Research Report
KTC 95-12

COST ESTIMATING AND FORECASTING FOR HIGHWAY WORK IN KENTUCKY

by
James D. Stevens
Associate Professor of Civil Engineering

Kentucky Transportation Center
College of Engineering
University of Kentucky

in cooperation with Kentucky Transportation Cabinet

and

Federal Highway Administration
U.S. Department of Transportation

June 1995

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
KTC 95-12	----	----

4. Title and Subtitle	5. Report Date
Cost Estimating and Forecasting for Highway Work in Kentukcy	June 1995
	6. Performing Organization Code: ----
7. Author(s): James D. Stevens	8. Performing Organization Report No.: KTC 95-12
9. Performing Organization Name and Address: Kentucky Transportation Center, College of Engineering, University of Kentucky, Lexington, KY 40506-0281	10. Work Unit No. (TRAIS): ----
	11. Contract or Grant No.: ----
	13. Type of Report and Period Covered: Interim
12. Sponsoring Agency Name and Address: Kentucky Transportation Cabinet, State Office Building, Frankfort, KY 40622	14. Sponsoring Agency Code: ----

15. Supplementary Notes

Prepared in cooperation with the Federal Highway Administration, US Department of Transportation.
Study Title: Cost Estimating and Forecasting for Highway Work in Kentucky

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%. Since enactment of KRS45.245 (1 July 1992) 263 overruns, totaling nearly $117 million, have been submitted to the Committee. All have been approved for additional funding.

A cost per mile database and estimating model were developed for preconstruction and construction. A cost per parcel database and model are being developed for estimating right of way. Recommendations for performance measurements to track improvements in cost forecasting abilitiy are presented.

17. Key Words	18. Distribution Statement
Estimating Cost Forecasting, Legislative Oversight Six-Year Highway Plan, Cost Overruns Interim Joint Committee on Transportation	Unlimited, with approval of the Kentucky Transportation Cabinet.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	35	

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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, is to investigate current practices and to recommend improvements for the estimating process. This report details the finding of the first two 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 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, 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 - 7/1/95), 263 overruns totaling nearly $117 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 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 is being developed to asset estimators make conceptual estimates based on a database of preconstruction and construction project costs for the past four years. A Cost-per-parcel Model and database is being developed to assist in estimating right-of-way costs, and updating the conceptual right-of-way estimate, once a route is established.

Emphasis for Year 3 of this study will be to complete the Preconstruction, Construction and Right-of-way databases and the Cost-per-mile and Cost-per-parcel Models; to develop and implement a training plan for the use of the models; and to recommend new and/or modified procedures to improve the ability of the KyTC to forecast highway costs.

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.

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 second interim report, discusses the findings of the first two years of the project:

- Summary of First Year's Findings - reviews the research findings presented in the first interim report, March 1994.

- Estimates During the Period of Study - presents an analysis of the cost overruns >15% during the research period.
- Preconstruction Cost-per-mile Database - reports on the collection of past project data for the three preconstruction phases: design, right-of-way, and utility relocation.
- Construction Cost-per-mile Database - reports on the collection of past project data for the construction phase.
- Cost-per-mile Model - presents a computer model that sorts data from the preconstruction and construction databases to assist an estimator make an estimate based on past performance.
- Performance Measurements - outlines procedures to allow the KyTC to measure quality improvement in the estimating process.
- Right-of-way, Cost-per-parcel Database - reports on the collection of past project data for the right-of-way phase and presents plans for a cost-per-parcel model to assist estimators in updating right-of-way estimate after project scope is determined.
- 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 third 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. 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.

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 - 7/1/95), 263 overruns, totaling $116,792,686 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.

