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16. Abstract

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The factors that influence construction prices were found to be the inflationary increase in the cost of construction inputs (labor, equipment, and material), characteristics of individual contracts, and the construction environment prevailing at the time of bidding. Contract characteristics found to be significant were contract size, duration, location, and time during the fiscal year in which the contract was let. Contract conditions found to influence contract prices were the total volume of contracts bid, variation in the bid volume, number of plan changes, and introduction of changed contract specifications, standards or practice.

The most influential factors in determining the cost of construction are the price of labor, equipment, and material. However, changes in contract characteristics and the contract environment also have an impact, causing fluctuations or incremental changes to the price of construction. The most important of these are contract size, duration, and location among the characteristics of individual contracts. Among contract conditions, number of plan changes, and changes to contract specifications, standards, or practice, are the most influential.

The impact of the factors on the cost of construction has been captured in a model which presents construction costs in terms of a construction price index similar to the Federal Highway Administration's Federal-Aid Highway Construction Composite Bid Price Index. The model closely reproduces past construction cost records when supplied with either disaggregate (i.e. contract level) or aggregate data. The model was used to predict future construction costs. Forecasts of labor, material and construction equipment costs were used together with the assumption that current contract characteristics and conditions will be maintained in the future. Under these assumptions, the model estimated that construction costs will double between 1998 and 2015 as measured in current dollars.

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TRENDS IN HIGHWAY CONSTRUCTION COSTS IN LOUISIANA

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ACKNOWLEDGMENTS

Glenn Chustz of the computer center of Louisiana Department of Transportation and Development (DOTD) prepared the data on which the analysis in this project was based. He also prepared the data coding sheets included as Appendix A in this report. His contribution to the study is gratefully acknowledged.

William T. Jack, director, management and programs, DOTD, initiated this research and conducted initial investigations of construction price trends in the department. He provided input, knowledge, and on-going guidance to the project. The author acknowledges his contribution and extends his appreciation for the assistance provided.

Kent Israel, program engineer administrator, DOTD, provided input on changes in design practice that have occurred in the department during the last 15 years. His assistance is acknowledged with gratitude.

IMPLEMENTATION STATEMENT

The results of this research can be implemented in two ways. First, by noting which factors influence construction costs and the magnitude of their impact, officials within DOTD can attempt to prepare contracts so as to minimize cost. This will involve preparing contracts with individual characteristics that are the most conducive to low bid prices and establishing a contracting environment in which fiscal uncertainty is minimized for contractors. Second, the results of this research can be used to forecast future construction costs in the state. These forecasts can be used to establish realistic construction programs for the future.

The forecasting model can be used as a composite model for all highway construction or as a means to estimate future construction costs in the specific areas of asphalt pavements, structural concrete, excavation and embankments, concrete pavements, or reinforcing steel. Alternatively, construction costs can be forecast for types of construction such as pavements or structural concrete by combining the influence of the cost of asphalt and concrete pavements or the cost of reinforcing steel and structural concrete, respectively, into single measures of construction cost for those types of construction.

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INTRODUCTION

One of the most important tasks facing a state Department of Transportation (DOT) is the planning and programming of future activities. It provides the public and legislators with a picture of how public funds are to be applied and the time scale in which it will occur. If the goals are not achieved, faith in the public agency is reduced and dissatisfaction is generated. On the other hand, if a DOT can develop programs that it consistently meets, trust is established, leading to greater cooperation and even enhanced funding.

In Louisiana, construction costs have varied considerably in the past. In the last ten years, construction costs have increased at a rate approximately 60 percent higher than the general rate inflation. In the decade prior to that, construction costs rose at a rate lower than the rate of inflation. Clearly, the general rate of inflation is not a good indicator of construction costs. To anticipate future construction costs it is necessary to identify all the factors that contribute to price change. The study documented in this report was launched to identify as many of these factors as possible and quantify them where feasible so that future construction costs can be estimated.

DOTs typically conduct two types of estimation of construction costs. The first is estimation of the total cost of a contract immediately before it is let. Typically, average unit costs from past contracts are applied to the quantities of the contract to estimate a total contract price. These estimates are current or very short-term forecasts of contract costs. The second type is the estimation of construction costs in the longer term. To produce a five-, ten-, or 20-year construction program, estimates must be made of future construction costs. This is the type of construction cost estimation considered in this study.

Many studies have set out to identify the factors that affect construction costs. Clearly, the input costs of labor, equipment, and materials, and their escalation in price due to inflation, are major factors. However, it has consistently been found by other researchers that other factors also have a significant impact on construction costs. Herbsman found that the total volume of contracts bid in a particular year tended to increase bid prices because competition was reduced as bid volume increased *[1]*. Olson and Epps found that the variation in bid volume from year to year tended to increase bid prices *[2]*. Others have suggested additional factors such as current interest rates, changing land value (as it affects expropriation costs), and governmental regulations *[3]*. Hegazy and Ayed found that among a sample of projects in Newfoundland, construction season, location, contract duration, contract size, type of facility, and site conditions, all had a measurable impact on construction costs *[4]*.

Few DOTs seem to have attempted to incorporate a comprehensive set of factors into a model that estimates future construction costs. In fact, few states have models of any form for this purpose. In a nationwide survey generating responses from 46 states, only 22 percent claimed to have a systematic procedure to estimate future construction costs *[1]*.

The procedure most often used to predict future construction costs has been the extrapolation of construction cost indices such as those prepared by the Federal Highway Administration or the Engineering News Record. Hartgen, Bowman and Horner used extrapolations of the Federal Highway Administrations Composite Bid Price Index (FHWA CBPI) to predict short-term future construction costs for all states for the years 1997-2001*[5]*. Koppula and Williams used time series analysis methods to extrapolate the Engineering News Record's Construction Cost Index (ENR CCI) *[6],[7]*. However, in those cases where extrapolation of past trends have been considered inadequate and the need existed to be able to test alternative policies or determine the sensitivity of individual contributory factors, the common procedure approach has been multivariate regression analysis. The main criticism leveled at this method is that it imposes a mathematical relationship that may be inconsistent with observed behavior, resulting in biased model parameters and obscured relationships. A further problem with past regression models, although not intrinsic to the regression procedure, is that they usually have included only a few of the factors that influence bid prices, resulting in low accuracy of model forecasts *[4]*.

The use of new analytical procedures such as neural networks and fuzzy set theory, seem to hold promise but they are still in the developmental phase. Adeli and Wu report on a neural network model that provides estimation advantages over the back-propagation type estimation procedure *[8]*. In an application on concrete pavements, credible results are produced even when operating with limited attribute information. Hegazy and Ayed report on a neural network model which operates on ten contract attributes *[4]*. They assessed different training methods for the model and came to the conclusion that an optimization method that can be operated within an Excel spreadsheet (called *GeneHunter*) gave the best performance.

The use of fuzzy set theory in construction cost forecasting seems to hold promise in incorporating subjective issues into the process in a systematic way. Fayek has demonstrated that it can be used to estimate the most appropriate profit margin a contractor should incorporate in a bid given the characteristics of the contract, the contractor, the competition, the client, subcontractors, and the economic and political environment surrounding the contract *[9]*. The desire a contractor has to win a particular contract, the extent to which they are comfortable working for a particular client, the extent to which the contract matches the expertise in the contractor's company, and the chance of inclement weather affecting progress with the contract are all examples of factors best described in terms of subjective assessments conveniently handled in fuzzy set theory. It is conceivable that fuzzy set theory could be usefully employed in estimating future construction costs as a whole.

In this study, an attempt has been made to identify from historical data, the factors that contribute to final construction costs. The relationship established between the factors and construction costs has been used to predict future construction costs in Louisiana to the year 2015. It has also been used to estimate the impact of policies aimed at limiting the increase of construction costs and identifying those factors most influential in determining future construction costs.

OBJECTIVE

The objectives of this study are to:

- observe trends in highway construction costs in Louisiana,
- identify factors that influence the price of highway construction,
- quantify the influence these factors have on highway construction costs, and,
- use the above information to establish a model to estimate future highway construction costs.

SCOPE

The research in this study was directed at the long-range trends in highway and bridge construction cost to the Louisiana Department of Transportation and Development. The contracts include the construction, rehabilitation, upgrading, and repair of roads, bridges, bridge approaches, drainage structures, intersections, weigh stations, and rest areas on the state highway network. Highway overlays were included among the projects.

The construction costs considered in this study are payments made by the department to contractors to construct the facilities in the contract. They include adjustment to the contract price following plan or quantity changes (if any) but do not include departmental expenses associated with a contract such as design, administration or overhead costs.

The analysis conducted in this study was based on historical data of highway and bridge construction costs incurred by the department between 1980 and 1997. Only a few contracts were included in the database in the initial years of the observation period (one contract in 1980, 21 in 1981, 69 in 1982, and 136 in 1983) but averaged approximately 200 for the years following 1984. Subsequently, many of the trends reported in this study of construction costs in Louisiana are limited to the period 1984-1997.

The results obtained in this study reflect only information that could be gleaned from the input data. The input data is restricted to quantitative information and is limited to the period 1980-1997. It is known that qualitative factors also influence construction prices and the information embodied in the data does not include qualitative data. Thus, the findings of the study must be interpreted as partial insight to factors affecting construction cost and not as an exhaustive list of influential factors.

METHODOLOGY

Introduction

The objectives of this study are to observe past trends in construction costs in Louisiana, identify factors that determine these costs, quantify their impact, and establish a model that can be used to predict future construction costs in Louisiana. Past studies have shown that the inflationary increase in input costs describe only a portion of the increase in construction costs *[10],[4]*. Recent research on bid prices show that even subjective factors such as the relationship between a contractor and client, or the contractors' attraction for a particular contract, can influence bid prices *[9]*. However, while a large number of factors may affect construction costs, they must be quantifiable and their impact on bid prices must be capable of estimation to feature in a model that is to be used to predict future construction costs.

This study uses past records of construction costs and the conditions under which they were incurred, to try to establish a relationship between construction costs and the factors that influence them. An effort was made to make this data comprehensive, so that the chances of capturing as many of the influential factors as possible were maximized.

Data was also accumulated on forecast values of the factors. For those factors which did not have forecast values, indicator values that did have forecast values and were closely associated in price trends with the factors were used. Identification and use of the indicator variables are described in the analysis section of the report.

Measuring construction costs

A common measure of highway construction cost used in the past has been cost per mile. For bridge construction, construction costs are often expressed in terms of cost per square foot of bridge deck area. However, measures of this type have not proved successful in tracking change in construction costs *[11]*. The main reason for their lack of success is the variability in their values caused by topography, local soil conditions, land price, class of facility, and other unique conditions of each site. Categorizing contracts into similar types and similar class of facilities reduces the variation but local conditions still account for large differences in individual values. In addition, the categorization process often reduces sample size sufficiently to introduce sampling error to estimates of average prices.

The general inadequacy of measures such as average costs per mile of highway to track change in construction costs over time can be demonstrated using data from highway contracts conducted for DOTD between 1983 and 1997. The two most frequent types of highway construction contract during this period were asphalt overlay on asphalt pavement

(23 percent of all contracts) and asphalt pavement rehabilitation (16 percent of all contracts). The functional class of facility most frequently appearing among the contracts was rural major collectors (34 percent of all overlay contracts and 38 percent of all rehabilitation contracts). The average cost per mile each year of each type of construction on rural major collectors are shown in figures 1 and 2.

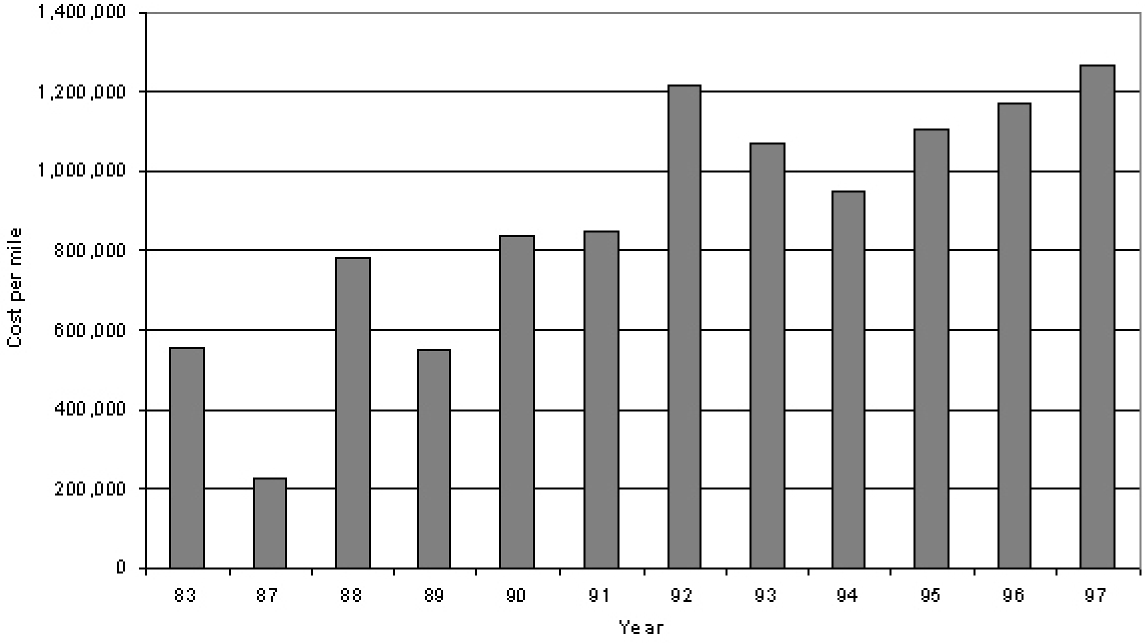


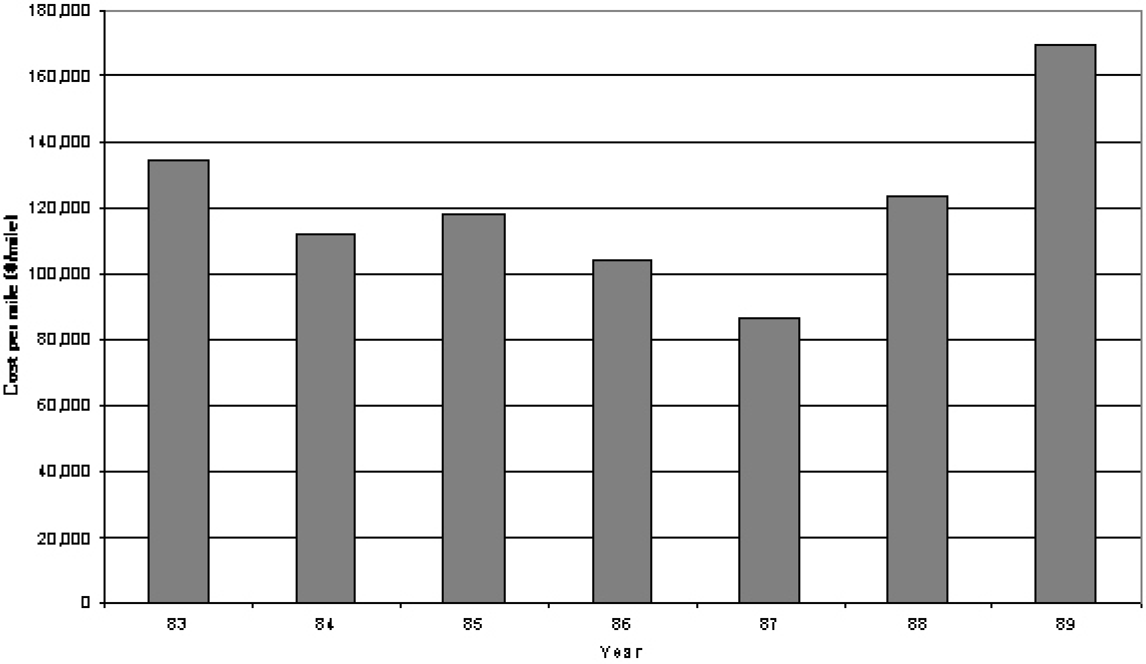
Figure 1 Asphalt overlay on rural major collectors

In figure 1, the number of contracts in the data prior to 1990 were low, varying between one and seven contracts per year. Thus, the values in this period are not reliable. During the period 1990 to 1997, the number of contracts were higher, varying between 11 and 36 per year for a total of 183 contracts in the period 1990-1997. The diagram shows high variation in average cost per mile for the entire analysis period although the variation is higher prior to 1990. Although a general increase in cost per mile is discernible, it is difficult to draw meaningful conclusions regarding the magnitude of the increase.

In figure 2, the number of contracts in years 1981-1982 and 1990-1997 varied between zero and three, making the number of observations too low to provide reliable average values. The number of observations for the period 1983 to 1989 varied between 12 and 47 contracts per year for a total of 163 contracts. The average cost of construction per mile of rural major collectors for the period 1983-1989 shown in figure 2 displays substantial variation.

Figure 2

Average cost of asphalt pavement rehabilitation of rural major collectors



Cost per lane mile would be preferable to cost per mile if lane information were available. Unfortunately, the data used in this analysis did not provide information on the number of lanes for many contracts in the data set. Subsequently, the number of observations were reduced when using lane miles and the degree of variation was not reduced when using that statistic due to the smaller sample size.

A much more reliable method of tracking construction costs is to observe the change in annual average price of individual pay items in construction contracts. Pay items are components of construction for which a price is bid in a construction contract. The same pay item may appear in a number of contracts, thus making their occurrence generally frequent. For example, a pay item such as “asphalt concrete” will occur in overlay, rehabilitation and new construction contracts of all functional classes of roads constructed of asphalt concrete.

If pay item prices are used to establish average prices each year, and these averages must be comparable between years, item prices must be expressed in common units. These units will typically be cubic yards, tons, or pounds of the same material. They may even be expressed in terms of square yards or linear feet if they refer to items of the same thickness and cross section, respectively.

Several construction cost indices have been used in the past to track construction costs. The two most popular indices are the Engineering News Record’s Construction Cost Index (ENR CCI) and the Federal Highway Administrations’ Composite Bid Price Index (FHWA CBPI). Each are compiled from the weighted average price of a set of representative pay items. In the case of the FHWA CBPI, the following six pay items are used *[12]*:

bituminous concrete surfaces ($/ton),
structural concrete ($/yd^3)
common excavation ($/yd^3),
Portland Cement Concrete surfaces ($/yd^2 of 9" thick pavement),
structural steel ($/lb), and,
structural reinforcing steel ($/lb),

The FHWA CBPI is prepared from data supplied by states on Federal-aid highway contracts of $500,000 or more. The analysis is conducted by the Federal-aid and Design Division, Office of Engineering, of the Federal Highway Administration. FHWA CBPI nationwide values are published in the Federal Highway Administrations’ annual “Highway Statistics” series *[13]*. Values of the FHWA CBPI for individual states can be obtained on request from the Office of Engineering of FHWA (tel: 202 366 4636).

A FHWA Bid Price Index can be calculated for individual pay items or it can be calculated for sets of pay items collectively. A FHWA Bid Price Index for an individual pay item is estimated using the following formulation:

$$FHWA\ BPI_{in} = \frac{\overline{P}_{in} \cdot Q_{ib}}{\overline{P}_{ib} \cdot Q_{ib}} .100$$

where,

$FHWA\ BPI_{in} =$ FHWA Bid Price Index of item i in year n.

$\overline{P}_{in} =$ average price of item i in year n (\$ / unit).

$Q_{ib} =$ total quantity of item i in base year b (units).

