TRC0705

Updating the AHTD Manpower Forecasting Program

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Abstract

The AHTD Manpower Forecasting Program is used by construction engineers to estimate the manpower inspection needs for the Resident Engineer (RE) offices throughout the State of Arkansas. This program has been updated using recent AHTD completed job data. Generally, the forecasting program estimates the labor required to inspect projects as they are constructed, determines when and where this labor is needed, and generates various reports on this information. Both man-hour prediction and job length prediction equations have been updated by performing linear regression analysis on AHTD completed job data. Almost all of the updated linear equations exhibited an increase in y-intercept value and a decrease in slope. These changes correspond to a lower man-hour prediction and a shorter length prediction for a given job cost. Completed AHTD job data was unavailable for several types of work which have historically been included in the forecasting program.

Introduction

The Arkansas State Highway and Transportation Department (AHTD) must be able to effectively and efficiently manage the budget, schedule, and quality of major projects. The Construction Division has been utilizing a computer program entitled "The Manpower Forecasting System Formulas Program" for over 30 years, since the 1970's. This program was developed "in-house" by AHTD engineers, and was last updated in 1992. The forecasting program is based upon historical AHTD job data, and has generally been utilized in conjunction with engineering judgment. Generally, the program accepts input data such as a dollar amount for the construction project, the type of facility (rural vs. urban), and the expected dates of letting and completion. In addition, the program distinguishes various types of highway construction work such as overlay, base and surfacing, widening, drainage, rehabilitation, etc. Using a table of projected data and regression analysis, the program yields a prediction of inspection manpower needed in "man-hours/month".

For a given length of roadway, the required inspection manpower needed for various types of work and different functional classifications has not significantly increased. However, the *costs* of various types of work for the different functional classifications have significantly increased over the past 15 years. As a direct result of these increases in construction costs, the manpower forecasting program became outdated, and began yielding unrealistic results when used to predict needed staffing levels for some of the AHTD's larger projects.

The purpose of this project was to utilize data from completed AHTD construction projects to develop new and updated regression coefficients in order to obtain the best possible "fit" with recent historical data.

Man-hour Prediction

The man-hour prediction equations are of the form: y = mx + b, where

Y – total man-hours needed

m – slope in units of man-hours/$

x – total cost in $

b – y intercept (man-hours)

The input to these equations is the total project cost, and the output is a prediction of man-hours needed to inspect the project.

Length Prediction

The length prediction equations are of the form: y = mx + b, where

Y – total length of the job in months

m – slope in units of months/$

x – total cost in $

b – y intercept (months)

The input to these equations is the total project cost, and the output is a prediction of the length of the job in months.

Road Types included in the Forecaster Program

The following road types are included in the existing program:

1) **Interstates**
2) **Other Freeways and Expressways**
3) **Other Principal Arterials**

4) **Minor Arterials**
5) **Collectors Streets**
6) **Major Collectors**
7) **Minor Collectors**
8) **Local Roads**

<u>Types of Work included in the Forecaster Program</u>

The following types of work are included in the existing program for the respective roadway types:

<u>Interstates</u>

Rehabilitation

<u>Other Principal Arterials</u>

Resurfacing

Grading and Structures

Structure and Approaches

Resurface and Shoulder

<u>Minor Arterials</u>

Reconstruction

Resurfacing

Resurface and Shoulder

<u>Major Collectors</u>

Reconstruction

Resurfacing

Base and Surfacing

Grading, Drainage and Base

Grading and Structures

Surfacing (gravel only)

Structure and Approaches

Resurface and Shoulder

Minor Collectors

Reconstruction

Resurfacing

Grading, Drainage and Base

Surfacing (gravel only)

Structure and Approaches

Local Roads

Reconstruction

Base

Base and Surfacing

Grading, Drainage and Base

Surfacing (gravel only)

New Location

Linear Regression Analysis

In order to perform the required linear regression analysis, the following data is required for each completed AHTD job:

a) **Cost in dollars ($)**
b) **Completion time in months**
c) **Functional Classification (type of roadway)**
d) **Type of Work**
e) **Required man-hours necessary to complete the job**

Once the above required data is obtained, the linear regression can be performed to obtain an updated linear equation. Specifically, the slope m and the y-intercept b are calculated from the given data.

For this project, completed AHTD job data were obtained from personnel in the computer department. Most of the AHTD job data provided were from 2002 and later. As expected, there were variations in the amount of completed AHTD job data that were available. Some types of functional classes had more available data than others, and some types of work had more recent data available than others. There were no recent data available for the classifications Minor Collectors or Local Roads. There were only limited data available for Major Collectors, and these were only for certain types of work.

Results

The results of the linear regression analysis are shown below.

