ACTIVITIES TIME ESTIMATES FOR ASPHALTIC ROAD CONSTRUCTION BY USING A MULTIPLE REGRESSION ANALYSIS

by

Mr. Kriangkrai Uthairat

A Final Report of the Three - Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
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Project Title	Activities Time Estimates for Asphaltic Road Construction by Using a Multiple Regression Analysis
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Academic Year	November 2000

The Graduate School of Assumption University has approved this final report of the three-credit course, CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

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ABSTRACT

The precise project time estimation is an important component for planning and managing of project success. Therefore, these projects present activities time estimates for asphaltic road construction so that the alternative way can efficiently reduce the degree of the error time estimation between contract time and actual time. The affected factors are determined to establish the multiple regression model.

The 35 completion projects data were gathered from Department of Highways in Thailand, which analyzed to establish the prediction time model. Computer software SPSS for Windows Version 10 was an available tool to analyze time estimation model. The derived model was tested and validated by using project information from all of 35 completion projects. Hence, the result of the tested model has shown the percentage of the error value less than 8 %. The prediction time model has coefficient of determination (R^2) = 0.924, and adjusted R^2 = 0.888. Therefore, This equation is fit to predict time because its adjusted R^2 is higher than 0.75.

This model has is accurate than the traditional models. The percentage error of prediction time equation (within 8%) is less than the traditional approach (within 22%). However, there is difficult to implement this model because of many variables were approached to 11. Therefore, this equation model should be developed in the computer software, and it can be designed in the entered data screen step by step in order to easily implementation. The values of the prediction time model are supporting the decision making of projects' owners in bidding construction and planning budget allocation in feasibility phase for asphaltic road construction in contract documents efficiently.

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L INTRODUCTION

1.1 Overview

At present, more traditional techniques predict to estimate project duration for asphaltic road construction. Most projects always use "production rate of construction machines and work quantities" appended with "judgment and experience of each estimators" for determining time estimation of asphaltic road construction. Therefore, this technique has not been standardized to estimate project duration because each estimator's judgment may be not the same way. Consequently, many road construction projects have been causing large errors of completion time from estimation. Especially; completion time delay projects have been rising for 3 years 1996(61%), 1997(64%), 1998(76%) of total projects as shown in Figure 1.1.

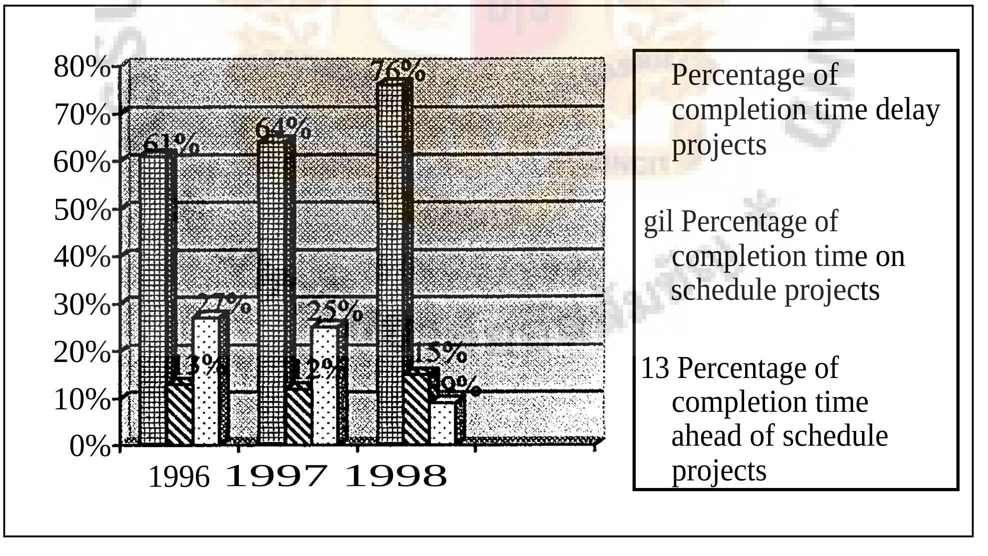

Figure 1.1. Percentage of Difference between Time Estimation and Actual Completion Time of Asphaltic Road Construction During 1996-1998 from Department of Highways in Thailand.

As a result, more effecting problems in asphaltic road construction projects occur, especially contractors can't control and allocate budget achieve goal on schedule because the time estimation projects in contract time is less than the actual time.

Some techniques apply the mathematical and statistical method to establish time estimation projects model in different ways that help estimating project duration easier and more accurate such as by using the multiple regression analysis model, simulation model, time series model, and etc. In this project, considering on techniques by using multiple regression models supports the accurate result with actual time. However, the traditional estimate of project duration has some weakness. For example, less affecting factors were applied in estimate time modelling such as only cost factor was considered (Chan 1999), and some estimate time modellings difficult to use.

This project presents a new alternative way that more precise estimating project duration of asphaltic road construction for successfully planning and managing project. In order to predict the model, using multiple regression analysis was considered the most suitable technique to derive the relationships between one dependent Y variable (Estimated Time) and several affected factors independent X variables (X_1, X2, X_3 . . . Xi_c) to find out the proper estimated time equation.

Multiple linear regression Y = I3o + OiXt + 02X2+ I33X3+ 134X4 +135X5 ...413kXic + e

The data come from interviews with project managers and surveys, journals, research, thesis, textbooks, and the like. In addition, the data from Department of Highways in Thailand of 35 completion projects by Taro Yamane (Alan and Robert 2000) technique are shown as follows:

$$n = \frac{N}{1+Ne^2}$$

n = Sample size of completion projects

N = Population size of completion projects

e = The degree of error from mean of distribution

*Giving data:

N = 340 completion projects (Department of Highways in Thailand 1992-1997)

e = 16%(0.16),

$$\frac{340}{1+340(0.16)^2} = 35.04 \text{ completion projects}$$

The result of the analysis of sample size is 35 completion projects in this project.

Since the number of independent variables (35 completion projects) made it more difficult to determine the best combinations of the most significant ones, partial correlation was useful in testing the probabilities of association between any two variables.

A backward selection procedure with a significance level of 5% (confidence interval 95%) was used to select statistically significant variables to be incorporated into the model. Data variables were added one at a time and the regression model re-run noting the changes at each step in the coefficient of determination (R^2) value and, more importantly, the significant level of variables. Only those variables with a value of probabilities of less than 5% were included in the final multiple regression model equations. A required minimal sample size of 35 was regarded as sufficiently large to guarantee an effective normal approximation as a general rule of thumb, regardless of the shape of the population frequency distribution.

After analysis of time estimation model, I decided to choose a computer software tool, which was SPSS for Windows Version 10. The result of analysis of time estimation would help the project's owner for decision making in the bidding construction and efficient budget planning.

1.2 Objectives

The main objectives of this project are as follows:

(1) To identify factors affecting time estimation for asphaltic road construction.

(2) To determine the model of time prediction equation for asphaltic road construction in contract time to support decision-making especially in bidding and planning budget for project's owner. Furthermore, this prediction model reduces the degree of errors activities time estimates with an actual time.

1.3 Scope

This project presents activities time estimate for asphaltic road construction by using multiple regression analysis models. Computer software SPSS for Windows Version 10 is chosen as suitable tools. The data of 35 completion projects are gathered from Department of Highways in Thailand during 1992 — 1997.

Limitations of factors into the model have not been considered on estimating project duration, because it couldn't collect the supporting data in this project as described below:

(1) Number of labors or employees.

(2) Quality of labors or employees.

1.4 Deliverables

The results of the project are as follows:

(1) The model of time prediction equation for asphaltic road construction was analyzed by computer software SPSS for Windows version 10.

(2) The benefits of the model are estimating project duration for asphaltic road in the project planning stage of contract time that can help the project owner with decision making in bidding, and efficient planning budget allocation.

II. LITLRATURE REVIEW

2.1 Overview

In general, project managers expressed satisfaction with their procedures for determining estimate in contract time. In this project, indicating estimation of construction duration may be consistently biased toward longer times than are likely to be required for actual construction. The use of bidding and contracting methods that place greater responsibility on the contractor for determining contract time have been successful in reducing the degree of errors between estimating project duration in contract time document and actual completion time. However, they are not yet widely used. The seeming bias toward longer time estimates in fact exist.

The potential saving that reduces construction times will bring to the road-using public and the opportunities to reduce the financial risks of underestimating contract time represent substantial benefits to be gained if construction durations can be more accurately estimated. Transportation agencies should collect and pool data on construction project durations and more the factors likely to affect duration, and analyze these data to produce new and accurate predictive models. Work to date on the parametric estimation method is a valuable start on such models, but must be extended substantially before results will be accepted within the scheduling profession.

While a stronger statistical base is badly needed for contract time estimation, the value of experience and need for professional judgment are substantial and inescapable. Computer applications that make such experience more widely available to practitioners have great potential to improve the accuracy of contract time estimation.

2.2 The Importance of Contract Time

The term "contract time" has a particular legal application, and can be understood in court proceeding to mean the owner's "warranty of design." As such contractors' claims based on unreasonable contract times are compensable if the time is found to be significantly at odds with conventional practice. Contract time must represent the time in which an average, competent contractor will be able to complete the project, and may be represented by working days, calendar days, or completion date. In the case of completion date, the agency must give the bidder a starting date as well.

If the allowed contract time is too short, bid prices may be higher, quality may be reduced, and the number of legal disputes may increase. If the contract time is too long, the public will endure unnecessary inconvenience and the local business community may suffer excessively.

Accurate estimation of construction time is always important, but particularly so when a series of independent contracts (i.e., projects) planned in the same area may be contingent on one another. Contingency may include interference between operations of various projects to the extent that the start of one depends on the completion of another, for example, when large quantities of soil removed from one project must be used as fill material in another project.

2.3 Determination of Contract Time Estimation for Asphaltic Road Construction

Contract time, the maximum time allowed for completion of all work described in contract documents, influences not only construction project duration, but also budgeting, resource planning, a project's impacts on the local economy, and contract claims experience. This pervasive influence makes contract time estimation one of the most important tasks in construction contracting. More traditional techniques to determine contract time estimation projects are as follows:

2.3.1 Time Estimation Projects by Using Production Rate and Estimator' s Judgment

Most projects in Thailand use "production rate of construction machine and work quantities" appended with "judgment and experience of each estimators" for determining time estimation of asphaltic road construction. Especially in Department of Highways in Thailand, it is used to calculate in this way. Therefore, this technique is not the standardization and there is uncertain estimating project duration because each estimator's judgment may be not the same.

Most agencies abroad use similar processes for estimating contract time of Department of Transportation in the United States and Canada (DOTs). The construction project is first described in terms of its use standard production rates, appended with estimators' judgment and experience (Herbsman 1995), in addition, Department of Highways in Thailand use this technique to estimating project duration too.

Most DOTs use a similar 7-steps process to determine contract time. Procedural details and analysis methods in individual agencies' practices are as follows:

<u>Step 1:</u> The Input Data

The DOTs scheduler gathers and reviews all the data necessary for estimating construction time, generally including design drawing, specifications, special provisions, bills of quantities, correspondence, and any other relevant data.

<u>Step 2:</u> List of Activities

After reviewing the input data, the scheduler prepares a list of activities representing the major tasks to be accomplished in the project's construction. In a number of DOTs this list consists only of major activities.

Step 3: The Use of Production Rate for Determining Activity Duration

The DOT scheduler determines the duration for each activity in the list using production rates and work quantities. "Production rate" is a quantity of production accomplished over a specific time period (e.g., cubic meters of concrete placed per day). Realistic production rates are the key in determining reasonable contract times.

Most DOTs have developed a list of standard production rates to assist the scheduler. See Table 2.1.

These rates are based on statistical analysis of historical data on construction in the state, and are based on the amount of work that atypical crew can be expected to accomplish in a working day.

Using the standard production rates and the work quantities, the scheduler can estimate the duration of each activity, using the following general equation:

$$Ti = Q_i / Pi$$

Where

Ti = The duration of activity i

Qi = Work quantity for activity i

P_i = Production rate for activity i

Table 2.1. Production Rates for Contract Time Determination of DOTs.

Section	Item	Contract Time
201	Clearing and Grubbing	1.5 Acrers/Day
202	Removal of Timber Bridge	2 Spans/Day
202	Removal of PCC Pavement	500 Yd^2 /Day
202	Removal of Concrete Box Culverts	1 /Day
202	Removal of Asphaltic Concrete Surfacing	1 Miles/Day 2 Lane Miles/Day
203	Excavation or Embankment (figure highest quantity only)	3,000 Yd^3 /Day (Rural) 1,000 Yd^3 /Day (Urban)
203	Borrow or Truck Hauled Embankment	500 Yd^3 /Day (Truck Hauled)
203	Mucking Ditches (consider section)	1,000 Ft./-0.5 Mile Day
203	Mucking (very large quantity)	3,500 Yd^3 /Day
203	Shaping Roadbed	1 Mile/Day
203	Shaping Roadway, Ditches & Slopes	0.5 Mile/Day
203	Shell Embankment	2,500 Yd^3 /Day
301	Base Course (Non-Stabilized)	1,500 Yd^3 /Day
301	Base Course (Class I)	1,000 Yd^3 /Day
302	Scarifying and Compacting Roadbed	1 Mile/Day 2 Lane Miles/Day
303	In-Place Cement Stabilized Base Course	6,000 Yd^2 /Day (Roadway) 4,000 Yd^2 /Day (Shoulders)
304	Lime Treatment (24 Ft. Width) (20 Ft. Width)	6,000 Yd^2 /Day 5,000 Yd^2 /Day
305	Subgrade Treatment (Working Table)	8,000 Yd^2
401	Aggregate Surface Course	300 Yd^3 /Day
501	Asphaltic Concrete (less than 20 tons or broken construction)	500-1,000 Tons/Day
501	Asphaltic Concrete (typical overlay or construction)	1,000 Tons/Day

For example, referring to Table 2.1, Louisiana's estimate for the time for placing 13,000 Yd^3 of aggregate surface course would be computed as follows:

$$Ti = 13,000 / 300$$

= Placing of aggregate surface course (section 401)

Q = 13,000 Yd^3

P = 300 Yd^3/day

Actual production rates in the field depend on many factors such as weather, topography, project size and characteristics of the specific crews performing the work.