$\overline{P}_{ib} =$ average price of item i in base year b (\$ / unit). (1)

A Bid Price Index (BPI) for two or more pay items is established by determining the weighted average price of the respective items. For example, an index representing the price of road surfacing is obtained by summing the product of price and quantity of Portland Cement Concrete surfaces and bituminous concrete surface pay items in the numerator and denominator of the formulation shown in equation 1. Similarly, a BPI for structures is obtained by summing the products of price and quantity of structural reinforcing steel, structural steel, and structural concrete.

The FHWA CBPI is the index representing the highway construction costs as a whole and is obtained by summing the products of all six representative pay items in the numerator and denominator as shown in equation 2 below:

$$FHWA\ CBPI_{n} = \frac{\sum_{i=1}^{6} \overline{P}_{in} \cdot Q_{ib}}{\sum_{i=1}^{6} \overline{P}_{ib} \cdot Q_{ib}} .100$$

where,

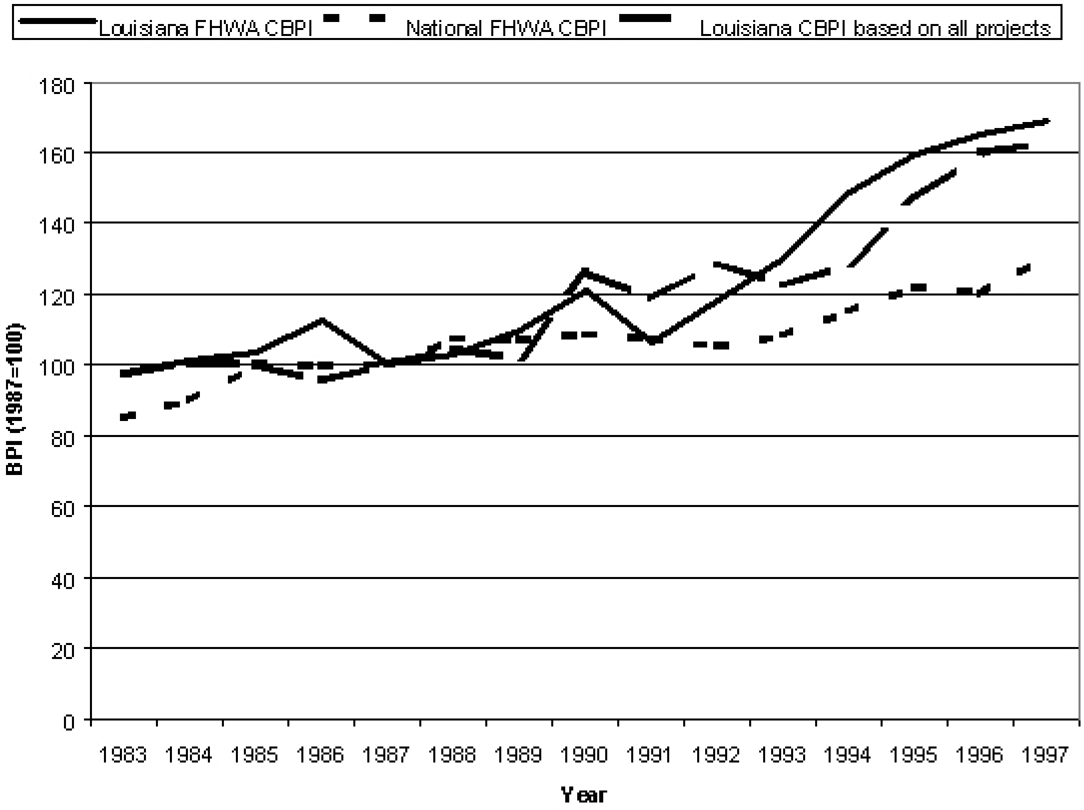
$FHWA\ CBPI_{n} =$ FHWA Composite Bid Price Index for year n. (2)

Since the FHWA Bid Price Indices are based only on those projects that receive federal aid and have contract amounts equal to or greater than \$500,000, it may be questioned whether the index provides a representative indication of construction costs overall. In Louisiana between 1980 and 1997, almost 39 percent of all contracts were for amounts under \$500,000 although expenditure on these contracts totaled only 4.6 percent of all contracts let during that period. Using the same formulation as that used in the

FHWA Composite Bid Price Index but including all contracts in Louisiana, a new Composite Bid Price Index for Louisiana was produced. As shown in figure 3, the values for this index are similar, but not identical to, the values for the Louisiana FHWA CBPI.

Figure 3
Bid price indices, 1983-1997

As a further comparison, the FHWA CBPI for the nation is included in figure 3. It shows that there is a greater difference between the national and Louisiana FHWA CBPI than there is between the Louisiana FHWA CBPI and the Louisiana CBPI using all contracts. Study of the results of the FHWA CBPI values for other states (not shown here) confirm that these results are typical; CBPI values vary from state to state and are not well represented by the national average. This confirms that construction cost trends cannot be usefully inferred from national averages; local conditions, policies, and practices are likely to affect local construction costs.



The FHWA Bid Price Index is calculated based on quantities in a chosen base year or base period. Since its inception in 1933, five different bases have been used for the FHWA BPI *[12]*. The first was the base period of 1925-1929, the next was the period 1957-1959, followed by single base years in 1967, 1977, and 1987 *[14], [12]*. The base establishes the weight assigned to each representative pay item in compiling the index. The large volume of contracts let nationwide in the last 40 years allows the quantities of pay items in individual years to be representative of the relative importance of each pay item. However, at state level, construction programs may vary from year to year making pay item quantities unique to a year rather than representative of construction in general over a period of time. Thus, at state level, it may be more appropriate to use a base period rather than a base year, as was done with the federal index in earlier years.

Overall trends in construction costs are conveniently described in terms of indices. However, as argued above, existing indices may not reflect construction costs in Louisiana well. Subsequently, it was decided to establish a local highway construction index which uses an appropriate base period and uses pay items that are representative of conditions in Louisiana.

Appropriate pay items are identified by first observing which construction sections experience major expenditure, and then identifying a pay item that is representative of each section. From data of highway contracts in Louisiana between 1980 and 1999, the ten highest expenditure sections in highway construction are shown in table 1 in order of magnitude. It is interesting to note that the six construction sections represented in the FHWA BPI correspond to the first, second, third, fourth, fifth and ninth sections in table 1. However, it should be noted that the sixth, seventh, and eighth sections in table 1 cannot feature in an index formulation since their pay items are not expressed in units that permit comparison among contracts. Specifically, “mobilization” is usually measured as a lump sum. “Bearing piles” are measured in units of linear feet but costs are dependent on the diameter and type of pile (steel, timber, concrete). “Culverts and storm drains” are usually quoted per linear foot but costs vary depending on the size of the culvert or pipe and type of material used (concrete or corrugated metal). In contrast, “reinforcement” is bid in dollars per pound of steel which allows comparison among contracts irrespective of bar diameter. Thus, the six most prominent construction sections in Louisiana that can be used in compiling a construction index correspond to the six sections used in the FHWA BPI.

Table 1

Ten highest highway construction cost sections in Louisiana, 1980-1997

Section no.	Section name	Total expenditure	Percent of total	Cumulative % of total
501	Asphaltic Concrete Mixtures	$1,203,159,766	20	20
805	Structural Concrete	$692,093,505	12	32
203	Excavation and Embankment	$479,990,142	8	40
601	PCC Pavement	$328,060,381	5	45
807	Structural Metalwork	$300,969,665	5	50
727	Mobilization	$283,761,459	5	55
804	Bearing Piles	$240,211,011	4	59
701	Culverts and Storm Drains	$180,426,662	3	62
806	Reinforcement	$163,885,784	3	64
303	In-place Cement Stabilized Base	$129,225,045	2	67

To identify an appropriate pay item to represent each construction section in the index formulation, the most important pay items in each section were identified from the Louisiana data. Table 2 lists the three highest expenditure items in each of the selected construction sections. The item constituting the largest proportion of the total expenditure in a section is selected as the representative pay item provided its cost is expressed in units that are common among contracts. An example of a dominant pay item not expressed in comparable units is shown in section 807 in table

Table 2
Three highest pay items in each section

Section	Pay item	Unit	Total cost	%of total
501	Asphaltic concrete	Ton	$865,888,667	72
	Asphaltic concrete type 8F wearing course	Ton	$117,557,918	10
	Asphaltic concrete	cub. yd.	$53,881,408	4
805	Class AA concrete	cub. yd.	$245,485,940	35
	Class A concrete (Bents)	cub. yd.	$105,819,634	15

	Precast-prestressed concrete girders (type III)	lin. ft.	$83,316,313	12
203	Embankment	cub. yd.	$185,629,229	39
	General excavation	cub. yd.	$91,385,819	19
	Nonplastic embankment (Shell)	cub. yd.	$49,806,595	10
601	Portland Cement Concrete pavement 10"thick	sq. yd.	$70,596,373	22
	Portland Cement Concrete pavement 13"thick	sq. yd.	$45,275,894	14
	Portland Cement Concrete pavement 8"thick	sq. yd.	$31,972,605	10
807	Structural metalwork	lump sum	$239,305,887	80
	Additional structural metalwork	lump sum	$39,671,073	13
	Structural metalwork	lump sum	$15,076,431	5
806	Deformed reinforcing steel	lbs.	$151,172,520	92
	Epoxy-installed deformed reinforcing steel	lbs.	$7,040,093	4
	Deformed reinforcing steel	lbs.	$4,048,277	2

2. There, all three main pay items are expressed in terms of lump sum cost for each individual contract making comparison of these pay item prices among contracts impossible. In fact, since these pay items constitute more than 98 percent of the expenditure on structural metalwork in the data, insufficient comparable pay item prices of structural metalwork exist to include it as section in a local construction price index. As a result, the number of construction sections used in constructing a Louisiana construction index was five rather than the six used in the FHWA BPI.

Based on the information in table 2, the representative pay items shown in table 3 were selected to represent five construction sections used to develop a new Louisiana Highway Construction Index (LHCI). The five construction sections, their representative pay items, and the corresponding pay items in the FHWA CBPI are shown in the table. It is interesting to note the representative pay items in the LHCI and FHWA indices are virtually identical with the exception of the use of “embankment” in the LHCI instead of “excavation” used in the FHWA CBPI. Plausibly, while embankment expenditures are higher than excavation in the rest of the country, embankment expenditures outstrip that of excavation in Louisiana because of the flat terrain and high water table.

Table 3
Comparison of representative pay items in LHCI and FHWA CBPI

Construction section	LHCI representative pay item	FHWA CBPI representative pay item
Asphaltic concrete mixtures	Asphaltic concrete	Bituminous concrete surfaces
Structural concrete	Class AA concrete	Structural concrete
Excavation and Embankment	Embankment	Common excavation
Portland Cement Concrete Pavement	Portland Cement Concrete pavement 8", 9", & 10"thick	Portland Cement Concrete surfaces 8", 9", & 10"thick
Reinforcement	Deformed reinforcing steel	Structural reinforcing steel

For the Portland Cement Concrete pavement section, the LHCI makes use of the same representative pay item as that used in the FHWA CBPI , namely eight, nine and ten inch thick pavements, with unit costs scaled to dollars per square yard of equivalent nine inch thick pavement. That is, costs for eight inch thick P.C.C. pavements were scaled up by 12.5 percent and ten inch thick P.C.C. pavement costs were scaled down by ten percent to represent the cost of equivalent nine inch thick pavement in dollars per square yard. This increased the number of observations in the data sample.

The LHCI is formulated as follows:

$$LHCI_n = \frac{\sum_{i=1}^{5} \overline{P}_{i,n} \cdot Q_i}{\sum_{i=1}^{5} \overline{P}_{i,1987} \cdot Q_i} .100$$

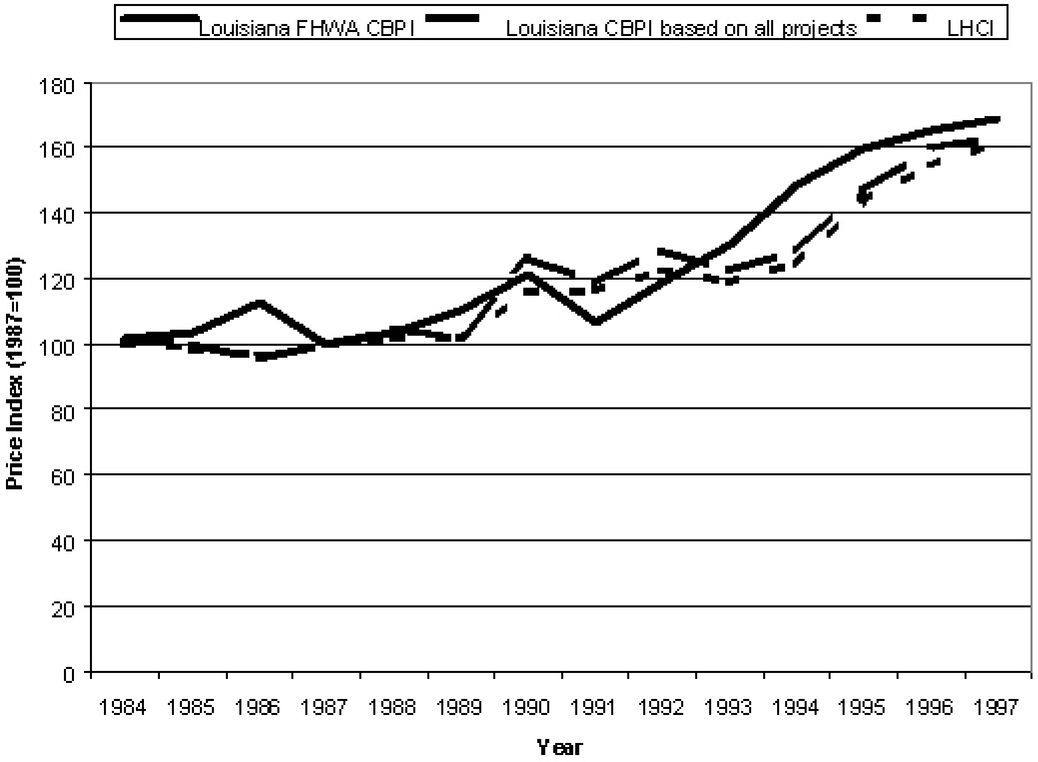
where,

$LHCI_n =$ *Louisiana Highway Construction Index for year n.*

$\overline{P}_{i,n} =$ *average price of representative item i in year n.*

$Q_i =$ *total quantity of representative item i in period 1981 - 1997.* (3)

In keeping with practice adopted in the FHWA CBPI, 1987 was adopted as the base year for the LHCI index. Subsequently, LHCI has a value of 100 in 1987. A base period from 1981-1997 was used to establish the quantities of the respective representative pay items in the LHCI. This allows the relative weight of each pay item to be dependent on the assignment of contracts in the state over an extended period of time.



The LHCI is graphed together with the Louisiana FHWA CBPI and the Louisiana CBPI based on all projects in figure 4. This shows a close comparison between the LHCI and Louisiana CBPI based on all projects. The LHCI was adopted as the overall measure of highway construction costs in Louisiana in this study.

Figure 4
Comparison of bid price indices

Construction cost indices have traditionally been used to portray past construction costs. However, they can also be used to reflect future construction costs provided representative pay item prices can be predicted. If this were done, it would provide a convenient, single-number measure of future construction costs that could be used in planning future construction programs. Such an index was formulated in this study. Its structure is similar to that used for past costs but depends on estimated average item prices rather than observed average prices. As a result, its values will be similar but not identical to that obtained from observed values. The estimated LHCI for future construction costs is defined as:

$$L\hat{H}CI_n = \frac{\sum_{i=1}^{5} \hat{\bar{P}}_{i,n} \cdot Q_i}{\sum_{i=1}^{5} \hat{\bar{P}}_{i,1987} \cdot Q_i} .100$$

$where,$

$L\hat{H}CI_n = \text{ estimated Louisiana Highway Construction Index in year } n.$

$\hat{\bar{P}}_{i,n} = \text{ estimated average price of representative pay item } i \text{ in year } n.$

$Q_i = \text{ total quantity of representative pay item } i \text{ in period 1981 - 1997.}$ (4)

Identifying factors influencing construction costs

In the LHCI, prices of five representative pay items are assumed to reflect the cost of highway construction in Louisiana in general. Thus, factors that affect the price of these five representative pay items can also be assumed to be factors that affect construction costs in general. This assumption has been made in this study and forms the basis of the method used to identify the factors affecting construction costs.

The approach adopted in this study has been to observe past prices of representative pay items and the conditions prevailing at the time of the bid, and then to identify which conditions significantly influence bid prices. Conditions were described in terms of factor values such as the price of labor or equipment, contract amount, or geographic location. While this approach has the appeal that it relies on past evidence to identify factors influencing item prices, it has at least two shortcomings. First, observable, quantifiable conditions are only a subset of all factors influencing individual bid prices. It is known from the literature and experience that many of the factors influencing bid prices cannot be found in historical records. Factors such as a contractor's need to get a contract because he has no other work beyond the current assignment, or his belief that his company's expertise and capabilities fit in well with the proposed contract, or he likes working for a specific client, are all factors that are not recorded and are difficult to quantify but do influence bid prices. Second, only factors that have an impact on bid prices during the observation period can be identified as influential factors in this process. For example, if annual bid volume influences bid prices by altering the level of competition but bid volume does not alter during the observation period, no impact of that factor will be present in the observed bid prices. Thus, while a factor may be potentially relevant to bid prices, if no variation in the factor occurs during the observation period its influence will not be observed in the bid prices and it could erroneously be considered as irrelevant.

To counter the shortcomings of the proposed investigative process as much as possible, an effort was made to accumulate a comprehensive set of factors describing the conditions of each contract. Collectively, these factors were grouped into those that related to an increase in input costs due to inflation; those that reflect the characteristics of individual contracts, and those that describe the contract environment in which each contract was let. After review of several data bases, the following factors were included in the data to be analyzed:

- Inflationary factors:
    - price of labor
    - price of material
    - price of equipment
- Contract characteristic factors:

  - pay item quantity
  - contract duration
  - contract location
  - quarter in which contract was let
- Contract environment factors:
  - annual bid volume
  - bid volume variance
  - number of plan changes
  - changes in standards or specifications

Each of the above factors were quantified, together with bid prices, in the historical data used in this study. Forecast values of the inflationary factors were also available either as direct values or in terms of indicator variables that served as proxies for the factors. Future contract characteristic and contract environment factors had to be estimated by the user.

Quantifying the impact of influencing factors

Quantifying the impact of influencing factors involved identifying the relative contribution of each relevant factor to the final bid price of each representative item in the historical data. As noted in the introduction of this report, the traditional method of relating factor influences to bid prices in the past has been regression analysis. The linear relationship of linear regression can be restrictive in a case such as this, where several of the factors are not expected to have a linear impact on bid price. For example, due to economies of scale, pay item quantity, bid volume, and bid volume variance are expected to have a non-linear impact on price. However, even more serious is the fact that the impact that individual factors have on bid price are, generally, not additive. That is, the impact of individual factors on price is generally affected by the value of other factors in the expression, and therefore is not accurately measured by an additive expression. Formally, this is referred to as “interaction” and was observed to be very significant among the factors collected in this study. To accommodate interaction within linear regression, the common remedy is to add terms of the product of the factors displaying interaction. When the parameter of a product term is found to be significant, interaction between the two terms in the product is shown to be significant.

