Predicting Non-Workdays For Highway Projects in Brazos County, Texas From Historical Weather Records and Daily Project Work Reports

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A relatively simple regression equation can be created for contractors that will allow them to estimate the number of non-work days for any month during a highway construction project. The variables used to predict non-work days are monthly precipitation, monthly temperature, number of weekend days per month and number of holidays per month. All the required input data to calculate the required non-work days are easily available on the web.

Keywords: predict workdays regression precipitation temperature

Introduction

Construction projects, in general, are executed in an outdoor environment and therefore are affected by weather conditions. Weather impact is reported to be one of the main factors causing delay and cost overruns on construction projects. A considerable number of construction activities, especially outdoor projects such as highway, bridge, and earthwork construction, are sensitive to weather conditions. When weather conditions prevent timely completion of major sequential components of a construction project, it often requires additional construction time, leading to delays and subsequent requests for contract time extensions (Baldwin et al. 1971; Koehn and Meilhede 1981; Laufer and Cohenca 1990).

Texas Department of Transportation is increasingly requiring contractors to bid on a set contract period, because the past experience has shown that significant time and effort were spent on settling disputes between what the contractor and department consider to be a reasonable number of weather related non-working days during the contracting period. This delivery method shifts some risk to the contractor since it does not allow for contract schedule extensions due to weather. So, it becomes very important for contractors to have a handy tool to calculate and predict a realistic number of working days likely to be lost because of adverse weather conditions and adjust critical schedules to minimize the effects of lost time (Xi, Balaji and Molenaar 2005).

This research will use statistical methods, in an attempt to develop a linear regression model that can be easily applied by contractors to predict the number of future non-working days given the historical weather data and project schedule.

The Problem and Its Setting

Problem Statement

The purpose of this study is to develop a regression model that predicts non-working days for any future highway project in Brazos County, Texas given the project start date and its duration.

Assumptions

1) The research assumes all the daily work reports used were complete and accurate.
2) The research assumes that the Local Climatological Data (LCD) as recorded at Easterwood Airport used in this research accurately reflects the site weather conditions for the study period.

Research Objectives

1) Identify the weather factors that statistically influence a contractor's ability to work.
2) Develop a linear regression model that predicts the number of non-work days for highway projects in Brazos County, Texas based on weather conditions as recorded at Easterwood Airport and actual non-working days as reported on the daily report log for a Texas Department of Transportation project in Brazos County.

Review of Literature

As mentioned earlier, many studies have shown the significant impact of weather on construction. Of all the weather phenomena, precipitation is probably affects construction the most (Xi, Balaji and Molenaar 2005).

According to Bruner and Conner (2002):

> Heavy precipitation reduces productivity of labor, materials and equipment employed in exposed conditions. Work invariably stops until after heavy rain is over, which depending on geographic location and season, may be minutes or months. Just when work can start again depends upon the impact of the rain upon the site. Rain has a pernicious impact upon site conditions extending well beyond short-term work stoppages during precipitation to longer term impact of surface runoff that can: (1) inhibit site access by making access roads impassable; (2) inhibit site work by flooding excavations and low areas; (3) increase the moisture content of soils so as to require additional compaction efforts; (4) raise ground water tables; (5) cause erosion requiring re-grading; and (6) damage installed work. Intensity of snowfall also affects productivity by impacting human mobility, access to work areas, visibility and the usual subsequent snow cleanup of exposed work areas, tools and equipment.

According to El-Rayes (2001), the magnitude of delays caused by precipitation is related to its amount as well as its timing relative to construction. It can also influence the type of work that can be accomplished. As an example, some specifications for asphalt paving do not allow it to be placed on a wet surface.

Research Method

Data Collection

The State of Texas Department of Transportation keeps daily work reports for most of their projects. To get a realistic count of non-working days for highway construction in College Station area, we requested a set of daily work reports for the phase 2 construction of highway FM 158. This project had a time span of two years (08/2002-07/2004). This daily work report describes every day's site condition. These include details such as the weather condition, the tasks contractor was working on and if everything is on schedule. After a careful review of all the reports, those days that the contractor was not able to work and the corresponding reason were listed on an excel worksheet. Then, for each month of the two years, the total non-working days were calculated.

The detailed weather conditions were downloaded from the NOAA, National Climatic Data Center. The data used are the LCD (Local Climatological Data) from the Easterwood Field Airport (CLL), College Station, TX. From the daily information, the monthly averages were calculated. The variables recorded there included average temperature, precipitation and wind speed.

Analysis

Variables

For each project month from August, 2002 through July, 2004 averages were calculated for temperature (degrees F), precipitation (inches) and wind speed (mph). These three were then used as independent variables. A fourth independent variable was calculated. It was the number of holidays and weekend days minus eight. In statistical terms this is called a transformation. Data transformations are made in order to achieve normality in the data set to meet statistical assumptions.

The dependent variable (variable of interest) was the number of non-workdays. These were simply totaled for each month of the project according to the daily project reports.

Stepwise Selection

Stepwise selection is a method that allows moves in either direction, dropping or adding variables at the various steps. *Backward stepwise selection* involves starting off in a backward approach and then potentially adding back variables if they later appear to be significant. The process is one of alternation between choosing the least significant variable to drop and then re-considering all dropped variables (except the most recently dropped) for re-introduction into the model.

Results

Weather

Average annual precipitation for College Station, Texas from 1971 through 2000 is 79.34 inches. Over that same period the average temperature was 20.3 degrees Celcius (National Oceanographic and Atmospheric Administration, 2004). For the study period from August 2002 through July 2004 the average temperature observed was also 20.3 degrees Celcius. However, the precipitation observed during this time was 108.75 inches. This is 37% above the long-term climatic average.

