# Model for Forecasting Highway Construction Cost

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## ABSTRACT

In recent years there has been a substantial increase in the number and complexity of projects in the highway construction industry. The complexity of these projects is one of the main reasons it takes so much time from inception to completion of a project. Those involved in decision making and budgeting need "tools" to help evaluate future costs. The literature survey conducted during this study has shown that the use of existing economic models is inadequate because of the unique factors that influence the highway industry. The development of a model for long-range forecasting of highway construction cost is described. This model is based on a statistical analysis of data gathered from Florida Department of Transportation projects around the state of Florida from 1968 to 1984. The research revealed that, in addition to the inflationary changes in the cost of basic elements (labor, materials, equipment), there are other factors that affect total cost. One of those factors, the bidding volume, was analyzed and incorporated into the model. Although this model was developed for a specific sponsor, it is based on general principles that can be adapted to other users.

Forecasting cost is one of the main elements of planning, budgeting, and decision making in the highway construction industry. Early knowledge of future costs is essential. In most cases 1 or 2 years will pass between the preliminary decision to start a new project and project completion.

Estimators and those responsible for budgeting need techniques to assist them in forecasting costs. The Florida Department of Transportation (FDOT), as well as other state and federal agencies, is required to prepare a multiyear budget in order to plan future requirements and expenditures. Recognizing the need for such a tool, which would assist the FDOT in their long-range estimating, the FDOT requested that the University of Florida develop a model to simulate the process of budget preparation. The development of such a model and the results obtained by the application of the model by the FDOT are described.

## SURVEY OF EXISTING METHODS

A survey was performed to evaluate the existing methods of forecasting construction cost. The survey was based on three sources:

1. A general literature survey,
2. Review of methods used by other state DOTs, and
3. Review of contractors' and suppliers' forecasting techniques.

### Literature Survey

The results obtained showed a variety of forecasting models in use. However, only a few were related to the specific conditions of the highway construction industry. Among these was the work of Erickson and Boyer (1) who examined the estimators' dilemma of how to forecast escalation in prices from the bidding time until construction. Other sources that dealt with cost forecasting (cost elements only) were Jones (2) who discussed change trends in oil products, Schexnayder and Hancher (3) who investigated the changes in the cost of replacing equipment, and Warszawski and Rosenfeld (4) who pointed out the problem of cost control in times of escalating prices. Lazar and Getson (5) suggested that commodity futures should be used in estimating. All of these sources recognized the problem of forecasting but did not find any comprehensive solution.

Other authors deal with statistical methods and their application to forecasting procedures. Koppula (6) suggests analyzing historical cost records with two methods:

- The Box Jenkins stochastic method and
- The Hout-Winters smoothing technique.

The author's computations were based on the Engineering News Record's (ENR's) cost indices. Using these indices from 1962 to 1978, Koppula found that if the Hout-Winters technique was used, the forecasting results were quite close to the actual data.

In a review of common statistical techniques used for forecasting, Globerman and Baesel (7) compared three methods:

- Weighted autoregression of past inflation rates,
- Forecasting based on expectation data from surveys, and
- Forecasting based on changes in interest rates.

The authors did not find any significant differences in the forecasting results using these methods. This conclusion is important because it shows that the highly complex statistical methods do not necessarily yield better results.

### Results of Department of Transportation Survey

The task of preparing a multiyear budget is not unique to the FDOT. Many state and federal agencies

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are required by law to prepare such budgets. To determine how other states are dealing with this subject, a questionnaire was sent to various DOTs inquiring about their methods of preparing long-range forecasts.

Analysis of the information in 45 survey replies showed that only 22 percent of the states participating in the survey have any type of systematic method. Most of the states use national cost indices prepared by FHWA, the ENR cost index, simple mathematical methods (regression), or in some cases even pure guesswork to try to forecast the budget. Only a few states like California and Minnesota have developed local models based on a limited number of cost elements.

### Survey of Contractors and Suppliers

The third source consisted of contractors and suppliers from all over Florida who were facing similar problems in producing construction estimates. Estimators have to evaluate the escalation rate from the bidding time to the actual construction time, which in transportation projects can be relatively long (1 to 3 years). This escalation rate has to be figured and incorporated into the estimates.

The results of the survey indicate that contractors' and suppliers' forecasting methods were mainly based on the intuition of professionals who had extensive experience with and knowledge of local conditions. The material supplier evaluates price escalations (concrete, steel, pipes, etc.) and the general contractor adds his forecast of labor and equipment cost changes to the supplier's quotations. Only a few contractors or suppliers had any systematic forecasting techniques.

