers have reduced working hours due to the Qatari government regulation forbidding outdoor work from 11 am to 3 pm in the summer. The reduction in labor productivity and working hours is a major source for construction delays. Hence, it is worth studying and quantifying the weather impact on labor productivity to better estimate activity durations and costs. The objective of the paper is to study and quantify the weather impact on labor productivity of several construction trades in Qatar, namely, formwork, masonry, plaster, and ceramic tile jobs.

2. Literature Review

Several researchers reported that weather conditions cause delays and cost overruns in construction projects

(Baldwin et al. 1971; Koehn and Meilhede 1981; Laufer and Cohenca 1990). Benjamin et al. (1973) reported that almost 50% of construction activities are sensitive to weather conditions. The impact of weather on construction activities can be in the form of reduced labor productivity and/or work stoppage. The National Cooperative Highway Research Program (NCHRP 1978) studied the impact of different weather conditions on different highway construction operations. According to the study, 45% of all construction activities are affected to some degree by weather, resulting in substantial additional costs that can run into billions of dollars annually. A number of studies have been conducted to establish the relationship between labor productivity and weather conditions. Benjamin et al. (1973) proposed a simulation model that integrates the interruptive effect of weather in project scheduling. The model simulates construction duration by making daily work/no-work decisions according to the historical hourly weather data and the sensitivity of activities to temperature, precipitation, and wind. Grimm and Wagner (1974) developed graphs to predict mason productivity in any location in the United States of America at any month of the year. Thomas and Yiakoumis (1974) developed a factor model for evaluating the productivity of labor intensive construction activities. Koehn and Brown (1985) proposed two equations that represent the relationship between labor productivity, temperature and humidity, respectively. Osama et.al. (1996) reported that the labor productivity loss due to the impact of weather on construction activities can be either partial or complete; a partial loss is generally attributed to reduced labor productivity and complete to work stoppage which interrupts those activities. They developed an automated decision support system, named WEATHER, for estimating the combined effect of reduced labor productivity and work stoppage caused by adverse weather conditions on construction sites. The system provides estimates of construction productivity, activity durations, and weather patterns that facilitate the application of risk analysis in planning and scheduling. Osama et.al. (1997) developed an automated support system for estimating the combined effect of reduced labor productivity and work stoppage caused by adverse weather conditions on construction sites. South Dakota DOT (SDDOT 1997) used available construction and weather records to determine the expected number of working days and delays due to extreme weather conditions. McDonald (2000) examined weather-related delay claims for construction projects and how they can be resolved. El-Rayes and Moselhi (2001) developed a decision support system for quantifying the impact of rainfall on the productivity and duration of highway construction operations. Moselhi and Zafar (2012) identified, analyzed, and ranked the parameters that affect job-site daily labor productivity to help job-site personnel in planning and comparing their daily targets and to fine-tune their resource allocations according to the daily situation. Apipattanavis et al. (2012) proposed an integrated framework to identify the weather attributes that cause construction delays and to quantify weather threshold values.

3. Methodology

The purpose of this research is to study the impact of weather conditions on labor productivity of four construction trades in Qatar, namely, plaster, block work, ceramic tile, and formwork. The weather condition is represented herein by three components, namely, temperature, humidity, and wind speed.

The study started with a daily collection of the labor productivity of the four selected trades. Then, an analysis was performed on the collected data to determine how the labor productivity of the four construction trades varies during the year due to temperature, wind speed, and humidity. Finally, linear regression equations were developed to predict the labor productivity of the four construction trades for a given weather condition.

The study considered the labor productivity of crews rather than individual laborers. The crew productivity data was collected and analyzed for a period of eight months (i.e., July 1, 2013 to February 28, 2014). It consisted of recording the work quantity completed daily and the number of labor crews that performed it. The collected data was used to determine the labor crew productivity. The weather data was also collected from the Weather Authority in Qatar for the same period. It consisted of collecting the daily temperature, wind speed, and humidity. The data collection covered the period between July 1, 2013 and February 28, 2014.

4. Productivity Results and Analysis

4-1. Plastering Work

Figure 1 shows the variation of the plastering work labor productivity over time. As shown in the figure, the productivity was lower in the summer months. However, it increased after the summer months until it reached its maximum value in the middle of the month of February.