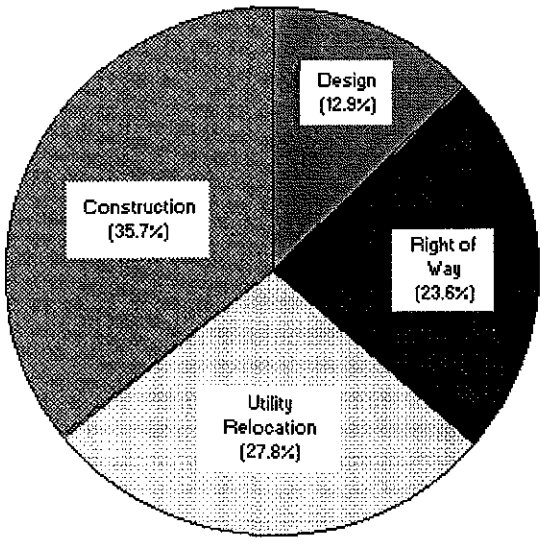

Figure 1 - Overrun Occurrences by Phase

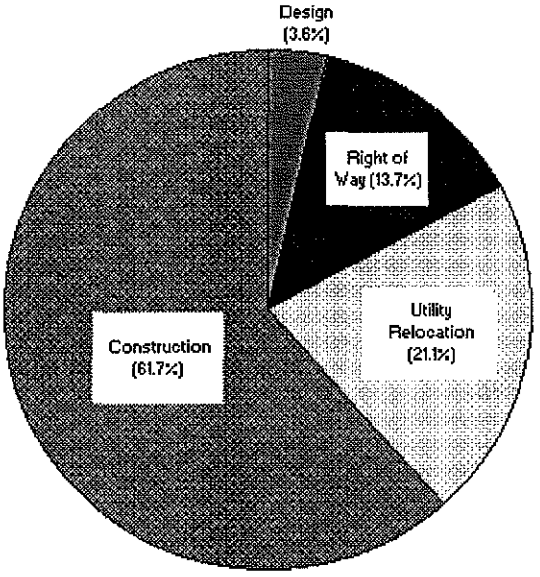

Figure 2 - Overrun Costs by Phase

Table 1 shows the cost and frequency breakdown, by phase, of the 263 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 previous report (7/1/92 - 2/13/94) 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	34 [13]	12.9% [9.7%]	$4,188,495 [$1,690,000]	3.6% [2.4%]
Right-of-way	62 [30]	23.6% [22.4%]	$15,949,500 [$6,646,000]	13.7% [9.6%]
Utility Relocation	73 [38]	27.8% [28.4%]	$24,650,568 [$14,808,000]	21.1% [21.3%]
Construction	94 [53]	35.7% [39.5%]	$72,004,123 [$46,359,094]	61.7% [66.7%]
Totals =	263 [134]	100%	$116,792,686 [$69,503,094]	100%

* percent of the 263 overruns that occurred in each phase
** percent of the total cost of the 263 overruns ($116,792,686) attributable to phase

Design Phase Overruns

Overruns in the design phase accounted for 12.9% of the total number and 3.6% of the total cost of all overruns: thirty-four (34) overruns @ $4,188,495. Table 2 shows that underestimation because consultant fees were higher than the estimated *in-house* design costs, underestimation of the complexity of the project, and scope changes due to worse than expected site conditions were the three primary causes for design phase overruns. These causes accounted for 64.8% of all design phase overruns, slightly lower than the 69.3%

presented in the previous report. Two justifications have been added to the updated table; original estimate doesn't account for *in-house* evaluation of routine design project outlays and metric units, and underestimation of cost of bridge inspection effort account for 17.6% of the updated overruns. Overall, the number of overruns caused in the design phase has risen 3.2% and the cost attributed to the design phase has risen 1.2%.

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	11 [3]	32.4% [23.1%]	5,88,89,143,12,14, 53,54,55,59,71
underestimation because consultant fees were higher than the estimated in-house design costs	7 [3]	20.6% [23.1%]	98, 99, 106,128,139,140,71
scope changes due to site conditions being worse than expected	4 [3]	11.8% [23.1%]	53, 96, 109,48
original estimate doesn't account for in-house evaluation of routine design project outlays and metric units	3 [0]	8.8% [0.0%]	144,145,146
underestimation of cost of bridge inspection effort	3 [0]	8.8% [0.0%]	25,42,43
shift in alignment necessitating a greater design effort than what was initially estimated	2 [1]	5.9% [7.7%]	2,65
initial estimate based on preliminary plans, maps, and data	2 [1]	5.9% [7.7%]	37,49
scope changes due to local and public pressure & involvement	1 [1]	2.9% [7.7%]	67
underestimation of design cost for large scale landscaping project	1 [1]	2.9% [7.7%]	25
Totals =	34 [13]	100%	

*underlined numbers refer to the current bienniun

Right-of-way Overruns

Overruns in the right-of-way phase accounted for 23.6% of the total number and 13.7% of the total cost of all overruns: sixty-two (62) overruns @ $15,949,500. Table 3 shows that the leading cause for right-of-way overruns was changes in project scope made during the design phase and after the initial estimate was made. 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. The second leading cause of right-of-way overruns were estimates based on preliminary plans, maps, and project information. In the previous report these accounted for 72.5% of the right-of-way overruns, but currently they only account for 68.7%. New justifications such as unusually high jury awards, acquisition of utility easements, settling of ROW parcels to speed up the process, and changes in priority necessitating changing sequence of parcel acquisition have raised the occurrences of Right-of-way overruns by 1.2% and the cost by 4.1% since the last report.