General Default Equations for Functional Categories

Funcat	slope	y-intercept	R squared	# of Jobs
DEF	5.21e-4	1730	0.23	204

OFE	**1.25e-3**	**623**	**0.37**	**8**
OPA	**8.48e-4**	**805**	**0.48**	**121**
MIA	**3.87e-4**	**2095**	**0.19**	**83**
MAC	**1.57e-3**	**930**	**0.48**	**76**
MIC	**1.99e-4**	**786**	**0.11**	**6**
LOC	**2.16e-3**	**972**	**0.69**	**11**

Equations for length

Funcat	slope	y-intercept	R squared	# of Jobs
DEF	**2.37e-6**	**14.67**	**0.33**	**204**
OFE	**-4.96e-6**	**19.39**	**0.17**	**8**
OPA	**2.36e-6**	**15.10**	**0.41**	**121**
MIA	**1.98e-6**	**16.18**	**0.38**	**83**
MAC	**5.51e-6**	**10.27**	**0.40**	**76**
MIC	**1.36e-5**	**-.706**	**0.97**	**6**

Equations for specific types of work

Funcat	typework	slope	y-intercept	R squared	# of Jobs

INT	06	8.64e-4	951	0.76	6
OPA	27	3.57e-4	495	0.18	6
OPA	19	-8.17e-5	4620	0.006	12
OPA	16	8.14e-4	498	0.27	5
OPA	7	1.10e-3	15.7	0.28	9
MIA	27	2.60e-3	-373	0.99	6
Funcat	typework	slope	y-intercept	R squared	# of Jobs
MIA	7	5.90e-4	385	0.53	7
MIA	3	1.42e-3	-235	0.24	10
MAC	7	1.11e-4	369	0.008	7
MAC	3	2.39e-4	1230	0.06	5
MAC	27	1.50e-3	-142	0.47	6
MAC	19	1.39e-3	1557	0.43	45
MAC	14	NA	NA	NA	0
MAC	15	NA	NA	NA	0
MAC	16	NA	NA	NA	0
MAC	18	NA	NA	NA	0
MIC	03	NA	NA	NA	0
MIC	07	NA	NA	NA	0
MIC	15	NA	NA	NA	0
MIC	18	NA	NA	NA	0
MIC	19	NA	NA	NA	0

LOC	**03**	**NA**	**NA**	**NA**	**0**
LOC	**08**	**NA**	**NA**	**NA**	**0**
LOC	**14**	**NA**	**NA**	**NA**	**0**
LOC	**15**	**NA**	**NA**	**NA**	**0**
LOC	**18**	**NA**	**NA**	**NA**	**0**
LOC	**28**	**NA**	**NA**	**NA**	**0**

Of the seven equations listed for functional categories (general default equations) all seven updated equations showed a *decrease* in slope, and all but OFA showed an *increase* in the value for the y-intercept. The results of this would be a decrease in the amount of manpower estimated for a given project cost input.

The six length equations each exhibited a decrease in slope and an increase in the y-intercept value. These results indicate a shorter length prediction for a given project cost input.

The twelve equations shown for the various types of work showed more variability in the regression results. While the majority of these showed a decrease in slope and an increase in the y-intercept value, some of these equations behaved differently. For example, for minor arterials (MIA), the task of "resurface and shoulder" indicated an *increase* in slope and a *decrease* in the y-intercept value. This is opposite of what was expected for the updated equations. These results would actually indicate *more* manpower for a given project cost input.

Discussion of R squared results

As indicated in the tables shown above, the regression analysis includes an "R-squared" value for each updated equation. In linear regression, the R-squared value is used to quantify the "goodness of fit" of the equation to the data being

analyzed. As shown above, R-squared ranged from a high value of 0.99 (indicating a relatively good fit) to a low value of 0.006.

The regression results were examined to determine if there was any correlation between the value of R-squared and the total number of completed jobs for that particular equation. After careful examination of the updated equations, it was determined that there was little or no correlation. In other words, some of the best R-squared values were obtained from equations where there were only a few jobs available for regression analysis, and some of the worst R-squared values were obtained from equations where there were a relatively large number of completed AHTD jobs to utilize.

Implementation

This project has been underway for over two years. During the duration of this project, engineers with the AHTD Construction Division have continued to use the forecasting program to estimate the manpower needed each year for the various districts in the State of Arkansas.

For the past several years leading up to this project, Construction Division engineers have utilized the "old" manpower forecasting program (last updated in 1992) and have had to "adjust" the results using experience, engineering judgment, and common sense. For reasons discussed earlier, some of the larger AHTD projects yielded very unrealistic predictions in terms of required inspection manpower.

When the updated equations from this current project were utilized in a manpower forecast, the results were "mixed". Some of the equations gave useful predictions, while some of the predictions were unreasonable and in some cases, even worse than the "old" (1992) equations. It has been determined that the equations yielding questionable results were the ones with low "R-squared" values. In other words, some of the updated equations appear to be useful and accurate, while others appear to give unusable results, thus requiring additional engineering judgment and experience to determine how to best allocate inspection resources.

Conclusion

The AHTD Manpower Forecasting Program has been updated by performing linear regression analysis on completed AHTD project data. There were sufficient data to update all seven of the existing "functional category" equations, including a default equation. Also, there were sufficient data to update all six of the existing "length prediction" equations, including a default equation. However, of the twenty-seven existing "type-work" equations, there was data for only twelve types of work. Therefore, only twelve of the existing twenty-seven type-work equations were updated. The values of R-squared for the linear regression analysis varied from 0.99 down to 0.006. When implemented into the manpower forecasting program, the updated equations gave "mixed" results. While some updated equations appear to be useful for predicting manpower requirements for certain types of work, some of the updated equations with low R-squared values appear to yield results that are not useful in their current form. It appears that the only realistic way to correct this is to utilize more complete and accurate AHTD completed project data.