## METHODOLOGY IN MODEL DEVELOPMENT

### General Principles

Following the literature survey, the decision was made to develop a forecasting model based on general principles that can be used universally even though the model was tailored to the specific conditions and needs of the highway construction industry in Florida. The design of the model is flexible enough so that every user can modify it to his specific needs, and future technological changes can be easily incorporated into the model.

Six submodels have been developed to forecast specific types of works. These submodels are

- Submodel 01--earthwork,
- Submodel 02--asphalt pavement,
- Submodel 03--concrete pavement,
- Submodel 04--structural concrete,
- Submodel 05--reinforcing steel, and
- Submodel 06--structural steel.

The combination of these submodels will create a composite model that will be used to forecast the

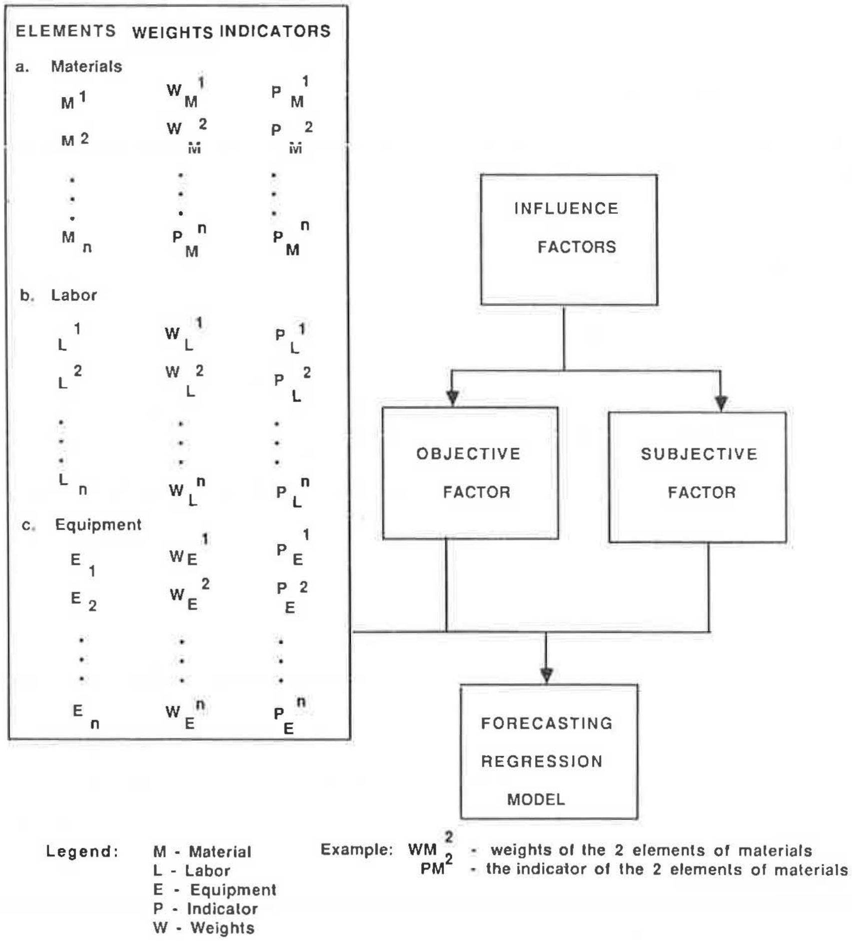

FIGURE 1 Schematic description of the model.

total cost (or budget) for the entire state of Florida. The submodel form and the composite model will give the user the flexibility to deal with only a certain type of job or with the total volume, depending on his need.

The data for the statistical analysis for the development of the model came from two large data bases that contained the records of most FDOT projects executed in Florida since 1968.

The first data base, Contract Administration System (CAS) (8), contains the results of the winning bids for projects executed throughout Florida since 1968. The data base includes the following records for each project: list of standard pay items, quantity of each item, and unit price and total price of each item. It also contains information about the total cost of every project, the total cost of a series of projects, and the total bidding volume per quarter and per year for the entire state.

The second data base is the Contract Estimating System (CES) (9), which contains a computerized library of about 3,000 standard pay items used in FDOT bids. Each item is analyzed for the different cost elements: labor, material, equipment, and overhead. This data base depends on price escalation and is updated on a quarterly basis.

## Model Description

The model is based on the following four components:

- The weight component,
- The indicator,
- The influence factor component, and
- The forecasting process component.

