Research Report
KTC 96-14

COST ESTIMATING AND FORECASTING FOR HIGHWAY WORK IN KENTUCKY

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16. Abstract

There is a need for better cost estimating and forecasting for highway work in the Commonwealth of Kentucky. KRS45.245 grants 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%. In recent years, the Kentucky Transportation Cabinet has suffered the loss of many resources necessary to produce good cost estimates.

Estimates developed using current methods are not sufficiently accurate to preclude cost overruns in excess of 15%. Over the 1992 and 1994 bienniums, 362 overruns totaling $162,487,511 have been submitted to the Committee. All have been approved for additional funding. KYEstimate, a cost-per-mile model, has been developed to improve estimates made in the district offices. This program uses preconstruction and construction data to calculate a unit cost for projects. New projects may then be estimated on past cost of similar projects.

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EXECUTIVE SUMMARY

There is a need for better cost estimating and forecasting for highway work in the Commonwealth of Kentucky. The objectives of this study, approved July 1993, are to investigate current practices and to recommend improvements for the estimating process. This report details the findings of the first three years of the research effort and outlines the path forward.

The Kentucky Transportation Cabinet (KyTC) is responsible for the creation of a six-year highway construction plan listing proposed projects which reflect 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, grants 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 have not proven sufficiently accurate to preclude cost overruns in excess of 15%. To date (7/1/92 - 7/1/96), 362 overruns totaling over $162 million, have been submitted to the IJCT--all have been approved for additional funding.* No concerted effort was made to track the number of cost underruns.

Estimates for highway projects are usually the responsibility of the 12 District Highway Offices, which have few resources allotted to estimating. Furthermore, initial estimates, based on very little information, don't 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

* Six additional overruns for the 1994 biennium were processed after this report was prepared.

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 model, KYEstimate, has been developed to assist estimators in making conceptual estimates based on databases of preconstruction and construction project costs for the past five years.

Emphasis for Year 4 of this study will be to enlarge the preconstruction and construction databases, refine KYEstimate, and develop and implement a training plan for the use of the model.

INTRODUCTION

There is a need for better cost estimating and forecasting for highway work in the Commonwealth of Kentucky. This need has been recognized by the Kentucky Transportation Cabinet (KyTC), the Kentucky Legislature and the Federal Highway Administration (FHWA). A 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 specifies 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.
- 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 and refine KYEstimate.

The impetus for improving cost forecasting for highway work comes from a law enacted during the 1992 General Assembly session. KRS 45.245, effective July 1, 1992, mandates 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 must include written certification from the State Highway Engineer that the overrun was caused by unanticipated circumstances, and provide specific details on the reasons for the cost overrun. The IJCT determines if the proposed additional money is reasonable and necessary, and also, if any alteration made or planned since its consideration by the General Assembly materially changed the project.

This, the third interim report, discusses the findings of the first three years of the project:

- Summary of First Year's Findings - reviews the research findings presented in the first interim report, March 1994.
- Summary of Second Year's Findings - reviews the research findings presented in the second interim report, July 1995.
- Estimates During the Period of Study - presents an analysis of the cost overruns >15% 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 an estimate based on past performance.
- Conclusions - reports conclusions based on research findings to date.
- Preliminary Recommendations - makes recommendations based on the research effort to date.
- Path Forward - work to be accomplished during the fourth year of the research.

SUMMARY OF FIRST YEAR'S FINDINGS

The section provides a summary of the status of the research effort when the first interim report 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 isn't satisfactory to either the KyTC or the Legislature. The reason seems to be not so much that the cost forecasting ability of the KyTC has declined of late, but that the Legislature has voted itself more oversight of the 2YP execution. The reporting requirements of the oversight law, KRS45.245, impose additional burdens on an already seriously understaffed highway department. The limits imposed, whereby reporting is required, are in some cases impossible 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 feasible. There are three ways to mitigate the problem of *poor* cost forecasting. 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 in 134 overruns worth over $69 million being presented to the IJCT for review during the current biennium to date (7/1/92 - 2/13/94). All of these overruns were approved. The IJCT makes no concerted effort to track cost underruns, which would provide as much evidence of poor cost forecasting as overruns do. The oversight seems to be used not so much to improve KyTC's cost forecasting ability as it is to make a political statement about who is in charge of getting highways constructed in the Commonwealth. If this is indeed the case, and if blanket approval of all overruns is assured, then perhaps a continuation of the status quo is acceptable. However, currently the KyTC is trying to appease the IJCT by 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 impossible, and has the potential of causing the loss of federal funds if and when there aren't enough projects in the 6YP ready to be advanced into the 2YP to utilize approved federal aid.