Some of these factors, e.g., weather or topography, are to some extent foreseeable, and some states have developed different standard production rates for various zones within their states or project types. Other agencies suggest a range or more than one rate for each activity (e.g., low, medium, and high productivity). Alaska has developed a unique approach for determining production rates, reflecting a statistical basis and assumptions about how a project is undertaken. The responsible scheduler must determine what rates to use and whether the standard rates should be modified for estimating duration of a particular project.

Step 4: Sequence of Construction

Based on experience, and with the aid of the list of activities and their durations, the scheduler describes the logical sequence of activities needed to construct the project. The sequence of activities shows the sequence of individual steps in the construction, process, which activities depend on or must follow completion of others, and which activities can be carried out concurrently. The sequence is generally shown as a precedence diagram suitable for scheduling, such as a bar chart (also known as the Gantt chart) and the critical path method (CPM) typically is used to compute the total project duration.

Step 5: Adjusting by Judgment

The DOT scheduler next adjusts the preliminary contract time, as calculated in step 4, to reflect the particular conditions under which the project will be constructed. The scheduler considers the effect of specific factors such as location, weather, and traffic, as summarized in Figure 2.1.

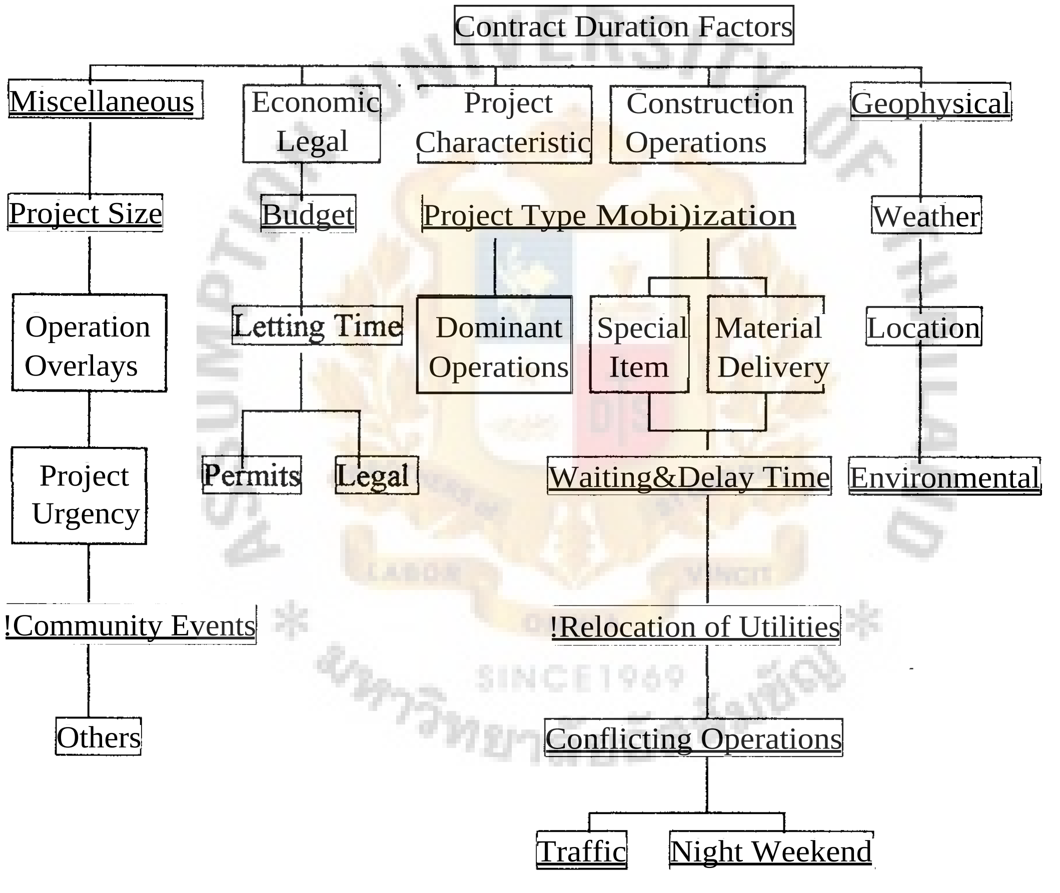

Figure 2.1. Major Factors Affecting Contract Time.

After identifying the factors that are likely to affect a specific project and their impact on the contract time, the scheduler adjusts the preliminary contract time. This adjusted contract time, in working days units, is converted to calendar days or completion dates in those states that represent contract time in these terms.

Step 6: Review

Experienced agency practitioners, as estimated in step 5, review the adjusted contract time. Some factors that reviewers consider are state budget, agency workload, contractors' availability, and current labor market. Some states (e.g., New Mexico, Delaware) are developing standard procedures based on statistical analysis of historical data to assist the reviewers.

Step 7: Final Contract Time

The review may lead to additional adjustments of the earlier estimate of contract time. Following these adjustments and final agency approval, the final contract time is incorporated into the bid documents and subsequently becomes part of the contract between the construction contractor and the agency.

2.3.2 Parametric Time Estimating (Historical Data Analysis)

Parametric time estimating, sometimes referred to as historical data analysis, is a major variation of the basic process of contract time determination that does not require a breakdown of tasks to be accomplished in the construction project. Instead, statistical regression analysis of historical data is used to estimate directly the relationships between construction time and parameters indicating project scale or magnitude.

The most commonly used parameter is the project' s cost that mostly used to study in researches as follows:

Bromilow (1974) from a survey of 370 Australian building projects, developed a model which predicts construction time in the form of the formula: $T = KC^B$,Where T is the actual construction time in working days, C is the final cost of contract in millions, K is a constant characteristic of building time performance, and B is a constant indicative of the sensitivity of time performance to cost level.

This model indicates that one factor (scope of the project as measured by construction costs in 1972 Australian dollars) principally determines construction time. This model was a function of the cost C of the project. The relationship may be summarized.

$$T = 313C''$$

Bromilow made use of mathematical models to show the relationship between cost and time, variations, and preconstruction time. These provided norms for the speed of the building process and the occurrence of variations. He also analyzed overruns on time and cost, which provided a measure of the accuracy of the industry's time and cost prediction.

Ireland (1983) reported similar research to predict the construction time of high-rise commercial projects in Australia. He concluded from an analysis of 25 high-rise building construction projects that the best predictor of average construction time of high-rise building based on cost (in millions indexed to June 1979) was:

$$T = 219C''^{7}$$

This result gave an R^2 value of 0.576 and a significance level of 0.001

Yeong (1994) studied the time-cost relationship of building projects in both Australia and Malaysia. Based on 67 Australian government projects, 20 Australian private projects and 51 Malaysian government projects, Yeong's study confirmed the

Bromilow's model at the 0.001 level of significance and that the time-cost relationships of the various projects could be represented by the following equations:

Australian private projects

$$T = 161C^{''67}$$

Australian government projects

$$T = 287C^{\circ 137}$$

All Australian projects

$$T = 269C^{\circ 115}$$

Malaysian government projects

$$T = 518C^{\circ 352}$$

The duration of Hong Kong construction (Chan 1999) has been by a time-cost formula expressed in the form of $T = KC^{B}$, The relationship to building projects in Hong Kong using time and cost data from 110 projects. Regression analysis was used to compute the value of K and B and check how well the model actually fits, and the best predictor of average construction time of building projects in Hong Kong is found to be

$$T = 152C^{\circ 19}$$

It is also found that the Hong Kong private sector takes a shorter time (120 days) to complete a hypothesized project with a contract sum of HK 1 million dollars (at December 1994 price) than its government counterpart (166 days). The time cost relationship serves as convenient tool for both project managers and clients for predicting the actual optimum time required for delivery of a building project.

The most commonly used parameter is the project's cost, but physical measurements such as length, area, and volume often are used as well. A more sophisticated version of parametric time estimating uses multiple regression on more than one project parameter. For example, the construction duration for a highway segment may be estimated as a function of cost, length, and number of lanes. The availability of easy to use statistical analysis software packages enables even a scheduler without extensive knowledge of statistics to develop this regression charts, and a simulation techniques to use often estimate project duration.

Dawood (1998) estimating project and activity duration: a risk management approach using network analysis Variations in the duration of activities are commonplace in the construction industry. This is due to the fact that the construction industry is influenced greatly by variations in weather, productivity of labor and plant, and quality of materials. Stochastic network analysis has been used by previous researchers to model variations in activities and produce more effective and reliable project duration estimates. A number of techniques have been developed in previous literature to solve the uncertain nature of networks, these are PERT (Program Evaluation and Review techniques), PNET (Probabilistic Network Evaluation technique), NRB (Narrow Reliability Bounds methods) and MCS (Monte Carlo Simulation). Although these techniques have been provided to be useful in modelling variations in activities, dependence of activity duration is not considered. This can have a serve impact on realistically modelling projects. In this context, the objective of the present research is to develop a methodology that can accurately model activity dependence and realistically predict project duration using a risk management approach. A simulation model has been developed to encapsulate the methodology and run experimental work. In order to achieve this, the following tasks are tackled: identify risk factors that cause activity variations using literature reviews and conducting interviews with contractors; model risk factors and their influence on activity variations through conducting case studies and identifying any dependence between them; develop a computer based simulation model that used a modified Monte Carlo technique to model activity duration and dependence of risk factors; and run experimental work to validate and verify the model.

Ahuja and Nandakumar (1995) simulation model to forecast project completion time Project cost is most sensitive to its schedule. The construction project environment comprising dynamic, uncertain, but predictable, variables such as weather, space congestion, workmen absenteeism, etc., is changing continuously, affecting activity durations. The reliability of project duration forecast can be enhanced by an explicit analysis to determine the variation in activity durations caused by the dynamic variables. A computer model is used to simulate the expected occurrence of the uncertainty variables. From the information that is collected normally for a progress update of the tactical plan and by simulating the project environment, the combined impact of the uncertainty variables is depicted for each progress period. By incorporating the combined impact in the duration estimates of each activity, the new activity duration distribution is generated. From these activity duration distributions, the probability of achieving the original project completion time and of completing the project at any other time is computed.

The detailed previously, the traditional estimating project duration has some weakness. For example, in case that using the regression analysis model considering on only one factor (cost), or considering less affecting factors were applied in time estimation project model. In addition; the projects that use production rate and judgment of each estimators is no standardization to estimating project duration. Therefore, this project that considering more affected factors to use in multiple analysis models so that generate standard in mathematics model and accuracy technique to estimate project durations by collect data from department of highways in Thailand of 35 completion projects during 1992-1997.

2.4 Multiple Regression Analysis

A multiple regression analysis consists of one dependent Y variable and several independent X variables, called explanatory variables or predictor variables. If there are k explanatory variables, X_1, X_2, X_3, ... X_k, and e is the error associated with this model.

The form of the relationship may be linear or nonlinear.

$$Y = f(X_1, X_2, X_3, X_k)$$

The form is linear if the value of Y changes by a constant amount for each unit increase in X.

A multiple linear regression model is shown in Figure 21.

Y = r3o 131Xi+ 132X2+ 83X3+ 134X4 05X5 +13kXk + e

This equation is similar to the equation for the simple linear regression model, except that the deterministic component is now:

131X1+ 02X2+133X3+04X4 + 135X5 • • • +1³kXk rather than 130 + 131X1. Once again the error term, e, is included to provide for deviations about the deterministic component.

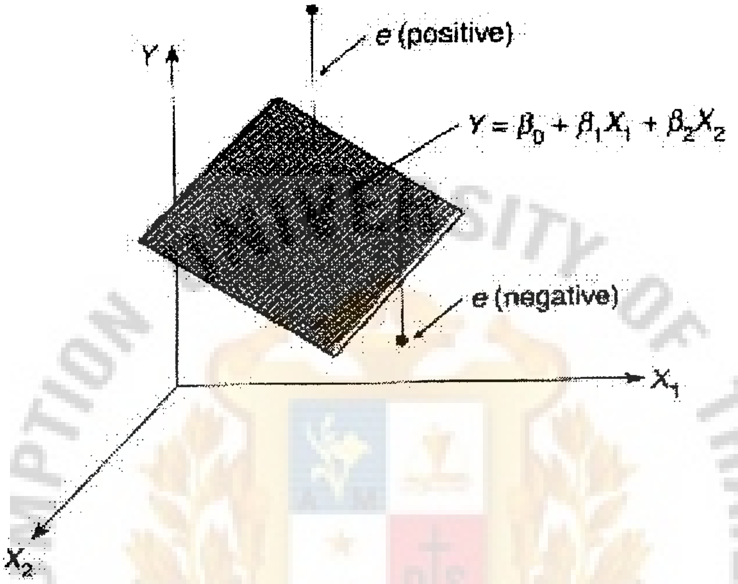

Figure 2.2. A Multiple Linear Regression Model, or Two Independent Variables (Alan and Robert 2000).

Sometimes the underlying nonlinear relationship between X and Y requires a data transformation to permit linear estimation. For example; suppose the underlying relationship or model has the following equation form:

$$Y = AB^x$$

This is called an exponential model, because X appears as an exponent. In this case, a logarithmic data transformation produces a linear expression. For instance, by taking the logarithms of both sides of the expression for the exponential model, the equation can be rewritten as:

$$\log Y = \log A + X(\log B)$$

If let $Y^* = \log Y$, $A^* = \log A$, $B^* = \log B$, Then express the last equation as:

$$Y^* = A^x + B^* X,$$

With the new formulation, linear regression analysis can be tried on the transformed variable Y^* and variable X to estimate the coefficients A^* and B^*. Predictions of the original dependent variable Y, given a value of X, require two steps: First, substitute the given value of X into the equation to obtain the estimate Y' *, second, find the antilog of * to obtain $Y^\wedge$ in original units. This will be our prediction of Y, given the value of X.

A multiple non linear equation model

$$Y \qquad a\, X_i^{b1}\, X_2^{b2}\, X_3^{b3} \ldots X_k^{bk}$$

Data transform to linear equation model

$$\text{Log}Y = \log a + b_i \log X_1 + b_2 \log X_2 + b_3 \log X_3 + bk \log Xk$$

HI. RESEARCH METHODOLOGY

In this section, the proposed methodology of modeling asphaltic road construction project duration was discussed as follows:

(1) To study the theories and techniques in time estimation for asphaltic road construction from research, journal, thesis, textbook, interview etc.,

(2) To study in statistical mathematic, related techniques such as multiple regression, and computer software SPSS for Windows version 10 were chosen as suitable tools to analyze, evaluate and to create the model in activities time estimates for asphaltic road construction.

(3) To determine the affected factors in time estimation of asphaltic road construction by interview project manager or related, people, and other related documents.