Figure 1 is a schematic flow chart of the model.

### Weight Component

The first step in the development of the model was to determine a series of elements for each of the submodels and for the composite model. These elements were defined as direct cost elements (labor, material, equipment) and indirect cost elements (overhead and profit). Using historical records (CAS), a list of common pay items was developed for each submodel. The combination of those pay items will generate the list for the composite model. Using the CES analysis of each item the weight of each element in every pay item was calculated to obtain the weight of each element for every submodel. Finally, the weight of each submodel and the element weights for the composite model were calculated. All calculations were performed using a 3-year moving average technique (10) with the earliest record being dropped from the system each time the most recent quarter was added.

An example of the computation for one submodel, 01--earthwork, will be shown later. (All the other computations were done in a similar way.) From the CES a list of common pay items was determined. Table 1 gives the list of pay items for submodel 01.

**TABLE 1 List of Pay Items for Submodel 01–Earthwork**

| Pay Item No. | Pay Item Description |
|---|---|
| 120-1 | Regular excavation |
| 120-2 | Borrow excavation |
| 120-3 | Lateral ditch excavation |
| 120-4 | Subsoil excavation |
| 120-5 | Channel excavation |
| 120-6 | Embankment |

For each pay item the breakdown of the cost elements was calculated. The following calculations were performed for Item 120-2, borrow excavation.

| | |
|---|---|
| Labor costs | |
| One foreman working 8 hr/day | \$ 67.68 |
| Two laborers working 8 hr/day | \$ 64.64 |
| Two dozer operators working 8 hr/day | \$ 84.32 |
| Two grader operators working 8 hr/day | \$ 93.28 |
| Two scraper operators working 8 hr/day | \$ 79.36 |
| One equipment mechanic working 8 hr/day | \$ 46.40 |
| Total labor cost | \$ 435.68 |
| | |
| Total material cost | \$2,670.50 |
| | |
| Equipment (based on a standard crew from CES 8 hr/day) | |
| Two motor graders (150 hp plus) | \$ 665.44 |
| Two motor diesel power scrapers | \$1,800.00 |
| Two dozers (straight heavy) | \$ 909.60 |
| One half-ton pickup truck | \$ 73.44 |
| One 1 1/2-ton flatbed truck | \$ 73.16 |
| Total equipment cost | \$3,522.64 |

| | |
|---|---|
| Cost for 1 $yd^3$ of borrow exclusively (productivity rate = 2,820 $yd^3$/8 hr) | |
| Labor costs = \$435.68/2,820 $yd^3$ | \$0.151/$yd^3$ |
| Material costs = \$2,670.50/2,820 $yd^3$ | \$0.951/$yd^3$ |
| Equipment cost = \$3,522.64/2,820 $yd^3$ | \$1.251/$yd^3$ |
| Total unit cost | \$2.351/$yd^3$ |

Therefore the percentage breakdown for Item 120-2 is as follows:

Labor = (0.155/2.352) x 100 = 6.66%
Material = (0.947/2.352) x 100 = 40.20%
Equipment = (1.250/2.352) x 100 = 53.14%
Total 100.00%

Table 2 gives a summary of the results for all the pay items of submodel 01 (this was calculated in the same way as Item 120-2). Table 3 gives the aver-

**TABLE 2 Element Cost Breakdown per Pay Item in Submodel 01**

| Pay Item No. | Material (%) | Labor (%) | Equipment (%) | Total (%) |
|---|---|---|---|---|
| 120-1 | 0.00 | 11.14 | 88.86 | 100.00 |
| 120-2 | 40.20 | 6.66 | 53.14 | 100.00 |
| 120-3 | 0.00 | 13.33 | 86.67 | 100.00 |
| 120-4 | 0.00 | 9.36 | 90.64 | 100.00 |
| 120-5 | 0.00 | 4.69 | 95.31 | 100.00 |
| 120-6 | 43.65 | 8.67 | 47.68 | 100.00 |

**TABLE 3 Work Volumes per Item in Submodel 01**

| Pay Item No. | Annual Work Volume (\$) | Percentage of Total |
|---|---|---|
| 120-1 | 810,820.00 | 3.64 |
| 120-2 | 2,113,410.00 | 9.50 |
| 120-3 | 94,653.00 | 0.43 |
| 120-4 | 1,887,150.00 | 8.48 |
| 120-5 | 63,888.00 | 0.29 |
| 120-6 | 17,287,000.00 | 77.67 |
| Total | 22,255,921.00 | 100.00 |

age yearly bid volume for 1979-1981 for each pay item in submodel 01 using the information from the CAS file.

