Research Report
KTC 98-18

COST ESTIMATING AND FORECASTING FOR HIGHWAY WORK IN KENTUCKY
(Study KYSPR-94-158)

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16. Abstract Starting 1 July 1992, KRS45.245 granted the Interim Joint Committee on Transportation oversight of the biennial highway plan, including a review of all authorized highway project phases that exceed their estimates by 15%.

Estimates developed using current methods were not sufficiently accurate to preclude cost overruns in excess of 15%. Estimates were prepared before design began in order for the project to be included in the six-year plan. These estimates were not revised after a more detailed scope was available.

There were 562 overruns >15% at a cost of approximately $265 million during the period 7/1/92-7/1/98. All overruns were approved for the necessary additional funding. The requirement for review of overruns >15% was canceled by the General Assembly (HB655) effective 1 July 1998.

There was a need for better cost estimating and forecasting for highway work in the Commonwealth of Kentucky. This research effort studied the causes of the 562 cost overruns >15% and attempted to improve the conceptual estimating process. A computerized conceptual estimating model, KYEstimate, was developed to assist estimators in preparing and justifying conceptual estimates that must be made prior to detailing scoping of projects. Recommendations and conclusions are presented.

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

There is a need for better cost estimating and forecasting for highway work in the Commonwealth of Kentucky. The objective of this study, approved July 1993, was to investigate current practices and to recommend improvements for the estimating process. This report details the findings of five years of research effort.

The Kentucky Transportation Cabinet (KyTC) is responsible for the creation of a six-year highway construction plan listing proposed projects which reflects the highway needs of the state. The General Assembly approves those projects that will be funded in the coming biennium. Reasonable cost forecasts for new and ongoing projects are required to ensure that funding is available and projects can be advanced on an orderly schedule.

KRS45.245, effective 1 July, 1992, granted the Interim Joint Committee on Transportation (IJCT) oversight of the biennial highway plan. Any phase of an authorized highway project--design, right-of-way, utility relocation, or construction--that exceeds the estimate shown in the plan by 15% must be reviewed by the IJCT. Estimates developed using current methods did not prove to be sufficiently accurate to preclude cost overruns in excess of 15%. During the reporting period (7/1/92 – 6/30/98), 562 overruns totaling approximately $265 million were submitted to the IJCT--all were approved for additional funding. No concerted effort was made by the IJCT to track the number of cost underruns. This review requirement was canceled by the General Assembly (HB 655) during the 1998 legislative session.

Estimates for highway projects are usually the responsibility of the 12 Highway District Offices, which have few resources allotted to estimating. Furthermore, initial estimates, based on very little information, do not statistically support a ±15% confidence level. In light of the high variability of estimates based on little information and the lack of resources dedicated to estimating, a reasonable approach is to base estimates on actual costs of past projects. For the conceptual estimate, the one used for initial authorization of a project, a cost-per-mile figure based on similar past projects can be used. After the design is completed

on a new project, estimates for the remaining phases--right-of-way, utility relocation, and construction--can be updated to reflect design decisions such as route, grade and drain, etc.

A cost-per-mile estimating model, KYEstimate, was developed to assist estimators in making conceptual estimates using databases of preconstruction (design, right-of-way acquisition, and utility relocation) and construction project costs for the past six years.

This study collected data for cost overruns, developed construction and preconstruction databases, established a standard for the storage of data in the databases, and developed a user-friendly computer program, KYEstimate, to assist estimators to use historic data to make and/or justify estimates. Training on the program was provided to estimators on request.

INTRODUCTION

There is a need for better cost estimating and forecasting for highway work in the Commonwealth of Kentucky. This need was recognized by the Kentucky Transportation Cabinet (KyTC), the Kentucky Legislature and the Federal Highway Administration (FHWA). A three-year research project was approved by the KyTC and the FHWA, starting in July 1993, to study current practices and to recommend improvements for the estimating process. The project timetable specified the following annual goals:

- Year 1 (7/93-6/94) - Study current practices and problems, and make preliminary recommendations for potential improvement areas.
- Year 2 (7/94-6/95) - Develop and/or modify procedures and tools to improve the estimating process.
- Year 3 (7/95-6/96) - Implement improvements and train KyTC personnel in their use.

In 1996 the study was extended for two years, with the following goals:

- Year 4 (7/96-6/97) - Collect additional cost data, refine KYEstimate and train KyTC personnel in its use.
- Year 5 (7/97-6/98) - Collect additional cost data.

The impetus for improving cost forecasting for highway work came from a law enacted during the 1992 General Assembly session. KRS 45.245, effective July 1, 1992, mandated that the amount authorized for expenditure on any project phase--design, right-of-way, utility relocation or construction--cannot exceed that stated in the current biennium highway plan (2YP) by more than 15% without being presented by the KyTC to the Legislature's Interim Joint Committee on Transportation (IJCT) for review. The presentation to the IJCT included written certification from the State Highway Engineer that the overrun was caused by unanticipated circumstances, and provided specific details on the reasons for the cost overrun. The IJCT determined if the proposed additional money was reasonable and

necessary, and also, if any alteration made or planned since its consideration by the General Assembly materially changed the project. The law was cancelled by HB655 during the 1998 General Assembly and there is no longer a requirement for formal review by the IJCT of cost overruns. During the law's six year life, 562 phase overruns >15%, for a total cost of approximately $260 million, were submitted to the IJCT and all were approved for additional funding.