Since our effort to include as many relevant factors as possible in the relationship resulted in a large number of factors in the formulation, a linear additive function with a full set of interaction terms made the expression very comprehensive and complex. One alternative that was attempted was to use a formulation which was partly additive and partly multiplicative. This model gave improved results over an entirely linear additive model but required solution through an iterative non-linear regression estimation process that rapidly became time-consuming and unstable with the large numbers of factors in the expression. The model form which proved to provide the best fit to the data was a fully multiplicative formulation. This accommodated higher order interaction and provided an easy form for estimation since once the log is taken of the expression it reverts to a linear expression estimable with standard estimation procedures.

It was subsequently proposed that expressions relating factor values to bid item prices be described in multiplicative form. An equation was proposed for each of the five representative pay items which form the basis of the Louisiana Highway Construction Index. Generically, each equation was proposed to be of the following form with the potential of containing any or all of the factors shown.

$$P_{ikn} = \alpha . I_{ln}^{\beta_1} . I_{en}^{\beta_2} . I_{mn}^{\beta_3} . Q_{ik\in n}^{\beta_4} . D_{k\in n}^{\beta_5} . BV_{n-1}^{\beta_6} . BVV_{n-1}^{\beta_7} . P_{n-1}^{\beta_8} . \beta_9^{S_n} . \beta_{10}^{T_k} . \prod_{j=1}^{8} \beta_{j+10}^{L_{kj}}$$

where,

$P_{ikn} =$ *price of representative item i of contract k in year n*

$\alpha, \beta_1 - \beta_{18} =$ *parameters*

$I_{ln} =$ *index value for labor in year n*

$I_{en} =$ *index value for equipment in year n*

$I_{mn} =$ *index value for material in year n*

$Q_{ik\in n} =$ *quantity of item i in contract k which was let in year n*

$D_{k\in n} =$ *duration of contract k which was let in year n*

$BV_n =$ *total bid volume of all contracts in year n*

$BVV_n =$ *bid volume variance in year n* $= (BV_{n-2} - BV_{n-1})^2 + (BV_{n-1} - BV_n)^2$

$P_n =$ *number of plan changes in year n*

$S_n =$ *1 if new specifications or standards were in effect in year n, 0 otherwise*

$T_k =$ *1 if contract k is let in the fourth quarter, 0 otherwise*

$L_{kj} =$ *1 if contract k is constructed in district j, 0 otherwise* $(j = 1, 2, \ldots . 8)$ (5)

The parameters β_1 to β_8 in equation (5) describe the sensitivity of the price of the item to the factors with which they are associated. Formally, the parameters are elasticities and, as such, reflect the percentage change in price that can be expected to follow a one percent change in the factor value with which the parameter is associated. The sign of the parameter indicates the resulting price change will be in the same direction as the factor change if the sign is positive, and in the opposite direction if the sign is negative. Elastic response is where the absolute value of the parameter is greater than one and indicates a price sensitive factor in that factor changes are more than proportionally matched by price change.

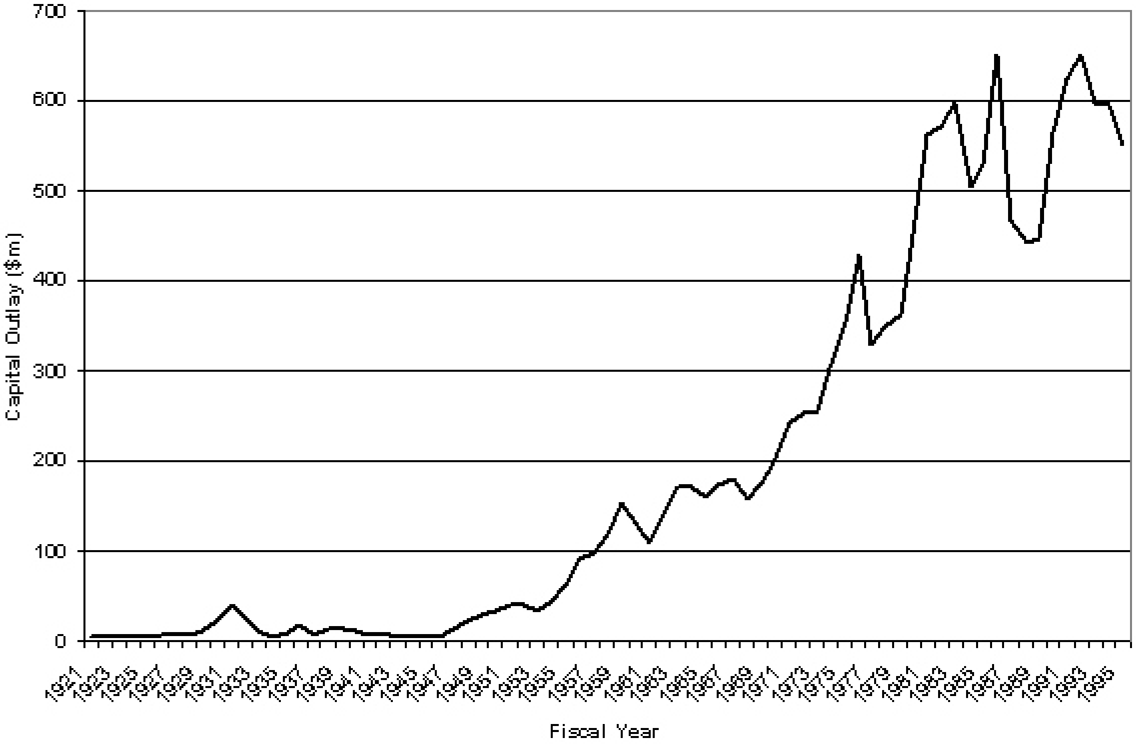
Parameters β_9 to β_{18} are associated with dummy (or binary) variables in the formulation. Dummy variables attain the value of one when a certain condition prevails and a value of zero when it does not. The parameter values β_9 to β_{18} are included in the formulation in such a manner that they are activated when the dummy variable value is one and attain the value of one when the dummy variable value is zero. Thus, their values reflect the proportional contribution of the dummy variable to the price of the representative item relative to the condition when the dummy variable is not in effect. For example, β_9 is associated with the dummy variable that attains the value of one when new specifications or standards are in effect, and zero otherwise. Thus, β_9 reflects the proportional change in item price due to the introduction of new standards or specifications. The deviation of the parameters β_9 to β_{18} from one can be interpreted as the proportional impact the respective variable has on the price of the pay item.

ANALYSIS

Past trends

Expenditure on highway construction in Louisiana has risen substantially over time. Percentage increase was the greatest following the Second World War but absolute increases were largest during the 1970's and early 1980's. Since the mid 1980's, expenditure on highway construction in Louisiana has stabilized in the region of $500 to $600 million annually. These trends are shown in figure 5 *[15]*. The values shown are in current dollars and therefore include the effect of inflation.

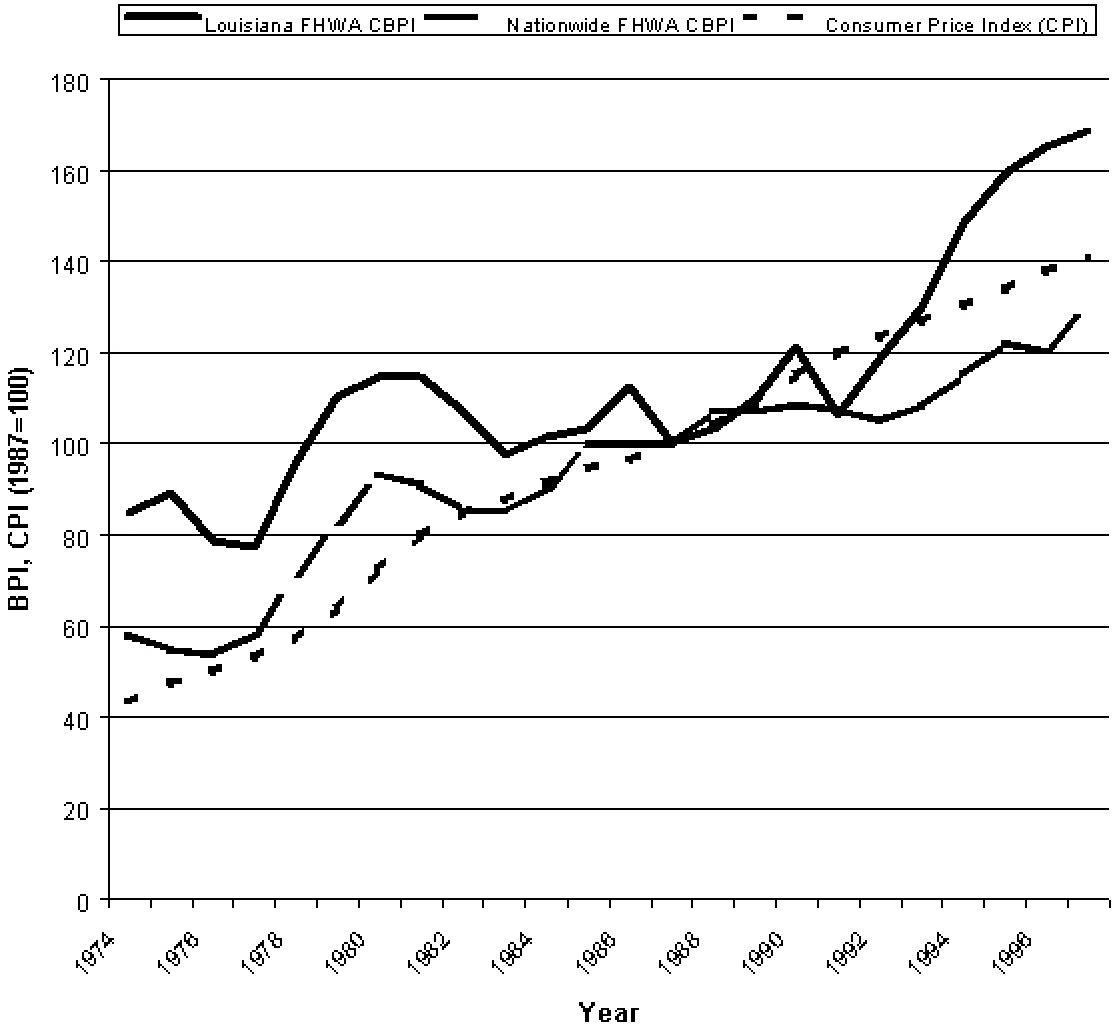
Figure 5



Louisiana state government capital outlay for highways, 1921-1995

Total expenditure shown in figure 5 does not reflect a change in unit construction costs. As argued earlier, unit construction costs are most conveniently and accurately described in terms of construction cost indices. Nationally, highway construction costs measured in terms of construction cost indices have risen at approximately the same rate as general inflation. However, within that overall trend, construction costs have varied considerably on an annual basis. This is demonstrated in figure 6, where the trends in Consumer Price Index (CPI) and the FHWA's national CBPI since 1974 are shown *[16]*, *[17]*. Both indices are scaled to a value of 100 in 1987 for comparison purposes.

Figure 6
Bid price index and consumer price index values



A similar situation exists when comparing the Louisiana FHWA CBPI , the national FHWA CBPI and the CPI as shown in figure 6. Between 1977 and 1987, growth in construction costs in Louisiana were lower than the national average but mirrored the national fluctuation in costs. In the following decade, on the other hand, construction prices in Louisiana deviated from national trends and rose 1.6 times faster than the rate of inflation and at an even faster growth rate when compared to the national growth in construction costs. Specifically, between 1987 and 1997, the Louisiana FHWA CBPI rose almost 70 percent compared to a 41 percent growth in CPI and 31 percent growth in national FHWA BPI in the same period.

The trends in figure 6 show that unit construction prices vary by period and location, and that the general rate of inflation is not a good predictor of construction costs. The more erratic change in construction index values when compared to the trend in general inflation shows there are significant influences, other than inflation, that affect highway construction costs.

The rapid rise in highway construction costs in Louisiana since 1992 was the main reason the study documented in this report was initiated. In keeping with the strong evidence that general inflationary trends were only a part of this growth, the search was extended to other contributory factors affecting construction costs.

Data

The data used in this analysis was obtained from a variety of sources. The main data were compiled from records of highway and bridge contracts let by Louisiana DOTD between 1980 and 1997. Supplemental historical and forecast data were also obtained from public sources such as the Department of Labor and Department of Commerce as well as from private vendors.

The data obtained from DOTD consisted of four separate data files. The first contained information on 2,927 contracts let by the department during the period 1980-1997. Information such as contract number, contract price, type of construction, functional class of facility, letting date, and duration of the contract was included in the contract data file. A full description of the variables in the file is provided in appendix A. To gain an appreciation of what the data file looks like, a copy of the first 46 lines of this file is included in appendix B, table B1.

The second file contained information on individual pay items in each contract. Pay items are individual components of construction for which prices are proposed by the contractor (i.e. they are bid) at the time of preparing a contract estimate. The file contained information on 119,607 individual pay items from the same contracts listed in the contract data file. Information in the file included unit price of the item, the unit in which the item was measured, item quantity, item description, the contract number to which the item is related, and price adjustments, if any. A full description of the variables in the file is attached in appendix A. A copy of the first portion of the file is also shown as table B2 in appendix B.

The third file consisted of information documenting contract plan changes. It contained information on 20,107 plan changes to contracts listed in the contract data file. The file included information on contract number, description of the change, total change in cost, change in contract days, and other information related to the contract change. A description of all the variables in the file is attached in appendix A. The first portion of the file is shown as table B3 in appendix B.

The fourth file contained information on 75,592 plan changes to items in the pay item data file. This file included information on contract number, item description, unit cost, original and revised total cost of the item, and original and revised quantity of the item. A description of all variables in the file is attached in appendix A. The first portion of the file is shown as table B4 in appendix B.

The four files above were checked for errors by first observing the range of values in each variable. Observations outside the feasible range were inspected. Second, consistency in units of measurement were ensured. Only those observations that were reported in the same units, or those that could be transformed into common units, were retained. Third, contracts which counted weekends and holidays as normal working days (one percent of all contracts in the data base) were omitted since unit costs are likely to be inflated due to higher labor costs. Lastly, within the pay item data file, outliers of unit costs were omitted. Outliers were identified by assuming unit costs to be normally distributed within each year and values with less than ½ percent chance of belonging to the population being labeled as outliers. This involved identifying those unit costs whose standard normal deviate had an absolute value greater than 2.575. The standard normal deviate *z* of the unit costs was calculated by:

$$z_{in} = \frac{p_{ink} - \bar{p}_{in}}{\sigma_{in}}$$

where,

$z_{in} =$ *standard normal deviate of unit cost of item i in year n.*

$p_{ink} =$ *unit cost of item i in year n in contract k.*

$\bar{p}_{in} =$ *average unit cost of item i in year n.*

$\sigma_{in} =$ *standard deviation of unit costs of item i in year n.* (6)

Data were also collected from officials within the DOTD regarding changes to construction standards, specifications, or practice during the period 1980-1997. Interviews were conducted with long-serving engineers familiar with construction practice in the department. The consensus from those interviewed was that while several gradual changes in construction practice had occurred during the period 1980-1997, a change in contract specifications in 1992 had a noticeable effect on the bid price of asphalt concrete. The gradual changes that had occurred were that an increasing percentage of crushed stone had been used in the base course of roads in place of shell during the observation period, pavement designs had become heavier due to increasing traffic volumes, paving under gaurdrails (to facilitate mowing) and temporary striping had increased as standard practice, and more attention had been given to erosion control and gaurdrail end-treatment in recent times. There was also the observation that proportionally more contracts were let in the fourth quarter of each fiscal year than in the other quarters, and that this situation probably generated higher bid prices during the fourth quarter than in other quarters. The reason more contracts were usually let in the fourth quarter was that each year some scheduled projects were delayed and the need to let all budgeted contracts within a fiscal year resulted in a larger proportion being let in the last quarter.

Data were also obtained from several external sources. Records of the Consumer Price Index for the period 1974-1997 were obtained from the Department of Labor. This information was used to compare the general rate of inflation to price trends in highway construction. Historical price trends in highway construction were obtained from the FHWA in the form of their CBPI and from Engineering News Records' Construction Cost Index. The Bureau of Economic Analysis (BEA) of the Department of Commerce publishes historical records of employment and earnings by industry, thereby making it possible to estimate average earnings per worker in each industry sector. This information was used to determine the average annual wage of construction workers for each year in the period 1980 to 1997. The BEA also makes projections of future employment and earnings by industry, and this information was used to provide predictions of future construction worker wages. The historical and predicted worker wages were transformed into an index of construction labor cost with a value of 100 in 1987. Index values for the period 1981-2015 are shown in appendix C.

The cost of construction equipment and material were represented by closely-associated indicator variables for which historical and forecast data were available. The indicator variables selected to represent the price change in construction equipment and the different construction material areas are shown in table 4. Data on the indicator variables were obtained from a company specializing in forecasting industrial data, Data Resources Incorporated (DRI). The indicator variable values were transformed to an index with a value of 100 in 1987. Index values of the indicator variables for the period 1981-2015 are shown in appendix C.

Table 4
Indicator variables

Equipment and material items	Indicator variable
Construction equipment	Construction machinery
Asphaltic concrete	Refined petroleum products and construction sand/gravel/crushed stone
Embankment	Construction sand/gravel/crushed stone
Class AA concrete	Concrete ingredients and related products
PCC concrete pavement	Concrete ingredients and related products
Deformed reinforcing steel	Concrete reinforcing bars, carbon

Historical data describing the characteristics of each contract were obtained from the data bases described above. The quantity of the pay item in each contract was read directly from the item file containing information on individual pay items compiled from sources within DOTD. These quantities were expressed in tons for asphalt concrete, cubic yards for structural concrete and embankment, square yards of equivalent nine inch thick pavement for Portland Cement Concrete pavements, and pounds for reinforcement. Contract duration data was obtained from the contract data file obtained from DOTD and was expressed in days. Contract location identified the district in which the contract was let; the districts used were the nine DOTD districts in the state. The quarter variable was a dummy variable attaining the value of one in cases where the contract was let in fourth quarter of the fiscal year and zero otherwise. The contract data file was used to compile the quarter variable information.

The data describing the environment or circumstances in which the contract was let were obtained from a variety of sources. Annual bid volume and bid volume variance were derived from data in the contract data file from DOTD. The number of plan changes were obtained from the contract plan change data file from DOTD, while the change in standards and specifications was obtained from DOTD officials and was expressed as a dummy variable which attained the value of one for all contracts let from 1992 onwards and zero for all contracts let prior to 1992.

Model estimation

As described in the methodology, identifying and quantifying the effect of factors that determine highway construction costs was achieved in this study by observing the relationship that had been demonstrated in the past between construction cost and measurable contract conditions. Construction cost is described as the collective, weighted price of five representative pay items in the LHCI (equation three). Estimation involved fitting observed data to equations of the type shown in equation five to the observed data. Estimation was achieved by taking the log of each equation and using linear regression analysis to estimate the parameter values. Taking the log of a generic equation like equation five produces the following linear expression:

$$\begin{aligned} ln(P_{ikn}) &= ln(\alpha) + \beta_1 ln(I_{ln}) + \beta_2 . ln(I_{en}) + \beta_3 . ln(I_{mn}) + \beta_4 . ln(Q_{ikcn}) + \beta_5 . ln(D_{kcn}) + \beta_6 . ln(BV_{n-1}) \\ &+ \beta_7 . ln(BVV_{n-1}) + \beta_8 . ln(P_{n-1}) + S_n . ln(\beta_9) + T_k . ln(\beta_{10}) + L_{k1} . ln(\beta_{11}) + L_{k2} . ln(\beta_{12}) + L_{k3} . ln(\beta_{13}) \\ &+ L_{k4} . ln(\beta_{14}) + L_{k5} . ln(\beta_{15}) + L_{k6} . ln(\beta_{16}) + L_{k7} . ln(\beta_{17}) + L_{k8} . ln(\beta_{18}) \end{aligned} \tag{7}$$

Equations of the form shown above were used to estimate the parameters for each of the five representative pay item equations forming the basis of the measure of construction cost. Results from these estimations are shown in tables five through nine. In some cases, districts were grouped together when their individual parameter values were found to be similar during estimation. This simplified the equation by creating fewer variables. The variables selected for inclusion in the equations were those that intuitively are expected to influence item prices, and those that displayed the correct sign and were found to be significant.