Table 4 gives the relative weight of the main elements in each pay item based on the results of Tables 2 and 3. For example, for Item 120-2 the labor weight in the item is 6.66 percent (from Table 2) and the pay item weight is 9.50 percent of the submodel total (Table 3). Therefore the relative weight for labor in Item 120-4 is 6.66 percent x 0.095 = 0.63.

TABLE 4 Breakdown of Weights for Each Item in Submodel 01

| Pay Item No. | Submodel (%) | Material (%) | Labor (%) | Equipment (%) |
|---|---|---|---|---|
| 120-1 | 3.64 | 0.00 | 0.41 | 3.23 |
| 120-2 | 9.50 | 3.82 | 0.63 | 5.05 |
| 120-3 | 0.43 | 0.00 | 0.06 | 0.37 |
| 120-4 | 8.48 | 0.00 | 0.79 | 7.69 |
| 120-5 | 0.29 | 0.00 | 0.01 | 0.28 |
| 120-6 | 77.67 | 33.90 | 6.73 | 37.03 |
| Total | 100.00 | 37.72 | 8.63 | 53.65 |

Table 5 gives a summary of the results of the element weights for all six submodels.

TABLE 5 Element Cost Breakdown by Submodels

| Model No. | Model Description | Material (%) | Equipment (%) | Labor (%) | Total (%) |
|---|---|---|---|---|---|
| 01 | Earthwork | 37.72 | 53.65 | 8.63 | 100.00 |
| 02 | Asphalt pavement | 82.04 | 14.16 | 3.69 | 100.00 |
| 03 | Concrete pavement | 64.57 | 27.17 | 8.26 | 100.00 |
| 04 | Structural concrete | 28.45 | 35.53 | 36.02 | 100.00 |
| 05 | Reinforcing steel | 74.39 | 7.40 | 18.20 | 100.00 |
| 06 | Structural steel | 97.21 | 1.72 | 1.07 | 100.00 |

### Indicator Component

To calculate future changes in the cost elements a series of indices had to be defined as indicators. For example, to forecast changes in equipment cost, a suitable indicator must be determined to represent this element. The selection of suitable indicators was one of the main considerations in developing the model. The guideline for selection was the availability of historical data for a substantial period of time. This information was necessary so that a detailed statistical analysis of each indicator could be calculated in order to check its performance against actual costs. It is also essential that data for indicators be available on a regular basis in the future. Because of user needs, it was decided to concentrate only on the main elements that constitute more than 3 percent of the total cost of the composite model. After historical records were analyzed, eight direct cost elements were defined. There are a few ways to calculate indirect cost, which consists of job overhead material, overhead, and profit. However, most of the participants in the highway construction process prefer to use one factor defined as markup. Therefore the indirect cost elements were calculated as a percentage of the total direct cost. For each element, several indicators were checked, and the one with the highest correlation with previous records was chosen. Table 6 gives the list of elements, their percentage of the total direct cost of the composite model, and related indicators.

Most of the indicators are based on information from the U.S. Bureau of Labor Statistics (BLS). BLS provided accurate data in the past for Producer Price Indices (PPI), which are related to the model elements. The BLS values for the indicators are given in Table 7.

Because the BLS does not forecast its indices, another source of future values was required. The source chosen for this research was Data Resources Inc. (DRI) (11), which is one of the most important research institutes dealing with forecasts. However, because the DRI does not project values for all the indicators of the model, some form of correlation between the DRI variables and the indicators had to be developed. Regression models were constructed that related to the historical data from the BLS and to the historical value of indices for which the DRI provided forecasts. For this purpose, three indices forecast by DRI were chosen to represent the model indicators. These indices were (a) fuels and related products, (b) metals and metal products, and (c) machinery and equipment.