This, the final report, discusses the findings of the five years of the project:

- Summary of First Year's Findings - reviews the research findings presented in the first interim report, KTC 94-9, March 1994.
- Summary of Second Year's Findings - reviews the research findings presented in the second interim report, KTC 95-12, July 1995.
- Summary of Third Year's Findings - reviews the research findings presented in the third interim report, KTC 96-14, July 1996.
- Summary of Fourth & Fifth Year's Findings - reviews the efforts presented in the fourth interim report, KTC 97-13, July 1996, and those of the fifth year.
- Estimates During the Period of Study - presents an analysis of the cost overruns >15% that were presented to the IJCT for review during the research period.
- Cost-per-mile Model - presents a computer model, KYEstimate, that sorts data from the preconstruction and construction databases to assist an estimator in making a conceptual estimate based on past performance.
- Conclusions - reports conclusions based on research findings.
- Recommendations - makes recommendations based on the research effort.
- Appendix I – contains explanations for codes used by KYEstimate.
- Appendix II – contains breakdown of cost overruns > 15% by causes.

SUMMARY OF FIRST YEAR'S FINDINGS

The section provides a summary of the status of the research effort when the first interim report, KTC 94-9, was issued in March 1994. The statements used reflect conditions at that time and may be updated later in this report to reflect current conditions.

The current process of forecasting costs for highway work in Kentucky is not satisfactory to either the KyTC or the Legislature. The reporting requirements of the new oversight law, KRS45.245, impose additional burdens on an already seriously understaffed highway department. The limits imposed for reporting are in some cases difficult to meet, and in other cases possible to meet only with additional staffing and/or by not performing current duties.

The choice seems to be to either accept the status quo or to try to mitigate the problem; Solving the problem entirely--insuring that no project phase overruns its estimate by 15%--is not reasonable. There are three ways to address the issue of cost estimate deficiencies and subsequent justification furnished to the Legislature. The first is for the Legislature to either forego the oversight or to modify it so the KyTC can meet the requirements with current staffing levels. The second is for the KyTC to change how the 6YP and the 2YP are developed, and the third is for the KyTC to staff up as necessary to improve its estimating ability. All of these options have financial and political implications.

The current oversight requirement had resulted, to date, in 134 overruns worth over $69 million being presented to the IJCT for review. All of these overruns were approved. The IJCT makes no concerted effort to track cost underruns, which would provide as much evidence as cost overruns to verify the accuracy of project estimates. In an effort to address this problem KyTC is increasing estimates to reduce the possibility of having to report phase overruns in the future. This practice makes the development of a realistic 6YP and 2YP unlikely.

The Legislature could either forego the oversight or modify it so the KyTC can meet the requirements with current staffing levels. A statute change would be required to forego the oversight or to change its provisions. Modifications that could mitigate the current problem include setting a realistic limit for both overruns and underruns based on the class of estimate in the 2YP, not 15% across the board; track overruns by overall project cost instead of by project phase; and/or establish a review process that requires the KyTC to inform the IJCT by report of all overruns and underruns, but to formally respond with backup data to only those overruns the IJCT truly thinks may need to be examined, not those that will be summarily approved.

The KyTC can change how the 6YP and the 2YP are developed. The most effective change would be to complete either an in-depth scoping study and/or preliminary design prior to adding a project to the 6YP. This would require that work performed prior to authorization of the 6YP be funded by state funds.

The KyTC can staff up to improve its estimating ability. Increased staffing would require either the Executive Branch's approval for hiring additional personnel and/or KyTC's commitment to reallocate resources. The increased staffing would primarily include right-of-way and utility personnel to be involved in preliminary estimating. Also, demands for on-the-spot estimates would have to be curtailed so the increased staff could scope the proposed project prior to submitting the initial estimate.

The three ways to mitigate the current problem are being used, to some degree, by other states. The largest notable difference between Kentucky and most other states is the legislative oversight requirement. While many states have some sort of progress review of the highway plan, almost none have legislative involvement after budget approval. Many states are better staffed for estimating than Kentucky and some states do a considerable amount of preliminary design work prior to a project being placed on the highway plan.

Regardless of which of the above-mentioned options, or combinations thereof, are selected to mitigate the current problem, improvement of the current estimating and cost forecasting process is possible. Areas this study will address during the next year are: how to better use existing data, what unused data sources are available, and how to improve current estimating procedures.

Estimates are a product of experience and information. Estimating experience has been disappearing rapidly in the KyTC. It is vitally important to develop databases and make them available to personnel throughout the state. These databases will not only improve estimating ability but will serve to help justify estimates that later turn out to be inaccurate.

This study offers an opportunity to make improvements to the KyTC's cost forecasting ability and to the relationship between the KyTC and the Legislature. In order to seize this opportunity, both the Legislature and the KyTC must communicate openly with each other, and with the researcher, in an effort to find a workable solution which considers both political and fiscal realities.

SUMMARY OF SECOND YEAR'S FINDINGS

The second interim report, KTC 95-12, issued in July 1995, is summarized in this section. Statements used in this section of the report reflect conditions at that particular time, and may be changed later to represent current conditions.

Research continues to show that the Legislature should either forego the oversight or modify it so the KyTC can meet requirements with the current staffing levels, the KyTC must change how the 6YP and the 2YP are developed, and/or the KyTC should increase its staff to improve the estimates.