(4) To Gather data that based on affected factors for asphaltic road construction from Department of Highways in Thailand of 35 completion projects from 1992 — 1997.

(5) To analyze data by using multiple analysis to develop the modelling in activities time estimates for asphaltic road construction from computer software (SPSS v.10.0).

(6) To test the developed modelling of completion projects from 1992 — 1997.

(7) Conclusion

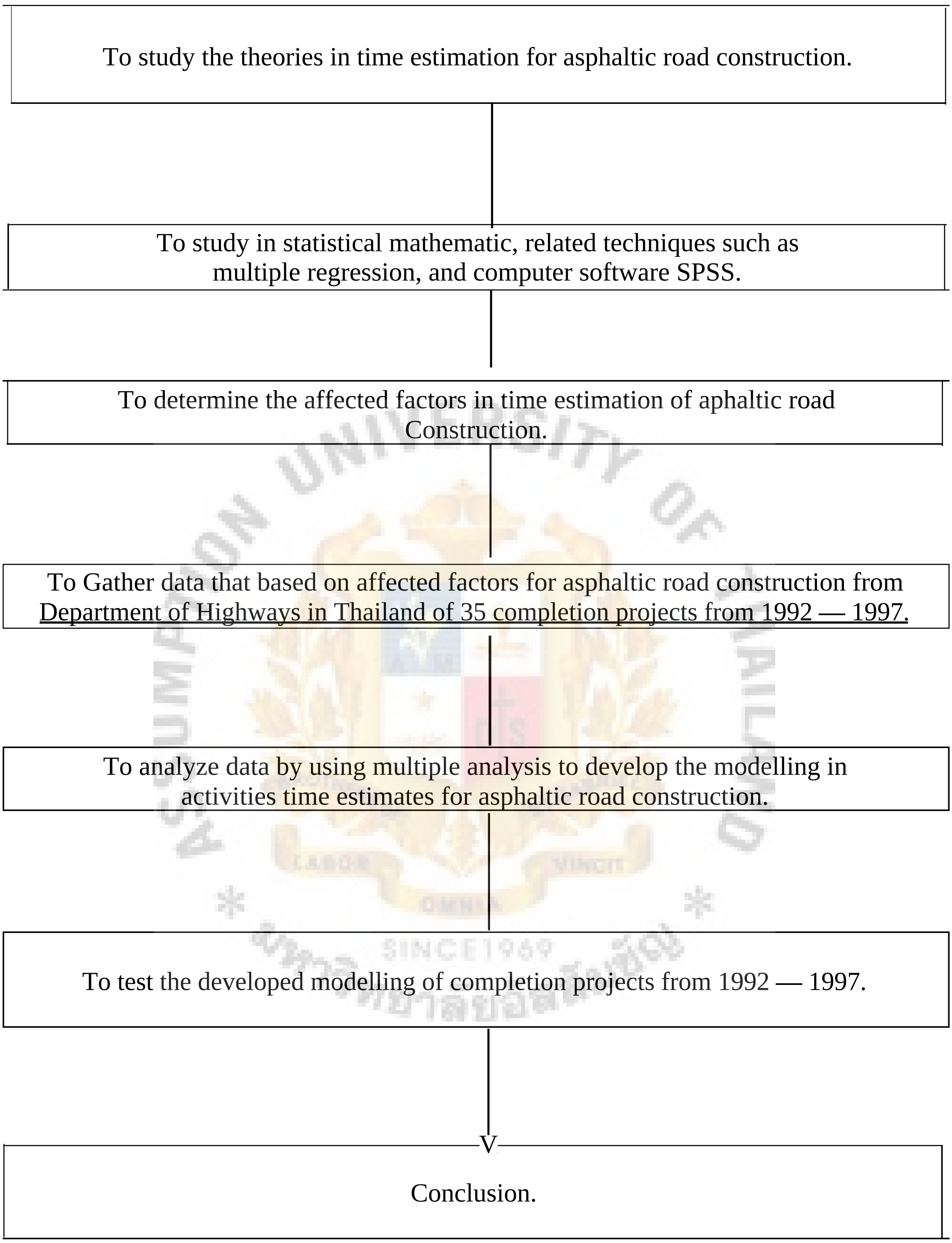

Figure 3.1. Research Methodology Flow Chart.

IV. SYSTEM DEVELOPMENT

Activities time estimates for asphaltic road construction model that determines affected factors and general equations to developed the modelling. After that gather data to generate multiple regression model to continue. Therefore, this section uses the statistical mathematics as a related theory in this project.

The multiple linear equation model to be selected.

$$Y = 13o + 1^{3}1X1 + 132X2 + I33X3 + 134X4 + 135X5 \qquad +13kXk + e$$

4.1 Correlation Analysis

A regression analysis is the proper tool when estimators use the X value to estimate or predict the value of Y. However, what interested estimators simply is the measurement of strength and direction of the linear association between X and Y.

Only a numerical measure that summarizes to what extent the linear movement of the two variables coincide. Correlation analysis fulfills this role. Whereas in regression analysis, only Y is the random variable, in correlation analysis, both X and Y are random variables.

4.1.1 Pearson's r

The most widely used measure of the strength and direction of the linear association between two quantitative variables is the linear correlation coefficient, p (Greek letter rho). The symbol p is assigned to the population parameter. The computed estimate of p from sample data is given the symbol r and is called Pearson's coefficient of linear correlation, or simply, the correlation coefficient or the Pearson r. The calculated sign and value of r therefore provide a sample summary measure that reports the direction and strength of the linear association between observed sample values of X and Y.

The possible values of r range from —1.00 to +1.00 indicate the different degrees of linear association that may be found. The extreme values, -1.00 and +1.00, indicate perfect negative correlation and perfect positive correlation, respectively. A particular r value implies the scatter of observations in a scatter diagram as shown in Figure 4.1.

The definitional formula for the Pearson r correlation coefficient is:

Pearson r correlation coefficient

$$r = \frac{E \quad -XXY - Y)}{\sqrt{(x -)02E(Y -))2}}$$

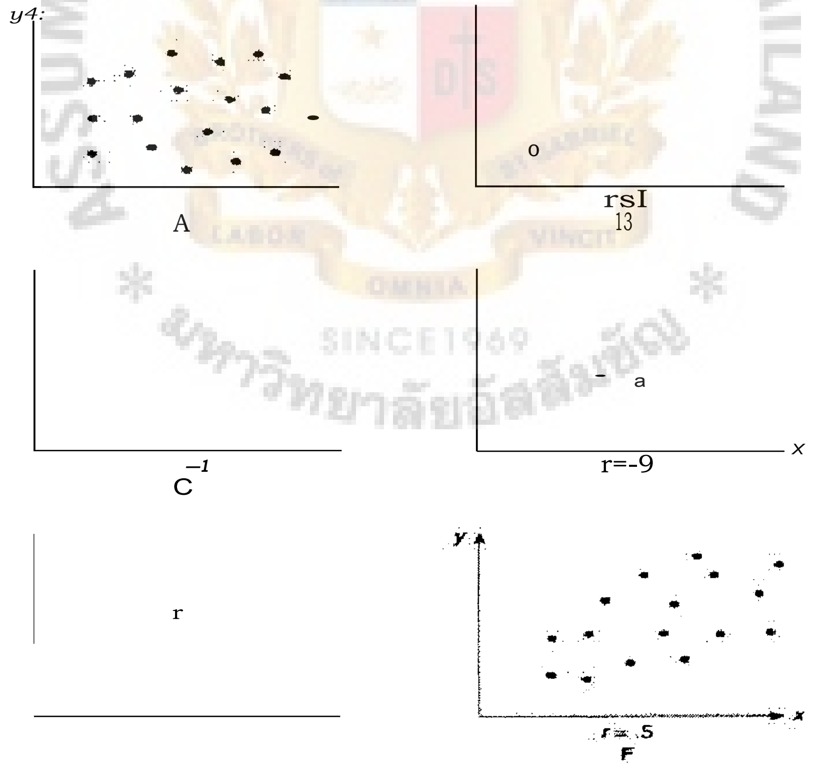

Figure 4.1. Scatter Diagram Showing Various Degrees of Correlation for the Observed Data (Alan and Robert 2000).

4.1.2 The Coefficient of Determination (R^2)

There is the method to measure of regression line fit called the coefficient of determination, r^2. This measure requires computation of explained variation (SSR) and total variation (SST) as follows:

$$r = \frac{SSR}{5.57''} = E()\% -))^2$$

Total Variation (SST)

In Figure 4.2, the green data point represents an observed Y value at a given X. Directly below this point is a point on the fitted regression line; this orange point represents the fitted Y value (Y) corresponding to the observed Y value. The mean value, Y, for all the Y values is shown in Figure 4.2 as a horizontal line. By drawing a vertical dashed line from the observed Y value to the Y line. It can be portrayed visually the size of the overall deviation.

The term in the denominator of the definitional formula for r^2 is computed from the overall deviations. This denominator is obtained by squaring each overall deviation term and summing all the squares. This quantity is called the total sum of squares, or total variation, and is denoted by SST:

$$SST = E(Y - Y)^2$$

Explained Variation (SSR)

Now consider in Figure 4.2 the portion of the vertical dashed line from the orange point (on the regression line) down to Y, shown as the difference YA - Y. This portion represents the part of the observed overall deviation that is accounted for by $\hat{Y}$.

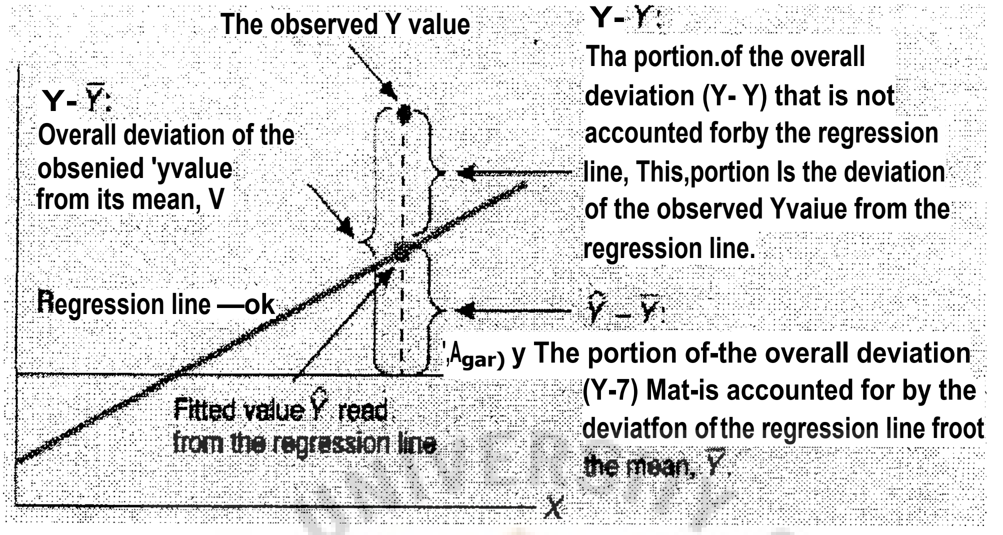

Figure 4.2. **Overall Deviation, Explained Portion, and Unexplained Portion for One Observed Value of Y (Mario and Albert 1993).**

The position or the height of the point on the regression line. By squaring these differences for all observations and summing the squared values, we obtain the numerator of r^2. This sum in the numerator of r^2 is called the explained variation; it is also called the sum of squares due to regression and is denoted by SSR:

$$SSR = \sum(\hat{Y} - \bar{Y})^2$$

Unexplained Variation (SSE)

In Figure 4.2, the segment $Y - \hat{Y}$ represents the residual, the portion of the observed overall deviation unaccounted for by the height of the point on the regression line. By squaring each difference and summing the squares, we obtain the quantity called the unexplained variation, or error sum of squares, denoted by SSE:

$$SSE = \sum(Y - \hat{Y})^2$$

The symbol of coefficient of determination is r^2, is use for only one independent variable but R^2 is applied symbol in multiple independent variables (multiple regression model). The criteria of coefficient of determination to consider as a conservative rule of thumb is shown in Table 4.1.

Table 4.1. A Conservative Rule of Thumb for Coefficient of Determination.

Coefficient of Determination (R^2)	Relationship
0 — 0.25	None
0.26 - 0.50	Low
0.51 — 0.75	Medium
0.75 — 1.00	High

Adjusted R^2, R^2_a

Mathematically, the R^2 statistic can never decrease in value when another explanatory variable is added to the current explanatory variables- not even when the newly included variable is a "nonsense" variable. The tendency for R^2 to show an increase with any added variable is a failure of the R^2 statistic that prompts the use of the adjust R^2 statistic, R^2_a. Like, R^2, the R^2_a statistic is a ratio, but, unlike the unadjusted R^2, both the numerator and denominator of R^2_a have been "adjusted for degrees of freedom." This degree of freedom adjustment enables us to detect whether the addition of an independent variable Y. If the newly included independent variable has contributed significantly, R^2_a will increase.

In measuring the gain in explanatory power of the equation when entering another explanatory variable, we use the following rules:

(1) Use R^e_a not R^2.

(2) If R^2_a increases, the variable has brought a significant increase in explanatory power, otherwise R^2_a will remain the same or increase.

4.2 Test of Hypothesis

In hypothesis testing, the state assumed or hypothesized value of the population parameter before beginning the sampling. The assumption that wish to test is called the null hypothesis and is symbolized Ho or "H sub-zero." If the sample results fail to support the null hypothesis, it must be concluded that something else is true. Whenever rejecting the hypothesis, the conclusion that do accept is called the alternative hypothesis and is symbolized H_1 ("H sub-one").

The purpose of hypothesis testing is not to question the computed value of the sample statistic but to make a judgment about the difference between that sample statistic and a hypothesized population parameter. If the null hypothesis is correct, the probability is that to reject null hypothesis will be called significance level (a). There is no single standard level of significance for testing hypothesis such as 0.05 or 0.01.

Statisticians use specific definitions and symbols for the concept illustrated in' Figure 4.3. Rejecting a null hypothesis when it is called a type I error, and its probability is symbolized a (alpha). Alternatively, accepting a null hypothesis when it is false is called a type II error, and its probability is symbolized (beta).