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, 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 must 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 must increase its staff to improve the estimates.

The current oversight requirement had resulted in 263 overruns worth over $116 million being presented to the IJCT since the law became effective (7/1/92 - 7/1/95). All of these overruns were approved. The IJCT continued to make no concerted effort to track cost underruns.

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

Projects in both databases were defined by twelve key attributes:

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

Functional classification - KyTC classification system (see appendix)

Number of lanes - number of lanes involved

Length - length in miles to three decimal points

Percent bridge length - [bridge length/project length]

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 was 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, was written in Microsoft EXCEL 5.0 and designed to aid in the estimating process. The program would allow estimators to access the databases and select past projects that were similar to a project they wanted to estimate. The program used the length of the project and total cost to calculate the unit cost of the project. The estimators could 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 could be printed and/or saved for later reference. The model was 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 were comfortable with their conceptual estimates, they were not sure what constituted 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 from federal turnovers at end of the federal FY
Standard Deviation of: [[A - E]/A]*100 for each year
Number of project overruns
Number of project underruns

The current process of forecasting costs for highway work in Kentucky isn't 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 over a certain amount be formally presented to the IJCT and others require only a paper notification.

ESTIMATES DURING THE PERIOD OF STUDY

Estimates developed using current methods have not proven sufficiently accurate to preclude cost overruns in excess of 15%. Since the law became effective, (7/1/92 - 7/1/96), 362 overruns, totaling $162,487,511 have been submitted to the IJCT.* All have been 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 summary, is submitted by the KyTC to the IJCT for a phase overrun >15% and is identified by a tracking number.

Figure 2 shows a breakdown of the number of overrun occurrences, by phase. Figure 3 shows a breakdown of overrun costs, by phase.

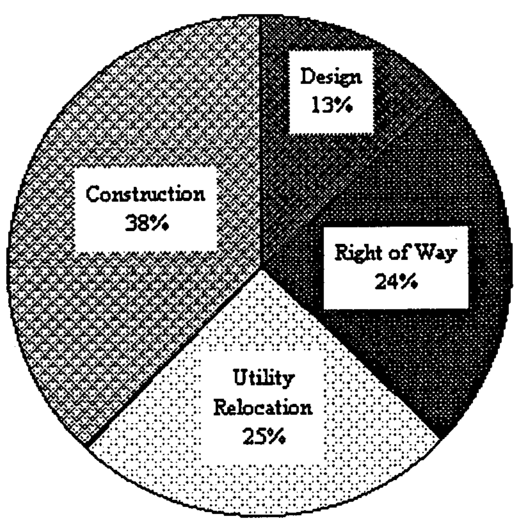

Figure 1 - Overrun Occurrences by Phase

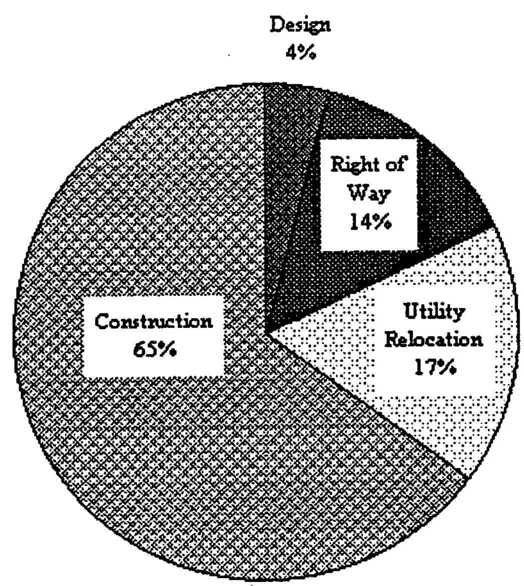

Figure 2 - Overrun Costs by Phase

* Six additional overruns for the 1994 biennium were processed after this report was prepared.