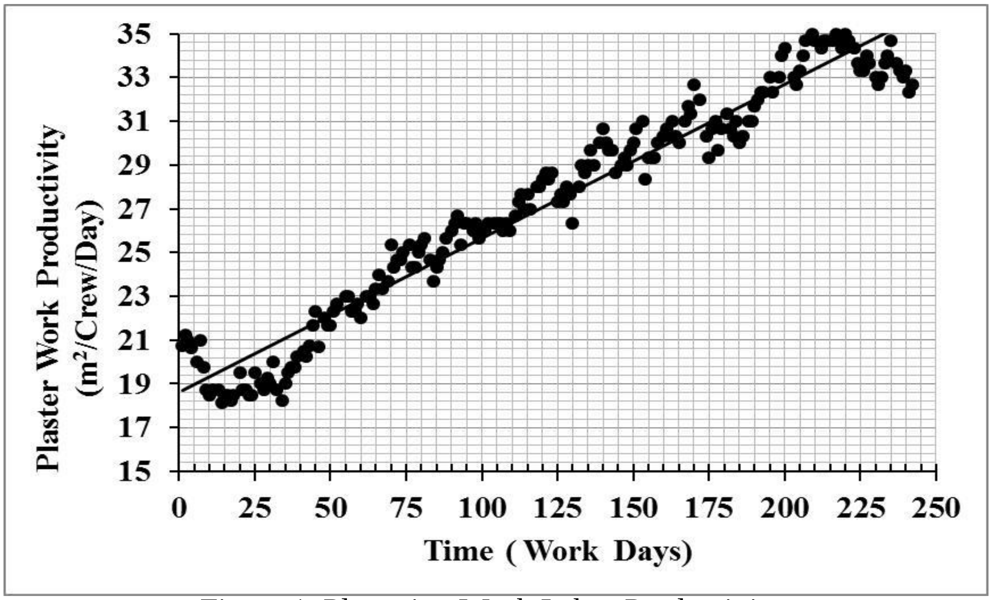

Figure 1. Plastering Work Labor Productivity

A regression analysis was conducted using Minitab software to find the relationship between the plastering work labor productivity and weather components. The analysis started by determining which independent variables shall be included in the model using the Subset Value process. Removing few variables may generate more accurate models. The analysis generated the following regression equation:

$$\text{Plaster Work Productivity} = 38.81 - 0.597 * MT + 0.052 * MS - 0.074 * MH \qquad (1)$$

Where PP = daily crew plastering work productivity (m^2/crew/day), MT = mean temperature (degrees Celsius), MH= mean relative humidity (%), and MS= mean wind speed (km/hr).

The regression analysis exhibited an adjusted coefficient of determination R^2_{adj} of 91.5%. This means that the regression equation will be able to predict the plastering work labor productivity with an accuracy of 91.5%.

4-2. Block Work

As shown in Figure 2, the block labor productivity shows a similar trend to that of plastering work. In other words, the labor productivity started low in the summer and increased to reach a maximum value in the winter. Then, it started to get stable and tended to decrease at the end of the winter.

The regression analysis that was performed using Minitab generated the following equation for the labor productivity of block work:

Block Work Productivity = 63.87 - 1.42 MT - 0.023 MH (2)

The regression analysis exhibited an R^2_{adj} of 94.7% which means the regression equation will be able to predict the labor productivity of block work with an accuracy of 94.7%.