By using the three DRI indices, autoregressive and ordinary least squares regression models were constructed for each indicator. An equation correlating the DRI value with historical data from the BLS was found and the equation with the best statistical properties (high correlation, significant coefficients, and low autocorrelation) was chosen to forecast future values of the indicator. From these regressions, an equation was developed that relates to past BLS values and to the future projection given by the DRI. The procedure is demonstrated using structural steel indicators as an example. The autocorrelation coefficient was sufficiently small for the straight regression method (0.060); therefore, this regression was chosen to represent the index. When the regression with the best statistical properties had been chosen, an equation was constructed

TABLE 6 Elements and Indicators in the Composite Model

| No. | Element | Percentage of Direct Cost[a] | Indicators |
|---|---|---|---|
| 1 | Aggregate fill | 22.10 | Construction sand and gravel |
| 2 | Liquid asphalt | 11.40 | Refined petroleum and products |
| 3 | Concrete and others | 6.10 | Concrete ingredients |
| 4 | Structural steel | 3.40 | Structural steel |
| 5 | Reinforcing steel | 3.40 | Rebars |
| 6 | Embankment | 14.40 | Construction sand and gravel |
| 7 | Labor | 10.60 | Highway and street workers |
| 8 | Equipment | 28.60 | Construction machinery |
| Total | | 100.00 | |

[a] Overhead and profit were calculated as a percentage of direct cost.

TABLE 7 Data Base Indicators on BLS Producer Price Index

| Year | Fabricated Structural Steel | Reinforcement Bars | Construction Machinery and Equipment | Paving Mixtures | Construction Sand and Gravel | Concrete Ingredients | Refined Petroleum Products | Average Hourly Earnings |
|---|---|---|---|---|---|---|---|---|
| 1968 | | 99.3 | 105.7 | 101.7 | 104.6 | 103.2 | 98.1 | 109.2 |
| 1969 | | 100.3 | 110.4 | 102.7 | 108.8 | 106.7 | 99.6 | 117.4 |
| 1970 | | 110.3 | 115.9 | 105.8 | 115.3 | 112.6 | 101.0 | 126.3 |
| 1971 | | 117.0 | 121.8 | 121.8 | 120.8 | 121.9 | 107.2 | 137.5 |
| 1972 | 126.1 | 114.7 | 125.7 | 123.9 | 123.3 | 126.9 | 108.9 | 143.4 |
| 1973 | 130.6 | 124.1 | 130.7 | 125.2 | 127.6 | 131.2 | 128.7 | 151.5 |
| 1974 | 159.1 | 201.5 | 152.3 | 222.9 | 139.1 | 148.7 | 223.4 | 163.6 |
| 1975 | 195.9 | 199.2 | 185.2 | 256.9 | 157.0 | 172.3 | 257.5 | 176.8 |

Note: Base year 1967 = 100.

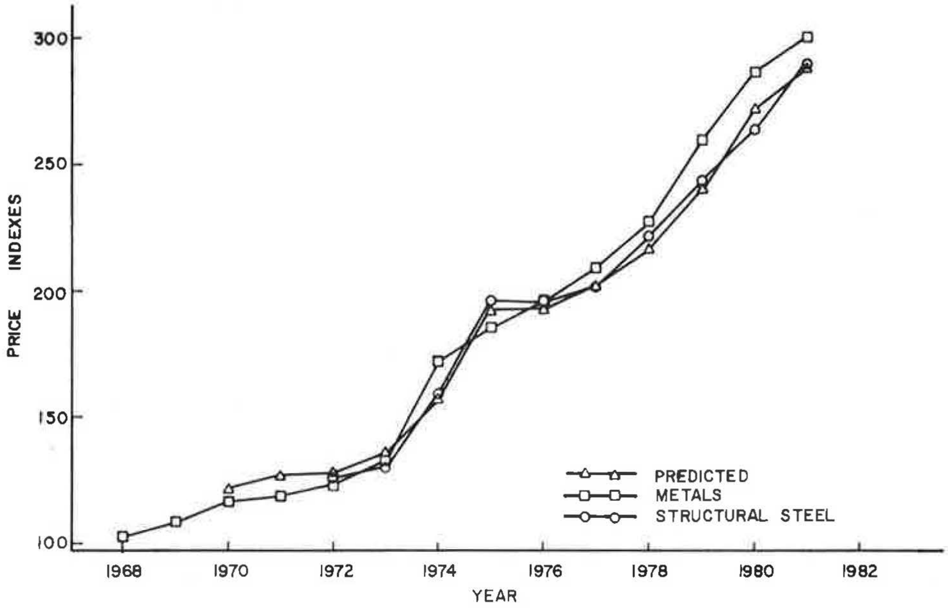

FIGURE 2 Comparison of structural steel indicators.

to calculate future values for each indicator. This equation is

$$(PF) = 21.22971 + 0.44817\ (M) + 081601\ (M1) - 0.39167\ (M2)$$

where

PF = desired indicator value in year Y,
M = value of the DRI metals index in year Y,
M1 = DRI metals index in year Y - 1, and
M2 = DRI metals index in year Y - 2.