The current oversight requirement had resulted, to date, in 263 overruns worth over $116 million being presented to the IJCT since the law became effective (7/1/92). All of these overruns were approved. The IJCT continued to make no concerted effort to track cost underruns.

Relevant cost data for both preconstruction and construction phases were collected to provide estimators with cost from past projects. These projects are stored in a manner that allows estimators to efficiently select data useful to their current project.

Projects in both databases are defined by twelve key attributes:

1 District	7 Length
2 Item #	8 Percent bridge length
3 County	9 Number of bridges or major culverts
4 Type of work	10 Award year
5 Functional classification	11 Route name
6 Number of lanes	12 TD-10 Number

District - state highway district or districts; by number 1 – 12
Item # - district identifier number
County - county or counties; by name
Type of work - FHWA Order M5600.1A, 12/87 (see Appendix I)
Functional classifications - KyTC classification system (see Appendix I)

Number of lanes - number of lanes involved
Length - length in miles to three decimal points
Percent bridge length - [bridge length/project length] x 100
Number of bridges - total number of bridges (or culverts > $50,000) in project
Award year - calendar year project was awarded for construction
Route Name - number of road: US60, KY109, etc.
TD-10 Number - number on the Project Authorization Form

Along with the above attributes are the cost of each preconstruction phase or construction phase and the fiscal year of the project. The search for data was limited to the last four years because of missing data related to the twelve attributes. Key characteristics were missing from many of the projects, precluding their inclusion in the databases.

The cost per mile model, KYEstimate, is written in Microsoft EXCEL 5.0 and designed to aid in the estimating process. The program will allow estimators to access the databases and select past projects that are similar to a project they want to estimate. The program uses the length of the project and total costs to calculate the unit costs of the project. The estimators can then use the historical data or enter their own estimate based upon their past experience. A summary sheet of all pertinent information about the estimate can be printed and/or saved for later reference. The model is still under development.

A model was also under development using a cost per parcel concept for the right-of-way phase. This program was also developed in Microsoft EXCEL 5.0. The database was defined by attributes such as: parcel number, owner's name, parcel type, cost of parcel, area of parcel, building purchase, and litigation. The model and data seemed to be insufficient for determining an accurate cost per parcel. There was an extremely high variation in values for similar projects, and as a result, this method for developing a conceptual estimate for the right-of-way phase was abandoned.

A questionnaire was sent to the twelve district highway offices asking about the current process for developing conceptual estimates, seventy percent were returned. Responses showed that although most estimators are comfortable with their conceptual estimates, they are not sure what constitutes a good conceptual estimate because of lack of feedback.

Performance measurements that were being investigated included:

Actual cost of project phases vs. Estimated cost of project phases
Number of projects let vs. Number of projects planned to let
Actual Revenues vs. Estimated Revenues
Number of projects negotiated vs. Number of projects litigated
Amount of money received form federal turnovers at end of the federal GY
Standard Deviation of [[A – E]/A]*100 for each year
Number of project overruns
Number of project underruns

The current process for forecasting costs for highway work in Kentucky is not satisfactory to either the KyTC or the Legislature. The overrun threshold, >15%, is arbitrary and causes much wasted effort by KyTC personnel. It would be more effective to use different thresholds for different phases. Another alternative would be to update estimates once the design phase is completed and a better scope of work is determined. An improvement to the current process would be to require that only overruns beyond a certain amount be formally presented to the IJCT and others require only a proper notification.

SUMMARY OF THIRD YEAR'S FINDINGS

This section provides a summary of the third year's annual report, KTC 96-14, issued in July 1996. The information stated is a reflection of conditions at the time of issue and may be updated later in this report to indicate current conditions.

Research continues to show that some changes must be enacted to reduce the amount and cost of overruns. Three possible solutions include: First, the Legislature should either forego the oversight or modify it so the KyTC can meet requirements with the current staffing levels. Second, the KyTC should change how the 6YP and the 2YP are developed. Third, the KyTC should increase its staff to improve the estimates.

The current oversight requirement had resulted, to date, in 362 overruns worth over $162 million being presented to the IJCT. All of these overruns have been approved for additional funding. No concerted effort was made by the IJCT to track cost underruns.

The cost-per-mile model, KYEstimate, was refined to incorporate an inflation factor and the ability to convert the database to metric units. This inflation factor enables KYEstimate to provide a more realistic prediction of project cost. The conversion of units from English to metric broadens the scope of the model and enhances its future value. The data are stored in English units and continue to be used mainly in this format. These changes were brought about by suggestions of estimators after the first release of KYEstimate.

The databases used for the model were enlarged and transferred into the database program DBASE IV. Microsoft QUERY was used to pull the data from DBASE IV into KYEstimate for use. This modification protects the data from being changed during the running of the cost estimate model and allows for easy addition of new projects to the database. The primary identifier for the data was changed from the TD-10 number to the Item number. These changes were made to make the data easier for estimators to find and use.

SUMMARY OF FOURTH AND FIFTH YEAR'S EFFORTS

This section provides a summary of the fourth and fifth year's effort. The fourth year's effort was reported in interim report, KTC 97-15, June 1997.

The oversight requirement resulted in 362 overruns worth over $162 million being presented to the IJCT from the time the law became effective (7/1/92) until the fourth interim report. By the time of cancelation of the IJCT review requirement, 562 overruns >15% for a total cost of approximately $265 million were presented by the KyTC. All of these overruns were approved for additional funding.