The inflationary input cost variables of labor, equipment, and material, were included in virtually all cases even when they were not significant since input costs are expected to influence item costs. In those cases where one or more of them are expected to play only a minor role in price determination, such as equipment in structural concrete construction, they were omitted. The level of significance of the individual parameters is portrayed by the t-statistic in tables five through nine.

Table 5

Asphalt concrete equation estimation results

Factor	Estimated Parameter	Estimated Value	t-statistic	Parameter Value
Constant	$\ln(\alpha)$	-12.277	-7.0	$\alpha = 4.658 \times 10^{-6}$
Labor	β_1	1.632	6.1	$\beta_1 = 1.632$
Equipment	β_2	1.178	5.1	$\beta_2 = 1.178$
Material	β_3	0.167	1.7	$\beta_3 = 0.167$
Quantity of item	β_4	-0.124	-57.2	$\beta_4 = -0.124$
Duration of contract	β_5	0.069	17.0	$\beta_5 = 0.069$
Bid volume	β_6	0.042	2.2	$\beta_6 = 0.042$
Bid volume variance	β_7	0.030	5.0	$\beta_7 = 0.030$
No. of plan changes	β_8	0.093	5.1	$\beta_8 = 0.093$
New specifications	$\ln(\beta_9)$	0.128	3.7	$\beta_9 = 1.137$
Quarter	$\ln(\beta_{10})$	0.023	3.0	$\beta_{10} = 1.023$
Districts 2,3,4,7,& 8	$\ln(\beta_{composite})$	0.047	6.8	$\beta_{composite} = 1.048$

No. of observations = 2,094

Standard Error of the Estimate = 0.155

R-squared value for the estimated model = 0.72

Table 6
Structural concrete equation estimation results

Factor	Estimated Parameter	Estimated Value	t-statistic	Parameter Value
Constant	$\ln(\alpha)$	-0.388	-0.3	$\alpha = 0.678$
Labor	β_1	0.372	2.7	$\beta_1 = 0.372$
Material	β_3	1.022	7.0	$\beta_3 = 1.022$
Quantity of item	β_4	-0.078	-12.9	$\beta_4 = -0.078$
Districts 4 & 58	$\ln(\beta_{composite})$	0.107	5.5	$\beta_{composite} = 1.113$

Number of observations = 439

Standard Error of the Estimate = 0.170

R-squared value for the estimated model = 0.43

Table 7
Embankment equation estimation results

Factor	Estimated Parameter	Parameter Value	t-statistic	Parameter Value
Constant	$\ln(\alpha)$	-7.992	1.4	$\alpha = 3.382 \times 10^{-4}$
Labor	β_1	0.369	0.5	$\beta_1 = 0.369$
Equipment	β_2	1.771	1.7	$\beta_2 = 1.771$
Material	β_3	0.195	0.1	$\beta_3 = 0.195$
Quantity of item	β_4	-0.141	-11.0	$\beta_4 = -0.141$
Districts 4 & 8	$\ln(\beta_{composite})$	-0.234	-4.8	$\beta_{composite} = 0.791$

Number of observations = 459

Standard Error of the Estimate = 0.499

R-squared value for the estimated model = 0.42

Table 8
Portland Cement Concrete pavement estimation results

Factor	EstimatedParameter	Estimate Value	t-statistic	Parameter Value
Constant	ln(α)	-6.466	-3.0	α=1.555 x 10^{-3}
Labor	β_1	0.576	1.8	β_1= 0.576
Equipment	β_2	0.147	0.3	β_2= 0.147
Material	β_3	1.556	2.9	β_3= 1.556
Quantity of item	β_4	-0.091	-13.6	β_4=-0.091
Districts 5 & 61	ln($\beta_{composite}$)	-0.112	-3.8	$\beta_{composite}$=0.894

Number of observations = 212

Standard Error of the Estimate = 0.175

R-squared value for the estimated model = 0.59

Table 9

Reinforcement equation estimation results

Factor	Estimated Parameter	Estimate Value	t-statistic	Parameter Value
Constant	ln(α)	-7.238	-5.6	α=7.187x10^{-4}
Labor	β_1	0.467	3.2	β_1= 0.467
Equipment	β_2	0.717	5.7	β_2= 0.717
Material	β_3	0.234	1.5	β_3= 0.234
Quantity of item	β_4	-0.073	-22.1	β_4=-0.073
Bid volume variance	β_7	0.015	2.4	β_7= 0.015
District 4	ln(β_{13})	0.090	4.5	β_{13}=1.094
Districts 58	ln(β_{17})	-0.078	-2.7	β_{17}=0.925

Number of observations = 761

Standard Error of the Estimate = 0.208

R-squared value for the estimated model = 0.51

The individual equations were tested for autocorrelation, heteroscedasticity, and multicollinearity. Using the Durban-Watson statistic, no evidence of autocorrelation was detected in the equations. Evidence of heteroscedasticity was sought by plotting the residuals of the model predictions as a function of the dependent variable value. No evidence of heteroscedasticity was found among the equations. Multicollinearity was investigated using the Condition Index and Variance Proportions *[18]*. Significant multicollinearity was detected between the labor, equipment, and materials indices in all the equations. In the asphalt concrete equation, multicollinearity was also detected between these indices and bid volume variance and the standards and specification dummy variable. However, multicollinearity does not bias the estimators but serves only to increase their variance *[19]*. Thus, for predictive purposes, multicollinearity among the included variables is not a serious condition and is preferable to excluding a relevant variable which can result in bias to the parameters of the included variables. For this reason multicollinearity in the model was tolerated.

Model interpretation

The results in tables five through nine indicate that the most significant determinant of item prices in all equations is the quantity of the item in the contract. Its negative sign shows that item prices decline as quantities increase (as expected). The rate of decline in price reduces as quantities increase, resulting in very little further decline in price as quantities become very large. Intuitively, this reflects a realistic characterization of the effect of economies of scale on price. The magnitude of the parameter values for the quantity variable vary by equation, being largest in the embankment equation and smallest in the reinforcement equation. This reflects the greater potential for the effects of economies of scale in embankment construction, where larger equipment and prolonged use of the equipment can effect large savings, than can be achieved in reinforcement involving the bending and manual fixing of steel.

All equations identify that location has a significant impact on item price. However, districts that show a reduced or increased price over the others, vary by equation. In some cases, a district will display lower than average price on one item and higher on another. For example, in district 4 (Shreveport) the equation estimates that structural concrete item prices are, on average, 11.3 percent higher than in other districts, district 58 excluded, but embankment unit prices are only 79.1percent of the price in other districts with the exclusion of district 8.

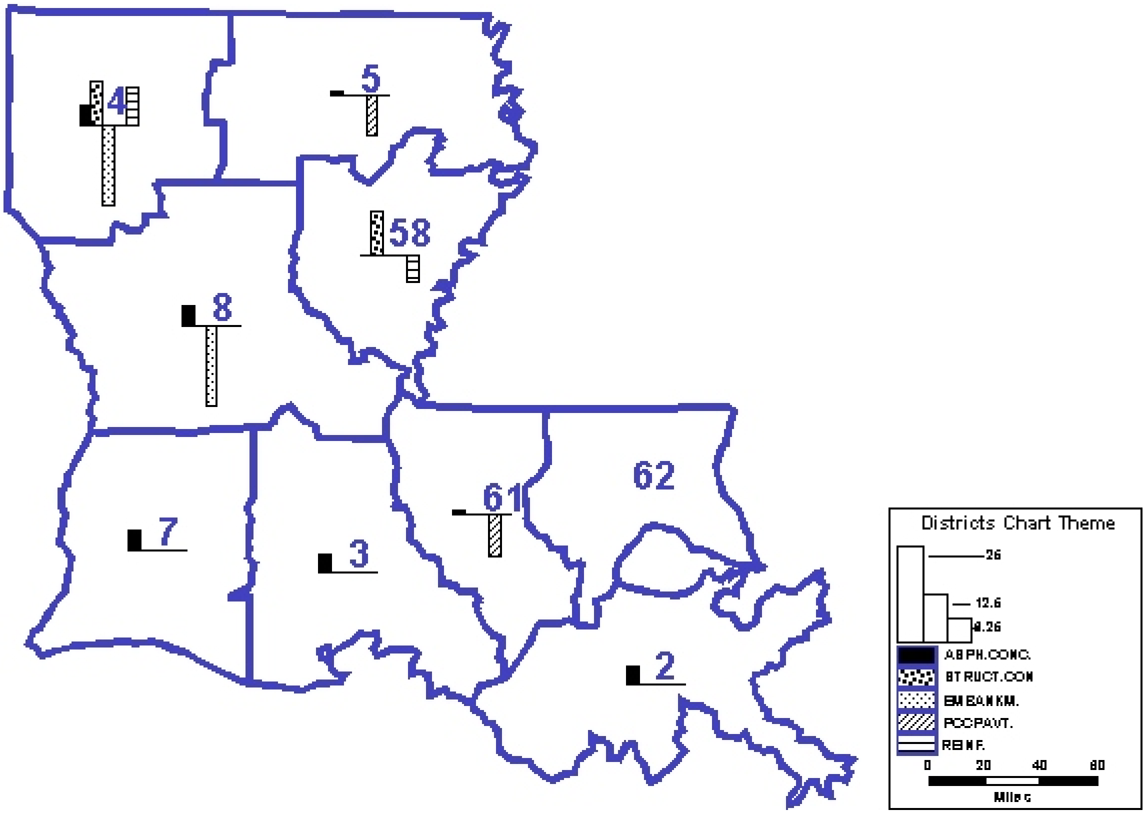


Figure 7
Impact of location on item prices

The percentage difference in estimated item price of each representative pay item in each district is shown in figure 7. The vertical bars in the figure show the positive and negative percentage difference in item price in each district relative to the price in those showing no change. District numbers are shown in bold numerals.

Analyzing the district differences shows some interesting trends. First, asphalt concrete is shown to be marginally more expensive in the southern and western districts of the state. One possible explanation is that they are further removed from the production points of asphalt at the refineries on the Mississippi river and less accessible to the sources of aggregate. Another interesting trend is that embankment is considerably cheaper in the northwestern districts of Shreveport and Alexandria (districts 4 and 8, respectively) than in the other distiicts. These districts have less wetlands than other districts and are likely to be able to use more in-situ material, on average, for embankments than is the case in other districts. Other differences between districts are more difficult to rationalize including the lower cost of Portland Cement Concrete pavement in Baton Rouge and Monroe districts (districts 61 and 5, respectively).

The parameter values for the factors measuring the input costs to construction (labor, equipment and material) vary considerably among the equations. Generally, their values seem reasonable but the confidence limits of the parameter values are large due to the high multicollinearity that exists among these factors. As a result, there is a greater chance that the estimated values may be different from the true parameter value although there is no tendency for the estimated value to be greater or smaller than the true value (i.e. no bias exists). Therefore, too much emphasis should not be placed upon the specific value of the estimated parameter for labor, equipment and material obtained in this study.

Only the asphalt concrete equation displayed an influence of an extended set of factors on item price. Contract duration, bid volume, bid volume variance, number of plan changes, new specifications and standards, and quarter all produced parameters that were significant and had the expected sign. The model captured 71 percent of the observed variation in individual contract asphalt concrete prices, suggesting that many of the factors influencing the price of asphalt concrete were included in the model.

In the asphalt concrete equation, contract duration is shown to increase bid price as contracts become longer. This is expected since longer contracts increase the uncertainty of input costs. However, the response is highly inelastic; a one percent increase in contract duration results in only a 0.069 percent increase in item price.

Bid volume, the total amount let in contracts in each fiscal year, is shown to increase the item price of asphalt concrete with increasing values. This is expected since increasing bid volume reduces the level of competition among contractors which, in turn, leads to higher item prices. However, the model suggests the response of item price to bid volume is highly inelastic with a one percent increase in bid volume leading to only a 0.042 percent increase in bid price.

The asphalt concrete equation suggests that bid volume variance, the amount of fluctuation in total bid price from year to year, also has the impact of raising asphalt concrete bid prices although its influence is not as great as bid volume. A one percent increase in bid volume variance will, according to the model, result in a 0.03 percent increase in the bid price of asphalt concrete.

The number of plan changes is expected to increase bid price due to the anticipated difficulties plan changes represent to the contractor. In the asphalt concrete equation, a one percent increase in plan changes is expected to raise the bid price of asphalt concrete by 0.093 percent. While this is a highly inelastic response, comparison of its value with that of contract duration, bid volume, and bid volume variance, show that it is a more influential factor than these other factors.

The dummy variable for new specifications and standards tests for an incremental difference in item price for contracts let after 1991. The model estimation results show that, on average, unit bid prices of asphalt concrete were 12.8 percent higher from 1992 onwards than they were prior to that date. This measures all change between these two periods and is not only the result of the change in specifications in 1991 but all the changes in construction practice in the second period relative to the first.

The expectation that item prices of contracts let in the fourth quarter of the fiscal year are incrementally higher than those let in other quarters is borne out by the results of the model estimation for asphalt concrete prices. The estimation results show that, on average, contracts let in the fourth quarter have bid prices for asphalt concrete 2.3 percent higher than those let in other quarters.

Model validation

The model was validated by comparing the estimates that emerged from the equations with the observed item prices in the historical data. This reflects the equations' ability to reproduce the individual pay item prices on which they were calibrated. As an example of the results obtained, the prices of the first 15 cases in each data file are shown in table 10. Overall, the average difference between observed and estimated individual item prices were 21, 17, 45, 19, and 25 percent for asphalt concrete, structural concrete, embankment, PCC pavement, and reinforcement, respectively, when measured by Root-Mean-Square-Error (RMSE). The high percentage RMSE for embankment reflects individual large variations between the model prediction and those observed from past contracts. This probably occurs because the model does not consider the line haul distance of the material being used in the embankment, the difficulty of obtaining the material and the soil conditions at the site of construction.

Table 10

Observed and estimated individual item prices

Asphalt concrete ($/ton)		Structural concrete ($/cub.yd.)		Embankment ($/cub.yd.)		PCC pavement ($/sq.yd.)		Reinforcement ($/lb.)	
Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.
46	48	300	244	3.50	3.16	28.13	29.42	0.40	0.39
41	36	190	229	1.90	2.27	36.00	29.26	0.35	0.33
45	51	250	226	4.00	4.53	25.92	25.41	0.50	0.45
35	39	350	274	2.50	4.01	35.10	25.52	0.42	0.33
50	50	300	240	3.50	3.42	22.50	25.83	0.40	0.39
26	29	197	186	10.00	3.69	40.00	35.34	0.35	0.40
19	26	385	271	1.24	1.42	25.88	24.54	0.50	0.46
26	25	365	250	7.50	2.37	22.16	21.19	0.60	0.50
26	26	225	216	5.00	3.13	21.99	19.07	0.38	0.38
35	49	246	235	0.73	1.63	30.00	24.22	0.45	0.53
28	28	245	199	1.59	1.82	46.13	39.32	0.32	0.40
28	28	325	258	3.25	2.69	42.00	33.03	0.37	0.34
33	34	242	225	4.00	2.76	23.40	23.58	0.50	0.50
30	26	200	251	4.00	2.44	20.70	24.96	0.33	0.42
25	31	236	215	3.00	2.14	23.40	19.79	0.40	0.40

The results in table 10 indicate that the equations are not very good at estimating the price of items at individual contract level. This is expected because many qualitative factors affecting individual item bid prices do not appear in the model. However, the purpose of the individual equations is to identify overall costs of construction and at that level they do a much better job. This is shown in table 11 where annual estimates of LHCI using price estimates from the equations are compared to the LHCI values estimated using observed prices. As can be seen, the estimated values approximate the observed values fairly closely. A chi-squared test of the similarity of the predicted and observed values in table 11 showed that the similarity of the values could not be rejected at the 99 percent level of significance.

Table 11

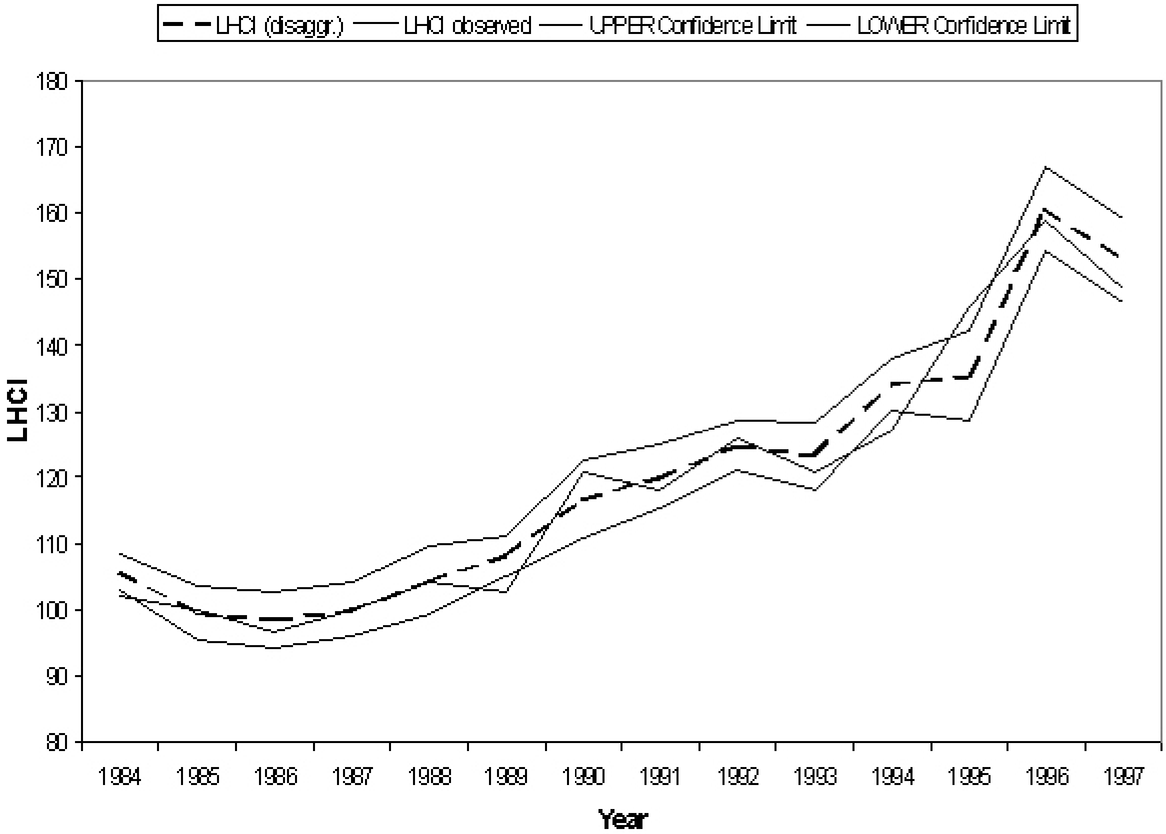
Observed and estimated LHCI values, 1984-1997

Letting year	Louisiana Highway Construction Index (LHCI)	
	Observed	Estimated
1984	102	106
1985	100	99
1986	97	98
1987	100	100
1988	104	104
1989	103	108
1990	121	117
1991	118	120
1992	126	125
1993	121	123
1994	127	134
1995	146	135
1996	159	160
1997	149	153

A visual presentation of the results in table 11 are shown in figure 8. Included in the diagram is the 95 percent confidence limits of the estimated LHCI estimated under the conservative assumption that the prices of the representative pay items in the LHCI are indepedent. To the extent that they are not independent and are positively correlated, the plotted confidence limit would be wider than shown in the diagram. As can be seen, the observed LHCI values fall within the 95 percent confidence limit of the estimated LHCI the majority of the time. This demonstrates that provided input data is accurate, the model is capable of containing true LHCI values within its 95 percent confidence limit.