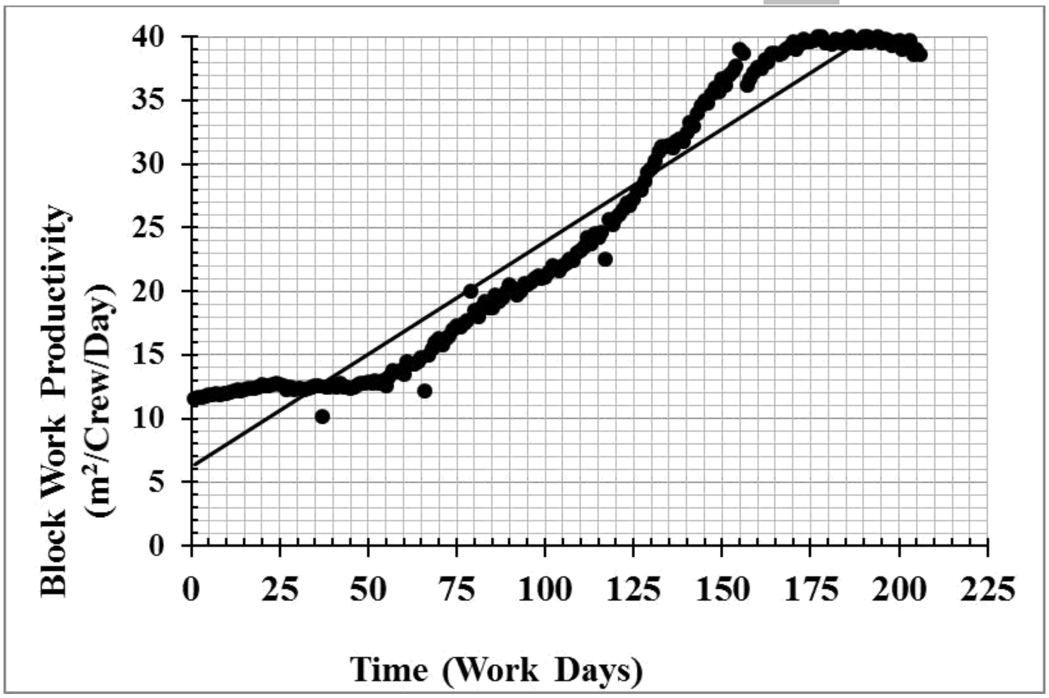

Figure 1. Block Work Labor Productivity

4-3. Ceramic Tile Work

The impact of weather conditions on the crew productivity of ceramic tile work was lower than those of plastering and block work. This is due to the fact that ceramic tile crews are always working in better weather conditions and not exposed directly to the sun.

Figure 3 shows that the ceramic work labor productivity follows a trend similar to those of plastering and block work. In other words, the productivity started low in the summer period, increased to reach a maximum value in the winter, and then started to decrease at the end of winter.

A regression analysis that was performed using Minitab generated the following equation for the labor productivity of ceramic tile work:

Productivity for Ceramic Work = 39.6 - 0.581 MT - 0.0163 MH (3)

The regression analysis exhibited an R-sq adj of 93.9% which means the regression equation will be able to predict the labor productivity of a ceramic tile crew with an accuracy of 93.9%.