The databases used for the model were enlarged using recent preconstruction and construction cost data. Some changes were made to KYEstimate to allow it to run on updated versions of Microsoft Excel.

ESTIMATES DURING THE PERIOD OF STUDY

Estimates developed using current methods have not proven to be significantly accurate to preclude cost overruns in excess of 15%. During the time the IJCT review requirement was in effect, 7/1/92-6/30/98, 562 overruns, totaling approximately $265 million were submitted to the IJCT for approval. All were approved for additional funding.

The following analysis is based on information compiled from all past copies of the **Notification to Legislature's Interim Joint Committee on Transportation Concerning Project Phase Cost Overruns > 15%**. This document, an overrun report, is submitted by the KyTC to the IJCT for a phase overrun >15% and is identified by a tracking number. A separate document is normally used for each phase request. A few documents were numbered and then withdrawn by the KyTC before consideration by the IJCT. Also, a few documents contained funding requests for two phases. The number of overruns used in the analysis, 562, differs slightly from the total tracking numbers.

Figure 1 shows a breakdown of the number of overrun occurrences by phase. Figure 2 shows a breakdown of overrun costs by phase. These graphs illustrate the percentage of occurrences and costs for all overruns during the time the law was in effect. The construction phase produced the most occurrences (2/5) and costs (2/3) of all overruns, followed by the right-of-way phase with about ¼ of the occurrences and 1/6 of the costs. Utility relocation phase contributed about 1/5 of the occurrences and 1/10 of the cost. The design phase accounted for the lease occurrences (1/7) and costs (1/20) of all overruns.

Table 1 shows the cost and frequency breakdown, plus percentages of the totals, by phase, of the 562 overruns. The **bold** number represent totals for the six years. Numbers in () are for the 1992 biennium, [] for 1994, and {} for 1992. Tables 2-5 show specific overrun causes for each phase and the number of occurrences of each. Because overruns may have more than one cause listed, the total number of cause occurrences may be higher than the total number of overruns for a phase. Appendix 2 contains a list of tracking numbers which refers to the specific documents included in the count.

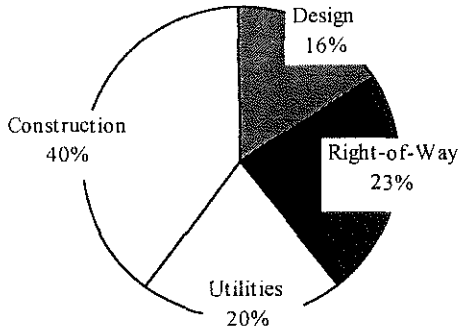

Figure 1 - Overrun Occurrences by Phase

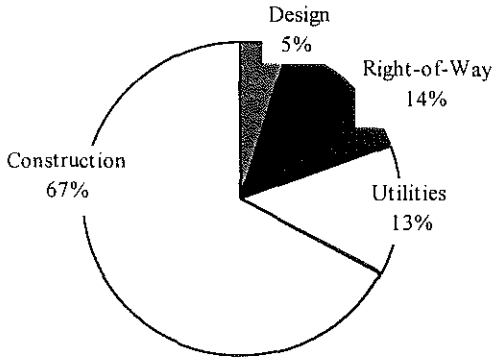

Figure 2 - Overrun Costs by Phase

Phase	Number of Occurrences	% Occurring *	Cost of Overruns (in millions)	% Cost **
Design	**91** (41) [29] {21}	**16** (21) [16] {12}	**$13** (6) [5] {2}	**5** (6) [6] {2}
Right-of-way	**132** (43) [46} {43}	**24** (22) [25] {24}	**$46** (15) [14] {17}	**18** (15) [17] {21}
Utility Relocation	**115** (25) [36] {54}	**20** (13) [19] {30}	**$27** (7) [9] {11}	**10** (7) [11] {13}
Construction	**224** (86) [74] {64}	**40** (44) [40] {35}	**$178** (71) [55] {52}	**67** (71) [66] {64}
Totals =	**562** (195) [185] {182}	**100**	**$265** (100) [83] {82}	**100**

* percent of the 562 overruns that occurred in each phase
** percent of the total cost of the 562 overruns ($265,000,000) attributable to each phase

Table 1: Breakdown of Highway Cost Estimate Overruns by Phase.

Design Phase Overruns

Overruns occurring in the design phase accounted for 16% of the total number and 5% of the total cost of all overruns: ninety (91) overruns @ $13 million. Table 2 contains a breakdown of causes of overruns for the design phase. Underestimation of the complexity of the project, underestimation because consultant fees were higher than the estimated *in-house* design costs, initial estimate based on preliminary data, and scope changes due to worse than expected site conditions were the main causes of design phase overruns. These causes accounted for nearly 90% of all design phase overruns. Due to the low percentage of cost, 5%, the design phase is not considered a major factor of overruns.

Cause/Justification of Overrun	Number of Occurrences as Causes for Design Phase Overruns	% Occurrence (% of All Design Phase Overruns)
Underestimation of complexity of project necessitating further design effort over what was originally envisioned	31	35
Underestimation because consultant fees were higher than the estimated in-house design costs	18	20
Initial estimate based on preliminary plans, maps, and data	14	15
Scope changes due to site conditions being worse than expected	9	10
Scope changes due to local and public pressure & involvement	8	9

Table 2: Major Causes of Design Phase Overruns.