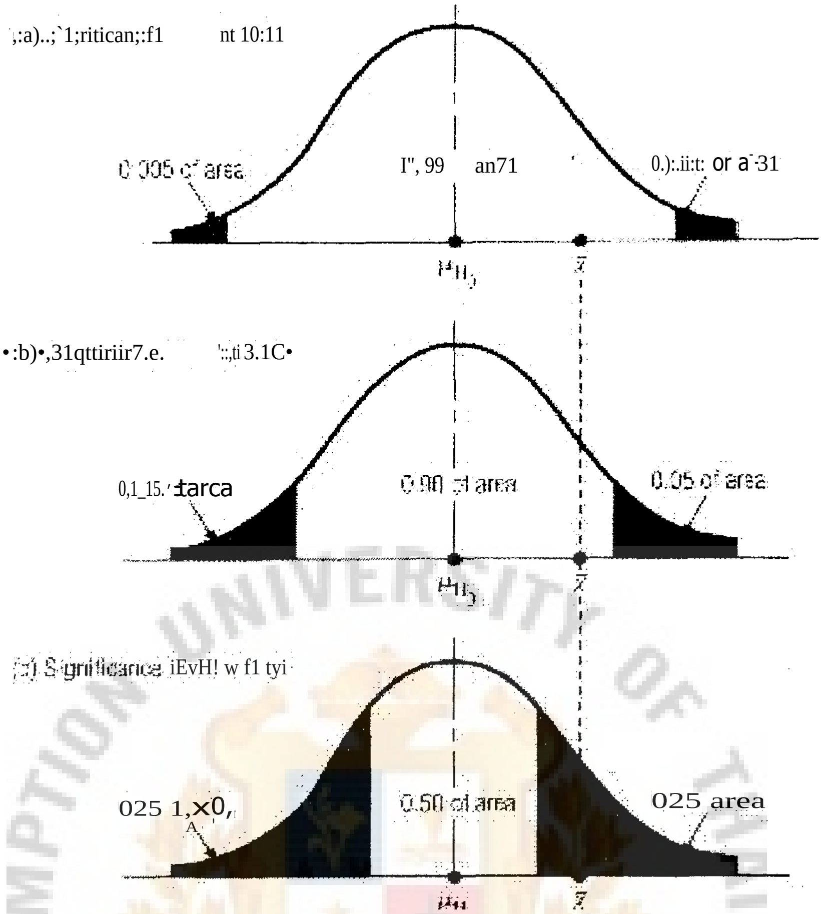

Figure 4.3. Three Difference Levels of Significance (Alan and Robert 2000).

4.2.1 Inference about the Regression Equation as a Whole

The test of the explanatory power of the regression equation as a whole is through using the F distribution. The null hypothesis H_o being tested claims that none of the explanatory variables used in the regression analysis has any explanatory power. If all Bi coefficients of the explanatory variables equal 0, then the population regression plane is horizontal (no fit) and the true population p^2 equals 0.

Ho: B1 $=B_2 = „ ,$ Bk = 0 (Y is not related to any X.)

H_1: At least one 13i 10 (Y is related to at least one X.)

The test statistic used to determine whether a multiple regression model contains at least one explanatory variable is the F statistic.

When testing H_o : all Bi 's = 0 (this set of predictor variables is no good at all) versus H_I: at least one B_i , 0 (at least one of these variables is a good predictor), the test statistic is:

$$\frac{MSR}{MSE}$$

Where,

$$MSR = \frac{SSR}{k}$$

$$MSE = \frac{SSE}{(n-k-1)}$$

$$SSR = E(9 - >)^2$$

$$SSE = E(Y - 9)^2$$

MSR stands for Mean Square for Regression

MSE stands for Mean Square foe Error

SSR stands for Sum of Squares for Regression

SSE stands for Sum of Squares for Error

Which has an F distribution with k and n-k-1 degree of freedom (df). The expression n-k-1 can be written as n-(k+1), where k+1 is the number of coefficient (Bi's) estimated including the constant term.

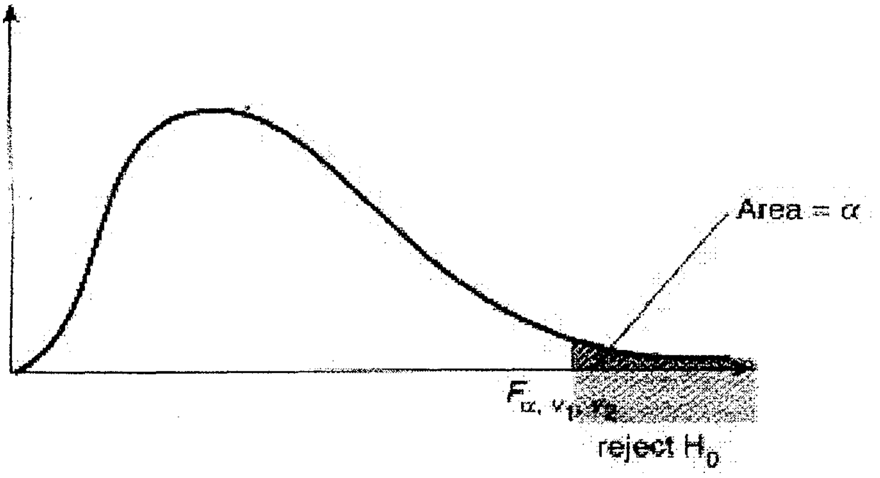

Figure 4.4. F Curve with k and n-k-1 df. The Lightly Shaded Area Is the Rejection Region (Alan and Robert 2000).

The testing procedure is to:

Reject H_o if $F > F_{a,}$ vi, v2

$F_{a,} v_{i,} v_2 = F_{a,} k,_{n}\_k\_i$ having a right-tail area = a see Figure 4.4.

4.2.2 Testing the Significance of the Individual Coefficients

Testing for the statistical significance of any observed Bi value. For example, by formulating the null hypothesis Ho :Bi = Bi,o and setting Bi,$_o$ = 0. Testing whether the observed bi value differs statistically from 0. If rejecting the null hypothesis statement that Bi is 0, the statement that no linear statistical relationship exists between Y and X.

This project uses t statistic procedure to test the effect of the individual variables in a multiple regression model. When examining the effect of an individual independent variable, Xi, on the prediction of a dependent variable, the hypotheses are:

H_o : Bi = 0

H_1 : **Bi 0**

The test statistic is:

$$t = \frac{bi}{Sb_i}$$

Where,

bi is the estimate of B_i

Sbi is the estimated standard error of bi

The df for the t statistic is n-k-1

The test of H_o versus HI is to:

Reject H_o ifl $t > t_c d2$,

4.3 Modelling with Dummy Variables

A regression equation that includes a dummy variable is a model designed to deal with qualitative data. A dummy variable is a variable with just two possible values, 0 or 1. When the particular quality considered is present, the dummy variable takes the value 1; otherwise it takes the value 0. Let Xi represent a dummy explanatory variable, and let bi be the coefficient of Xi. The product has a value of O. That is, $b_i = 0$ when $X_i = 0$ (quality absent). Simply said, b_i is the estimated quantitative impact on Y of the presence of a qualitative factor.

4.4 Multicollinearity

The condition of multicollinearity exists in multiple regression when the XI explanatory variables are not statistically independent; that is, one or more of the XI explanatory variables are interdependent (highly correlated) with one or more of the other XI explanatory variables. This situation may pose a problem, depending on whether the purpose of the regression analysis is the estimation of the regression coefficients or the prediction of Y. Multicollinearity may seriously impede reliable estimation of the regression coefficients, while having little effect on the prediction of Y.

The solution in this problem, determining in each pairs of correlation coefficient of (R). If R in each pairs > 0.7, is eliminating the low correlated variable with the whole multiple regression equation (or low R^2 to be eliminated from equation).

4.5 Selection Techniques for Independent Variables in Multiple Regression Equation

One possibility is to include all these variables in the model and to use the t tests to decide which variables are significant predictors. However, this procedure invites multicollinearity, because the model is more apt to include correlated predictors, severely hindering the interpretation of the model. In particular, two independent variables that are very highly correlated may both have small t values, causing estimators possibly to discard both of them from the model.

A better way to proceed here is to use one of the several stepwise selection procedures. These techniques either choose or eliminate variables, one at a time, in an effort not to include those variables that either have no predictive ability or highly correlated with other predictor variables. A word of caution- these procedures do not provide a guarantee against multicollinearity; however, they greatly reduce the chances of including a large set of correlated independent variables.

These procedures consist of 3 different selection techniques as follows:

Forward Regression

The forward regression method of model selection puts variables into the equation, one at a time, beginning with that variable having the highest correlation (or R^2) with Y. For sake of argument, call this variable X_i.

Next, it examines the remaining variables for the variable that, when included with X_1, has the highest R^2. The predictor (with X_i) is inserted into the model. This procedure continues until adding the "best" remaining variable at that stage results in an insignificant increase in R^2 according to the partial F-test.

Backward Regression

Backward Regression is the opposite of the forward regression: it begins with all variables in the model and, one by one, removes them. It begins by finding the "worst" variable — the one that causes the smallest decrease in R^2 when removed from the complete model. If the decrease is insignificant, this variable is removed, and the process continues.

The variables among those remaining in the model that cause the smallest decrease in the new R^2 is considered next. To continue this procedure of removing variables until a significant drop in R^2 is obtained, at which point to replace this significant predictor and terminate the selection.

Stepwise Regression

Stepwise regression is a modification of forward regression. It is the most popular and flexible of the three selection techniques. It proceeds exactly as does forward regression, except that at each stage it can remove any variable whose partial F-value indicates that this variable does not contribute, given the present set of independent variables in the model. Like forward regression, it stops when the "best" variable among those remaining produces an insignificant increase in R^2.

Figure 4.5, illustrates this procedure with an example of predicting divisional profits (the data are not shown).Data from all 12 independent variables, as well as from Y, are used as input to a stepwise regression program. One possible outcome from this analysis is shown in below:

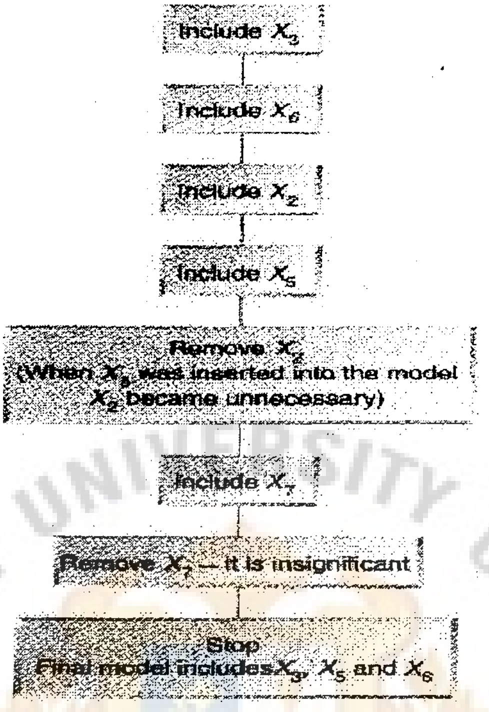

Figure 4.5. Possible Solution Using Stepwise Regression on Divisional Profits Data (Alan and Robert 2000).

4.6 The Affected Factors of Activities Time Estimates to Generate Model

The affected factors were determined by interviews with project managers, related people and survey literature review such as journal, research, thesis, textbook... e.g. In addition, the data from Department of Highways in Thailand of 35 completion projects were also collected. The affected factors are shown in Table 41.

Table 4.2. The Affected Factors of Activities Time Estimate to Generate Model.

Factors Value List	Unit	Type
1. Rainfall	-	Qualitative
2. % Roadway	Percentage	Quantitative
3. Geography 3.1 Flat 3.2 Hill 3.3 Hill & Mountain 3.4 Mountain	-	Qualitative
4.California Bearing Ratio (CBR) 4.1 CBR Bad 4.2 CBR Medium 4.3 CBR Good	-	Qualitative
5. Land Acquisition	-	Qualitative
6. Infrastructure Contract 6.1 Power, Water, Telephone	-	Qualitative
7. Length	Kilometers	Quantitative
8. Wide	Meters	Quantitative
9. Lane	Lanes	Quantitative
10. Machine & Equipment 10.1 Tractor (D4,D5,D6,D7) 10.2 Grader 10.3 Backhoe . 10.4 Loader 10.5 Rubber 10.6 Steel	No. of Machine No. of Machine No. of Machine No. of Machine No. of Machine No. of Machine No. of Machine	Quantitative Quantitative Quantitative Quantitative Quantitative Quantitative Quantitative
10.7 Vibration Roller 10.8 Asphalt Distfibutor 10.9 Truck	No. of machine No. of machine No. of machine	Quantitative Quantitative Quantitative
11. Clearing	Square Meters	Quantitative
12. Embankment	Cubic Meters	Quantitative
13. Excavate	Cubic Meters	Quantitative
14. Subbase Volume	Cubic Meters	Quantitative
15. Base Volume	Cubic Meters	Quantitative
16. Surface treatment Volume	Square Meters	Quantitative
17. Asphalt Concrete Volume	Cubic Meters	Quantitative
18. Sodding	Sguare Meters	Quantitative
19. Painting	Meters	Quantitative
20. Curb&Ditch	Square Meters	Quantitative
21. Slope Protection	Square Meters	Quantitative
22. Subbase Thick	Centimeters	Quantitative
23. Base Thick	Centimeters	Quantitative
24. Surface Thick	Centimeters	Quantitative

4.6.1 The Definition of Affected Factors of Activities Time Estimate to Generate Model.

(1) Rainfall

Rainfall is the rainfall area that can be broken down into 2 areas. (Department of Highways in Thailand).

High-density rainfall area is the province that receives rainfall volume of more than 1,500 mm. annually as follows: Chiang Rai, Nongkai, Sakonnakorn, Nakornpanom, Prajeanburi, Juntaburi, Trad, Choomporn, Ranong, Suratthani, Krabi, Nakornsithamarat, Pungha, Songhla, Phuket, Puttani, Trung, Narativas, Pattalung, Yala, and Satoon.

Low-density rainfall area is the province that receives rainfall volume of less than 1,500 mm. annually: otherwise province from high-density rainfall area.

Set data value:

0 is low density rainfall area of the province that receives rainfall volume of less than 1,500 mm. annually.

1 is high density rainfall area of the province that receives rainfall volume of more than 1,500 mm. annually.