Table 1 shows the cost and frequency breakdown, by phase, of the 362 overruns to date. Tables 2-5 show specific overrun causes for each phase and the number of occurrences of each. Because some overruns have more than one cause listed, the total number of cause occurrences may be higher than the total number of overruns for a phase. Entries in the column, **Contributing Track Numbers**, refer to the specific documents where a cause is used as justification for an overrun. A brief synopsis of the impact of the overruns in each phase is also provided. For comparison, the figures from the 1992 biennium are found in brackets beside the updated figures.

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

Phase	Number of Occurrences	% Occurring *	Total Cost of Phase Overruns	% Cost **
Design	47 [20]	13.0 [11.0]	$6,946,919 [$1,900,000]	4.3 [2.3]
Right-of-way	88 [43]	24.3 [23.6]	$22,575,500 [$9,220,500]	13.9 [11.2]
Utility Relocation	90 [54]	24.9 [29.7]	$27,963,568 [$18,781,000]	17.2 [22.9]
Construction	137 [65]	37.8 [35.7]	$105,001,524 [$52,148,035]	64.6 [63.6]
Totals =	362 [182]	100.0	$162,487,511 [$82,049,535]	100.0

* percent of the 362 overruns that occurred in each phase
** percent of the total cost of the 362 overruns ($162,487,511) attributable to phase

Design Phase Overruns

Overruns in the design phase accounted for 13.0% of the total number and 4.3% of the total cost of all overruns: forty-seven (47) overruns @ $6,946,919. Table 2 shows that underestimation of the complexity of the project, underestimation because consultant fees were higher than the estimated *in-house* design costs, and scope changes due to worse than expected site conditions were the three primary causes for design phase overruns. These causes accounted for 61.1% of all design phase overruns, slightly lower than the 65.0% from the previous biennium. Three justifications were used during the 1994 biennium only; underestimation of cost of bridge inspection effort, part of design inadvertently omitted, and additional administration costs accounted for 13.1% of the design overruns in the 1994 biennium. While there were 20 causes for design phase overruns in the 1992 biennium, there were 34 in the 1994 biennium, an increase of 70%. Over the last biennium, the number of overruns occurring and the cost attributed to the design phase has risen 2.0%.

Table 2: Breakdown of Design Phase Overruns.

Cause/Justification of Overrun	Number of Occurrences as Causes for Design Phase Overruns	% Occurrence (% of All Design Phase Overruns).	Contributing Track Numbers
underestimation of complexity of project necessitating further design effort over what was originally envisioned	16 [4]	29.6 [20.0]	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	9 [6]	16.7 [30.0]	71,77,79 [98,99,106,128, 139,140]
scope changes due to site conditions being worse than expected	8 [3]	14.8 [15.0]	48,164,169,172,173 [53,96,109]
initial estimate based on preliminary plans, maps, and data	6 [2]	11.1 [10.0]	49,159,163,169 [25,37]
original estimate doesn't account for in-house evaluation of routine design project outlays and metric units	4 [3]	7.4 [15.0]	172 [144,145,146]
underestimation of cost of bridge inspection effort	3 [0]	5.6 [0.0]	25,42,43
part of design inadvertently omitted	3[0]	5.6 [0.0]	111,121,172
scope changes due to local and public pressure & involvement	2 [1]	3.7 [5.0]	79 [67]
shift in alignment necessitating a greater design effort than what was initially estimated	2 [1]	3.7 [5.0]	174 [2]
additional administration costs	1[0]	1.9 [0.0]	77
Totals =	54 [20]	100	