The equation is used to calculate the future values of the structural steel indicator at intervals of 1 year. An example of the results for this element is shown in Figure 2. The same procedure was followed for each element. At the end of this procedure an equation was established for forecasting the cost of each element.

### Adjusting Process

If the inflationary fluctuation in prices were the only factor influencing the changes in the cost of transportation projects, the model could be based on the element weights and their indicators. However, because there are more factors involved, those factors must be identified and incorporated in the model. To verify the existence of additional factors a statistical analysis was performed on the historical cost of projects during the years 1968-1981. The actual cost represented by the FDOT composite cost index was compared with the composite model cost based on inflated element prices and using suitable indicators. If there were not any other factors, a high correlation between those figures had to be found. Table 8 gives the results of those calculations.

TABLE 8 Composite Model Cost Compared with Actual Cost

| Year | FDOT Composite Cost Index (1) | Composite Model Cost (2) | Differentiated Cost Indices [(1) - (2)] |
|---|---|---|---|
| 1978 | 126.60 | 108.40 | 18.20 |
| 1979 | 152.80 | 124.60 | 28.20 |
| 1980 | 173.20 | 147.00 | -26.20 |
| 1981 | 150.50 | 163.10 | -12.60 |
| 1982 | 138.40 | 167.00 | -28.60 |
| 1983 | 133.00 | 167.00 | -34.00 |
| 1984 | 155.00 | 176.00 | -21.00 |

Note: Base year 1977 = 100.

It was obvious that there are factors other than "pure inflation" that have an effect on cost fluctuation. Those factors, such as interest rates (12), unemployment (13), public expectation (14), and others, were defined as influence factors, although they can be found in professional literature under various names (15).

To incorporate these factors into the model a quantitative relationship between the factors and the cost had to be calculated. One factor was found to have a systematically dominant effect. This was the bidding volume factor, which is the total volume of bids in a certain area (county, district, state) during a defined period of time. By using historical records from the CAS the effect of the bidding volume was calculated and incorporated into the model.

Without sacrificing the flexibility of the design of the model, the option of including more factors was added. These factors are called subjective factors and they do not have an accurately quantifiable influence. The user can add these factors according to his knowledge, experience, or intuition. An example of such a factor can be the influence of election years (1988, 1992, etc.). If the user finds that in those years project costs will be 1 percent more than the escalation that is caused by all the other factors, he can add this percentage to his forecast for those years.

### Forecasting Computations and Results

The final step was to combine all the components into one system based on a combination of subprograms for each separate step and a central program that produced the final reports. All the data were based on the existing data bases of FDOT that were also incorporated into the system.

The system has been in operation since 1983, on a regular basis, using a 3-year moving average. Figure 3 shows the schematic chart of the forecasting system.

The format for introducing the results was developed to meet the users' needs in the form of cost indices that represent cost changes compared with a base year (1977 = 100). The system can provide six different cost indices for different types of projects and a composite cost index for the general budget of the agency. The results can forecast a 10-year budget based on calendar or fiscal years.

To test the validity of the model a simulation test was performed. This was done by "forecasting" previous FDOT composite cost indices and comparing them with actual data. The results of the simulation, from 1969 to 1981, were found to be quite accurate within a 95 percent confidence interval. The results showed that if an FDOT estimator had used this model in the past, his budget projections would have been quite close to the actual cost. Figure 4 shows the results of this simulation.

The FDOT has been using the model on a regular basis since 1982 and the actual results of the Florida composite cost index (FCCI) compared with the ones predicted by the model are quite accurate and prove the validity of the model. For the regular operation of the model, the user supplied the data for future bid volumes.

Table 9 gives the forecast of the FDOT composite price index for calendar years 1985-1991. An option is also provided to produce the output per fiscal year for the composite cost index as well as for every submodel.

## SUMMARY AND CONCLUSIONS

The objective of this research project was to provide those who deal with budgeting and estimating highway construction cost with a mathematical tool to help them forecast costs in a systematic way. The model developed is based on only a few principles that can be adjusted to the specific needs of any user. By using a system of submodels and a composite model, the user can forecast the cost of certain types of work such as asphalt or concrete or deal instead with the total cost of the system (district, state, etc.).