(2) % Roadway through traffic (% Roadway)

% Roadway through traffic is the percentage of road through the traffic jam area such as construction through urban, city area ...etc. This equation is:

$$\text{\% Road through traffic} = \frac{\text{Length of road through the traffic jam area}}{\text{Total length of road construction}} \times 100$$

(3) Geography

Geography is the characteristic of project location. It can be divided:

Flat has 0-3% of gradient. (Set data value, 0 or 1)

Hill has 3-5% of gradient. (Set data value, 0 or 1)

Hill & Mountain has 5-7% of gradient. (Set data value, 0 or 1)

Mountain has more than 7% of gradient. (Set data value, 0 or 1)

0 its means does not this geography characteristic way.

1 its means is geography characteristic way.

(4) California Bearing Ratio (CBR)

CBR is the characteristic of subgrade quality in each project locations:

CBR Bad has less or equal than 2 (Set data value, 0 or 1)

CBR Medium has 3 — 5 (Set data value, 0 or 1)

CBR Good has more or equal than 6 (Set data value, 0 or 1)

0 its means does not this CBR characteristic way.

1 its means is CBR characteristic way.

(5) Land Acquisition

Land Acquisition can be broken down into 2 categories:

Land Acquisition has no problems about acquisition (Set data value, 0).

Land Acquisition has any problems about acquisition (Set data value, 1).

(6) Infrastructure Contract

Infrastructure Contract is the contract condition to join between the power, water supply, or Telephone line configuration. (Set data value, 0 has not contract condition, 1 is otherwise)

(7) Length

Length is the total length of road construction, and the unit is kilometers.

(8) Width

Width is the width of road construction in 1 Lane, and the unit is meters.

(9) Lane

Lane is the number of road construction lanes.

(10) Tractor, Grader, Backhoe, Loader, Rubber, Steel, Vibration Roller, Asphalt-Distributor, and Truck is the type of machine, equipment. The unit is no. of machines.

(11) Clearing

Clearing is the preparing volume such as clearing, grubbing through the project duration. The unit is square meters.

(12) Embankment

Embankment is the filled soil volume through the project duration. The unit is cubic meters.

(13) Excavation

Excavation is the moved soil volume through the project duration. The unit is cubic meters.

(14) Subbase Volume

Subbase Volume is the soil volume in subbase floor through the project duration. The unit is cubic meters.

(15) Base Volume

Base Volume is the soil volume in base floor through the project duration. The unit is cubic meters.

(16) Surface Treatment Volume (ST Volume)

ST Volume is the soil volume in Surface Treatment floor through the project duration. The unit is cubic meters.

(17) Asphalt Concrete Volume (AC Volume)

AC Volume is the soil volume in Asphalt Concrete floor through the project duration. The unit is cubic meters.

(18) Sodding

Sodding is the sodding volume. The unit is square meters.

(19) Painting

Painting is the painting volume such as traffic signal, lines on highways, and signal. The unit is square meters.

(20) Curb & Ditch

Curb & Ditch is the side ditch, and curb &gutter volume. The unit is meters.

(21) Slope Protection

Slope Protection is the slope protection volume in the foot of the bridge area, and high gradient area. The unit is square meters.

(22) Subbase Thick

Subbase Thick is the thickness of subbase floor. The unit is centimeters.

(23) Base Thick

Base Thick is the thickness of base floor. The unit is centimeters.

(24) Surface Thick

Surface Thick is the thickness of surface floor. The unit is centimeters.

(25) The Project duration (Y)

The Project duration is the total actual completion through project duration in the final report. The unit is days.

4.7 The Selected Independent Variables in Multiple Regression Equation Model

The above mentioned describes the affected factors of activities time estimates. This section defines the dependent variable (Estimated Time, Y), and independent variables from Table 4.2.

The relationship of multiple regression model is as follows:

The Prediction Time Model = f (Rainfall, % Roadway, Flat, Hill, Hill & Mountain, Mountain, CBR Good, CBR Medium, CBR Bad, Land Acquisition, Infrastructure Contract, Length, Width, Lane, Tractor, Grader, Backhoe, Loader, Rubber, Steel, Vibration Roller, Asphalt Distributor, Truck, Clearing, Embankment, Excavation, Subbase Volume, Base - Volume, ST Volume, AC Volume, Sodding, Painting, Curb&Ditch, Slope - Protection, Base Thick, Subbase-Thick, Surface Thick)

Computer software program, SPSS for Windows Version 10, is chosen to analyze activities time estimate model.

V. SYSTEM EVALUATION

The above section describes the affected factors of activities that generated the model. After that, the project information collected for establishes the prediction model from Department of Highways in Thailand of 35 completion projects. These data are assigned to construct the model by using multiple regression analysis as follows:

5.1 Data Analysis

The result of 35 final reports for asphaltic road construction from the Department of Highways in Thailand (from 1992-1997) can eliminate some affected factors from the prediction model as follows:

(1) Base Thick, every asphaltic road construction in final report has the same base thick about 20 centimeters.

(2) Flat, the method to correct dummy variable must emphasize the fact that C-1 (Column-1) dummy variables should be used to represent C categories if all dummy variables are to be inserted into the regression Therefore, eliminating in Flat out of Hill, Hill &Mountain, and Mountain.

(3) CBR Good, the method to correct dummy variable must to emphasize that C-1 (Column-1) dummy variables should be used to represent C categories if all dummy variables are to be inserted into the regression, thus eliminating in CBR Good out of CBR Medium, and CBR Bad.

The relationship of considered factors model in prediction time model as follows:

The Prediction Time Model = gRainfall, % Roadway, Hill, Hill & Mountain, Mountain, CBR Medium, CBR Bad, Land Acquisition, Infrastructure Contract, Length, Width, Lane, Tractor, Grader, Backhoe, Loader,Rubber,Steel, Vibration Roller, Asphalt Distributor, Truck, Clearing, Embankment, Excavation, Subbase - Volume, Base Volume, ST Volume, AC Volume, Sodding, Painting, Curb & Ditch, Slope- Protection, Subbase Thick, Surface Thick)

5.2 Correlation Coefficient Analysis (r)

The most widely used measure of the strength and direction of the association between two variables is the correlation coefficient (r). In this project, determining the correlation coefficient in order to multicollinearity protection that affects in the hypothesis is a large error.

The result of data analysis from Appendix B to determine the correlation coefficient of each pairs. If r of any pairs more than 0.7, it will eliminate one variable from the model (eliminated less r of oneself with prediction equation, when r of any pairs > 0.7).

The eliminated variables in multiple regression model (From Appendix B) is as follows:

CBR Medium, Total Length, Base Volume, Subbase Volume, Lane, Asphaltic Volume, Grader, and Rubber.

The multiple regression model is analyzed in both of linear and non-linear exponential models by taking dependent variables and independent variables into regression model, and then using Backward Elimination approach to eliminate less influence independent variables from the regression model until proper independent variables in the prediction model. This model is considering on correlation of determination analysis (R^2) and test of hypothesis (F-test for whole equation, and T-test for individual coefficients).

5.3 Coefficient of Determination Analysis (R^2)

In this section, consideration on the highest adjusted R^2 in both of multiple linear regression equation and multiple exponential regression equation is as follows (From Appendix C and D):

Table 5.1. Coefficient of Determination in Each Multiple Regression Equations.

Regression Equation	R^2	Adjusted R^2
Linear	0.924	0.888
Exponential(non-linear)	0.835	0.800

The result of adjusted R^2 in Table 5.1 selects the multiple linear regression equation to apply in this project because it's higher than exponential regression equation.

5.4 Test of Hypothesis

Test of hypothesis in both of F-distribution for whole equation, and T-distribution for individual coefficients is discussed below.

5.4.1 F-Distribution Testing

The test of the explanatory power of regression equation as a whole is through using F-test.

Sig F > 0.05, means the prediction equation is not related to any variables

Sig F < 0.05, means the prediction equation is related to any variables

Multiple linear regression equation, F-test has 25.567, Sig F has 0.000 (From Appendix C). Therefore, the prediction time equation in linear regression is related to any variables.

5.4.2 T-Distribution Testing

Testing for the statistical significance of any observed value by using T-Distribution to test the effect of the individual variables in multiple regression equation.

Sig T > 0.05, means the observed value is zero.

Sig T < 0.05, means the observed value is not zero.

The result of T-Distribution is seen in Table 5.2 as follows:

Table 5.2. Testing Hypothesis of T-Distribution. (From Appendix C)

Linear Regression Equation	T	Sig T
Constant	-0.988	0.034
Rainfall	6.310	0.000
CBR Bad	7.231	0.000
Wide	2.707	0.013
Truck	-3.744	0.001
Clearing	-2.050	0.042
Excavate	1.778	0.033
Subbase Volume	3.685	0.001
Surface Volume	2.119	0.045
Sodding	3.633	0.001
Painting	2.665	0.014
Curb & Ditch	-2.177	0.040

Multiple linear regression, the overall of Sig T is less than 0.05.Therefore, All of unstandardized coefficients (B) is validation in the prediction model, or it means the overall of the observed values is not zero.

5.5 Test of the Error Analysis

The prediction model is validated, using 35 completion projects, which are incorporated into the model. The percentage errors between project duration estimated by the prediction model and actual project time is determined

The error of project duration estimated has formula as follows.

$$\text{Percentage errors of project duration} = \frac{(\text{Estimated Time} - \text{Actual})\ \text{x}100}{\text{Actual}}$$

Table 5.3. The Percentage of Errors in Traditional Approach.

Number of project	Actual Time	Contract Time	Percentage of Errors in Traditional Approach
1	635	660	3.9370
2	695	720	3.5971
3	647	750	15.919
4	708	750	5.9320
5	520	630	21.1530
6	485	620	27.8350
7	475	450	-5.2631
8	798	500	-37.3430
9	920	720	-21.7390
10	570	600	5.2631
11	995	900	-9.5477
12	860	715	-16.8600
13	805	900	11.8012
14	675	540	-20.0000
15	785	720	-8.2802
16	409	510	24.6940

Table 5.3. The Percentage of Errors in Traditional Approach. (Continued)

Number of project	Actual Time	Contract Time	Percentage of Errors in Traditional Approach
17	505	443	-12.2772
18	875	800	-8.5714
19	600	720	20.0000
20	650	430	-33.8461
21	1093	850	-22.2320
22	859	600	-30.1513
23	490	872	77.9591
24	1010	750	-25.7425
25	579	540	-6.7357
26	417	480	15.1079
27	888	660	-25.6756
28	958	660	-31.1064
29	1056	690	-34.6590
30	1150	650	-43.4782
31	765	600	-21.5686
32	501	510	1.7964
33	735	685	-6.8027
34	607	510	-15.9802
35	770	540	-29.8701

Table 5.4. The Percentage of Errors in Prediction Time Model.

Number of project	Estimated Time	Actual Time	Percentage of Errors in Prediction Time Model
1	521.6833	635	-17.8451
2	675.9120	695	-2.7464
3	632.3219	647	-2.2686
4	704.3661	708	-0.5132
5	504.5606	520	-2.9691
6	544.9316	485	12.3570
7	551.0006	475	16.0001
8	806.6652	798	1.0858
9	925.1432	920	0.5590
10	560.4126	570	-1.6819
11	1004.259	995	0.9306
12	894.722	860	4.0374
13	824.3335	805	2.4016
14	688.7357	675	2.0349
15	845.3101	785	7.6828
16	532.1758	409	30.1161
17	407.7202	505	-19.2633
18	880.579	875	0.6376
19	552.541	600	-7.9097
20	711.3069	650	9.4318
21	1109.393	1093	1.4999
22	810.1529	859	-5.6865
23	524.721	490	7.0860
24	997.3652	1010	-1.2509
25	565.7673	579	-2.2854
26	443.2267	417	6.2894
27	790.8053	888	-10.9453
28	967.899	958	1.0333
29	997.2124	1056	-5.5670
30	1133.170	1150	-1.4634
31	653.472	765	-14.5700
32	614.2723	501	22.6090
33	710.7421	735	-3.3004
34	597.410	607	-1.5803
35	804.466	770	4.4761

Table5.5. The Percentage Average Errors of Project Duration.

Estimated Time Model	% average error (+)	% average error (-)
Traditional	+18.0767	-21.2606
Prediction Equation	+7.2372	-5.9915

Table 5.5, compares the percentage error estimated by the prediction model (within 8%) with the percentage errors estimated by traditional approach (within 22%). The result indicated that the prediction model could produce valid estimation for the project duration.

5.6 Importance of Independent Variables Analysis to Affect with Dependent Variable

This section describes the analyzed independent variables to affect with dependent variable in the multiple regression by considering in Beta Coefficients that represent the change of dependent variables when independent variables change in one unit of standard score in Table 5.6 as follows:

Table 5.6. The Beta Coefficients of Multiple Linear Regression Equation. (From Appendix C)

Linear Regression Equation	Standardized Coefficients (Beta)	UnStandardized Coefficients (B)
Constant		-234.591
Rainfall	0.431	171.579
CBR Bad	0.499	219.831
Wide	0.228	97.657
Truck	-0.256	-2.997
Clearing	-0.253	$-1.633\text{x}10^{4}$
Excavate	0.140	$2.677\text{x}10^{4}$
Subbase Volume	0.304	$1.913\text{x}10^{-3}$
Surface Volume	0.235	$3.39\text{x}10^{-4}$
Sodding	0.432	$1.013\text{x}10^{-3}$
Painting	0.235	$1.053\text{x}10^{-2}$
Curb & Ditch	-0.147	$-2.985\ \text{x}10^{-3}$

The result of Beta Coefficients from Table 5.6. found that the variables with great impact on time are CBR Bad, Sodding, and Rainfall sequentially.

Hence, Estimators and planners should alert these variables when using the prediction model carefully.

VL CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The main objective of this project is to establish project time prediction model for asphaltic road construction in contract documents. The project data is obtained from the historical final report of 35 completion projects between 1992 and 1997 from Department of Highways in Thailand.

Many precedent projects use "production rate of construction machine and work quantities" appended with "judgment and experience of each estimator" for determining time estimation of asphaltic road construction. Especially in the Department of Highways in Thailand, it is used to calculate in this way. Another way is historical data analysis such as regression analysis, and simulation.

The evaluation process is explained as below:

(1) To determine dummy variables and some variables that can be eliminated from this equation before analysis in the next steps. Therefore, the eliminated variables are as follows: Base Thick, CBR Good, and Flat.

(2) To determine correlation coefficient (r) of each pair in this equation to prevent the problem of multicollinearity. The eliminated variables in multiple regression models are as follows: CBR Medium, Total Length, Base Volume, Subbase Volume, Lane, Asphaltic Volume, Grader, and Rubber.