Figure 8
Observed and estimated LHCI, 1984-1997

When the model is used to estimate LHCI values in conditions in which data at individual contract level are not available, modifications have to be made to the way in which the model is applied. When individual contract-level data is not available, the only alternative is to use average or aggregate data that describes the overall conditions that will exist. However, using average values in place of individual values in non-linear expressions can produce large errors. This is because in non-linear models, the average of model estimates from individual observations are not the same as the model estimates from the average of individual observations values. Representative pay item equations are non-linear when the parameters β_1-β_8 are unequal to one.



In this study, the non-linearity of the equations are accommodated by approximating the non-linear function in each equation by a piece-wise linear function. For each non-linear factor in the equations, five intervals of values were established. For each interval, the average value was used to represent all values in the category. Describing the data on these factors involved specifying the proportion of items in each interval.

The need to establish intervals for input data is restricted to those factors that describe contract characteristics because input costs and contract environment factors are common to all contracts and subsequently only have a single value for each year. Thus, in the equations constituting the LHCI model only factors describing item quantity and contract duration have to be linearized in discrete intervals. To establish appropriate interval breakpoints, historical data of the particular factors for the period 1980-1997 were analyzed to identify five equal percentiles. The intervals obtained are shown in table 12.

Table 12
Contract characteristic factor intervals

Factor	Intervals
Quantity of asphaltic concrete (tons)	<2,000 2,000-7,000 7,000-12,000 12,000-20,000 >20,000.
Quantity of class AA structural concrete (yds^3)	<250 250-500 500-1,000 1,000-2,500 >2,500 yds^3.
Quantity of embankment material (yds^3)	<10,000 10,000-20,000 20,000-50,000 50,000-150,000 >150,000
Quantity of 9" thick Portland Cement Concrete pavement (yds^2)	<1,500 1,500-5,000 5,000-15,000 15,000-35,000 >35,000
Quantity of deformed reinforcing bars (lbs)	<4,500 4,500-40,000 40,000-100,000 100,000-300,000 >300,000
Contract duration (days)	<40 40-50 50-80 80-180 >180

Aggregate conditions of factors represented as dummy variables in the equations are expressed as the proportion of contracts in each year for which the dummy variable is applicable. For example, the aggregate representation of the dummy variable for the quarter in which the contract was let is expressed as the proportion of contracts let in the fourth quarter in each year. Similarly, the aggregate representation of districts which have item prices different to others is the proportion of all contracts in those districts each year.

The estimation of pay item prices using aggregate data involves using the equation parameters shown in tables five through nine but accommodating the interval breakdown for the quantity and duration factors, and using proportions for quarter and district as described above. To illustrate, the equation to estimate the price of asphalt concrete using aggregate data is:

$$\hat{P}_{asphalt\ concrete,n} = \alpha .\, I_{l,n}^{\beta_1} .\, I_{e,n}^{\beta_2} .\, I_{m,n}^{\beta_3} .\, (q_{1,n}.1000^{\beta_4} + q_{2,n}.4500^{\beta_4} + q_{3,n}.9500^{\beta_4} + q_{4,n}.16000^{\beta_4} + q_{5,n}.30000^{\beta_4}).$$

$$(d_{1,n}.20^{\beta_5} + d_{2,n}.45^{\beta_5} + d_{3,n}.65^{\beta_5} + d_{4,n}.130^{\beta_5} + d_{5,n}.250^{\beta_5}).\, BV_{n-1}^{\beta_6} .\, BVV_{n-1}^{\beta_7} .\, P_{n-1}^{\beta_8} .\, \beta_9^{S_n} .\, (1 - t_n(1-\beta_{10})).$$

$$\prod_{j=1}^{8} (1 - l_{j,n}(1-\beta_{j+10}))$$

where,

$\hat{P}_{asphalt\ concrete,n} =$ estimated price of asphalt concrete in year n ($/ton)

$\alpha, \beta_1 - \beta_{18} =$ estimated parameters

$I_{l,n} =$ index value for labor in year n

$I_{e,n} =$ index value for equipment in year n

$I_{m,n} =$ index value for combined petroleum products and sand, gravel, and crushed stone in year n

$q_{m,n} =$ proportion of contracts with asphalt concrete quantities in the m^{th} interval in year n

$d_{m,n} =$ proportion of contracts with duration in the m^{th} interval in year n

$BV_n =$ total bid volume of all contracts in year n ($)

$BVV_n =$ bid volume variance in year n $= (BV_{n-2} - BV_{n-1})^2 + (BV_{n-1} - BV_n)^2$

$P_n =$ number of plan changes in year n

$S_n =$ 1 if new specifications or standards were in effect in year n, 0 otherwise

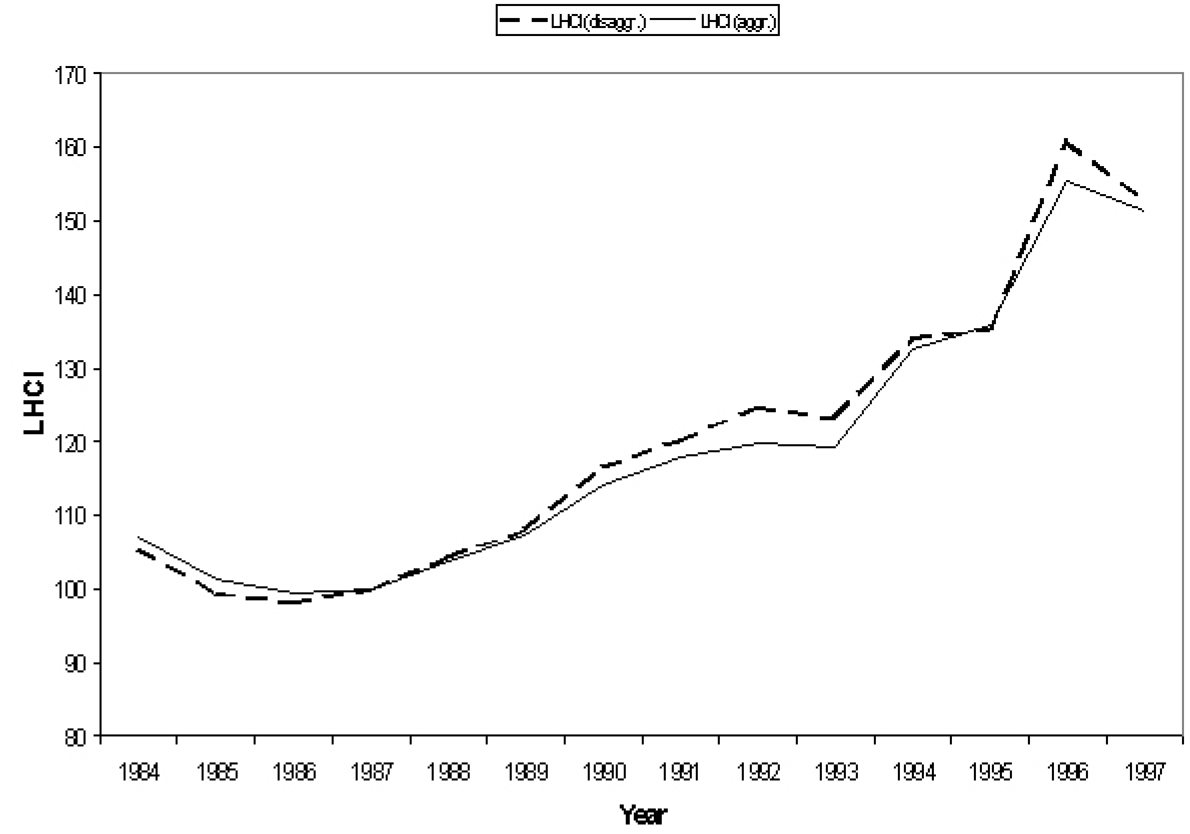
$t_n =$ proportion of contracts let in the fourth quarter in year n

$l_{j,n} =$ proportion of contracts in district j, $(j = 1,2,....8)$, in year n

(8)

Using aggregate data for the period 1984-1997, estimates were made of the LHCI. The predictions of LHCI from aggregate data are plotted together with LHCI values estimated from disaggregate data in figure 9. As can be seen, aggregate predictions closely approximate those obtained with disaggregate data.

Figure 9
Aggregate and disaggregate predicted LHCI values, 1984-1997



Sensitivity analysis

The relative contribution that each factor has in determining the estimated cost of construction, can be estimated through a sensitivity analysis exercise. Changing each factor in the representative pay item equations a specific amount and observing the impact on the estimated LHCI, allows identification of the most influential factors affecting change in constructon costs. It should be noted that the elasticities represented by the parameter values in the individual pay item equations provide the sensitivity of factor changes to individual pay item prices and not to LHCI as sought in this analysis.

The estimated percentage change in LHCI following a one percent change in each factor is shown in table 13. The impact of changes to location is shown for district 4 only because the impact is insignificant to the third decimal place for the other districts.

Table 13
Sensitivity analysis of factors affecting construction costs

Factor	Percentage change in LHCI
Labor	1.010
Equipment	0.994
Material	0.333
Quantity	0.119
Duration of contract	0.074
Bid volume	0.021
Bid volume variance	0.016
Number of plan changes	0.045
Change in specifications	0.059
Proportion of contracts in 4th quarter	0.003
Proportion of contracts in district 4	0.002

From table 13 it is clear that labor and equipment costs are the most significant factors determining construction costs. Each percent increase in labor or equipment cost is almost matched with the same percentage increase in construction costs. The cost of material is less influential in determining the overall cost of construction; each percent increase in material cost is matched with only one-third the comparative increase in construction costs. Collectively, input costs, as portrayed in the costs of labor, equipment, and material, are shown by the results in table 13 to be by far the most influential factors in determining the average cost of construction. Specifically, the results imply that input costs account for approximately 87 percent of the change in construction costs that result from a fixed percentage change in each of the factors. This result may not be an accurate representation of reality because the equations were constructed to always include input cost factors even when they were not significant whereas other factors were excluded when they were not significant. This can bias the results to suggest that input factors are more important in the determination of construction costs than they really are.

Input costs are factors over which state highway officials have little control. On the other hand, they do have control on many of the remaining factors in table 13. The results suggest that the most effective strategy officials could adopt to limit the increase in construction costs would be to increase the size of contracts and reduce their duration. However, this clearly must be done with discretion considering each contract individually. Indiscriminate increase of contract size or reduction in duration may, in reality, result in raising prices in certain cases. However an overall strategy of letting larger contracts or limiting the time to be taken on contracts (probably both in the same contract would be counter productive), promises to be the most productive strategy that can be adopted to limit the future increase in construction costs.

Those factors that form the general conditions in which contracts are let such as the bid volume, bid volume variance, number of plan changes in the previous year, changes in specifications, the proportion of contracts let in the fourth quarter and the proportion of contracts let in the different districts have relatively little impact on construction costs for incremental changes in their values. The most influential factor among this group is change in specifications which reduces construction cost by 0.059 percent for each one percent decrease in the change in specifications from those in power prior to 1992. If the new specifications, including new construction practice since 1992, were returned to those in operation prior to 1992, construction costs would be, according to the model, 5.9 percent lower than they currently are.

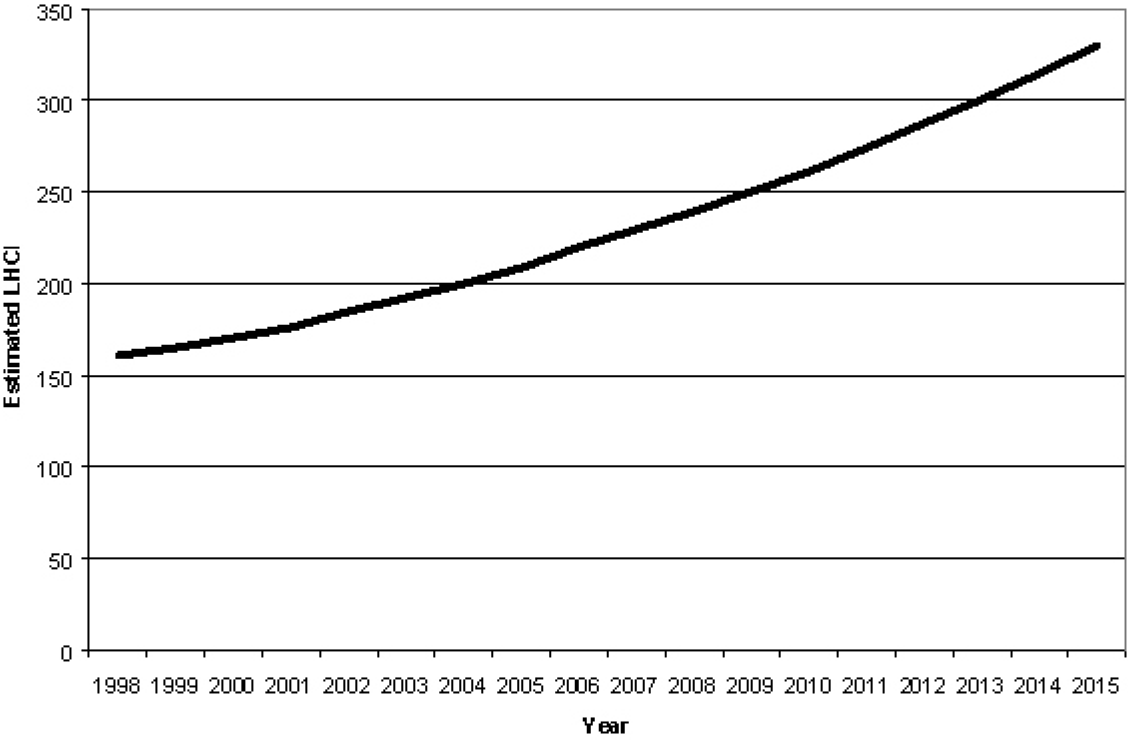
Model application

One of the advantages of identifying and capturing the major determinants of construction costs is the ability this provides to estimate future construction costs. This can be achieved by identifying the most likely future values of the factors in the five equations, estimating future pay item prices and using these to estimate a LHCI for each forecast year.

Future values of labor, equipment and material costs are expressed as index values obtained from external sources as described in the methodology section of this report, and reported in Appendix C. Given that no change is made to current practice, the most likely characteristics of future contracts, and the environment in which they are let are the same as existed in the past. Assuming, therefore, that the contract characteristics and contract environment that existed during the period 1993-1997 are maintained in the future, and the cost of labor, equipment and material are as forecast by DRI, estimates of LHCI can be obtained which reflect the most likely cost of highway construction in Louisiana in the period 1998-2015. The results of such an estimate are shown in figure 10.

Figure 10
Predicted LHCI, 1998-2015

According to the model, highway construction costs in Louisiana are estimated to rise significantly in the future. In fact, the rate of growth in the future is similar to the growth in highway construction costs experienced in Louisiana in the period 1987-1997. During that period, highway construction prices in Louisiana rose almost 70 percent whereas the model predicts prices will increase approximately 50 percent in the next decade and 100 percent in the period 1998-2015. Since the contract characteristic and contract environment factors are assumed to remain unaltered during this period, all of the predicted increase is due to the projected increase in the cost of labor, equipment, and materials.



The model can be used to estimate future construction costs under different scenarios. A scenario is a set of consistent conditions describing a feasible future state. By studying different scenarios, the construction costs associated with a range of feasible future states can be identified. By selecting the scenarios to span the range of likely future conditions, limits of future highway construction costs can be identified which are likely to include actual future values.

Table 14 describes an optimistic and pessimistic scenario of the future. These scenarios are intended to describe the limits of feasible conditions that are likely to exist in the future. In the optimistic scenario, the price of labor, equipment, and material is assumed to increase 20 percent less than forecast by DRI. In addition, the size of contracts are assumed to gradually increase over the period 1999-2003 from the level they had in the period 1993-1998 to sizes that are on average 20 percent larger. After 2003 they are assumed to retain their larger average size up to the year 2015. It is assumed that this increase in contract size will be achieved with no increase in average contract duration. Bid volume is assumed to reduce continuously by two percent per year from 1999 onwards. This maintains a competitive bidding environment among the contractors. Bid volume variance is assumed to reduce continuously by two percent per year from 1999 onwards as highway officials strive to establish a stable market environment. Plan changes are assumed to reduce continuously by two percent per year from 1999 onwards and the proportion of contracts let in the final quarter of each fiscal year is assumed to shrink by 20 percent from current levels from year 2000 onwards. The new specifications introduced in 1991 are considered to be maintained and the proportion of contracts in each of the nine districts is assumed to remain unaltered from what it was in the past.

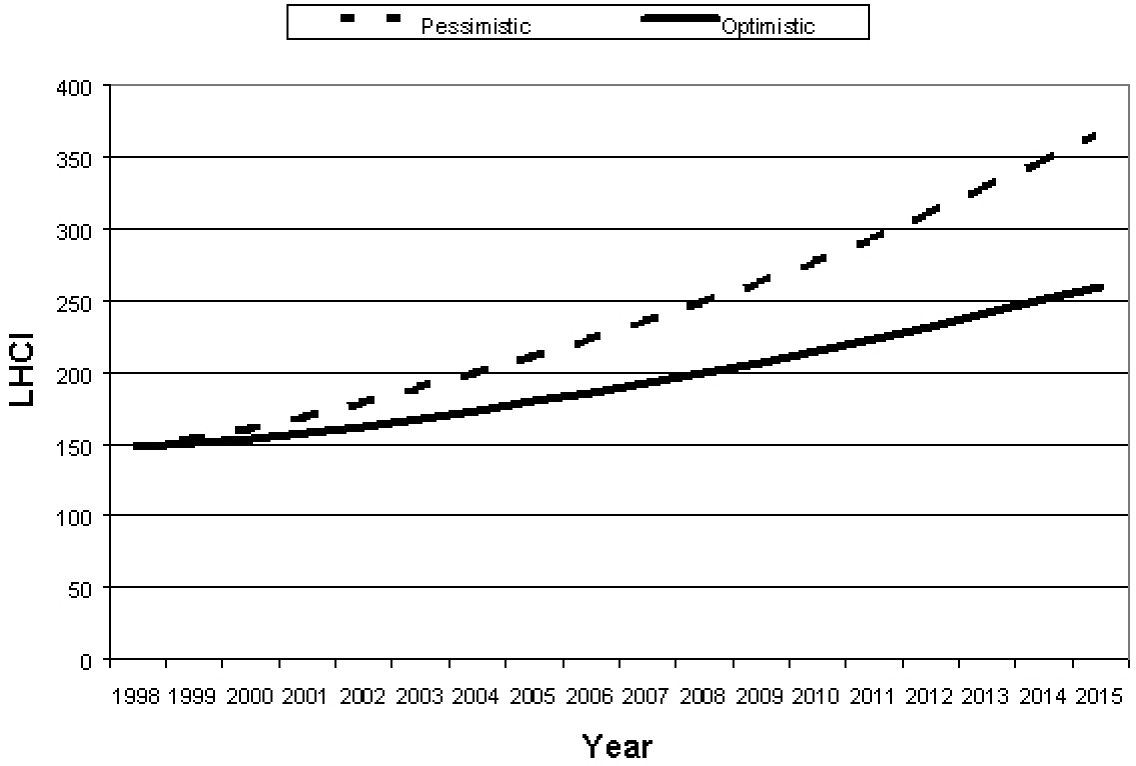
Table 14
Optimistic and pessimistic scenarios of the future

Factor	Percent change in factor values, 1999-2015	
	Optimistic scenario	Pessimistic scenario
Labor	20% lower growth in cost	20% higher growth in cost
Equipment	20% lower growth in cost	20% higher growth in cost
Material	20% lower growth in cost	20% higher growth in cost
Quantity of item	20% increase over 5 years (1998-2003) then kept constant	20% decrease over 5 years (1998-2003) then kept constant
Duration of contract	No change	No change
Bid Volume	2% decrease per annum	2% increase per annum
Bid Volume Variance	2% decrease per annum	2% increase per annum
No. of plan changes	2% decrease per annum	2% increase per annum
Letting in 4th quarter	-20%from 2000 onwards	+20% from 2000 onwards
New specifications	No change	No change
Proportion in districts	No change	No change

The pessimistic scenario is the reverse of the optimistic scenario; input costs are assumed to rise 20 percent more rapidly than current forecasts and it is assumed state officials are not able to manipulate contract characteristics and contract conditions to their advantage; in fact, they are assumed to deteriorate to the same degree they were assumed to improve under the optimistic scenario.