Right-of-way Overruns

Overruns in the right-of-way phase accounted for 24% of the total number and 18% of the total cost of all overruns: One hundred and thirty two (132) overruns @ $46 million. Table 3 shows the major causes of overruns for the right-of-way phase. Initial estimate made with very preliminary plans, maps, and generalized data; and changes in project scope as a result of decisions made in design were the two major causes of overruns. These two causes contributed to over half of the total overruns. Two other major causes are unusually high jury award and land values increased in vicinity of proposed right-of-way, causing 26.4% of the overruns.

Cause/Justification of Overrun	Number of Occurrences as Causes for ROW Phase Overruns	% Occurrence (% of All ROW Phase Overruns)
Initial estimate made with very preliminary plans, maps, and generalized data: estimate updated based on more design detail	50	31
Changes in project scope as a result of decisions made in design	39	24
Unusually high jury award	25	16
Land values increased in vicinity of proposed right-of-way	18	11
Changes in project scope as a result of worse than expected site conditions	9	6

Table 3: Breakdown of Right-of-way Phase Overruns

Utility Relocation Phase Overruns

Overruns in the utility phase accounts for 20% of the total number and 10% of the total cost of all overruns: one-hundred and fifteen (115) overruns @ $27 million. Table 4 shows that the three most common causes were initial estimate made with very preliminary plans, maps, and generalized data, changes in scope from design changes, and increased relocation costs. These causes contributed about 90% of the total causes.

Cause/Justification of Overrun	Number of Occurrences as Causes for Utility relocation Phase Overruns	% Occurrence (% of All Utility relocation Phase Overruns).
Initial estimate made with very preliminary plans, maps, and generalized data. Estimate updated based on more design detail	48	31
Changes in project scope as a result of decisions made in design	39	25
Increase in relocation costs over what was expected	27	17
Inadvertent omission	15	10
Changes in scope due to worse than expected site conditions	13	8

Table 4: Breakdown of Utility Relocation Phase Overruns.

Construction Phase Overruns

Overruns in the construction phase accounted for 40% of the total number and 67% of the total cost of all overruns: two hundred and twenty-four (224) overruns @ $178 million. The majority of overruns still occur in the construction phase. In addition, the construction phase still comprises the largest percentage of the total overrun cost, much greater than the three other phases. Table 5 shows that the major causes for construction overruns was higher than expected unit bid prices and/or individual work item costs. This one cause contributes one third (1/3) of the total causes for construction overruns. Two other major causes were changes in project scope as a result of decisions made in design and changes in scope due to worse than expected site conditions, contributing a combined 31% of the overruns.

Cause/Justification of Overrun	Number of Occurrences as Causes for Construction Phase Overruns	% Occurrence (% of All Construction Phase Overruns).
Higher than expected unit bid prices and/or individual work item costs	136	38
Changes in project scope as a result of decisions made in design	58	16
Changes in scope due to worse than expected site conditions	40	11
Utility work done in construction phase	32	9
Inadvertent omission	22	6
Initial estimate made with very preliminary plans, maps, and generalized data: estimate updated based on more design detail	25	7
Change in KyTC policy for contingency percent add-on	13	4

Table 5: Breakdown of Construction Phase Overruns.

The following conclusions can be drawn from the data presented in Tables 1-5.

- While design phase overruns account for 16% of all overruns, they only account for 5% of the total cost reported. Design phase overruns are not a major problem.
- Based on the 562 overruns >15%, the following would likely have occurred if estimates had been subject to the 15% overrun limitation only after the design phase was completed:
- Approximately 50% of the right-of-way overrun causes would have been eliminated.
- Approximately 50% of the utility relocation overrun causes would have been eliminated.
- Approximately 25% of construction overrun causes would have been eliminated.
- Changes in project scope as a result of worse than expected site conditions contributed 10% of the causes listed for design phase overruns; 6% for right-of-way overruns, 8% for utility relocation overruns, and 11% for construction overruns. This cause provided fewer overruns in later bienniums, but increased site investigation by designers and estimators might reduce these overruns further. However, some soil conditions and contamination will always present a problem.
- The construction phase accounted for 2/3 of the total cost of all overruns, but only 40% of the occurrences. Reducing the construction overruns will have a major impact on the cost to the state. Approximately 38% of overrun causes could be reduced if accurate unit bid price data was used.
- Causes for overruns resulting from omissions in the estimates, transposing numbers, or switching of work between phases cannot be avoided unless estimates are updated periodically.

COST-PER-MILE MODEL

The Cost-per-mile Model, KYEstimate, is a computer based program, written in Microsoft EXCEL 5.0, that:

a) allows an estimator to access the preconstruction and construction databases through DBASE IV software and Microsoft Query,

b) allows an estimator to select a set of past projects that are similar to the new project,

c) processes the data related to the set of past projects producing a conceptual estimate based on historical data,

d) allows an estimator to either accept the estimate based on historical data or to enter a new estimate,

e) provides statistical information about the predicted accuracy of the new estimate based on past projects, and

f) produces a Summary Sheet with the new estimate and important information about what the model predictions.

The model, called KYEstimate, is very user-friendly. It went through several iterations during its development. A copy of the program, with a user's manual, was distributed to the 12 highway districts in January of 1996. After allowing the estimators a few weeks to experiment with the model, researchers went to each of the districts to answer questions and get feedback on the program.