(3) To compare adjusted correlation of determination (R^2) between linear equation and exponential equation, and to select time prediction equation with the highest value. The result selecting is multiple linear equation R^2 = 0.924 adjusted R^2 = 0.888.

(4) The results of the test of hypotheses are as follows:

Multiple linear regression, F-test has 25.567, Sig F has 0. Therefore, the prediction time equation is related to any variables multiple linear regression. Furthermore, the overall of Sig T is less than 0.05. Hence, all of unstandardized coefficients (B) is validation in the prediction model, or its means the overall of the observed values are not zero.

(5) The analysis of the percentage error estimated by prediction time equation (within 8%) is less than the traditional prediction (within 22 %). Hence, the prediction time equation is more accurate than traditional approach.

(6) The results of Beta Coefficients found that the variables with great impact on time are CBR Bad, Sodding, and Rainfall.

The result of above section can be concluded in the prediction time equation as follows:

$$
\begin{aligned}
\text{The Prediction Time Equation} = & -234.591 + 171.579\text{Rainfall} + 219.831\text{CBR Bad} \\
& + 97.657\text{Width} — 2.997\text{Truck} — 1.633\text{x}10^{4}\text{Clearing} \\
& + 2.677\text{x}10^{4}\text{Excavation} + 1.913\ \text{x}10^{-3}\text{Subbase Volume} \\
& + 3.39\ \text{x}\ 10^{4}\text{Surface Volume} + 1.013\ \text{xleSodding} \\
& + 1.053\ \text{x}\ 10^{-2}\text{Painting} — 2.985\ \text{x}10^{-3}\text{Curb\&Ditch}
\end{aligned}
$$

6.2 Recommendations

The benefit of this model is the efficient estimating duration for asphaltic road construction in contract time document. It can help in decision making for projects' owners in bidding and planning allocate budget in feasibility phase.

Nowadays, limitations of this model are as follows:

(1) Some variables could not be applied into the model because they can not be collected from any sources as follows:

(a) Number of labors or employees.

(b) Quality of labors or employees.

Hence, These data should be collected in the form of database system in order to develop the model more conveniently and accurately in the future.

(2) This model is more accurate than the traditional models. The percentage error of prediction time equation (within 8%) is less than the traditional approach (within 22%). However, it is difficult to implement this model because many variables were approached to 11. Therefore, this equation model should be developed in the computer software, and it can be designed in the entered data screen step by step for easy implementation.

This project is the first step to develop the multiple regression model for asphaltic road. It can be developed for more accuracy in the future.

APPENDIX A

DATA FOR USING IN MULTIPLE REGRESSION EQUATION

Table A.1. Data for Using in Multiple Regression Equation.

Number of Project	Rainfall	%Roadway	Hill	Hill And Mountain	Mountain	CBR Bad	CBR Medium
1	0	30.52	0	0	0	0	1
2	0	4.1	0	0	0	0	1
3	0	0	0	0	0	0	1
4	0	4.14	0	0	0	0	0
5	0	2.9	0	0	0	0	1
6	0	27.71	0	0	0	0	0
7	0	7.203	0	0	0	0	0
8	1	31.45	0	0	0	1	0
9	1	2.774	0	0	0	1	0
10	0	10.44	0	1	0	0	1
11	1	4.697	0	0	0	0	1
12	1	21.93	1	0	0	0	1
13	1	29.43	0	0	1	0	1
14	0	4.126	0	0	0	1	0
15	1	5.92	1	0	0	0	1
16	0	3.786	0	0	0	0	1
17	0	10.77	0	0	0	0	1
18	1	57.07	0	0	0	0	1
19	0	29.94	0	0	0	0	1
20	1	12	0	0	0	0	1
21	1	36.28	0	0	0	0	0
22	1	30.14	0	1	0	0	1
23	0	13.52	0	0	0	0	1
24	1	39.1	0	0	0	1	0
25	0	9.085	0	0	0	0	1
26	0	13.29	1	0	0	0	1
27	0	25.73	0	0	0	1	0
28	1	14.07	0	1	0	1	0
29	1	27.69	0	0	0	1	0
30	0	21	0	0	0	1	0
31	1	32.7	1	0	0	0	1
32	0	18.72	0	0	0	1	0
33	1	31.03	1	0	0	0	1
34	1	28.42	0	0	1	0	0
35	1	67	0	0	1	1	0

Table A.1. Data for Using in Multiple Regression Equation. (Continued)

Number of Project	Land of Acquisition	Length	Width	Lane	Tractor	Backhoe	Grader	Loader
1	1	24.571	6	2	2	3	4	2
2	1	40.88	7	2	3	4	4	1
3	0	28.558	6.5	2	1	3	3	1
4	0	48.3	6.5	2	1	4	3	1
5	0	34.474	7	2	1	7	6	1
6	0	53.778	6	2	4	5	6	4
7	1	23.6	6	2	3	4	6	2
8	0	12.107	6	2	1	1	2	0
9	0	28.835	6	2	3	6	6	4
10	0	36.409	6	2	3	6	3	0
11	0	38.319	7	2	4	3	5	4
12	1	22.043	6.5	2	3	3	3	2
13	1	32.37	6	2	4	6	5	0
14	1	16.358	6	2	1	2	2	0
15	1	33.783	6	2	4	6	4	2
16	0	21.132	6	2	2	5	5	1
17	1	17.635	6	2	3	6	3	1
18	0	29.35	7	4	8	8	6	0
19	1	36.356	6	2	4	2	4	2
20	0	15.422	7	2	2	5	1	0
21	1	34.45	7	4	4	7	5	3
22	0	26.873	7	4	7	7	11	4
23	1	23.3	6	2	2	4	3	1
24	0	5.117	7	4	5	3	2	1
25	1	33.02	6	2	2	3	4	0
26	1	11.286	6	2	1	2	3	1
27	0	12.048	7	2	1	2	3	1
28	0	28.425	6	4	2	9	8	5
29	1	7.565	6.5	2	2	1	2	2
30	1	19.2	7	4	9	7	6	3
31	0	23.513	6	2	3	2	1	0
32	0	5.341	7	2	6	4	3	2
33	0	27.069	6	2	1	2	4	4
34	1	4.926	7	2	2	0	3	1
35	1	9.771	7	2	2	4	2	2

Table A.1. Data for Using in Multiple Regression Equation. (Continued)

Number of Project	Rubber	Steel	Vibration Roller	Asphalt Distributor	Truck
1	6	0	4	1	15
2	5	2	6	1	25
3	7	1	2	1	14
4	7	1	3	1	8
5	9	9	7	2	60
6	4.	0	4	0	40
7	7	4	5	1	12
8	2	0	2	1	8
9	6	4	5	1	50
10	4	2	3	1	40
11	10	5	6	1	60
12	4	2	2	1	10
13	6	4	6	1	7
14	3	2	1	1	15
15	4	2	3	1	17
16	5	6	5	2	15
17	4	2	3	1	40
18	4	2	8	1	25
19	6	2	4	2	35
20	1	0	2	0	5
21	8	5	6	1	48
22	12	0	12	1	50
23	3	3	3	1	15
24	3	2	3	1	6
25	2	4	4	1	5
26	0	3	3	1	12
27	1	1	3	1	10
28	9	5	14	2	24
29	2	2	0	1	9
30	7	4	8	1	2
31	1	4	1	1	14
32	6	4	3	1	33
33	3	4	4	1	20
34	6	2	7	1	12
35	6	2	3	1	50

Table A.1. Data for Using in Multiple Regression Equation. (Continued)

Number of Project	Clearing	Embankment	Excavation	Subbase of Volume	Base of Volume.	Surface of Volume
1	427815	65170	51434	54100	39181	194418
2	832291	46191	70252	104678	102117	4203
3	856748	276812	137778	52858	61388	109170
4	416908	33863	73209	67667	122528	163416
5	252625	31734	48241	57221	72962	95390
6	1197284	34827	154398	58498	179340	609883
7	155348	23390	35975	33136	65369	176138
8	164941	22217	8846	19226	21115	102696
9	965300	345025	33305	57700	68100	140350
10	612691	78585	192354	74184	68248	331756
11	733625	114468	81477	100415	114099	1963
12	236816	71768	29614	134613	132437	162020
13	723262	153000	262330	55000	46355	319000
14	165518	61476	69196	26247	31938	0
15	744823	144311	116189	61226	75084	0
16	348437	173329	26766	35469	42734	212644
17	376350	75159	43492	27934	33597	168503
18	616350	236040	124690	85500	137400	0
19	843862	191354	45518	57529	89665	344631
20	376621	92410	62522	23546	35179	0
21	855000	798500	278075	113500	194000	0
22	751459	521663	161014	94930	112040	0
23	459800	100041	28750	50516	50313	222996
24	458467	495776	9942	35589	21232	0
25	789428	85974	88954	54098	52338	259704
26	221403	36489	48472	25710	16373	81321
27	194624	379267	14167	21074	25947	35871
28	368500	304740	267090	72600	85100	0
29	73206	70239	6935	14909	9067	44453
30	836200	739410	41694	100637	73345	0
31	125200	34400	20800	24470	14723	201500
32	84605	55707	1133	7413	18963	0
33	913500	111060	510305	40845	49936	242681
34	50000	8400	20000	7000	10300	0
35	180700	211000	10600	28100	26400	0

Table A.1. Data for Using in Multiple Regression Equation. (Continued)

Number of Project	Asphalt Concrete Volumne	Sodding	Painting	Curb & Ditch	Slope Protection	Subbase Thick
1	0	75055	2591	447	804.8	20
2	16868	119832	11034	6806	3453	15
3	10800	159217	7380	0	1438	15
4	22594	157538	4602	5442	2206	20
5	12480	99827	2266	1030	341	15
6	0	127803	4214	8325	2846	15
7	0	98685	2686	0	0	15
8	0	34607	2352	6355	0	20
9	8500	288200	4530	5580	255	15
10	0	83829	3628	0	309	20
11	43700	336979	13867	6250	874	20
12	0	53485	1620	0	274	15
13	0	54970	9613	0	876	15
14	7838.5	73308	4420	0	0	15
15	17981	231489	11050	1382	5080	15
16	11200	74429	6081	1291	1128	15
17	0	99521	1395	0	3647	15
18	49280	244350	15500	57660	5450	15
19	0	110402	9573	2620	786	15
20	15455	30270	7100	0	1174	15
21	83550	311500	17925	7900	5860	15
22	91689	207453	6812	14893	3769	15
23	0	93200	1872	215	540	20
24	9412	138035	3725	0	1501	20
25	0	90172	4903	0	181	15
26	0	58681	1490	290	0	20
27	4026.8	95473	3406	1718	797	15
28	22448	64500	9230	5250	100	15
29	0	97190	9610	182	0	15
30	50185	258023	13525	200.6	0	15
31	0	5200	6700	1193	2200	15
32	5075	29821	1278	0	0	15
33	6.3	95000	400	179	4856	15
34	4153	7800	1500	7200	0	15
35	10025	54400	3400	1372	0	20

Table A.1. Data for Using in Multiple Regression Equation. (Continued)

Number of Project	Base Thick	Surface Thick	Actual Project Duration	Contract Time	Exponential Project duration
1	20	5	635	660	6.45362
2	20	8	695	720	6.54391
3	20	5	647	750	6.47234
4	20	6	708	750	6.56244
5	20	5	520	630	6.25383
6	20	5	485	620	6.18415
7	20	5	475	450	6.16331
8	20	5	798	500	6.68211
9	20	5	920	720	6.82437
10	20	5	570	600	6.34564
11	20	10	995	900	6.90274
12	20	5	860	715	6.75693
13	20	5	805	900	6.69084
14	20	5	675	540	6.51471
15	20	5	785	720	6.66568
16	20	5	409	510	6.01372
17	20	5	505	443	6.22456
18	20	10	875	800	6.77422
19	20	5	600	720	6.39693
20	20	9	650	430	6.47697
21	20	10	1093	850	6.99668
22	20	10	859	600	6.75577
23	20	5	490	872	6.19441
24	20	10	1010	750	6.91771
25	20	5	579	540	6.36130
26	20	5	417	480	6.03308
27	20	5	888	660	6.78897
28	20	8	958	660	6.86485
29	20	5	1056	690	6.96224
30	20	10	1150	650	7.04752
31	20	5	765	600	6.63988
32	20	10	501	510	6.21661
33	20	5	735	685	6.59987
34	20	9	607	510	6.69332
35	20	10	770	540	6.64639

APPENDIX B

CORRELATION OF COEFFICIENTS IN MULTIPLE REGRESSION EQUATION

Table B.1. Correlation of Coefficients in Multiple Regression Equation.