Predictive Statistics

Analysis of variance shows that total precipitation, average daily temperature and non-working days minus eight are all significant at $p \le 0.05$. This means they all have an effect on the number of non-work days. The adjusted R Square is 0.704. This means that the model explains over 70% of the variability in the variable of interest, non-work days. The regression model itself is significant at 0.000. This is much better than our threshold of 0.05. The final equation is Non workdays per month = 11.449 + 0.465 Avg Monthly Precipitation - 0.153 Average Monthly Temperature + 0.903 (Weekend Days + Holidays –8).

Even though the sample size in this study was relatively small, all the statistical diagnostics were positive. The residuals are randomly scattered around 0. This not only indicates a linear relationship between the independent and dependent variables, but also shows that the residuals are relatively even distributed. At the same time, the descriptive statistics (below) of the residual showed that the mean of error term equals zero, just as we assumed.

As the sample size is small, the degree of freedom is less than 50, we used the Shapiro-Wilk test to test the normality of the residual (below). Given the significance level equals 0.713 (greater than 0.05), we can not reject the hypothesis that the residual is normal.

Since the data is normal, we then could use the Breusch-Pagan test to test if we have a constant variance. Given Ho: the dataset has homoscedasticity(constant variance), the Breusch-Pagan test gave out a P-value equals 0.2552 (greater than 0.05). Again, we can not reject the hypothesis that we have constant variance (Refer Figure 11).

Table 1

Model Summary

Model	**R**	**R Square**	**Adjusted R Square**	**Standard Error of Estimate**
1	.862	.742	.704	1.4996

Table 2

ANOVA

Model		**Sum of Squares**	**Df**	**Mean Square**	**F**	**Significance**
1	Regression	129.484	3	43.161	19.194	.000
	Residual	44.974	20	2.249		
	Total	174.458	23			

Table 3

Coefficients

	Unstandardized Coefficients		**Standardized Coeffeicents**		
Model	**B**	**Std Error**	**Beta**	**T**	**Significance**
1 Constant	11.449	1.221		9.378	.000
Precipitation	0.465	0.104	0.509	4.483	.000
Temperature	-0.153	0.046	-0.389	-3.297	.004
Weekend days and holidays minus eight	0.903	0.216	0.492	4.178	.000

Application

Using the unstandardized coefficients from Table 3 it is a simple matter to predict the number of actual work days for any contract period. As shown before, non workdays per month = 11.449 + 0.465 Avg Monthly Precipitation - 0.153 Average Monthly Temperature + 0.903 (Weekend Days + Holidays –8). Predicted workdays can then be calculated by subtracting predicted non workdays from the days in the month. As can be seen in Table 4, for the month of August 2002, non workdays = 11.449 + (0.465 * 2.63) – (0.153 * 29.3) + (0.903 * 1) = 9.1 days. Workdays then equal 31 – 9.1 = 21.9 days.

Table 4

			1971 – 2000		Non Workdays		Workdays		
Month	**Days**	**Wknd /Hldys–8**	**Temp (C)**	**Precip (in)**	**Predicted**	**Actual**	**Predicted**	**Actual**	**Deviation**
8-02	31	1	29.3	2.63	9.1	11	21.9	20	-1.9
9-02	30	1	26.5	3.91	10.1	11	19.9	19	-0.9
10-02	31	2	21.4	4.22	11.9	17	19.1	14	-5.1
11-02	30	3	15.6	3.18	13.3	15	16.7	15	-1.7
12-02	31	5	11.2	3.23	15.8	19	15.2	12	-3.2
1-03	31	1	10.1	3.32	12.3	10.5	18.7	21	1.8
2-03	28	0	12.5	2.38	10.6	15	17.4	13	-4.4
3-03	31	2	16.4	2.84	12.1	12.5	18.9	19	-0.4
4-03	30	0	19.9	3.20	9.9	8.5	20.1	22	1.4
5-03	31	1	24.1	5.05	11.1	9	20.0	22	2.0
6-03	30	1	27.6	3.79	9.9	12	20.1	18	-2.1
7-03	31	1.5	29.2	1.92	9.2	10.5	21.8	21	-1.3
8-03	31	2	29.3	2.63	10.0	10	21.0	21	0.0
9-03	30	1	26.5	3.91	10.1	12.5	19.9	18	-2.4
10-03	31	0	21.4	4.22	10.1	9.5	20.9	22	0.6
11-03	30	4.5	15.6	3.18	14.6	14	15.4	16	0.6
12-03	31	4	11.2	3.23	14.9	12	16.1	19	2.9
1-04	31	3	10.1	3.32	14.2	13	16.8	18	1.2
2-04	29	1	12.5	2.38	11.6	15	17.4	14	-3.4
3-04	31	0	16.4	2.84	10.3	8	20.7	23	2.3
4-04	30	0	19.9	3.2	9.9	9	20.1	21	0.9
5-04	31	3	24.1	5.05	12.8	12	18.2	19	0.8
6-04	30	0	27.6	3.79	9.0	10	21.0	20	-1.0
7-04	31	3	29.2	1.92	10.6	11	20.4	20	-0.4
Annual	365.5				136.61	143.5	228.89	222.00	-6.89
					100%	105%	100%	97%	-3%

Conclusions

A relatively simple regression equation can be created for contractors with projects in Brazos County, Texas that will allow them to estimate the number of non-work days for any month during a highway construction project. The variables used to predict non-work days are monthly precipitation, monthly temperature, number of weekend days per month and number of holidays per month. All the required input data to calculate the required non-work days are easily available on the web.

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