Right-of-way Overruns

Overruns in the right-of-way phase accounted for 24.3% of the total number and 13.9% of the total cost of all overruns: eighty-eight (88) overruns @ $22,575,500. Table 3 shows that the leading causes for right-of-way overruns in the 1992 biennium were changes in project scope made during the design phase and after the initial estimate was made. The leading cause in the 1994 biennium was that the estimate was made with very preliminary plans, maps, and data. Both of these causes together total 59.7% of the right-of-way overruns, as compared to the last biennium, 70.3% Scope changes in design arose for a variety of reasons. Oftentimes, changes were made to provide an improved facility over what was originally envisioned. At other times, design calculations (i.e., hydraulic analysis, sight distance requirements, traffic impact studies, etc.) led to changes involving different right-of-way parcels demands. These design changes included shifts in roadway alignment, widening of the proposed roadway and lengthening of bridges and approaches. New justifications to the 1994 biennium were acquisition of utility easements and settling of right-of-way parcels to speed up the process. Causes of right-of-way overruns in the 1992 biennium numbered 54, as compared to 114 in the 1994 biennium. That is an 111% increase in causes. The percent occurring of right-of-way overruns has increased by 0.7 and the percent cost of the overruns has increased by 2.7.

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

Cause/Justification of Overrun	Number of Occurrences as Causes for ROW Phase Overruns	% Occurrence (% of All ROW Phase Overruns)	Contributing Track Numbers
initial estimate made with very preliminary plans, maps, and generalized data: estimate updated based on more design detail	36 [18]	31.6 [33.3]	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, 71,102,105,117,124,130, 152,154,159]
changes in project scope as a result of decisions made in design	32 [20]	28.1 [37.0]	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]

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Table 3: Breakdown of Right-of-way Phase Overruns. (continued)

unusually high jury award	12 [1]	10.5 [1.9]	58,88,90,102,116, 118,139,153,154,160,161 [132]
land values increased in vicinity of proposed right-of-way	9 [2]	7.9 [3.7]	10,56,85,93,112,138,144 [16,158]
changes in project scope as a result of worse than expected site conditions	8 [3]	7.0 [5.6]	38,57,61,93,132 [38,59,136]
inadvertent omission	6 [5]	5.3 [9.3]	50 [1,58,70,76,158]
improvement made to right-of-way after initial estimate was made	6 [2]	5.3 [3.7]	57,123,145,158 [72,133]
new or modified legislation enacted after initial estimate made	3 [3]	2.6 [5.6]	[16,51,64]
acquisition of utility easements (usually part of the utility phase)	1 [0]	0.9 [0.0]	10
settling of ROW parcel to speed up process	1 [0]	0.9 [0.0]	24
Totals =	114 [54]	100	

Utility Relocation Phase Overruns

Overruns in the utility relocation phase have decreased (unlike any other phase) since the 1992 biennium. They currently accounting for 24.9% of the total number and 17.2% of the total cost of all overruns: ninety (90) overruns @ $27,963,568. Table 4 shows that the most frequent cause for utility relocation overruns, like that for the right-of-way phase, came from the initial estimate being made with very preliminary plans, maps and generalized data. Similarly, the second leading cause for utility relocation phase overruns was due to changes made in the project scope during the design phase. Combined, these two causes account for 57.3% of all the utility relocation phase overruns, somewhat less than the 70% last biennium. The cause of overruns in the utility phase has decreased by almost 26% since the 1992 biennium, going from 70 causes to just 52. The number of utility overruns occurring and the cost attributed to them have both dropped by about 5%.

Table 4: Breakdown of Utility Relocation Phase Overruns.