The results of the model’s predictions of LHCI values for the two scenarios are shown in figure 11. The results indicate that feasible limits of increase in highway construction costs to 2015 vary between approximately 75 and 150 percent of current prices. Thus, irrespective of what actions are taken by highway officials to contain highway construction costs, and even if input costs are 20 percent lower than anticipated, highway construction costs are likely to grow at least 75 percent between the years 1998 and 2015. If the impact of the actions taken by the highway officials are considered alone, LHCI values are reduced by 3.6 percent.

Figure 11
Optimistic and pessimistic prediction of LHCI, 1998-2015



CONCLUSIONS

The objective of this study was to observe past trends in highway construction cost in Louisiana, identify factors affecting construction costs, quantify their impact, and develop a means to estimate future highway construction costs. The findings of this study are summarized below together with the conclusions that can be drawn from the findings.

Past trends

Highway construction costs in Louisiana rose very slowly in the period 1978-1988 and then very rapidly during the next decade. By studying the data on item prices it can be seen that the main reason for this phenomenon was that petroleum product prices and construction worker wages decreased in real terms during the first decade of this period while the price of construction equipment, concrete, and reinforcement rose substantially in the second. Introduction of new contract specifications and contract practices increased highway construction costs in Louisiana by an estimated 5.9 percent from 1992 onwards, adding to the escalation caused by other factors.

Factors affecting highway construction costs

Using historical data of the cost of highway contracts, it was found that the following factors have influenced the cost of highway construction in Louisiana in the last two decades:

- cost of labor, equipment, and material
- contract size
- contract duration
- contract location
- quarter within the fiscal year in which the contract is let
- annual total bid volume
- variation in total bid volume from year to year
- number of plan changes
- changes in construction practice, standards, or specifications.

The above factors are limited to quantitative factors. Subjective factors are known to also affect prices on individual contracts but they are seldom measured or recorded. These include factors such as a contractors' liking of a particular client, a contractors' belief a particular contract fits in well with his company's skills and capabilities, the urgency of winning a new contract to keep all employees busy, the need to use expensive equipment that a contractor already owns, availability of funds to finance purchase of new equipment, etc. As influential as these subjective factors may be in determining the price of individual contracts, they have not been quantified in the past and, therefore, it is impossible to determine their impact on construction prices. However, their impact is likely to cancel out in the aggregate. For example, the impact of individual desirable clients are likely to be canceled out by the effect of undesirable clients, competitive conditions with uncompetitive conditions, and so on. Thus, while subjective factors were omitted from consideration in this study because no information on them was available, their omission was not expected to make a major difference to the results obtained at the aggregate level.

Quantifying the impact of factors affecting the cost of construction

The impact of factors on construction cost was estimated by fitting past data to equations relating factor values to the prices of five representative pay items of construction. The parameters of the equation showed the relative impact of each factor on the price of each representative pay item. The prices of the five representative pay items were combined into the LHCI.

The impact of changes in factor values on construction costs was determined through sensitivity analysis and found that, on a percentage basis, labor and equipment costs are the most influential. For each percent change in these factors, construction costs are expected to change by the same percentage amount. Change in material costs are expected to alter construction costs by only one-third the percentage change in material costs. Collectively, changes to the input costs to construction (i.e. the cost of labor, equipment, and material) are expected to account for approximately 87 percent of all changes to construction cost that result from incremental changes to factor values. However, the approach used in compiling the equations used in this analysis, and the high level of multicollinearity between input factors, could influence the magnitude of these numbers, making them less reliable than otherwise would be the case.

The impact of factors describing the characteristics of individual contracts are quite important. The most significant is the quantity of each representative pay item. This can best be described as the size of a contract since it is sensitive to quantity of each of the five representative pay items. For each percent change in contract size, construction cost is estimated to change 0.12 percent in the opposite direction. That is, for example, a contract that is twice the size of another will, on average, be 12 percent cheaper. Another contract characteristic that was found to be influential was contract duration. For each percent decrease in the duration of a contract, construction costs will, on average, decrease by 0.07 percent. This reflects the reduction in uncertainty on input costs as contracts become shorter and does not mean that insisting on completing contracts in a shorter period of time reduces costs; the estimation process used in this analysis ensures that only the impact of duration is reflected in the parameter values while the effect of other included variables, such as quantity, are removed.

Other contract characteristics, such as whether the contract is let in the fourth quarter or what district it is located in, have small influences. For each percent change in the proportion of contracts in the fourth quarter or the proportion of contracts in district 4 (Shreveport), construction costs are only expected to alter by 0.003 and 0.002 percent respectively. Thus, even if the number of contracts let in the fourth quarter are halved, construction prices are, on average, only expected to increase by 0.3 percent. Similarly, if the proportion of contracts in general were doubled in district 4, construction prices for the department would on average rise only 0.2 percent. However, these aggregate measures hide much at the disaggregate level. For example, the price of asphalt concrete is expected to be, on average, 2.3 percent cheaper when the contract is not let in the fourth quarter and reinforcement prices are expected to be, on average, 9.4 percent higher and embankment prices 20.9 percent lower when let in district 4 than in other districts.

The conditions existing at the time the contract is bid affects contract prices. The most significant of these factors is the contract specifications or contract practice in force. Changes in contract specifications and contract practice between the pre- and post-1992 period resulted in an estimated 13.7 percent increase in the price of asphalt concrete. No noticeable difference was observed on the price of other representative items. On average, the introduction of these changes resulted in an increase in the price of contracts in general of 5.9 percent. Besides the change in specifications in 1991, these changes were the gradual changes in construction practice such as the increasing use of aggregate rather than shell in the base course, heavier pavement designs, more attention to guard rail end treatment, paving under guardrail posts, etc.

Other factors describing the contract environment at the time of bidding is the number of plan changes in the previous year, the bid volume, and the variance in bid volume over the last couple of years. The analysis shows that each percent reduction in the number of plan changes stands to reduce the cost of construction by 0.045 percent. Thus, halving current levels of the number of plan changes could reduce construction cost by 2.25 percent. For bid volume and bid volume variance, each percent change is estimated to result in 0.021 and 0.016 percent change in construction cost. As bid volume and bid volume variance increase, construction prices are expected to increase. While state employees do not have much opportunity, or desire, to limit bid volume, stabilizing bid volumes from year to year so that bid volume variance is reduced does seem achievable. It would seem plausible to institute large reductions in bid volume variance with the establishment of a stabilization fund.

Estimating future costs of highway construction

It is estimated that highway construction costs will increase by approximately 108 percent in current dollars in the period 1998-2015. This represents an annual compound growth of 4.4 percent. This estimated increase in cost is due entirely to the expected increase in the cost of labor, equipment, and materials in highway construction and can, therefore, be thought of as the inflationary increase in the costs of highway construction. Given that the increase in revenues from fuel taxes in Louisiana has historically been one percent per annum in current dollars *[20]*, the department is going to have to contend with a budget that is effectively shrinking by 3.4 percent each year if construction receives the same proportion of funding as it has in the past. Thus, in broad terms, construction will be able to purchase approximately 71 percent of what it currently does in 10 years time and 50 percent of what it currently does in 20 years time. If the portion of the budget assigned to maintenance, administration, safety, or any of the other areas is increased, construction will have to contend with effectively even larger reductions in budget.

Recognizing that the future is not known with any certainty, alternative scenarios of the future were considered. An optimistic scenario where input costs grow 20 percent slower than anticipated and highway officials manage the contracting business in such a manner to contain costs wherever possible, leads to a projected 75 percent increase over current expenses by the year 2015, or 3.3 percent increase in current dollars per year. Given the one percent increase in fuel consumption, this still leaves an effective decrease in money available for construction of 2.3 percent per annum or purchasing power of 79 percent of current levels in 10 years time and 63 percent of current levels in 20 years time.

The impact highway officials can have on highway construction input costs is limited to factors they can change such as contract size, contract duration, proportion of contracts in the fourth quarter, location of contracts, number of plan changes, bid volume, bid volume variance, and contract specifications and practice. Some of these factors officials would not want to change or, if they did, they would only want to change them marginally. For example, the proportion of all contracts in each district is the outcome of a prioritization process and officials would not want to alter that to get a small advantage in construction costs. Similarly, changes in bid volume are more likely to be driven by other considerations and officials are likely to only effect marginal changes to improve construction costs. If the most favorable changes are made to all factors that can reasonably be considered as feasible, this reduces construction cost by an estimated 3.6 percent only. Thus, the conclusion is drawn that highway officials have little opportunity to limit the escalation in highway construction costs in the future.

RECOMMENDATIONS

It is recommended that:

1. DOTD use the projected increase in highway construction costs in this report to plan long-term construction programs.

2. DOTD estimate LHCI values each year from contracts let and compare them with model predictions to assess the performance of the model.

3. DOTD track the costs of construction labor, equipment, and materials to determine whether the forecast values of these items are correct.

4. DOTD institute measures to increase contract size and reduce contract duration where feasible, reduce the number of contracts let in the fourth quarter, stabilize bid volumes, and reduce the number of plan changes.

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APPENDIX A: DESCRIPTION OF CONTRACT DATA FILES

FIELD DESCRIPTIONS FOR CONTRACT.DBF FILE

Field Name	Type	Width	Contents
CONTRACT	C	11	Contract number XXX-XX-XXXX
NAME1	C	30	Contract Name - part 1
NAME2	C	30	Contract Name - part 2
DISTRICT	N	2	District Number (02, 03, 04, 05, 07, 08, 58, 61, 62)
PARISH	N	2	Parish Number (01 - 64)
FUNC_CLASS	N	2	Functional Class 01-RURAL PRINCIPAL ARTERIAL - INTERSTATE 02-RURAL PRINCIPAL ARTERIAL - OTHER 06-RURAL MINOR ARTERIAL 07-RURAL MAJOR COLLECTOR 08-RURAL MINOR COLLECTOR 09-RURAL LOCAL 11-URBAN PRINCIPAL ARTERIAL - INTERSTATE 12-URBAN PRINCIPAL ARTERIAL - OTHER FREEWAYS 14-URBAN PRINCIPAL ARTERIAL - OTHER 16-URBAN MINOR ARTERIAL 17-URBAN COLLECTOR 19-URBAN LOCAL SYSTEMS
ROUTE	C	8	Route Number (I-XXXX, LAXXXX, USXXXX)
EST_COST	N	12.2	DOTD Estimated Contract Cost
CONT_COST	N	12.2	Actual Contract Letting Cost
APPR_COST	N	12.2	Approved Contract Cost (Letting Cost + Plan Changes)
TODATECOST	N	12.2	Total Amount Earned to date by the Contractor
LENGTH	N	7.3	Length of the contract in miles
TYPE_CONT	C	20	Type of Contract (codes expanded in-line)
TYPE_DAYS	C	4	Type of Contract days (W-work days, C-Calendar days). On a Calendar-day job, every day is a work day, rain-or-shine, Saturday/Sunday/holidays included.
CONTR_DAYS	N	4	Original (letting) number of contract days
AMEND_DAYS	N	4	Amended contract days (original + plan change)
DAYS_USED	N	4	Actual contract days used.
DAYS_EXTD	N	4	Contract days extended beyond the approved days

			before liquidated damages will be charged.
DAYS_LIQUI	N	4	Actual number of days for which liquidated damages will be charged.
COMPDAYSLQ	N	4	Number of days the program computed for which liquidated damages should be paid. (Note: this is a new field which may not be valid for all contracts.)
COST_ASPH	N	9.4	The base cost of asphalt at the time of the contract.
COST_CEM	N	9.4	The base cost of cement
COST_GAS	N	9.4	The base cost of gas
COST_DIESL	N	9.4	The base cost of diesel
VAR_ASPH	N	6.4	The amount by which the cost of asphalt must vary (up or down) before which price adjust-ments will be paid for certain items. This is always .05.
VAR_CEM	N	6.4	Similar to VAR_ASPH
VAR_FUEL	N	6.4	Similar to VAR_FUEL
LET_DATE	Date	8	The date the contract was let.
CONTR_DATE	Date	8	The date the contract was signed.
FINAL_INSP	Date	8	The final inspection date
FINAL_ACCP	Date	8	The final acceptance date.
PCT_COMPL	N	5.1	Percent complete (todatecost / appr_cost)
LAST_UPD	Date	8	The last date the contract screen was updated. (This is not an important date.)
LIQUIDATON	C	1	A "1" indicates that liquidated damages will be charged.
METRIC	C	1	An "E" indicates that the job specifications are in English units. An "M" indicates metric units.
BEGMI	N	5.2	Beginning Logmile (From the TOPS system)
ENDMI	N	5.2	Ending Logmile (From the TOPS system)
NUM_LANES	N	2	Current number of lanes on that control-section. (From the Highway Needs file). (Note: the control-section is the first 5 digits of the project number: XXX-XX)
LANE_WIDTH	N	2	Current lane width on that control-section. (From the Highway Needs file).

FIELD DESCRIPTIONS FOR ITEM.DBF FILE

Field Name	Type	Width	Contents
CONTRACT	C	11	Contract Number XXX-XX-XXXX

ITEM_TYPE	C	1	0 - Force Account, Stockpile 1 - Regular item 2 - Special item
ITEM_NUM	C	16	Item Number
DESCRIPT1	C	50	Item Description part 1
DESCRIPT2	C	50	Item Description part 2
PAY_UNIT	C	12	Unit of measure (FEET, EACH, SQ YD, etc.)
DECIMALS	C	1	Maximum number of decimal places that the item quantity may be measured at.
UNIT_COST	N	9.4	The Unit cost of the item ($ / pay_unit)
CONT_QTY	N	8.4	The original contract quantity.
APPR_QTY	N	8.4	The current approved quantity (contract + plan change)
TODATE_QTY	N	8.4	The quantity used to date.
CONT_COST	N	9.2	The original contract cost.
APPR_COST	N	9.2	The current approved cost (contract + plan change)
TODATE_CST	N	9.2	The cost to date (based on todate_qty).
ASPH_ADJ	C	1	X - Indicates that asphalt price adjustments are allowed for this item.
CEM_ADJ	C	1	X - Indicates that cement price adjustments are allowed for this item.
FUEL_ADJ	C	1	X - Indicates that fuel price adjustments are allowed for this item.
DIESL_FACT	N	2.4	A factor used in determining the fuel price adjustments for the item. (see below)
GAS_FACT	N	2.4	A factor used in determining the fuel price adjustments for the item.
DATE_ADJUS	Date	8	If entered, this date is used for determining price adjustments instead of the contract date.
PRICE_ADJ	N	9.2	The total amount ($) of price adjustments paid for this item to date.

Price adjustments are computed as follows:

Fuel Price Adjustments:

F = G + D

where G = Gas Price Adjustment

D = Diesel Price Adjustment

$G = (C - U) \times Q \times F$
where G = Gas price adjustment
C = The current price of gasoline
U = Upper-limit of gas price = $B \times V$
where B = Base price of gasoline (contract date)
V = variance of gas (usually .05)
Q = Quantity of item to be adjusted
F = Gas factor (gallons per unit)

$D = (C - U) \times Q \times F$
where D = Diesel price adjustment
C = The current price of diesel
U = Upper-limit of diesel price = $B \times V$
where B = Base price of diesele (contract date)
V = variance of gas (usually .05)
Q = Quantity of item to be adjusted
F = Diesel factor (gallons per unit)

Asphalt Price Adjustments:
$A = (C - U) \times Q \times \% \times (1 + S)$
where A = Asphalt price adjustment
C = The current price of asphalt
U = Upper-limit of asphalt price = $B \times V$
where B = Base price of asphalt (contract date)
V = variance of asphalt (usually .05)
Q = Quantity of item to be adjusted
$\%$ = Percent of asphalt used in the mix
S = sales tax

FIELD DESCRIPTIONS FOR PLNCNG.DBF FILE

Field Name	Type	Width	Contents
CONTRACT	C	11	Contract Number XXX-XX-XXXX
PLAN_CNG	C	3	Plan Change Number
STATUS	C	1	A - Approved P - Pending D - Disapproved
OVER_UNDER	C	1	1 - overrun 2-underrun

ADD_DAYS	N	4	Number of contract days to be added
DESCRIPT	T	50	Description
AMOUNT	N	9.2	Total cost of plan change
RECD_CONST	Date	8	Date received by the Contruction Division
RECD_EST	Date	8	Date received by the Estimates Section

FIELD DESCRIPTIONS FOR PCITEM.DBF FILE

Field Name	Type	Width	Contents
CONTRACT	C	11	Contract Number XXX-XX-XXXX
PLAN_CNG	C	3	Plan Change Number
ITEM_TYPE	C	1	0 - Force Account, Stockpile 1 - Regular item 2 - Special item
ITEM_NUM	C	16	Item Number
DESCRIPT1	C	50	Item Description part 1
DESCRIPT2	C	50	Item Description part 2
PAY_UNIT	C	12	Unit of measure (FEET, EACH, SQ YD, etc.)
DECIMALS	C	1	Maximum number of decimal places that the item quantity may be measured at.
UNIT_COST	N	9.4	The Unit cost of the item ($ / pay_unit)
ORIG_QTY	N	8.4	The quantity before the plan change
ORIG_COST	N	9.2	The cost before the plan change
REV_QTY	N	8.4	The quantity after the plan change
REV_COST	N	9.4	The cost after the plan change
ASPH_ADJ	C	1	X - Indicates that asphalt price adjustments are allowed for this item.
CEM_ADJ	C	1	X - Indicates that cement price adjustments are allowed for this item.
FUEL_ADJ	C	1	X - Indicates that fuel price adjustments are allowed for this item.
DIESL_FACT	N	2.4	A factor used in determining the fuel price adjustments for the item. (see below)
GAS_FACT	N	2.4	A factor used in determining the fuel price adjustments for the item.