Reception to the program varied across the state. While some estimators seemed pleased to finally get some help with their conceptual estimates, others were not very receptive to using the program. The number one complaint of the estimators was the size of the database. Many districts only had 15 to 20 projects and therefore could not get a reasonable estimate.

Estimators were also asked what parts of the program were most beneficial to them, or if there were unnecessary components within the program. Many suggested that the work type list was too defined, giving many maintenance projects that just would not be used.

Others suggested the program provide metric units and that an inflation factor be applied to the estimate. Each highway district was left with a copy of their district's projects and asked to make any corrections they felt were needed. Only five of the twelve districts returned any information on their data.

After the visit with the districts, several changes were made to the model. Most were only cosmetic changes. Some of the data were moved around to make it easier for the estimators to find. Item number became the primary identifier rather than TD-10 number. Some classifications in the database were deleted because they were not valuable to the estimators.

The databases are DBASE IV files, which facilitate updating the data. Upon opening the program, the database (either preconstruction or construction depending on what the user specifies) is pulled into the program using Microsoft QUERY. This protects the database from being changed within the program, but allows someone to update the DBASE IV file and send it to the districts. The updated copy of KYEstimate was released during February 1997.

The size of the databases increased as more project phases were completed. With increases in projects the model becomes more valuable, using a much larger database to predict unit costs. Problems with incomplete data continue to limit the number of projects that can be included. Estimators may throw out projects with extremely high or low cost and still be left with a sufficient number of projects to use for their estimate.

A metric option was added to the program. The database is in English units, but once in KYEstimate, it may be changed to metric. An inflation factor, default of 3%, is used on the estimates. Estimators can change the inflation factor if they believe the 3% is not accurate. Also, the inflation factor is now projected to the approximate time the project will be used, 2 years for preconstruction and 4 years for construction projects.

Projects in the database can be selected by nine key attributes:

1 District
2 Construction Fiscal Year
3 Construction Type
4 Route
5 Work Type
6 Number of Lanes
7 Functional Class
8 Length
9 Lane Width

District – state highway district or districts; by number 1 – 12

Construction Fiscal Year – year the construction phase took place

Construction Type – types of work done in construction phase (see appendix)

Route – road abbreviation and road number: US 60, KY 109, etc.

Work Type – FHWA Order M5600.1A, 12/87 (see appendix)

Number of lanes – number of lanes involved

Functional classification – KyTC classification system (see appendix)

Length – length in miles to three decimal points

Lane Width – the width of the particular route

EXAMPLE

A new estimate is needed for the construction phases of a 2-lane rural resurfacing project in Clark County. The road length is three miles and includes shoulder improvements.

All information relevant to the estimate is provided on the Estimate Summary Sheet screen shown in Figure 3 (page 21).

After entering the information identifying the project, etc. (Estimate Identification, Figure 3), the estimator moves to the construction database and selects criteria to use in the search for completed projects similar to the new project. The criteria are set by selecting combinations of items under each of the headings in Table 3. These items may be combined by using logical queries. In the case of text, the queries may be AND, OR, =,

ESTIMATE SUMMARY SHEET

ESTIMATE IDENTIFICATION

PROJECT ID #	123456
ROAD NAME	US 60
DISTRICT	7
ESTIMATOR	J.Walton
UNITS(ENG/METRIC)	ENG
DATE OF ESTIMATE	10/1/98

STATISTICAL ANALYSIS - (COMPUTER RESULTS)

	DESIGN	ROW	UTILITY	CONSTR	TOTAL
MEAN UNIT COST				58,839	58,839
STANDARD DEVIATION				34,225	34,225
HISTORICAL MAX UNIT COST				141,192	141,192
HISTORICAL MIN UNIT COST				24,575	24,575
SIZE OF DATABASE				13	

USER ESTIMATE

	DESIGN	ROW	UTILITY	CONSTR	TOTAL
USER ESTIMATE (UNIT COST)					
PROB OF EXCEEDANCE (%)					
Z= # OF STD DEVS AWAY					
% UNDER/OVER MEAN UNIT COST					

6 YP ESTIMATE

APPROXIMATE PROJECT LENGTH IN	MILES	3.000
INFLATION FACTOR (%)		3.0

	DESIGN	ROW	UTILITY	CONSTR	TOTAL
MEAN ESTIMATE ($)				176,516	176,516
USER ESTIMATE ($)					
6 YP ESTIMATE ($)				198,670	$198,670

SUMMARY OF DATABASE SEARCH CRITERION

	SEARCH 1	SEARCH 2	SEARCH 3	SEARCH 4	SEARCH 5	SEARCH 6	SEARCH 7
DIST	7						
CONST_FY							
CON_TYPE	H						
ROUTE							
WORK_TYPE	72						
# LNS1	2						
FCLASS1	R						
LENGTH							
LN_WDTH							

ESTIMATE JUSTIFICATION/SPECIAL CONDITIONS:

Project numbers 920437 and 940637 were deleted from the construction page to leave only 11 projects fitting the above criteria. Those specific projects had certain conditions that made them unuseful in estimating a project of this type.

Figure 3 – Estimate Summary Sheet

etc. In the case of numbers, the queries may be =, >=, etc. A new system allows the user to type in his/her selection and click the "Filter" button.

In this case, after trying various combinations, the estimator selects the following: Construction database, District 7, Construction Type H, Work Type 72, 2 lanes, and Rural roads. The search of the construction database using these criteria finds the projects data shown in Table 6.