Cause/Justification of Overrun	Number of Occurrences as Causes for Utility relocation Phase Overruns	% Occurrence (% of All Utility Relocation Phase Overruns).	Contributing Track Numbers
initial estimate made with very preliminary plans, maps, and generalized data. Estimate updated based on more design detail	37 [22]	30.3 [31.4]	6,9,41,57,61,64,83,84,89, 91,97,134,136,140,155 [3,6,7,9,22,23,36,39,60,68, 69,71,82,95,102,105,117, 124,133,152,153,154]
changes in project scope as a result of decisions made in design	33 [27]	27.0 [38.6]	13,18,21,31,32,89 [3,4,50,51,52,55,62,71,75, 77,86,87,90,95,103,104, 117,119,120,122,123,127, 131,134,137,141,159]
increase in relocation costs over what was expected	21 [6]	17.2 [8.6]	1,2,13,17,31,57,63,72,95, 96,97,117,133,155,162 [48,49,51,62,120,129]
changes in scope due to worse than expected site conditions	11 [3]	9.0 [4.3]	13,22,38,61, 72,110,122, 133 [38,71,82]
inadvertent omission	10 [8]	8.2 [11.4]	31,119 [8,11,49,52,82,91,135,159]
underestimation of state force involvement cost	7 [2]	5.7 [2.9]	31,72,110,117,133 [120,129]
new installation in proposed ROW after estimate made	3 [2]	2.5 [2.9]	1 [48,120]
Totals =	122 [70]	100	

Construction Phase Overruns

Overruns in the construction phase accounted for 37.8% of the total number and 64.6% of the total cost of all overruns >15%: one hundred thirty-seven (137) overruns @ $105,001,524. The majority of overruns to date still occur in the construction phase. In addition, the construction phase still comprises the largest percentage of the total overrun cost. Table 5 shows that the three leading causes for construction overruns were higher than expected unit bid prices and/or individual work item costs, changes in project scope as a result of changes made in the design phase, and changes in scope due to worse than expected site conditions. These three causes made up nearly two-thirds of the construction overruns at 63.5%. Higher than expected unit bid prices and/or individual work item costs saw one of the biggest increases over the two bienniums with about 125%. Two justifications, change in KyTC policy for contingency percent add-on and poor initial estimate, were new to the 1994 biennium. The 1992 biennium had a total of 94 causes attributing to construction cost overruns, while the 1994 biennium had 147. That's a 56% increase in causes. The overall occurrence of construction overruns and total cost of those overruns had both increased by 2.1% and 1%, respectively.

Table 5: Breakdown of Construction Phase Overruns.

Cause/Justification of Overrun	Number of Occurrences as Causes for Construction Phase Overruns	% Occurrence (% of All Construction Phase Overruns).	Contributing Track Numbers
higher than expected unit bid prices and/or individual work item costs	75 [23]	31.1 [24.5]	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	44 [30]	18.3 [31.9]	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	34 [20]	14.1 [21.3]	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]

(continued on next page)

Table 5: Breakdown of Construction Phase Overruns. (continued)

inadvertent omission	18 [6]	7.5 [6.4]	19,45,69,100,105,106,131, 137,150,151,156,168 [19,42,43,85,93,101]
utility work done in construction phase	16 [5]	6.6 [5.3]	3,5,7,34,60,66,76,81,113, 156,168 [45,116,126,150,157]
initial estimate made with very preliminary plans, maps, and generalized data: estimate updated based on more design detail	16 [4]	6.6 [4.3]	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 [0]	5.4 [0.0]	30,35,36,45,46,47,67,68,86, 148,149,150,151
addition of work materials to make safe facility realized during the construction phase	7 [1]	2.9 [1.1]	27,40,113,131,147,151 [138]
complexity of construction underestimated	6 [2]	2.5 [2.1]	4,67,81, 86 [21,157]
poor initial estimate	5 [0]	2.1 [0.0]	98,101,107,142,168
bonuses for minimal traffic impact given	3 [1]	1.2 [1.1]	124,156 [85]
higher than expected inspection costs	2 [1]	0.8 [1.1]	114 [97]
two separate construction phases combined to minimize overall cost to state	2 [1]	0.8 [1.1]	80 [100]
Totals=	241 [94]	100	

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

- While design phase overruns account for 13.0% of all overruns, they only account for 4.3% of the total cost reported. Design phase overruns are not a major problem.

- Based on the 362 overruns to date, the following would likely have occurred if estimates had been subject to the 15% overrun limitation only after the design phase was completed:
    - 59.7% of the right-of-way overrun causes would have been eliminated.

- 57.3% of the utility relocation phase overrun causes would have been eliminated.
- 24.9% of construction overrun causes would potentially have been eliminated.