APPENDIX B: FIRST PORTIONS OF CONTRACT DATA FILES

Table B1: Portion of contract file

CONTRACT	NAME1	NAME2	DISTRICT	PARISH	FUNC_CLASS	ROUTE	EST_COST	CONT_COST	APPR_COST	TODATECOST	LENGTH	TYPE_CONT
001-01-0026	TEXAS STATE LINE-JUNCTION LA 5	26	4	9	7	US 80	2863000.00	3132968.78	3204479.05	3200543.36	9.337	05-ASPH OVLY ASPH PV
001-02-0022	MONKHOUSE DRIVE TO CURTIS LANE	(SHREVEPORT)	4	9	14	US 80	1116000.00	1292695.60	1192354.91	1195982.47	0.904	18-ASPHALT PVT REHAB
001-02-0024	GARY ST. TO JCT RT. LA 3036		4	9	14	US 80	232000.00	190974.58	145493.86	145239.84	0.820	18-ASPHALT PVT REHAB
001-02-0025	CURTIS LAND - LINWOOD AVENUE		4	9	14	US 80	910000.00	792691.86	724745.88	723021.63	2.674	05-ASPH OVLY ASPH PV
001-03-0052	RED RIVER BRIDGE (TEXAS ST)	REPAIRS	4	8	14	US 80	3453000.00	3286962.65	4403643.55	4401897.44	0.613	04-BRIDGES RCND
001-03-0056	JCT LA 3 TO JCT LA 72 (BOSSIER	CITY)	4	8	14	US 80	1420000.00	1488348.13	1573353.99	1578694.39	1.526	17-ASPH WDN + OVLY
001-03-0057	JUNCTION LA 72-MERRYWOOD HWY.		4	8	14	US 80	925000.00	832906.00	886440.09	873434.33	8.000	18-ASPHALT PVT REHAB
001-03-0059	MERRYWOODS BLVD. TO WEBSTER PA	RISH LINE	4	8	14	US 80	781000.00	690302.44	778325.16	780599.69	7.120	18-ASPHALT PVT REHAB
001-03-0061	CADDO PARISH LINE - JCT LA. 3		4	8	14	US 80	388000.00	340288.47	333005.78	333312.89	1.319	05-ASPH OVLY ASPH PV
001-04-0027	US 80 & LA 7 LEFT TURN LANES I	N DIXIE INN	4	60	12	US 80	45000.00	44822.60	48472.00	49483.56	0.250	09-MISCELLANEOUS
001-04-0028	BOSSIER PARISH LINE - END OF F	OUR LANE	4	60	7	US 80	2253000.00	1977176.89	2160631.05	2164317.71	5.175	02-ASPH OVLY CON PVT
001-04-0030	MINDEN (WEST) CITY LIMITS TO M	INDEN (EAST) CITY LIMITS US 80	4	60	16	US 80	981000.00	1089098.64	1136233.28	1138866.11	4.850	05-ASPH OVLY ASPH PV
001-05-0013	JCT I-20 & US 80		4	60	14	US 80	2700000.00	2326971.31	2336623.26	2310490.13	2.058	05-ASPH OVLY ASPH PV
001-06-0035	I-20-GIBSLAND HWY. (BRIDGES)		4	7	7	US 80	2576000.00	1935775.00	1926657.84	1919518.21	0.776	07-BRIDGES NEW
001-06-0042	SALINE BAYOU & RELIEF BRIDGES		4	7	7	US 80	1547000.00	1609332.88	1570055.99	1573148.11	0.902	07-BRIDGES NEW
001-07-0024	STATE ROUTE IN RUSTON		5	31	14	US 80	145000.00	162356.43	159494.96	153420.19	1.045	17-ASPH WDN + OVLY
001-07-0025	ADAMS BOULEVARD - TRENTON STRE	ET	5	31	16	US 80	194000.00	186052.10	176278.96	173263.68	0.420	05-ASPH OVLY ASPH PV
001-08-0031	STATE ROUTE IN RUSTON	ROUTE US 80	5	31	14	US 80	187000.00	150626.74	151030.44	150488.03	1.411	17-ASPH WDN + OVLY
001-08-0032	MILLS AVENUE - JUNCTION I-20 (	RUSTON) ROUTES: US 80 & US 167	5	31	16	US 80	663000.00	696072.41	612824.19	611495.11	1.798	05-ASPH OVLY ASPH PV
001-09-0058	LOUISVILLE AVE. BRIDGE	(REPAIRS)	5	37	14	US 80	20000.00	19530.00	19530.00	19530.00	0.000	04-BRIDGES RCND
001-09-0060	INTERSECTION IMPROVEMENTS, RT.	US80& WELL ROAD (WEST MONROE	5	37	14	US 80	136000.00	120598.19	129985.56	129633.26	0.000	02-ASPH OVLY CON PVT
001-09-0061	RIVERSIDE DRIVE - NORTH TENTH	STREET	5	37	14	US 80	128000.00	130440.31	126204.16	126447.20	0.710	05-ASPH OVLY ASPH PV
001-09-0063	JCT LA 546 - JCT NORTH SEVENTH	STREET	5	37	14	US 80	1711000.00	1738625.20	1619433.09	1631290.33	6.005	05-ASPH OVLY ASPH PV
001-09-0064	JUNCTION LA 143 OUACHITA RIVER	BRIDGE, ROUTE: U.S. 80	5	37	16	US 80	601000.00	569045.30	531611.97	531671.20	1.627	05-ASPH OVLY ASPH PV
002-01-0030	POWELL AVENUE - JCT LA 139		5	37	12	US 80	478000.00	516167.60	483468.95	476206.38	2.899	05-ASPH OVLY ASPH PV
002-02-0027	START - RAYVILLE HIGHWAY		5	42	7	US 80	289000.00	259702.90	265394.80	265708.89	4.600	18-ASPHALT PVT REHAB
002-02-0028	CREW LAKE - START		5	42	7	US 80	251000.00	186320.95	167543.81	171998.93	2.245	05-ASPH OVLY ASPH PV
002-03-0035	JUNCTION LA 137 - JUNCTION LA	583, ROUTE: US 80	5	42	7	US 80	1030000.00	835804.02	906433.14	914159.88	5.942	05-ASPH OVLY ASPH PV
002-04-0032	JCT LA 577 - TALLULAH (WEST SE	CTION)	5	33	2	US 80	551000.00	579280.00	575686.78	594697.99	7.935	05-ASPH OVLY ASPH PV
002-04-0033	QUEBEC - TALLULAH		5	33	7	US 80	685000.00	669954.87	678822.47	689118.43	5.574	05-ASPH OVLY ASPH PV
003-02-0030	DISTRICT 07		7	10	7	US 90	997000.00	797265.98	797265.98	0.00	60.280	09-MISCELLANEOUS
003-03-0019	SRD CANAL - JUNCTION LA 27 (SU	LFUR)	7	10	16	US 90	304000.00	349427.82	334902.25	337273.45	0.949	05-ASPH OVLY ASPH PV
003-04-0047	SULPHUR-WESTLAKE HIGHWAY (DRAI	NAGE IMPROVEMENTS)	7	10	14	US 90	175000.00	188691.94	196591.17	196684.78	0.105	27-UTILITIES
003-04-0058	POST OAK ROAD - JCT. I-L0		7	10	14	US 90	391000.00	410526.23	405355.91	409252.75	3.870	18-ASPHALT PVT REHAB
003-04-0059	I-10 OVERPASS BRIDGE HANDRAIL	REPAIRS	7	10	14	US 90	10000.00	7300.00	7300.00	7300.00	0.000	04-BRIDGES RCND
003-04-0060	WEST OF JUNCTION LA 27 - END 4	LANE , ROUTE: US 90	7	10	14	US 90	692000.00	679570.19	676871.84	678210.46	1.695	05-ASPH OVLY ASPH PV
003-05-0022	ALBERT STREET (LAKE CHARLES) -	JCT LA 397 HIGHWAY	7	10	14	US 90	448000.00	421694.49	441270.22	436592.21	2.879	18-ASPHALT PVT REHAB
003-06-0015	EAST & WEST BAYOU LACASSINE BR	IDGES & APPROACHES	7	27	7	US 90	780000.00	769675.15	784335.74	783985.24	0.247	07-BRIDGES NEW
003-07-0016	BAYOU AND CANAL BRIDGES AND	APPROACHES	7	27	7	US 90	693000.00	682328.59	715512.18	715715.31	0.374	07-BRIDGES NEW
003-07-0021	EAST JUNCTION LA 99-R/R OVERPA	SS	7	27	7	US 90	641000.00	757223.19	672711.60	674024.13	8.355	05-ASPH OVLY ASPH PV
003-07-0022	S.P.T. RAILROAD OVERPASS - JCT	LA. 26 (JENNINGS)	7	27	16	US 90	115000.00	104782.40	89931.62	89924.90	0.410	05-ASPH OVLY ASPH PV
003-08-0014	NORTH CUTTING AVE.- DAVIES ST	INT. (LEFT & RIGHT TURN LANES)	7	27	14	US 90	257000.00	236151.54	226769.00	225891.01	0.257	27-UTILITIES
003-08-0015	JCT LA 3055 - ACADIA PARISH LI	NE	7	27	2	US 90	371000.00	357068.87	326252.07	325406.34	4.280	05-ASPH OVLY ASPH PV
003-09-0024	ESTHERWOOD - CROWLEY BRIDGES A	ND APPROACHES	3	1	14	US 90	1184000.00	1114185.32	1135946.30	1140385.06	0.708	07-BRIDGES NEW
003-10-0009	RAYNE - LAFAYETTE PARISH LINE	HIGHWAY	7	1	14	US 90	389000.00	339931.88	307244.62	289200.07	2.506	18-ASPHALT PVT REHAB
003-10-0010	JCT LA 13 - RAYNE		3	1	14	US 90	480000.00	443847.73	506740.55	519928.09	6.272	18-ASPHALT PVT REHAB

Table B2: Portion of item file

CONTRACT	ITEM_TYPE	ITEM_NUM	DESCRIPT1	DESCRIPT2	PAY_UNIT	DECIMALS	UNIT_COST	CONT_QTY	APPR_QTY	TODATE_QTY	CONT_COST	APPR_COST	TODATE_CST
001-01-0026	1	202(02)(C)	REMOVAL OF PORTLAND CEMENT CONCRETE PAVEMENT		SQUARE YARD	1	5.0000	2361.4000	2234.5000	2234.3000	11807.00	11172.50	11171.50
001-01-0026	1	202(02)(D)	REMOVAL OF CONCRETE WALKS AND DRIVES		SQUARE YARD	1	5.3400	0.0000	222.1000	222.1000	0.00	1186.01	1186.01
001-01-0026	1	202(02)(H)	REMOVAL OF GUARD RAIL		LINEAR FOOT	1	2.2000	1639.0000	1639.0000	1639.0000	3605.80	3605.80	3605.80
001-01-0026	1	202(02)(I)	REMOVAL OF SHOULDER SURFACING		SQUARE YARD	1	2.0000	5990.5000	1541.0000	1541.2000	11981.00	3082.00	3082.40
001-01-0026	1	202(02)(J)	REMOVAL OF CONCRETE HEADWALLS		EACH	2	500.0000	18.0000	21.0000	21.0000	9000.00	10500.00	10500.00
001-01-0026	1	202(02)(K)	REMOVAL OF BRIDGE DECK SURFACING		SQUARE YARD	1	3.0000	1128.9000	1128.9000	1119.9000	3386.70	3386.70	3359.70
001-01-0026	1	202(02)(L)	REMOVAL OF SHOULDER SURFACING AND STABILIZED BASE		SQUARE YARD	1	5.0000	1176.9000	1072.7000	1073.7000	5884.50	5363.50	5368.50
001-01-0026	1	202(02)(X)	REMOVAL OF EXISTING SIGNAL EQUIPMENT		LUMP SUM	2	10000.0000	1.0000	1.0000	1.0000	10000.00	10000.00	10000.00
001-01-0026	1	203(08)	BORROW (VEHICULAR MEASUREMENT)		CUBIC YARD	1	8.0000	15000.0000	15000.0000	15367.4000	120000.00	120000.00	122939.20
001-01-0026	1	204(02)	TEMPORARY BALED HAY OR STRAW		TON	3	1000.0000	1.0000	0.0000	0.0000	1000.00	0.00	0.00
001-01-0026	1	302(01)(A)	CLASS II BASE COURSE (STONE)		CUBIC YARD	1	40.0000	1036.0000	842.3000	863.6000	41440.00	33692.00	34544.00
001-01-0026	1	303(01)(C)	IN-PLACE CEMENT STABILIZED BASE COURSE (10" THICK)		SQUARE YARD	1	6.0000	55554.0000	60759.2000	58067.2000	333324.00	364555.20	348403.20
001-01-0026	1	303(02)	CEMENT		CWT	3	0.0100	39165.5000	31680.2000	31680.2000	391.65	316.80	316.80
001-01-0026	1	304(05)	LIME (TYPE E TREATMENT)		TON	3	100.0000	52.1700	0.0000	0.0000	5217.00	0.00	0.00
001-01-0026	1	401(02)	AGGR. SURFACE COURSE (ADJ.VEHICUL. MEASUREMENT)		CUBIC YARD	1	40.0000	80.0000	200.0000	200.6000	3200.00	8000.00	8024.00
001-01-0026	1	402(01)	TRAFFIC MAINT. AGGREGATE (VEHICULAR MEASUREMENT)		CUBIC YARD	1	10.0000	1200.0000	33.5000	33.5000	12000.00	335.00	335.00
001-01-0026	1	501(01)	ASPHALTIC CONCRETE		TON	3	40.0000	23981.2000	23839.5000	24130.7000	959248.00	953580.00	965228.00
001-01-0026	1	501(01)(A)	ASPHALTIC CONCRETE (PAVED DRIVES & TURNOUTS)		TON	3	45.0000	1733.4000	1015.1600	1015.1600	78003.00	45682.20	45682.20
001-01-0026	1	501(01)(B)	ASPHALTIC CONCRETE (TYPE 8F WEARING COURSE)		TON	3	40.0000	10768.4000	10768.4000	10778.1300	430736.00	430736.00	431125.20
001-01-0026	1	501(01)(R-B)	ASPHALTIC CONCRETE REBATE (PROFILOGRAPH BUMPS)		EACH	2	500.0000	0.0000	-2.0000	-2.0000	0.00	-1000.00	-1000.00
001-01-0026	1	509(01)	COLD PLANING ASPHALTIC PAVEMENT		SQUARE YARD	2	0.3500	0.0000	126581.0000	121797.9000	0.00	44303.35	42629.26
001-01-0026	1	601(01)(K)	PORTLAND CEMENT CONCRETE PAVEMENT (10" THICK)		SQUARE YARD	1	80.0000	4731.8000	4731.8000	4731.8000	378544.00	378544.00	378544.00
001-01-0026	1	701(03)(F)	STORM DRAIN PIPE (15 INCH REINFORCED CONC. PIPE)		LINEAR FOOT	2	32.6000	0.0000	64.0000	64.0000	0.00	2086.40	2086.40
001-01-0026	1	701(05)(G)	SIDE DRAIN PIPE (18")		LINEAR FOOT	2	24.0000	0.0000	20.0000	20.0000	0.00	480.00	480.00
001-01-0026	1	701(10)(G)	REINFORCED CONCRETE PIPE (EXTENSION)(18")		LINEAR FOOT	1	60.0000	38.0000	50.0000	50.0000	2280.00	3000.00	3000.00
001-01-0026	1	701(10)(I)	REINFORCED CONCRETE PIPE (EXTENSION)(24")		LINEAR FOOT	1	70.0000	52.0000	56.0000	56.0000	3640.00	3920.00	3920.00
001-01-0026	1	701(10)(O)	REINFORCED CONCRETE PIPE (EXTENSION) (48")		LINEAR FOOT	2	125.0000	0.0000	40.0000	40.0000	0.00	5000.00	5000.00
001-01-0026	1	702(03)(A)	CATCH BASINS (CB-01)		EACH	2	2518.8200	0.0000	1.0000	1.0000	0.00	2518.82	2518.82
001-01-0026	1	702(04)(A)	ADJUSTING MANHOLES		EACH	2	1000.0000	3.0000	2.0000	2.0000	3000.00	2000.00	2000.00
001-01-0026	1	702(04)(B)	ADJUSTING CATCH BASINS		EACH	2	2000.0000	3.0000	7.0000	7.0000	6000.00	14000.00	14000.00
001-01-0026	1	704(01)(B)	GUARD RAIL (SINGLE BEAM)(6'-3" POST SPACING)		LINEAR FOOT	1	35.0000	1873.0000	1873.0000	1817.0000	65555.00	65555.00	63595.00
001-01-0026	1	704(01)(D)	GUARD RAIL (SINGLE BEAM)(3'-11/2" POST SPACING)		LINEAR FOOT	1	46.0000	417.0000	417.0000	419.2000	19182.00	19182.00	19283.20
001-01-0026	1	704(03)	BLOCKED OUT GUARD RAIL		LINEAR FOOT	1	18.0000	800.0000	725.2000	725.2000	14400.00	13053.60	13053.60
001-01-0026	1	704(08)(A)	GUARD RAIL TRANSITIONS (DOUBLE THRIE BEAM)		LINEAR FOOT	1	38.0000	375.0000	375.0000	375.1000	14250.00	14250.00	14253.80
001-01-0026	1	706(02)(C)	CONCRETE DRIVE (6" THICK)		SQUARE YARD	2	28.6900	0.0000	160.8000	160.7600	0.00	4613.35	4612.20
001-01-0026	1	706(03)(A)	INCIDENTAL CONCRETE PAVING (4" THICK)		SQUARE YARD	1	40.0000	224.6000	203.6000	204.7000	8984.00	8144.00	8188.00
001-01-0026	1	712(03)	SACKED CONCRETE REVETMENT		SQUARE YARD	1	50.0000	66.0000	198.7000	198.7000	3300.00	9935.00	9935.00
001-01-0026	1	713(01)	TEMPORARY SIGNS & BARRICADES		LUMP SUM	2	80000.0000	1.0000	1.0000	1.0000	80000.00	80000.00	80000.00
001-01-0026	1	713(03)(E)	TEMPORARY PAVEMENT MARKINGS (24" WIDTH)		LINEAR FOOT	1	1.7500	128.0000	0.0000	0.0000	224.00	0.00	0.00
001-01-0026	1	713(04)(A)	TEMP. PAVT. MARKINGS (BROKEN LINE)(4" W)(4' LENGTH)		MILE	3	300.0000	17.4110	26.7480	25.8970	5223.30	8024.40	7769.10
001-01-0026	1	713(04)(B)	TEMP.PAVT. MARKINGS (BROKEN LINE)(4" W)(10' LENGTH)		MILE	3	440.0000	11.6030	4.4770	4.4770	5105.32	1969.88	1969.88
001-01-0026	1	713(05)(A)	TEMPORARY PAVEMENT MARKINGS (SOLID LINE)(4" WIDTH)		MILE	3	880.0000	65.3020	28.7680	28.7680	57465.76	25315.84	25315.84
001-01-0026	1	714(02)	WATER		M GALLONS	3	10.0000	4.0000	0.0000	0.0000	40.00	0.00	0.00
001-01-0026	1	716(01)	VEGETATIVE MULCH		TON	3	400.0000	8.0000	21.0000	21.0000	3200.00	8400.00	8400.00
001-01-0026	1	716(02)	EMULSIFIED ASPHALT		GALLON	0	2.0000	600.0000	3300.0000	3305.0000	1200.00	6600.00	6610.00
001-01-0026	1	717(01)	SEEDING		POUND	0	8.0000	120.0000	450.0000	450.0000	960.00	3600.00	3600.00
001-01-0026	1	718(01)	FERTILIZER		POUND	0	0.3000	4000.0000	13991.0000	13991.0000	1200.00	4197.30	4197.30
001-01-0026	1	722(01)	PROJECT SITE LABORATORY		EACH	2	3000.0000	1.0000	1.0000	1.0000	3000.00	3000.00	3000.00