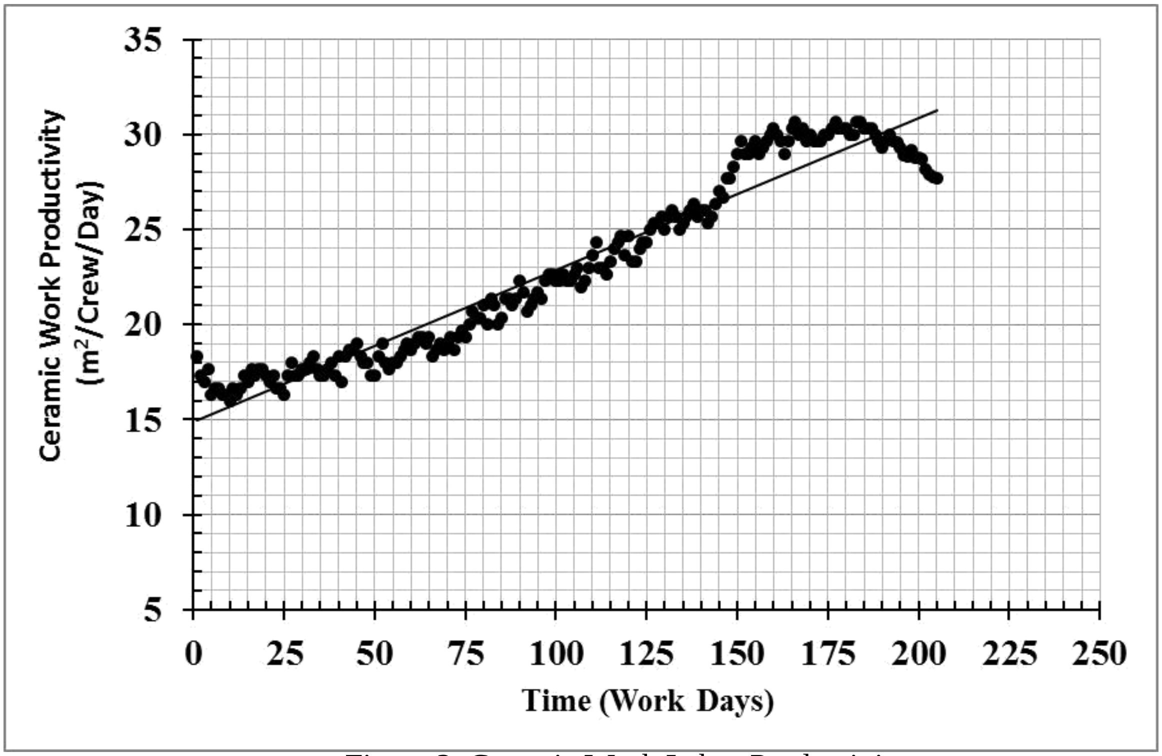

Figure 2. Ceramic Work Labor Productivity

4-4. Formwork (Shuttering) Work

A significant difference in labor productivity results was found between vertical (i.e., columns, core walls, and shear walls) and horizontal (i.e., slabs and beams) formwork. That's why a separate analysis was performed for horizontal and vertical forms. One important point to mention here is that formwork crews are composed of one carpenter only because the shuttering work is usually done without the help of laborers. Therefore, the number of crews in the shuttering trade is usually equal to the number of carpenters working on the site. Another point is that the formwork productivity can't be recorded every day unless all wood molds are ready for concrete casting.

Horizontal Formwork

The shuttering productivity is computed at the end of each shuttering period using the following equation:

$$\text{Crew Daily Productivity} = \frac{\text{Total volume of concrete shuttering}}{\text{Number of crews} \times \text{Number of days}} \quad (4)$$

The regression analysis yielded the following equation for the labor productivity of horizontal shuttering work:

$$\text{Horizontal Shuttering Productivity} = 9.44 - 0.142\ \text{MT} - 0.0094\ \text{MH} \quad (5)$$

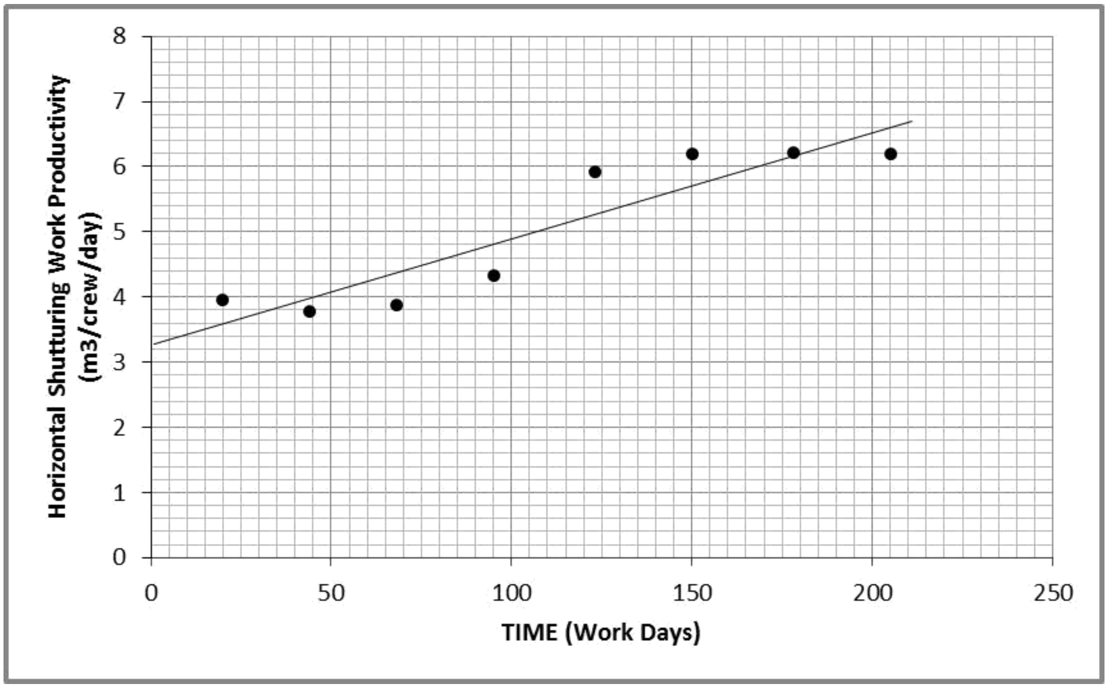

Figure 3. Horizontal Shuttering Labor Productivity

Vertical Formwork

The productivity of vertical shuttering was lower than that of horizontal forms. The formwork productivity of columns is lower than that of shear walls and reinforced cores. That's why the productivity data from construction sites that had columns, shear walls, and reinforced cores in each floor was collected herein.