The conclusion drawn from the research is that it

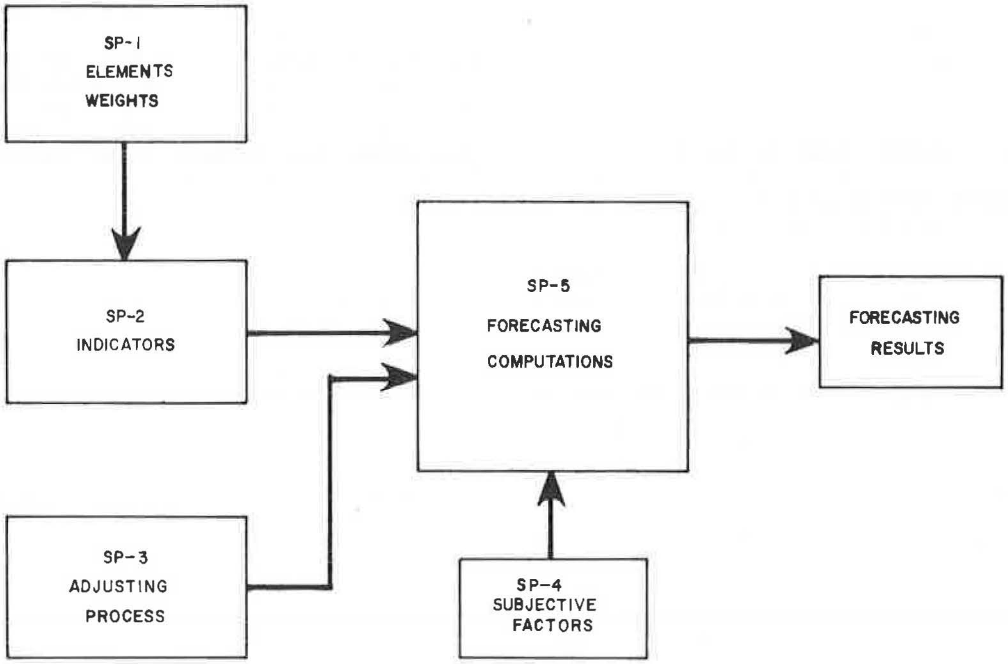

FIGURE 3 Schematic description of the forecasting system.

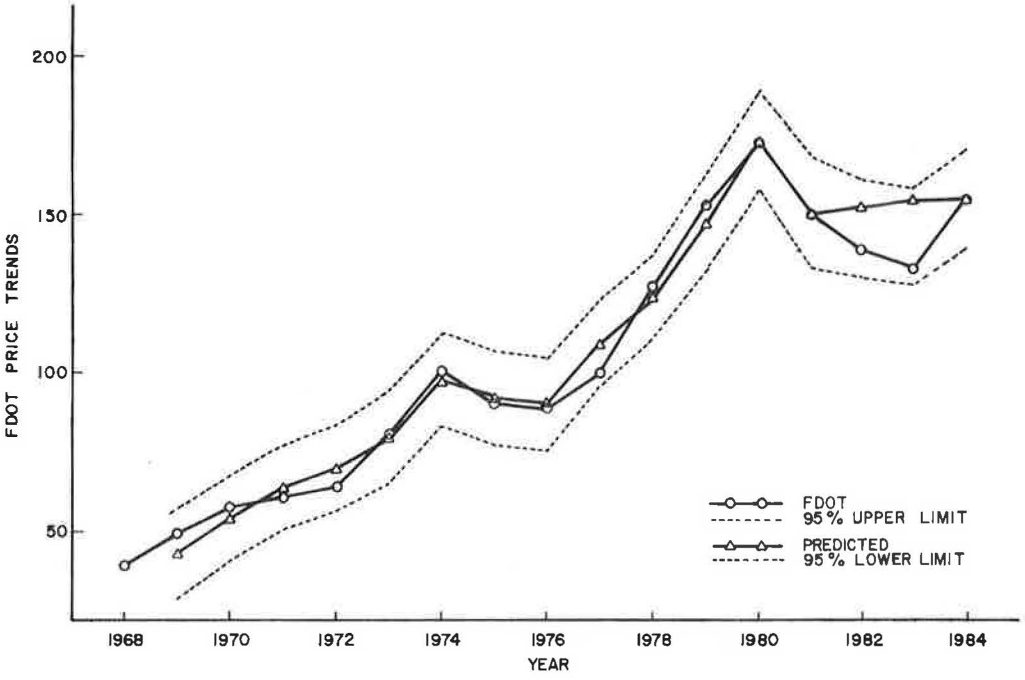

FIGURE 4 FDOT composite cost index versus model-predicted value.