Table 7. Search Results

DISTRICT	ITEM_NO	LENGTH	LN_WDTH	TOTAL	FY	UNIT COST	UNIT COST INFLATED
7	920302	0.856	9	18146	1992	$21,199	$23,859
7	920302	6.024	9	145489	1992	$24,152	$27,183
7	940372	5.356	10	183082	1994	$34,183	$36,264
7	910301	1.016	6	31906	1991	$31,404	$36,405
7	910301	4.269	8	140776	1991	$32,976	$38,229
7	920765	6.74	11	265621	1992	$39,410	$44,356
7	940372	0.584	12	24789	1994	$42,447	$45,032
7	930182	8.241	10	362919	1993	$44,038	$48,122
7	930182	1.613	9	77096	1993	$47,797	$52,229
7	930182	0.226	10	13867	1993	$61,358	$67,048
7	940637	0.472	11	34622	1994	$73,352	$77,819
7	920437	1.853	12	179451	1992	$96,843	$108,998
7	940637	2.535	10	327550	1994	$129,211	$137,080

The cost-per-mile of the selected past projects is calculated and presented on the screen (Statistical Analysis, Figure 3).

The estimator can use the estimates for each phase determined by means of the actual costs of past projects in the selected set or enter a new estimate. If a new estimate is entered, statistical information about the probability of the estimate's accuracy based on past data is presented (User Estimate, Figure 3). The estimate to be used in the six-year plan is shown (6 YP Estimate, Figure 3). The estimator then records the criteria used for the set of projects used in the trial estimate (Search Criteria, Figure 3.). Also, any justification for the new estimate being higher or lower than the historical data would predict is recorded (Estimate Justification, Figure 3).

The model, while simple in concept, is actually quite complex.

An experienced estimator would likely make a better estimate than would KYEstimate. However, an experienced estimator is not always available, and it is sometimes difficult to justify an estimate when actual costs are quite different. Using KYEstimate and making a new estimate in line with past experience is a conservative approach to conceptual estimating and provides justification based on past experience.

CONCLUSIONS

The process of forecasting costs for highway work in Kentucky, in 1992, wasn't satisfactory to either the KyTC or the Legislature. The reporting requirements of the oversight law, KRS45.245, imposed additional work on the KyTC. The limits imposed, ~~whereby reporting was required~~, were in some cases impossible to meet, and, in other cases, possible to meet only with additional staffing and/or by some staff members not performing normal duties.

The oversight requirement (7/92-7/98) resulted in 562 overruns worth approximately $265 million being presented to the Interim Joint Committee on Transportation for review. All of these overruns were been approved. The IJCT made no concerted effort to track cost underruns which demonstrate a poor estimate as much as an overrun.

The overrun threshold, >15%, was arbitrary and caused a lot of wasted effort by KyTC personnel. It would have been better to use different thresholds for different phases, or to allow updating estimates once the design phase is completed and a better scope of work is available.

The conceptual estimating process can be improved by using actual costs of past projects to develop estimates for new projects. To do this requires that critical data be kept on all projects. KYEstimate can process historical data to allow estimators to use only those projects with like characteristics when preparing a new estimate.

Estimates for right-of-way costs have not seen improvement with use of actual costs of past projects. The cost per parcel model and database that was being developed showed a high variation in unit costs and was abandoned.

Estimates are a product of experience and information. Estimating experience has been disappearing rapidly in the KyTC. It is vitally important to develop databases and make them

available to personnel throughout the state. These databases will not only improve estimating ability but will serve to help justify estimates that later turn out to be inaccurate.

This study offered an opportunity to make improvements to the KyTC's cost forecasting ability and to the relationship between the KyTC and the Legislature. A tool was developed that should improve the KyTC's conceptual estimating ability as well as provide justification for estimates that vary widely from actual costs.

RECOMMENDATIONS

The following recommendations are made, based on the findings of this five-year study.

- Look for innovative ways to improve both estimates and relations with the Legislature.
- Educate legislators in the art/science of estimating and the limitations of what can be done with current resources.
- Develop and maintain statewide and regional databases of highway costs.
- Assign more resources to estimating, with a method to account for their utilization.
- Set up a budget from either new or reallocated funds for the estimating effort, so that a cause and effect relationship can be established.
- Develop a standard estimating procedure and train all estimating personnel on its use.
- Establish a formal review policy and schedule for all estimates.
- Require an estimator's name, date and estimate class for all estimates appearing on the *Project Authorization Form* (TC-10).

APPENDIX I

1.	Planning phase, project planning studied	P
2.	Design phase, design projects	D
3.	Right-of-way phase, right-of-way projects	R/W
4.	Construction phase	U
	a. Grade, drain, and surfacing	C
	b. Grade and drain	G
	c. Surfacing on new route or reconstruction	S
	d. Bridge construction	B
	e. Roadside improvement	I
	f. Traffic Services	T
	g. Service facilities	F
	h. Resurfacing	H

Functional Class Codes

1. Rural Principal Arterial – Interstate	RPAI
2. Rural Principal Arterial – Other	RPAO
6. Rural Minor Arterial – Other	RMNA
7. Rural Major Collector	RMJC
8. Rural Minor Collector	RMIC
9. Rural Local Road	RLR
11. Urban Principal Arterial – Interstate	UPAI
12. Urban Principal Arterial – Freeway/Expressway	UPAFE
14. Urban Other Principal Arterial	UOPA
16. Urban Minor Arterial	UMNA
17. Urban Collector	UC
19. Urban Local Street	ULS