Table B3: Portion of contract plan change file

CONTRACT	PLAN_CNG	STATUS	OVER_UNDER	ADD_DAYS	DESCRIPTION	AMOUNT	RECD_CONST	RECD_EST
001-01-0026	001	A	1	0	TO REVISE THE TYPICAL SHOULDER SECTION	25599.90	2/2/96	2/2/96
001-01-0026	002	A	1	0	WILL ELIMINATE THE 2 MILES RESTRICTIONS	0.00	2/2/96	2/2/96
001-01-0026	003	A	1	0	WILL REVISE THE SURFACE TOLERANCE TEST PATH	0.00	2/23/96	2/23/96
001-01-0026	004	A	1	0	WILL COMPENSATE CONTRACTOR FOR ADDITIONAL PATCHING	25742.50	3/1/96	3/1/96
001-01-0026	005	A	1	0	WILL ALLOW FOR COLD PLANING THE 24 FOOT ROADWAY	80613.53	3/14/96	3/15/96
001-01-0026	006	A	1	0	WILL ALLOW FOR THE REMOVAL OF CONC. DRIVEWAYS	7671.72	3/14/96	3/15/96
001-01-0026	007	A	1	0	FOR THE INSTALLATION OF A CATCH BASIN	4605.22	5/22/96	5/28/96
001-01-0026	008	A	1	0	TO IMPLEMENT CONSTRUCTION MEMO 345	0.00	5/22/96	5/28/96
001-01-0026	009	A	1	0	FOR AN 48 INCH REINFORCED CONC. PIPE	5000.00	6/20/96	6/20/96
001-01-0026	010	A	1	0	FOR INSTALLATION OF AN 18 INCH SIDE DRAIN PIPE	480.00	6/20/96	6/20/96
001-01-0026	011	A	1	0	FOR INSTALLATION OF SACK REVETMENT	6635.00	6/28/96	6/28/96
001-01-0026	012	A	2	0	TO REBATE THE DEPARTMENT FOR BUMPS	-1000.00	7/29/96	7/29/96
001-01-0026	013	A	2	0	TO ADJUST FINAL QUANTITIES	-87393.00	10/16/96	10/16/96
001-01-0026	014	A	1	0	TO COMPENSATE CONTRACTOR FOR PAVEMENT PATCHING	3555.40	10/16/96	10/16/96
001-02-0022	001	A	0	0	INCORPORATE PLAN SHEETS 4A AND 5A	0.00	9/11/84	9/18/84
001-02-0022	002	A	0	0	BARRIER C & G TO MOUNTABLE C & G	0.00	9/24/84	9/26/84
001-02-0022	003	A	1	0	COMBINATION MESH AND BARBED WIRE FENCE	369.60	5/15/85	5/23/85
001-02-0022	004	A	2	0	CONSTRUCTION OF JEFFERSON PAIGE AND HWY. 80	-8280.00	8/26/85	8/27/85
001-02-0022	005	A	2	0	FINAL PLAN CHANGE	-92430.29	12/16/85	12/16/85
001-02-0024	001	A	2	0	"FINAL QUANTITIES"	-45762.24	4/20/89	4/20/89
001-02-0024	002	A	1	0	FINAL QUANTITIES-STRIPING-24"	281.52	2/6/92	2/7/92
001-02-0025	001	A	2	0	OVERRUNS AND UNDERRUNS	-9986.08	9/23/90	9/27/93
001-02-0025	002	A	2	0	UNDERRUN AND OVERRUN REVISED	-56959.90	11/19/93	11/19/93
001-02-0025	003	A	2	0	ELIMINATE ITEM NO. 724(03) FROM CONTRACT	-1000.00	3/4/94	3/4/94
001-03-0052	001	A	1	0	INC ITEM S-204 & ADD ITEM S- 206	0.00	12/14/81	12/16/81
001-03-0052	002	A	1	0	INC ITEM S-204 & ADD ITEM S- 206	7505.36	4/20/82	4/21/82
001-03-0052	003	A	2	0	DEC. ITEM S-114	-36000.00	6/29/82	7/14/82
001-03-0052	004	A	1	0	REPLACEMENT OF JOINTS ON DECK	176481.40	00000000	00000000
001-03-0052	005	A	2	0	DECREASE 501(1)(A)	-1482.00	00000000	00000000
001-03-0052	006	A	1	0	ADD ITEM NO S-210, "CONCRETE GIRDER ANCHOR"	19894.90	8/4/82	8/13/82
001-03-0052	007	A	1	0	ADD ITEM NO. S-208, "SAWING & SEALING"	8964.64	8/4/82	8/13/82
001-03-0052	008	A	1	0	INCREASE ITEM NO. S-108	77600.00	9/2/82	9/15/82
001-03-0052	009	A	1	0	ADD ITEM S-210, CONCRETE GIRDER ANCHOR	1824.74	12/28/82	1/6/83
001-03-0052	010	A	0	0	TO APPROVE SUSPENSION OF CONTRACT TIME	0.00	9/7/82	9/15/82
001-03-0052	011	A	1	0	APPROVE REPAIR WORK REVEALED BY DECK REMOVAL	676559.60	9/13/82	9/15/82
001-03-0052	012	A	1	0	INCREASE ITEM NOS. S-107 AND S-109	65400.00	9/23/82	10/7/82

Table B4: Portion of item plan change file

CONTRACT	PLAN_CNG	ITEM_TYPE	ITEM_NUM	DESCRIPT1	DESCRIPT2	PAY_UNIT	DECIMALS	UNIT_COST	ORIG_QTY	ORIG_COST	REV_QTY	REV_COST
001-01-0026	001	1	303(01)(C)	IN-PLACE CEMENT STABILIZED BASE COURSE (10" THICK)		SQUARE YARD	1	6.0000	55554.0000	333324.00	60759.2000	364555.20
001-01-0026	001	1	303(02)	CEMENT		CWT	3	0.0100	39165.5000	391.65	42835.3000	428.35
001-01-0026	001	1	501(01)	ASPHALTIC CONCRETE		TON	3	40.0000	23981.2000	959248.00	23839.5000	953580.00
001-01-0026	004	1	724(01)(A)	PAVEMENT PATCHING (12" MINIMUM THICKNESS)		SQUARE YARD	1	35.0000	950.0000	33250.00	1685.5000	58992.50
001-01-0026	005	1	509(01)	COLD PLANING ASPHALTIC PAVEMENT		S.Y.	2	0.3500	0.0000	0.00	126581.0000	44303.35
001-01-0026	005	1	713(04)(A)	TEMPORARY PAVEMENT MARKINGS (BROKEN LINE)(4"	WIDTH)(4' LENGTH)	MILE	3	300.0000	17.4110	5223.30	26.7480	8024.40
001-01-0026	005	1	713(04)(B)	TEMPORARY PAVEMENT MARKINGS (BROKEN LINE)(4"	WIDTH)(10' LENGTH)	MILE	3	440.0000	11.6030	5105.32	17.6440	7763.36
001-01-0026	005	1	713(05)(A)	TEMPORARY PAVEMENT MARKINGS (SOLID LINE)(4" WIDTH)		MILE	3	880.0000	65.3020	57465.76	100.3600	88316.80
001-01-0026	006	1	202(02)(D)	REMOVAL OF CONCRETE WALKS AND DRIVES		SQUARE YARD	1	5.3400	0.0000	0.00	295.5000	1577.97
001-01-0026	006	1	706(02)(C)	CONCRETE DRIVE (6" THICK)		SQUARE YARD	2	28.6900	0.0000	0.00	212.4000	6093.75
001-01-0026	007	1	701(03)(F)	STORM DRAIN PIPE (15 INCH REINFORCED CONC. PIPE)		L.F.	2	32.6000	0.0000	0.00	64.0000	2086.40
001-01-0026	007	1	702(03)(A)	CATCH BASINS (CB-01)		EACH	2	2518.8200	0.0000	0.00	1.0000	2518.82
001-01-0026	009	1	701(10)(O)	REINFORCED CONCRETE PIPE (EXTENSION) (48")		L.F.	2	125.0000	0.0000	0.00	40.0000	5000.00
001-01-0026	010	1	701(05)(G)	SIDE DRAIN PIPE (18")		L.F.	2	24.0000	0.0000	0.00	20.0000	480.00
001-01-0026	011	1	712(03)	SACKED CONCRETE REVETMENT		SQUARE YARD	1	50.0000	66.0000	3300.00	198.7000	9935.00
001-01-0026	012	1	501(01)(R-B)	ASPHALTIC CONCRETE REBATE (PROFILOGRAPH BUMPS)		EACH	2	500.0000	0.0000	0.00	-2.0000	-1000.00
001-01-0026	013	1	202(02)(C)	REMOVAL OF PORTLAND CEMENT CONCRETE PAVEMENT		SQUARE YARD	1	5.0000	2361.4000	11807.00	2234.5000	11172.50
001-01-0026	013	1	202(02)(D)	REMOVAL OF CONCRETE WALKS AND DRIVES		SQUARE YARD	1	5.3400	295.5000	1577.97	222.1000	1186.01
001-01-0026	013	1	202(02)(I)	REMOVAL OF SHOULDER SURFACING		SQUARE YARD	1	2.0000	5990.5000	11981.00	1541.0000	3082.00
001-01-0026	013	1	202(02)(J)	REMOVAL OF CONCRETE HEADWALLS		EACH	2	500.0000	18.0000	9000.00	21.0000	10500.00
001-01-0026	013	1	202(02)(L)	REMOVAL OF SHOULDER SURFACING AND STABILIZED BASE		SQUARE YARD	1	5.0000	1176.9000	5884.50	1072.7000	5363.50
001-01-0026	013	1	204(02)	TEMPORARY BALED HAY OR STRAW		TON	3	1000.0000	1.0000	1000.00	0.0000	0.00
001-01-0026	013	1	302(01)(A)	CLASS II BASE COURSE (STONE)		CUBIC YARD	1	40.0000	1036.0000	41440.00	842.3000	33692.00
001-01-0026	013	1	303(02)	CEMENT		CWT	3	0.0100	42835.3000	428.35	31680.2000	316.80
001-01-0026	013	1	304(05)	LIME (TYPE E TREATMENT)		TON	3	100.0000	52.1700	5217.00	0.0000	0.00
001-01-0026	013	1	401(02)	AGGR. SURFACE COURSE (ADJUSTED VEHICULAR	MEASUREMENT)	CUBIC YARD	1	40.0000	80.0000	3200.00	200.0000	8000.00
001-01-0026	013	1	402(01)	TRAFFIC MAINTENANCE AGGREGATE (VEHICULAR	MEASUREMENT)	CUBIC YARD	1	10.0000	1200.0000	12000.00	33.5000	335.00
001-01-0026	013	1	501(01)(A)	ASPHALTIC CONCRETE (PAVED DRIVES & TURNOUTS)		TON	3	45.0000	1733.4000	78003.00	1015.1600	45682.20
001-01-0026	013	1	701(10)(G)	REINFORCED CONCRETE PIPE (EXTENSION)(18")		LINEAR FOOT	1	60.0000	38.0000	2280.00	50.0000	3000.00
001-01-0026	013	1	701(10)(I)	REINFORCED CONCRETE PIPE (EXTENSION)(24")		LINEAR FOOT	1	70.0000	52.0000	3640.00	56.0000	3920.00
001-01-0026	013	1	702(04)(A)	ADJUSTING MANHOLES		EACH	2	1000.0000	3.0000	3000.00	2.0000	2000.00
001-01-0026	013	1	702(04)(B)	ADJUSTING CATCH BASINS		EACH	2	2000.0000	3.0000	6000.00	7.0000	14000.00
001-01-0026	013	1	704(03)	BLOCKED OUT GUARD RAIL		LINEAR FOOT	1	18.0000	800.0000	14400.00	725.2000	13053.60
001-01-0026	013	1	706(02)(C)	CONCRETE DRIVE (6" THICK)		SQUARE YARD	2	28.6900	212.4000	6093.75	160.8000	4613.35
001-01-0026	013	1	706(03)(A)	INCIDENTAL CONCRETE PAVING (4" THICK)		SQUARE YARD	1	40.0000	224.6000	8984.00	203.6000	8144.00
001-01-0026	013	1	713(03)(E)	TEMPORARY PAVEMENT MARKINGS (24" WIDTH)		LINEAR FOOT	1	1.7500	128.0000	224.00	0.0000	0.00
001-01-0026	013	1	713(04)(B)	TEMPORARY PAVEMENT MARKINGS (BROKEN LINE)(4"	WIDTH)(10' LENGTH)	MILE	3	440.0000	17.6440	7763.36	4.4770	1969.88
001-01-0026	013	1	713(05)(A)	TEMPORARY PAVEMENT MARKINGS (SOLID LINE)(4" WIDTH)		MILE	3	880.0000	100.3600	88316.80	28.7680	25315.84
001-01-0026	013	1	714(02)	WATER		M GALLONS	3	10.0000	4.0000	40.00	0.0000	0.00
001-01-0026	013	1	716(01)	VEGETATIVE MULCH		TON	3	400.0000	8.0000	3200.00	21.0000	8400.00
001-01-0026	013	1	716(02)	EMULSIFIED ASPHALT		GALLON	0	2.0000	600.0000	1200.00	3300.0000	6600.00
001-01-0026	013	1	717(01)	SEEDING		POUND	0	8.0000	120.0000	960.00	450.0000	3600.00
001-01-0026	013	1	718(01)	FERTILIZER		POUND	0	0.3000	4000.0000	1200.00	13991.0000	4197.30
001-01-0026	013	1	731(02)	REFLECTORIZED RAISED PAVEMENT MARKERS		EACH	2	4.5000	1590.0000	7155.00	2117.0000	9526.50
001-01-0026	013	1	732(01)(C)	PLASTIC PAVEMENT STRIPING (8" WIDTH)		LINEAR FOOT	1	1.0000	1430.0000	1430.00	2965.0000	2965.00

APPENDIX C: LABOR, EQUIPMENT AND MATERIAL COST INDEX DATA

Table C1: Labor, equipment, and material cost index data

Year	Construction labor	Construction Equipment	Concrete Ingredients	Sand/gravel/ crushed stone	Reinforcing bars	Petroleum Products
1981	129.0	86.7	86.6	79.7	106.1	186.2
1982	125.5	91.4	90.5	84.7	98.9	175.8
1983	125.3	93.3	91.5	86.2	91.6	158.0
1984	118.4	95.2	95.1	89.8	98.1	153.7
1985	112.2	97.4	98.2	93.7	100.3	146.0
1986	106.0	98.5	99.1	96.7	101.4	93.8
1987	100.0	100.0	100.0	100.0	100.0	100.0
1988	101.5	102.5	101.4	102.2	112.5	94.8
1989	100.8	108.0	102.5	104.1	114.5	107.6
1990	99.0	112.2	104.4	106.2	109.0	131.3
1991	96.4	115.8	107.2	109.0	102.2	118.2
1992	94.8	119.8	108.1	110.6	99.3	113.7
1993	94.1	123.3	111.8	113.5	103.6	109.2
1994	95.2	125.4	116.6	116.8	114.1	104.1
1995	96.3	128.2	121.9	120.6	114.8	107.0
1996	97.3	131.8	125.7	123.3	114.1	123.3
1997	98.3	134.0	129.0	125.6	120.8	119.7
1998	99.2	136.4	131.6	128.3	125.2	104.3
1999	99.5	139.1	132.8	130.1	127.3	106.5
2000	99.7	142.0	134.8	133.0	128.3	110.1
2001	100.3	145.3	137.4	136.3	130.5	114.2
2002	100.9	149.0	140.4	139.5	135.4	118.5
2003	101.5	153.2	143.9	143.6	139.5	123.2
2004	102.1	157.3	147.3	148.0	143.8	128.2
2005	102.7	161.8	150.6	152.0	148.9	133.4
2006	103.3	166.5	154.2	156.6	152.9	138.9
2007	104.0	171.3	157.8	160.9	157.3	144.8
2008	104.6	176.0	161.5	165.2	161.8	151.0
2009	105.3	180.7	165.2	169.7	166.5	157.7
2010	105.9	185.7	169.0	174.3	171.0	164.7
2011	106.6	191.1	173.3	179.2	176.0	172.4
2012	107.3	196.8	177.9	184.5	180.7	180.4
2013	108.0	202.6	182.5	189.7	185.0	189.0
2014	108.6	208.2	187.2	195.1	189.2	198.0
2015	109.3	213.9	192.1	200.5	193.7	207.6

APPENDIX D: ORIGINAL INDICATOR VARIABLE DATA FROM DRI

Table D1: Indicator data from Data Resources Incorporated

Year	Concrete ingredients and related products	Construction sand/ gravel/crushed stone	Construction machinery	Fabricated structural metal	Concrete reinf. bars, carbon	Petroleum products, refined
	1982 = 1.0	1982 = 1.0	Dec. 1980 = 1.0	JUNE 1982 = 1.0	JUNE 1982 = 1.0	1982 = 1.0
1981	0.96	0.94	1.06	#N/A	1.07	1.06
1982	1.00	1.00	1.12	0.99	1.00	1.00
1983	1.01	1.02	1.14	0.98	0.92	0.90
1984	1.05	1.06	1.17	1.00	0.99	0.87
1985	1.08	1.11	1.19	1.03	1.01	0.83
1986	1.09	1.14	1.21	1.04	1.02	0.53
1987	1.10	1.18	1.23	1.07	1.01	0.57
1988	1.12	1.21	1.26	1.13	1.13	0.54
1989	1.13	1.23	1.32	1.18	1.15	0.61
1990	1.15	1.25	1.38	1.19	1.10	0.75
1991	1.18	1.29	1.42	1.17	1.03	0.67
1992	1.19	1.31	1.47	1.17	1.00	0.65
1993	1.23	1.34	1.51	1.18	1.04	0.62
1994	1.29	1.38	1.54	1.22	1.15	0.59
1995	1.35	1.42	1.57	1.26	1.16	0.61
1996	1.39	1.46	1.62	1.31	1.15	0.70
1997	1.42	1.48	1.64	1.33	1.22	0.68
1998	1.45	1.51	1.67	1.35	1.26	0.59
1999	1.47	1.54	1.71	1.38	1.28	0.61
2000	1.49	1.57	1.74	1.40	1.29	0.63
2001	1.52	1.61	1.78	1.43	1.32	0.65
2002	1.55	1.65	1.83	1.46	1.37	0.67
2003	1.59	1.69	1.88	1.50	1.41	0.70
2004	1.63	1.75	1.93	1.56	1.45	0.73
2005	1.66	1.79	1.98	1.59	1.50	0.76
2006	1.70	1.85	2.04	1.63	1.54	0.79
2007	1.74	1.90	2.10	1.67	1.59	0.82
2008	1.78	1.95	2.16	1.70	1.63	0.86
2009	1.82	2.00	2.22	1.74	1.68	0.90
2010	1.87	2.06	2.28	1.78	1.72	0.94
2011	1.91	2.12	2.34	1.83	1.77	0.98
2012	1.96	2.18	2.41	1.87	1.82	1.03
2013	2.02	2.24	2.48	1.92	1.87	1.07
2014	2.07	2.30	2.55	1.96	1.91	1.13
2015	2.12	2.37	2.62	2.00	1.95	1.18