- Changes in project scope as a result of worse than expected site conditions contributed 14.8% of the causes listed for design phase overruns; 7.0% for right-of-way overruns, 9.0% for utility relocation overruns, and 14.1% for construction overruns. Increased site investigation by designers and estimators might have reduced these overruns, however, some soil conditions and contamination will always present problems.

- Construction phase overruns accounted for nearly 2/3 of the total cost of all overruns. It was stated that 24.9% of construction overrun cause occurrence could potentially be eliminated if estimates were made after design was complete. An additional 31.1% of overrun cause occurrences could be reduced if accurate unit bid price data were used.

- Causes for overruns resulting from omissions in the estimates, transposing of numbers, or switching of work between phases cannot be avoided unless estimates are updated periodically.

COST-PER-MILE MODEL

The Cost-per-mile Model 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 an 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) allows an estimator to specify metric or English units and an inflation factor for the new project,
f) provides statistical information about the predicted accuracy of the new estimate based on past projects, and
g) produces a Summary Sheet with the new estimate and important information about what the model predicts.

The model, called KYEstimate, is very user-friendly. A copy of the program, with a user's manual, was distributed to all of the twelve highway districts in December of 1995 and January of 1996. After allowing the estimators a few weeks to experiment with the model, researchers went to each of the districts to answer any 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, other were not very receptive to the program. Some had not even opened the software. 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 be made to perform in metric and 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 was 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.

Perhaps one of the biggest changes involved the database. In order to make changes to the databases, they were changed to DBASE IV files. Upon opening the program, the database (either preconstruction or construction depending on what the user specifies) would be 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.

Since the last interim report, the size of the construction database has increased by several hundred projects. The preconstruction database is currently the same size, but projects will soon be added to it also. With this increase in projects, the model has become more valuable, using a much larger database to predict unit costs. Estimators may throw out projects with extremely high or low costs and still be left with plenty 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.

Projects in the database could 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 - number of road: 60, 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

<u>EXAMPLE</u>

A new estimate is needed for the construction phase 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.

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, =, 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.

ESTIMATE SUMMARY SHEET

ESTIMATE IDENTIFICATION

KYEstimate

PROJECT ID #	
ROAD NAME	US60
DISTRICT	7
ESTIMATOR	J. WALTON
UNITS(ENG/METRIC)	ENG
DATE OF ESTIMATE	6/26/96

STATISTICAL ANALYSIS - (COMPUTER RESULTS)

	DESIGN	ROW	UTILITY	CONSTR	TOTAL
MEAN UNIT COST				43,826	43,826
STANDARD DEVIATION				15,612	15,612
HISTORICAL MAX UNIT COST				75,552	75,552
HISTORICAL MIN UNIT COST				23,164	23,164
SIZE OF DATABASE				11	

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 ($)				131,477	131,477
USER ESTIMATE ($)					
6 YP ESTIMATE ($)				131,477	$131,477

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						
# LNS I	2						
FCLASS I	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

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 6. Database Search Results

DIST	ITEM_NO	LENGTH	LN_WDTH	TOTAL	FY	UNIT COST	UNIT COST INFLATED
7	920302.00	0.856	9	18146	1992	$21,199	$23,164
7	920302.00	6.024	9	145489	1992	$24,152	$26,391
7	940372	5.356	10	183082	1994	$34,183	$35,208
7	910301	1.016	6	31906	1991	$31,404	$35,345
7	910301	4.269	8	140776	1991	$32,976	$37,115
7	920765.00	6.740	11	265621	1992	$39,410	$43,064
7	940372.00	0.584	12	24789	1994	$42,447	$43,720
7	930182	8.241	10	362919	1993	$44,038	$46,720
7	930182.00	1.613	9	77096	1993	$47,797	$50,707
7	930182.00	0.226	10	13867	1993	$61,358	$65,095
7	940637.00	0.472	11	34622	1994	$73,352	$75,552
7	920437	1.853	12	179451	1992	$96,843	$105,824
7	940637	2.535	10	327550	1994	$129,211	$133,087

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 the 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 current process of forecasting costs for highway work in Kentucky isn't satisfactory to either the KyTC or the Legislature. The reporting requirements of the oversight law, KRS45.245, impose additional work on the KyTC. The limits imposed, whereby reporting is required, are in some cases impossible to meet, and, in other cases, possible to meet only with additional staffing and/or by not performing current duties.