	Actual Time	Rainfall	%Roadway	Hill	Hill & Mountain
Actual Time	1	0.621	0.34	-0.033	0.104
Exponential Time	-	0.680	0.371	-0.032	0.104
Rainfall	0.621	1	0.472	0.257	0.111
%Roadway	0.34	0.472	1	0.019	-0.04
Hill	-0.033	0.257	0.019	1	-0.125
Hill & Mountain	0.104	0.111	-0.04	-0.125	1
Mountain	-0.001	0.315	0.424	-0.125	-0.094
CBR Bad	0.459	0.145	0.201	-0.258	0.032
CBR Medium	-0.339	-0.083	-0.193	0.354	0.059
Land Acquisition	0.276	0.38	0.425	0.024	0.059
Infrastructure of Contract	-0.053	-0.144	0.059	0.093	-0.298
Total Length	-0.072	-0.195	-0.288	-0.041	0.149
Width	0.409	0.211	0.28	-0.288	-0.063
Lane	0.6	0.316	0.374	-0.186	0.402
Tractor	0.388	0.159	0.326	-0.13	0.15
Grader	0.158	0.043	-0.057	-0.209	0.504
Backhoe	0.175	0.055	-0.051	-0.222	0.449
Loader	0.357	0.236	0.022	0.041	0.291
Rubber	0.208	0.062	-0.094	-0.381	0.381
Steel	-0.009	-0.034	-0.257	0.06	-0.06
Vibration Roller	0.245	0.174	0.056	-0.261	0.561
Asphalt Distributor	-0.037	-0.135	-0.133	-0.057	0.206
Truck	0.004	0.071	0.044	-0.206	0.267
Clearing	0.173	-0.022	-0.086	-0.065	0.079
Embankment	0.666	0.209	0.263	-0.205	0.194
Excavation	0.157	0.254	0.082	0.214	0.342
Subbase Volume	0.416	0.103	-0.059	0.048	0.261
Base Volume	0.226	0.044	0.015	-0.07	0.151
Surface Volume	-0.472	-0.347	-0.064	0.05	-0.022
Asphalt Concrete Volume	0.526	0.291	0.169	-0.192	0.323
Sodding	0.535	0.158	-0.08	-0.145	-0.001
Painting	0.598	0.287	0.116	-0.164	0.036
Curb &Ditch	0.203	0.265	0.419	-0.146	0.081
Slope Protection	0.172	0.248	0.211	0.24	-0.01
Subbase Thick	-0.053	-0.049	0.135	-0.053	0.053
Surface Thick	0.344	0.224	0.299	-0.225	-0.251

Table B.1. Correlation of Coefficients in Multiple Regression Equation. (Continued)

	Hill & Mountain	Mountain	CBR Bad	CBR Medium	Land of Acquisition
Actual Time	0.104	-0.001	0.459	-0.339	0.276
Exponential Time	0.104	0.128	0.422	-0.343	0.351
Rainfall	0.111	0.315	0.145	-0.083	0.380
%Roadway	-0.04	0.424	0.201	-0.193	0.425
Hill	-0.125	-0.125	-0.258	0.354	0.024
Hill & Mountain	1	-0.094	0.032	0.059	0.059
Mountain	-0.094	1	0.032	-0.147	0.265
CBR Bad	0.032	0.032	1	-0.73	-0.091
CBR Medium	0.059	-0.147	-0.73	1	0.067
Land Acquisition	0.059	0.265	-0.091	0.067	1
Infrastructure Of Contract	-0.298	0.315	-0.108	0.033	-0.083
Total Length	0.149	-0.231	-0.542	0.296	0.168
Width	-0.063	0.157	0.165	-0.195	0.053
Lane	0.402	-0.139	0.216	-0.219	0.088
Tractor	0.15	-0.056	0.055	-0.017	0.129
Grader	0.504	-0.106	-0.135	0.041	0.127
Backhoe	0.449	-0.119	-0.08	0.096	-0.092
Loader	0.291	-0.142	0.153	-0.251	0.158
Rubber	0.381	0.119	-0.103	-0.061	0.109
Steel	-0.06	-0.008	-0.037	0.081	-0.307
Vibration Roller	0.561	0.097	-0.051	-0.012	0.049
Asphalt Distributor	0.206	-0.043	0.066	0.121	-0.161
Truck	0.267	-0.003	-0.092	0.07	0.199
Clearing	0.079	-0.178	-0.304	0.242	0.443
Embankment	0.194	-0.084	0.294	-0.271	0.233
Excavation	0.342	0.02	-0.271	0.187	0.287
Subbase Volume	0.261	-0.229	-0.307	0.259	0.243
Base Volume	0.151	-0.251	-0.376	0.04	0.263
Surface Volume	-0.022	-0.032	-0.405	0.225	0.184
Asphalt Concrete Volume	0.323	-0.129	-0.069	-0.038	0.125
Sodding	-0.001	-0.288	-0.041	-0.037	0.288
Painting	0.036	-0.083	-0.07	0.054	0.094
Curb &Ditch	0.081	-0.039	-0.132	0.071	0.234
Slope Protection	-0.01	-0.202	-0.426	0.269	0.229
Subbase Thick	0.053	0.053	0.062	-0.019	0.113
Surface Thick	-0.251	0.224	0.273	-0.337	-0.041

Table B.1. Correlation of Coefficients in Multiple Regression Equation. (Continued)

	Infrastructure of Contract	Total Length	Wide	Lane	Tractor
Actual Time	-0.053	-0.072	0.409	0.6	0.388
Exponential Time	-0.038	-0.097	0.437	0.542	0.334
Rainfall	-0.144	-0.195	0.211	0.316	0.159
%Roadway	0.059	-0.288	0.28	0.374	0.326
Hill	0.093	-0.041	-0.288	-0.186	-0.13
Hill & Mountain	-0.298	0.149	-0.063	0.402	0.15
Mountain	0.315	-0.231	0.157	-0.139	-0.056
CBR Bad	-0.108	-0.542	0.165	0.216	0.055
CBR Medium	0.033	0.296	-0.195	-0.219	-0.017
Land Acquisition	-0.083	0.168	0.053	0.088	0.129
Infrastructure Of Contract	1	-0.141	-0.158	-0.139	-0.014
Total Length	-0.141	1	-0.214	-0.032	0.062
Width	-0.158	-0.214	1	0.396	0.375
Lane	-0.139	-0.032	0.396	1	0.645
Tractor	-0.014	0.062	0.375	0.645	1
Grader	-0.156	0.42	0.063	0.522	0.46
Backhoe	-0.183	0.399	0.112	0.561	0.487
Loader	-0.128	0.238	0.05	0.325	0.239
Rubber	-0.105	0.359	0.312	0.371	0.334
Steel	-0.034	0.095	0.009	0.067	-0.005
Vibration Roller	-0.146	0.247	0.238	0.647	0.422
Asphalt Of Distributor	0.004	0.01	-0.128	0.121	-0.108
Truck	-0.218	0.345	0.213	0.071	0.16
Clearing	-0.09	0.704	-0.089	0.221	0.348
Embankment	-0.041	-0.043	0.406	0.788	0.526
Excavation	-0.162	0.415	-0.185	0.247	0.001
Subbase Volume	0.066	0.604	0.214	0.434	0.428
Base Volume	-0.085	0.757	0.161	0.375	0.359
Surface Volume	-0.031	0.514	-0.639	-0.398	-0.151
Asphalt Concrete Volume	-0.129	0.209	0.543	0.744	0.576
Sodding	-0.09	0.426	0.279	0.457	0.492
Painting	0.072	0.355	0.309	0.52	0.515
Curb &Ditch	-0.24	0.183	0.289	0.473	0.479
Slope Protection	-0.102	0.401	0.12	0.344	0.304
Subbase Thick	-0.049	-0.074	-0.05	-0.094	-0.207

Table B.1. Correlation of Coefficients in Multiple Regression Equation. (Continued)

	Grader	Backhoe	Loader	Rubber	Steel
Actual Time	0.158	0.175	0.357	0.208	-0.009
Exponential Time	0.112	0.089	0.307	0.210	-0.080
Rainfall	0.043	0.055	0.236	0.062	-0.034
%Roadway	-0.057	-0.051	0.022	-0.094	-0.257
Hill	-0.209	-0.222	0.041	-0.381	0.06
Hill & Mountain	0.504	0.449	0.291	0.381	-0.06
Mountain	-0.106	-0.119	-0.142	0.119	-0.008
CBR Bad	-0.135	-0.08	0.153	-0.103	-0.037
CBR Medium	0.041	0.096	-0.251	-0.061	0.081
Land Acquisition	0.127	-0.092	0.158	0.109	-0.307
Infrastructure Of Contract	-0.156	-0.183	-0.128	-0.105	-0.034
Total Length	0.42	0.399	0.238	0.359	0.095
Width	0.063	0.112	0.05	0.312	0.009
Lane	0.522	0.561	0.325	0.371	0.067
Tractor	0.46	0.487	0.239	0.334	-0.005
Grader	1	0.652	0.618	0.721	0.252
Backhoe	0.652	1	0.291	0.492	0.306
Loader	0.618	0.291	1	0.559	0.152
Rubber	0.721	0.492	0.559	1	0.295
Steel	0.252	0.306	0.152	0.295	1
Vibration Roller	0.864	0.641	0.51	0.699	0.301
Asphalt Distributor	0.276	0.15	0.083	0.361	0.596
Truck	0.422	0.396	0.458	0.57	0.297
Clearing	0.454	0.379	0.411	0.273	-0.04
Embankment	0.404	0.442	0.379	0.353	0.09
Excavation	0.354	0.315	0.372	0.199	0.145
Subbase Volume	0.51	0.502	0.365	0.495	0.113
Base Volume	0.535	0.505	0.429	0.47	0.026
Surface Volume	0.029	-0.065	-0.012	-0.171	-0.068
Asphalt Concrete Volume	0.599	0.536	0.379	0.601	0.067
Sodding	0.481	0.439	0.469	0.472	0.138
Painting	0.304	0.427	0.173	0.313	0.138
Curb &D it ch	0.36	0.352	-0.022	0.128	-0.127
Slope Protection	0.239	0.351	0.153	0.086	-0.111
Subbase Thick	-0.302	-0.229	-0.135	-0.084	-0.217
Surface Thick	-0.216	0.116	0.032	0.068	0.174

Table B.1. Correlation of Coefficients in Multiple Regression Equation. (Continued)

	Vibration of Roller	Asphalt Of Distributor	Truck	Clearing	Embankment
Actual Time	0.245	-0.037	0.004	0.173	0.666
Exponential	0.251	-0.063	-0.020	0.132	0.587
Rainfall	0.174	-0.135	0.071	-0.022	0.209
%Roadway	0.056	-0.133	0.044	-0.086	0.263
Hill	-0.261	-0.057	-0.206	-0.065	-0.205
Hill & Mountain	0.561	0.206	0.267	0.079	0.194
Mountain	0.097	-0.043	-0.003	-0.178	-0.084
CBR Bad	-0.051	0.066	-0.092	-0.304	0.294
CBR Medium	-0.012	0.121	0.07	0.242	-0.271
Land Acquisition	0.049	-0.161	0.199	0.443	0.233
Infrastructure of Contract	-0.146	0.004	-0.218	-0.09	-0.041
Total Length	0.247	0.01	0.345	0.704	-0.043
Width	0.238	-0.128	0.213	-0.089	0.406
Lane	0.647	0.121	0.071	0.221	0.788
Tractor	0.422	-0.108	0.16	0.348	0.526
Grader	0.864	0.276	0.422	0.454	0.404
Backhoe	0.641	0.15	0.396	0.379	0.442
Loader	0.51	0.083	0.458	0.411	0.379
Rubber	0.699	0.361	0.57	0.273	0.353
Steel	0.301	0.596	0.297	-0.04	0.09
Vibration Roller	1	0.369	0.32	0.276	0.421
Asphalt Distributor	0.369	1	0.175	-0.17	0.078
Truck	0.32	0.175	1	0.285	0.13
Clearing	0.276	-0.17	0.285	1	0.38
Embankment	0.421	0.078	0.13	0.38	1
Excavation	0.35	-0.007	0.138	0.524	0.201
Subbase Volume	0.449	0.074	0.288	0.559	0.415
Base Volume	0.39	-0.083	0.413	0.615	0.321
Surface Volume	-0.208	-0.1	0.016	0.38	-0.343
Asphalt Concrete Volume	0.6	0.007	0.371	0.335	0.711
Sodding	0.323	-0.038	0.423	0.627	0.604
Painting	0.353	0.059	0.135	0.441	0.529
Curb &Ditch	0.394	-0.045	0.174	0.175	0.142
Slope Protection	0.166	-0.181	0.216	0.486	0.274
Subbase Thick	-0.225	-0.082	0.021	-0.169	-0.148
Surface Thick	0.109	-0.106	0.038	-0.062	0.261

Table B.1. Correlation of Coefficients in Multiple Regression Equation. (Continued)

	Excavation	Subbase of Volume	Base of Volume	Surface of Volume	Asphalt Concrete Volume
Actual Time	0.157	0.416	0.226	-0.472	0.526
Exponential Time	0.157	0.364	0.180	-0.491	0.483
Rainfall	0.254	0.103	0.044	-0.347	0.291
%Roadway	0.082	-0.059	0.015	-0.064	0.169
Hill	0.214	0.048	-0.07	0.05	-0.192
Hill & Mountain	0.342	0.261	0.151	-0.022	0.323
Mountain	0.02	-0.229	-0.251	-0.032	-0.129
CBR Bad	-0.271	-0.307	-0.376	-0.405	-0.069
CBR Medium	0.187	0.259	0.04	0.225	-0.038
Land Acquisition	0.287	0.243	0.263	0.184	0.125
Infrastructure of Contract	-0.162	0.066	-0.085	-0.031	-0.129
Total Length	0.415	0.604	0.757	0.514	0.209
Width	-0.185	0.214	0.161	-0.639	0.543
Lane	0.247	0.434	0.375	-0.398	0.744
Tractor	0.001	0.428	0.359	-0.151	0.576
Grader	0.354	0.51	0.535	0.029	0.599
Backhoe	0.315	0.502	0.505	-0.065	0.536
Loader	0.372	0.365	0.429	-0.012	0.379
Rubber	0.199	0.495	0.47	-0.171	0.601
Steel	0.145	0.113	0.026	-0.068	0.067
Vibration Roller	0.35	0.449	0.39	-0.208	0.6
Asphalt Distributor	-0.007	0.074	-0.083	-0.1	0.007
Truck	0.138	0.288	0.413	0.016	0.371
Clearing	0.524	0.559	0.615	0.38	0.335
Embankment	0.201	0.415	0.321	-0.343	0.711
Excavation	1	0.299	0.363	0.216	0.246
Subbase Volume	0.299	1	0.81	-0.013	0.589
Base Volume	0.363	0.81	1	0.197	0.578
Surface Volume	0.216	-0.013	0.197	1	-0.46
Asphalt Concrete Volume	0.246	0.589	0.578	-0.46	1
Sodding	0.181	0.608	0.613	-0.217	0.696
Painting	0.209	0.546	0.516	-0.282	0.66
Curb &Ditch	0.106	0.287	0.434	-0.171	0.466
Slope Protection	0.514	0.353	0.528	-0.031	0.499
Subbase Thick	-0.196	-0.057	-0.158	0.006	-0.122
Surface Thick	-0.085	0.074	0.074	-0.465	0.208

Table B.1. Correlation of Coefficients in Multiple Regression Equation. (Continued)