TABLE 9 Forecast of the FDOT Composite Cost Index

| No. | Year | Limit | FCCI | Limit | Percentage Change |
|---|---|---|---|---|---|
| 1 | 1985 | 136.6 | 180.7 | 224.7 | 16.6 |
| 2 | 1986 | 144.7 | 188.9 | 233.0 | 4.5 |
| 3 | 1987 | 155.5 | 199.1 | 242.7 | 5.4 |
| 4 | 1988 | 175.8 | 221.2 | 266.6 | 11.1 |
| 5 | 1989 | 194.0 | 240.5 | 287.0 | 8.7 |
| 6 | 1990 | 208.9 | 256.6 | 304.2 | 6.7 |
| 7 | 1991 | 222.6 | 271.6 | 304.2 | 5.9 |
| 8 | 1992 | 236.8 | 287.7 | 338.5 | 5.9 |
| 9 | 1993 | 250.9 | 315.4 | 359.8 | 9.6 |

Note: The forecast results are per calendar year and are based on future bidding volume provided by FDOT.

is not adequate to figure the expected price escalation of different elements; there are more factors that affect the cost of projects and sometimes their influence is much greater than that of direct price escalation. One of these factors, the bidding volume factor, was quantified and incorporated into the model. This conclusion is significant to those involved in budgeting and resource allocation. The sensible spread of bids over a certain period of time can substantially reduce the cost of heavy construction projects.

The second conclusion stresses the importance of managing data bases of cost records for a long period of time. The existence of those records is of utmost importance and without them the development of this model would have been impossible.

## ACKNOWLEDGMENTS

The research was conducted under a contract to the FDOT by a team from the University of Florida, led by the author. Special thanks to the other members of the team who helped to conclude this research, T.P. Rothorock and W.W. Coons. The project would not have been possible without the help of the personnel from the Bureau of Estimates of the FDOT, especially the State Estimates Engineer, T. Drawdy, and the Preliminary Estimates Engineer, C.F. Grimsley. Valuable help was also provided by H. Presley, W.L. Chance, F. Maier, and B.T. Dietrich. Special thanks should be given to T.E. Dady who helped with the initial steps of the project and contributed throughout.

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Publication of this paper sponsored by Committee on Construction Management.

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# Using Accelerated Contracts with Incentive Provisions for Transitway Construction in Houston

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ABSTRACT

The Metropolitan Transit Authority of Harris County and the State Department of Highways and Public Transportation agreed to jointly construct authorized vehicle lanes or transitways in Houston, Texas. Federal assistance was provided by UMTA and FHWA. Some unique agreements were reached for funding and construction. To build a transitway on Interstate 45 North as quickly as possible and terminate an experimental contraflow lane, some innovative contracting techniques were used to shorten the construction period. Contractors were given the opportunity to bid the number of days for project completion with each day representing a specific dollar value. The number of days bid was used along with unit item quantities to determine the low bidder. In addition, an incentive provision allowed the contractor to earn a bonus for each day the project was completed early. It is believed that competitive bidding shortened the contract performance period from 975 to 360 days and that the incentive further reduced the performance period by 90 days, because the contractor developed innovative construction methods that allowed him to go for the full incentive. This paper provides the results of the construction effort and an initial look at the impacts on the Metropolitan Transit Authority, the State Department of Highways and Public Transportation, the contractor, and the motoring public. A contract management and administration system, which could be used as a model for future joint projects, evolved from this project.

The Metropolitan Transit Authority (Metro) of Harris County and District 12 of the State Department of Highways and Public Transportation (SDHPT) in Houston, Texas, agreed to jointly construct an authorized vehicle land (AVL) on the North Freeway at the same time the main lanes were widened and new breakdown shoulders were added. It was decided that Metro would award the first three contracts for construction of the first 9.6 mi of this project and the SDHPT would contract for the next 4.6 mi. To build the AVL as quickly as possible and terminate an existing contraflow operation on Interstate 45 North (North Freeway), Metro proceeded with an accelerated, incentive-type contract to build a temporary or interim AVL. The historical background of this initiative is reviewed and how the incentive contract was administered is described. An analysis of the estimated period for construction using critical path method (CPM) techniques and the results of competitive bidding played a key role in reducing the construction performance period.

During construction a unique project management system evolved that became the standard for contract execution and coordination among Metro's project manager and contract administrator, the SDHPT resident engineer, and the contractor. The most significant lessons learned from the incentive contract were ascertained by looking at its impact on the contractor and the agencies involved. This analysis will provide an insight into the costs, not necessarily in dollars, to participants in an accelerated

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