Work Type Classification

Code	Explanation
010	New Route
020	Relocation
031	Reconstruction to Freeway
032	Reconstruction with More Lanes
033	Reconstruction to Wider Lanes
034	Pavement Reconstruction with Alignment Improvements
035	Pavement Reconstruction
040	Major Widening
050	Minor Widening
060	Restoration and Rehabilitation
071	Resurfacing with Shoulder Improvements and Portland Cement Concrete Pavement Restoration
072	Resurfacing with Shoulder Improvements and Bituminous Pavement Restoration
077	Resurfacing with Portland Cement Concrete Pavement Restoration
078	Resurfacing with Bituminous Pavement Restoration
080	Bridge Replacement
081	Bridges Rehabilitation
082	Minor Bridge Rehabilitation
090	Safety
091	Traffic Control Systems
092	Environmental Enhancement

APPENDIX II

Major Causes of Design Phase Overruns

Cause/Justification of Overrun	# Occurrences as Causes	Contributing Track Numbers
Underestimation of complexity of project necessitating further design effort over what was originally envisioned	31	6,26,50,88,90,94,95,99,139,140,141,158, 175,176,183 [12,14, 53,54,55,59,65,71,79, 121,146,152] {5,88, 89,143}
Underestimation because consultant fees were higher than the estimated in-house design costs	18	5,42,43,50,76,77,96, 97,106,109 [71,77,79] {98,99,106,128, 139,140}
Initial estimate based on preliminary plans, maps, and data	14	7,8,9,60,61,62,63,107,161 [49,159,163,169] {25,37}
Scope changes due to site conditions being worse than expected	9	3 [48,164,169,172,173] {53,96,109}
Scope changes due to local and public pressure & involvement	8	[25,42,43]

Major Causes of Right-of-way Phase Overruns

Cause/Justification of Overrun	# Occurrences as Causes	Contributing Track Numbers
Initial estimate made with very preliminary plans, maps, and generalized data: estimate updated based on more design detail	50	6,26,50,88,90,94,95,113,136,138,154, 156,160,165 [8,26,41, 50,56,57,58,61,89,91,92,93,94,96,103,118,135,138] {3,6,7,9, 10,16,40,59,69,71,102,105,117,124,139,152,154,159}
Changes in project scope as a result of decisions made in design	39	73,87,89,118,155,167,168 [10,11,16,21,23,39,51,52,58,62, 89,116] {3,24,51,55, 62,63,70,71,76,83,86,95,108, 117,118, 127,139,140,141,158}
Unusually high jury award	25	1,2,3,25,48,53,71,83,114,157,166,192,193 [58,88,90,102, 116,118,139,153,154, 160,161] {58}
Land values increased in vicinity of proposed right-of-way	18	14,59,69,74,75,84,86,87,89 [10,56,85, 93,112,138,144] {16, 158}
Changes in project scope as a result of worse than expected site conditions	9	59 [38,57,61,93,132] {38,59,136}

Major Causes of Construction Phase Overruns

Cause/Justification of Overrun	# Occurrences as Causes	Contributing Track Numbers
Higher than expected unit bid prices and/or individual work item costs	136	12,16,17,18,19,20,21,22,23,24,29,30,31,36,39,45,46,47,54, 66,78,79,80,81,82,85,93,104,105,119,120,121,122,126,127, 128,129,130,131,133,134,135,143,147,148,150,151,152,163, 164,178,179,180, 181,182,184,185,189,194,195,196 [3,4, 7,19,20,28,29,30,33,35,36,37,44,46,47, 60, 66,67,68,75,76, 81,82,86,98,99,100,105,106,107,108,109,113,114,115,120, 124,125,126,127, 129,130,131,142,148,149,151,156,157,165, 166,167] {12,15, 19,20,21,26,28,34,35,42,43,44,46,47,54,56, 57,66,79,142,147,151,157}
Changes in project scope as a result of decisions made in design	58	16,21,29,37,38,45,57,58,82,102,145,146,153,162 [5,7, 15,33, 45,66,69,100,113, 130,141,143,170,171] {13,18, 21,26,30,31, 34,35,41,46,54,56,61,66,74,79,80, 101,107,110,111,112,125, 126,147,148,149,150,151,155}
Changes in scope due to worse than expected site conditions	40	11,30,39,56,187,188 [20,27,46,47,70,75, 82,114,124,148,149, 150,151,156] {14, 17,27,32,33,65,73,74,78, 82,84,85,92,94, 97,112,113,142,151,156}
Utility work done in construction phase	32	12,17,21,24,30,31,57,58,85126,144,149,151,152,153,164 [3,5,7,34,60,66,76,81, 113, 156,168] {45,116,126, 150,157}
Inadvertent omission	22	18,21,55,100 [19,45,69,100,105,106,131,137,150,151,156, 168] {19,42,43,85,93, 101}
Initial estimate made with very preliminary plans, maps, and generalized data: estimate updated based on more design detail	25	19,23,35,36,56,123,123,125,132,186 [46, 47,80,81,109,114, 127,128, 129,142,143,167] {15,29,57,81}
Change in KyTC policy for contingency percent add-on	13	[30,35,36,45,46,47,67,68,86,148,149, 150,151]