The regression analysis yielded the following equation for the labor productivity of vertical shuttering work:

$$\text{Vertical Shuttering Productivity} = 9.03 - 0.113\ \text{MT} - 0.0133\ \text{MH} \tag{6}$$

The regression analysis exhibited an R-sq adj of 90.01% which means the regression equation will be able to predict the labor productivity of a vertical shuttering work crew with an accuracy of 90.01% .

5. Conclusions

This study investigated the impact of weather conditions on the labor productivity of four construction trades, namely, plastering work, block work, ceramic tile work, and concrete shuttering work construction trades. A full data of specific weather components, namely, temperature, wind speed, and humidity, were recorded along with the labor productivities of four construction trades between the months of July, 2013 and February, 2014. The analysis of the results showed that the weather components had a high impact on the labor productivity of the four construction trades. The labor productivity during the summer months can be as low as half of that in the winter months. This shows the large difference in labor productivities due to the weather. Linear regression equations were developed to predict the labor productivity of the four construction trades for a given temperature, wind speed, and humidity. This study has the potential of reducing Qatari construction project delays due to weather conditions. It allows taking into account the effects of weather conditions on activity durations during the scheduling of Qatari construction projects. This allows project schedulers and managers to have a more realistic project schedules.

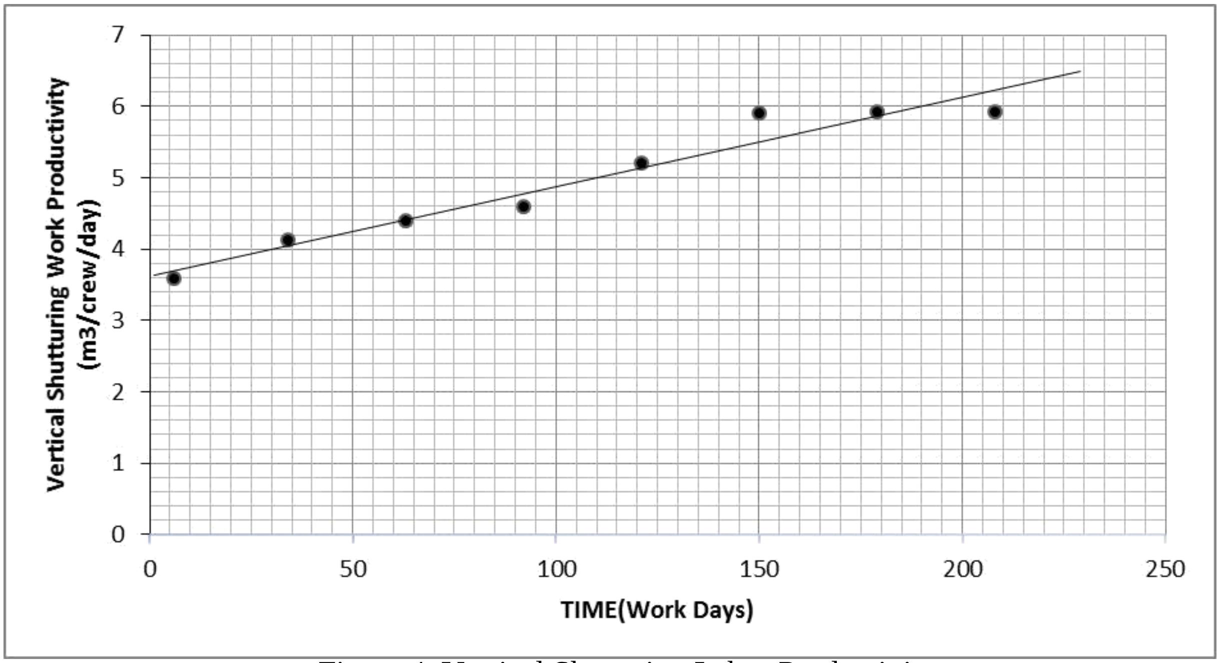

Figure 4. Vertical Shuttering Labor Productivity

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