	Sodding	Painting	Curb & Ditch	Slope of Protection	Subbase of Thickness	Surface of Thickness
Actual Time	0.535	0.598	0.203	0.172	-0.053	0.344
Exponential Time	0.459	0.542	0.225	0.165	-0.072	0.350
Rainfall	0.158	0.287	0.265	0.248	-0.049	0.224
%Roadway	-0.08	0.116	0.419	0.211	0.135	0.299
Hill	-0.145	-0.164	-0.146	0.24	-0.053	-0.225
Hill & Mountain	-0.001	0.036	0.081	-0.01	0.053	-0.251
Mountain	-0.288	-0.083	-0.039	-0.202	0.053	0.224
CBR Bad	-0.041	-0.07	-0.132	-0.426	0.062	0.273
CBR Medium	-0.037	0.054	0.071	0.269	-0.019	-0.337
Land Acquisition	0.288	0.094	0.234	0.229	0.113	-0.041
Infrastructure of Contract	-0.09	0.072	-0.24	-0.102	-0.049	0.002
Total Length	0.426	0.355	0.183	0.401	-0.074	-0.206
Width	0.279	0.309	0.289	0.12	-0.05	0.584
Lane	0.457	0.52	0.473	0.344	-0.094	0.336
Tractor	0.492	0.515	0.479	0.304	-0.207	0.315
Grader	0.481	0.304	0.36	0.239	-0.302	-0.216
Backhoe	0.439	0.427	0.352	0.351	-0.229	0.116
Loader	0.469	0.173	-0.022	0.153	-0.135	0.032
Rubber	0.472	0.313	0.128	0.086	-0.084	0.068
Steel	0.138	0.138	-0.127	-0.111	-0.217	0.174
Vibration Roller	0.323	0.353	0.394	0.166	-0.225	0.109
Asphalt Distributor	-0.038	0.059	-0.045	-0.181	-0.082	-0.106
Truck	0.423	0.135	0.174	0.216	0.021	0.038
Clearing	0.627	0.441	0.175	0.486	-0.169	-0.062
Embankment	0.604	0.529	0.142	0.274	-0.148	0.261
Excavation	0.181	0.209	0.106	0.514	-0.196	-0.085
Subbase Volume	0.608	0.546	0.287	0.353	-0.057	0.074
Base Volume	0.613	0.516	0.434	0.528	-0.158	0.074
Surface Volume	-0.217	-0.282	-0.171	-0.031	0.006	-0.465
Asphalt Concrete Volume	0.696	0.66	0.466	0.499	-0.122	0.208
Sodding	1	0.661	0.372	0.458	-0.029	0.195
Painting	0.661	1	0.436	0.43	-0.247	0.385
Curb &Ditch	0.372	0.436	1	0.482	-0.111	0.223
Slope Protection	0.458	0.43	0.482	1	-0.253	0.015
Subbase Thick	-0.029	-0.247	-0.111	-0.253	1	0.123
Surface Thick	0.195	0.385	0.223	0.015	0.123	1

APPENDIX C

THE ANALYSIS OF MULTIPLE LINEAR REGRESSION EQUATION

Table C.1. Correlation of Determination in Multiple Linear Regression Equation.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.984	0.968	0.845	79.33
2	0.984	0.967	0.861	75.17
3	0.983	0.967	0.875	71.36
4	0.983	0.967	0.886	68.02
5	0.983	0.966	0.895	65.46
6	0.982	0.964	0.899	64.02
7	0.981	0.963	0.903	63.02
8	0.98	0.96	0.903	62.99
9	0.978	0.957	0.902	63.17
10	0.977	0.954	0.903	62.83
11	0.975	0.950	0.90	63.68
12	0.972	0.946	0.897	64.70
13	0.969	0.939	0.89	66.79
14	0.967	0.936	0.891	66.74
15	0.967	0.935	0.894	65.60
16	0.965	0.931	0.893	66.08
17	0.961	0.924	0.888	67.47

Table C.2. F-Distribution in Multiple Linear Regression Equation.

		Sum of Squares	df	Mean Square	F	Sig F
1	Regression	1340953.3	27	49664.9	7.891	0.004
	Residual	44055.836	7	6293.69		
	Total	1385009.1	34			
2	Regression	1339810	26	51531.2	9.121	0.002
	Residual	45199.102	8	5649.89		
	Total	1385009.1	34			
3	Regression	1339179.7	25	53567.2	10.52	0.000
	Residual	45829.441	9	5092.16		
	Total	1385009.1	34			
4	Regression	1338743	24	55781	12.057	0.000
	Residual	46266.14	10	4626.61		
	Total	1385009.1	34			
5	Regression	1337880	23	58168.7	13.577	0.000
	Residual	47129.154	11	4284.47		
	Total	1385009.1	34			
6	Regression	1335825.5	22	60719.3	14.815	0.000
	Residual	49183.597	12	4098.63		
	Total	1385009.1	34			
7	Regression	1333378.9	21	63494.2	15.987	0.000
	Residual	51630.283	13	3971.56		
	Total	1385009.1	34			
8	Regression	1329457.5	20	66472.9	16.752	0.000
	Residual	55551.682	14	3967.98		
	Total	1385009.1	34			
9	Regression	1325147.1	19	69744.6	17.476	0.000
	Residual	59862.079	15	3990.81		
	Total	1385009.1	34			
10	Regression	1321843.1	18	73435.7	18.601	0.000
	Residual	63166.035	16	3947.88		
	Total	1385009.1	34			
11	Regression	1316064.5	17	77415.6	19.089	0.000
	Residual	68944.673	17	4055.57		
	Total	1385009.1	34			
12	Regression	1309665.9	16	81854.1	19.556	0.000
	Residual	75343.2	18	4185.73		
	Total	1385009.1	34			

Table C.2. F-Distribution in Multiple Linear Regression Equation. (Continued)

		Sum of Squares	df	Mean Square	F	Sig F
13	Regression	1300257.9	15	86683.9	19.433	0.000
	Residual	84751.269	19	4460.59		
	Total	1385009.1	34			
14	Regression	1295921.4	14	92565.8	20.781	0.000
	Residual	89087.706	20	4454.39		
	Total	1385009.1	34			
15	Regression	1294640.5	13	99587.7	23.142	0.000
	Residual	90368.631	21	4303.27		
	Total	1385009.1	34			
16	Regression	1288948.4	12	107412	24.6	0.000
	Residual	96060.743	22	4366.4		
	Total	1385009.1	34			
17	Regression	1280302.5	11	116391	25.567	0.000
	Residual	104706.6	23	4552.46		
	Total	1385009.1	34			

Table C.3. Selected Model in Multiple Linear Regression Equation.

		Unstandardized Coefficients		Standardized Coefficients	T Result	SigT Result
		B	Std. Error	Beta		
17	Constant	-234.591	237.414		-0.988	0.034
	Rainfall	171.579	27.194	0.431	6.31	0.000
	CBR Bad	219.831	30.4	0.499	7.231	0.000
	Width	97.657	36.073	0.228	2.707	0.013
	Truck	-2.997	0.801	-0.256	-3.744	0.001
	Clearing	-1.63×10^{-4}	0.000	-0.253	-2.05	0.042
	Excavation	2.68×10^{-4}	0.000	0.14	1.778	0.033
	Subbase Volume	1.91×10^{-3}	0.001	0.304	3.685	0.001
	Surface Volume	3.39×10^{-4}	0.000	0.235	2.119	0.045
	Sodding	1.01×10^{-3}	0.000	0.432	3.633	0.001
	Painting	1.05×10^{-2}	0.004	0.235	2.665	0.014
	Curb &Ditch	-2.99×10^{-3}	0.001	-0.147	-2.177	0.040

Model 1:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Asphalt Distributor, Hill, Loader, CBR Bad, Tractor, Mountain, Hill&Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Slope Protection, Clearing, Vibration Roller, Width, Sodding

Model 2:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Hill, Loader, CBR Bad, Tractor, Mountain, Hill&Mountain, Truck, Surface Volume, Curb &Ditch, Excavate, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Slope Protection, Clearing, Vibration Roller, Width, Sodding

Model 3:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Hill, Loader, CBR Bad, Tractor, Mountain, Hill&Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Clearing, Vibration Roller, Width, Sodding

Model 4:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Loader, CBR Bad, Tractor, Mountain, Hill&Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Clearing, Vibration Roller, Width, Sodding

Model 5:

Predictors: (Constant), Infrastructure Contract, Land Acquisition, Subbase Thick, Loader, CBR Bad, Tractor, Mountain, Hill&Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Clearing, Vibration Roller, Width, Sodding

Model 6:

Predictors: (Constant), Infrastructure Contract, Land Acquisition, Subbase Thick, Loader, CBR Bad, Tractor, Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Clearing, Vibration Roller, Width, Sodding

Model 7:

Predictors: (Constant), Land Acquisition, Subbase Thick, Loader, CBR Bad, Tractor, Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Clearing, Vibration Roller, Width, Sodding

Model 8:

Predictors: (Constant), Subbase Thick, Loader, CBR Bad, Tractor, Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Clearing, Vibration Roller, Width, Sodding

Model 9:

Predictors: (Constant), Subbase Thick, Loader, CBR Bad, Tractor, Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Clearing, Vibration Roller, Width, Sodding

Model 10:

Predictors: (Constant), Subbase Thick, Loader, CBR Bad, Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Clearing, Vibration Roller, Width, Sodding

Model 11:

Predictors: (Constant), Loader, CBR Bad, Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Clearing, Vibration Roller, Width, Sodding

Model 12:

Predictors: (Constant), Loader, CBR Bad, Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Clearing, Vibration Roller, Width, Sodding

Model 13:

Predictors: (Constant), Loader, CBR Bad, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Clearing, Vibration Roller, Width, Sodding

Model 14:

Predictors: (Constant), CBR Bad, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Clearing, Vibration Roller, Width, Sodding

Model 15:

Predictors: (Constant), CBR Bad, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Clearing, Width, Sodding

Model 16:

Predictors: (Constant), CBR Bad, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, %Roadway, Subbase Volume, Rainfall, Clearing, Width, Sodding

Model 17:

Predictors: (Constant), CBR Bad, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Subbase Volume, Rainfall, Clearing, Width, Sodding

APPENDIX D

COEFFICIENT OF DETERMINATION IN MULTIPLE EXPONENTIAL EQUATION

Table D.1. Coefficient of Determination in Multiple Exponential Regression Equation.

Model	R	R Square	Adjusted R Square
1	0.976	0.952	0.769
2	0.976	0.952	0.796
3	0.976	0.952	0.817
4	0.975	0.951	0.833
5	0.975	0.950	0.845
6	0.974	0.949	0.856
7	0.974	0.949	0.866
8	0.973	0.947	0.871
9	0.972	0.945	0.875
10	0.969	0.940	0.872
11	0.964	0.930	0.859
12	0.960	0.922	0.852
13	0.955	0.912	0.842
14	0.951	0.905	0.838
15	0.948	0.899	0.837
16	0.945	0.893	0.835
17	0.941	0.886	0.832
18	0.934	0.873	0.820
19	0.927	0.859	0.808
20	0.924	0.854	0.809
21	0.918	0.843	0.803
22	0.914	0.835	0.800

Model 1:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Asphalt Distributor, Hill, Loader, CBR Bad, Tractor, Mountain, Hill&Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Slope Protection, Clearing, Vibration Roller, Width, Sodding

Model 2:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Asphalt Distributor, Hill, Loader, CBR Bad, Tractor, Hill&Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Slope Protection, Clearing, Vibration Roller, Width, Sodding

Model 3:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Asphalt Distributor, Hill, Loader, CBR Bad, Tractor, Hill&Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Painting, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Clearing, Vibration Roller, Width, Sodding

Model 4:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Asphalt Distributor, Hill, Loader, CBR Bad, Tractor, Hill&Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Clearing, Vibration Roller, Width, Sodding

Model 5:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Asphalt Distributor, Loader, CBR Bad, Tractor, Hill&Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Clearing, Vibration Roller, Width, Sodding

Model 6:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Asphalt Distributor, Loader, CBR Bad, Tractor, filll&Mountain, Truck, Surface Volume, Curb &Ditch, Excavate, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Clearing, Vibration Roller, Sodding

Model 7:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Loader, CBR Bad, Tractor, Hill&Mountain, Truck, Surface Volume, Curb &Ditch, Excavation, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Clearing, Vibration Roller, Sodding

Model 8:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Loader, CBR Bad, Tractor, Hill&Mountain, Truck, Surface Volume, Curb &Ditch, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Clearing, Vibration Roller, Sodding

Model 9:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Loader, CBR Bad, Tractor, Hill&Mountain, Truck, Curb &Ditch, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel; Embankment, Clearing, Vibration Roller, Sodding

Model 10:

Predictors: (Constant), Surface Thick, Infrastructure Contract, Land Acquisition, Subbase Thick, Loader, CBR Bad, Tractor, Hill&Mountain, Truck, Curb &Ditch, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Vibration Roller, Sodding

Model 11:

Predictors: (Constant), Infrastructure Contract, Land Acquisition, Subbase Thick, Loader, CBR Bad, Tractor, Hill&Mountain, Truck, Curb &Ditch, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Vibration Roller, Sodding

Model 12:

Predictors: (Constant), Infrastructure Contract, Land Acquisition, Subbase Thick, Loader, CBR Bad, Tractor, Truck, Curb &Ditch, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Embankment, Vibration Roller, Sodding

Model 13:

Predictors: (Constant), Infrastructure Contract, Land Acquisition, Subbase Thick, Loader, CBR Bad, Tractor, Truck, Curb &Ditch, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Vibration Roller, Sodding

Model 14:

Predictors: (Constant), Land Acquisition, Subbase Thick, Loader, CBR Bad, Tractor, Truck, Curb &Ditch, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Vibration Roller, Sodding

Model 15:

Predictors: (Constant), Subbase Thick, Loader, CBR Bad, Tractor, Truck, Curb &Ditch, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Vibration Roller, Sodding

Model 16:

Predictors: (Constant), Subbase Thick, Loader, CBR Bad, Truck, Curb &Ditch, Backhoe, %Roadway, Subbase Volume, Rainfall, Steel, Vibration Roller, Sodding

Model 17:

Predictors: (Constant), Subbase Thick, Loader, CBR Bad, Truck, Curb &Ditch, Backhoe, %Roadway, Subbase Volume, Rainfall, Vibration Roller, Sodding

Model 18:

Predictors: (Constant), Loader, CBR Bad, Truck, Curb &Ditch, Backhoe, %Roadway, Subbase Volume, Rainfall, Vibration Roller, Sodding

Model 19:

Predictors: (Constant), Loader, CBR Bad, Truck, Curb &Ditch, Backhoe, Subbase Volume, Rainfall, Vibration Roller, Sodding

Model 20:

Predictors: (Constant), Loader, CBR Bad, Truck, Backhoe, Subbase Volume, Rainfall, Vibration Roller, Sodding

Model 21:

Predictors: (Constant), CBR Bad, Truck, Backhoe, Subbase Volume, Rainfall, Vibration Roller, Sodding

Model 22:

Predictors: (Constant), CBR Bad, Truck, Backhoe, Subbase Volume, Rainfall, Sodding

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