The current oversight requirement has resulted in 362 overruns worth over $162 million being presented to the Interim Joint Committee on Transportation for review to date (7/1/92 - 7/1/96). All of these overruns have been approved. The IJCT makes no concerted effort to track cost underruns.

The overrun threshold, >15%, is arbitrary and causes a lot of wasted effort by KyTC personnel. It would be 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.

An improvement to the current process would be to require that only overruns over a certain amount be formally presented to the IJCT and others require only a paper notification. The amount would be determined by a statistical analysis of overruns during the past few years.

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 cost and has been 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 offers an opportunity to make improvements to KyTC's cost forecasting ability and to the relationship between the KyTC and the Legislature. 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.

PRELIMINARY RECOMMENDATIONS

The following preliminary recommendations are made, based on the findings of the first three years 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 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).
- IJCT adapt the oversight implementation to better track performance and reduce the added burden on the KyTC.
- Track project phase underruns of >15% as well as overruns.
- Limit formal reports of overruns to those that have a potential of being disapproved.
- Instead of a flat >15% limit, use different limits based on class of estimate.
- Let projects be carried through Phase I design without the 15% limitation.

A small group, representing both legislators and the KyTC, should work with the researcher to articulate details of a process that meets political and fiscal realities. This would facilitate the implementation of needed improvements and lead to better relations within state government.

PATH FORWARD

Specific goals for year 4 are:

- to refine the cost-per-mile database, KYEstimate,
- to work with the KyTC to get project data recorded in a place and format that can be used to update the databases being developed,
- to improve the size and quality of both the preconstruction and construction databases
- to develop tools and standard estimating procedures for KyTC estimators,
- to develop a plan and a program to train KyTC personnel on the new estimating tools and procedures, and
- to maintain contact with officials within the KyTC and the Legislature in an effort to develop a cost forecasting strategy that will satisfy both parties and will benefit the citizens of Kentucky.

APPENDIX

Construction Type

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

Work Type Classification

10	New Route
20	Relocation
31	Reconstruction to Freeway
32	Reconstruction with More Lanes
33	Reconstruction to Wider Lanes
34	Pavement Reconstruction with Alignment Improvements
35	Pavement Reconstruction
40	Major Widening
50	Minor Widening
60	Restoration and Rehabilitation
60A	Pavement Milling and Bituminous Overlay
60B	Replace Cross Drains
60C	Install Edge Drains
60D	Correct Embankment Slide/Slide Correction
60E	Spot Improvements/Patching
60F	Install Median Drains
60G	Replace Storm Sewer
60H	Culvert Replacement
60I	Break, Seat, and Place Bituminous Overlay, Install Pavement edge drains, remove/ replace/reset guardrail as necessary
60K	Off Ramps on Interstate
60L	Guardrail
71	Resurfacing with Shoulder Improvements and Portland Cement Concrete Pavement Restoration
72	Resurfacing with Shoulder Improvements and Bituminous Pavement Restoration

77	Resurfacing with Portland Cement Concrete Pavement Restoration
78	Resurfacing with Bituminous Pavement Restoration
80	Bridge Replacement
81	Bridge Rehabilitation
83	Culvert
100A	Replace or Refurbish Signs
100B	Construct One Turn Lane
100C	Construct More Than One Turn Lane
100E	Reconstruct Intersection
100EA	Construct Intersection
100F	Install Signs and Signals at Intersection
100G	Construct Flush Median
100J	Construct Sidewalk
100K	Improve Sight Distance
100L	Construct Access Road/Entrance
100M	Construct Welcome Center
100N	Construct Interchange Ramps
100O	Install Lighting
100P	Pavement Markers
107	Environmental
109J	Fill Slip Corrections

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