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*
changes in project scope as a result of decisions made in design	31 [16]	37.4% [40%]	3,24,51,51,55,62,63,70, 71,76,83,86,95,108,117, 118,127,139,140,141, 158,10,11,16,21,23,39, 51,52,58,62
initial estimate made with very preliminary plans, maps, and generalized data: estimate updated based on more design detail	26 [13]	31.3% [32.5%]	3,6,7,9,10,16,40,59,69, 71,102,105,117,124,130, 152,154,159,8,26,41,50, 56,57,58,61
inadvertent omission	6 [4]	7.2% [10%]	1, 58, 70, 76,158,50

(continued on next page)

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

changes in project scope as a result of worse than expected site conditions	5 [2]	6.0% [5%]	38, 59,136,57,61
land values increased in vicinity of proposed right-of-way	4 [1]	4.8% [2.5%]	16,158,10,56
new or modified legislation enacted after initial estimate made	3 [3]	3.6% [7.5%]	16, 51, 64
improvement made to right-of-way after initial estimate was made	3 [1]	3.6% [2.5%]	72,133,57
unusually high jury award	2 [0]	2.4% [0%]	132, 58
acquisition of utility easements (usually part of the utility phase)	1 [0]	1.2% [0%]	10
settling of ROW parcel to speed up process	1 [0]	1.2% [0]	24
changes in priority necessitating changing sequence of parcel acquisition	1 [0]	1.2% [0]	38
Totals =	83 [40]	100%	

*underlined numbers refer to the current biennium

Utility Relocation Phase Overruns

Overruns in the utility relocation phase have decreased just less than one percent since last reported, currently accounting for 27.8% of the total number and 21.1% of the total cost of all overruns: seventy-three (73) overruns @ $24,650,568. Table 4 shows that the most frequent cause for utility relocation overruns, like that for the right-of-way phase, came from changes made in the project scope during the design phase. Similarly, the second leading cause for utility relocation phase overruns was due to initial estimates being made based on very preliminary plans, maps, and project information. Combined, these two causes account for 59.2% of all the utility relocation phase overruns, just less than the 66.6% last reported. Three new justifications accounted for just 3% of the utility overruns. These new justifications included: unknown regulations forcinc more expensive solution for relocation, court decision establishing "prior rights status", and unforeseen relocation required for contractor's staging area.

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*
changes in project scope as a result of decisions made in design	33 [20]	32.0% [37%]	3, 4, 50, 51, 51, 52, 55,62,71, 75, 77, 86, 87, 90,95,103, 104, 117, 119, 120,122,123,127,131,134, 137,141,159,13,18, 21,31, 32
initial estimate made with very preliminary plans, maps, and generalized data. Estimate updated based on more design detail	28 [16]	27.2%[29.6%]	3,6,7,9,22,23,39,60,68,69, 71,82,95,102,105,117,124, 133,152,153,154,6,9,41,57, 61,64
increase in relocation costs over what was expected	11 [1]	10.7% [1.9%]	49,129,1,13,31,57,63,72, 72,72,72
changes in scope due to worse than expected site conditions	8 [4]	7.8% [7.4%]	38, 71, 82, 82,13,22,61,72
inadvertent omission	6 [3]	5.8% [5.6%]	11, 49, 52,135,159,31
underestimation of state force involvement cost	4 [1]	3.9% [1.9%]	120,129,31,72
new installation in proposed ROW after estimate made	3 [2]	2.9% [3.7%]	48, 120,1
accidental transposition of two estimates in development of Y	2 [2]	1.9% [2.1%]	8, 91
new laws enacted necessitating higher utility relocation costs	2 [2]	1.9% [2.1%]	51, 62
no inflation factor on estimate	1 [1]	1.0% [1.0%]	82
utility line thought to be privately owned is actually publicly owned (this required full relocation reimbursement)	1 [1]	1.0% [1.0%]	48

(continued on next page)

Table 4: Breakdown of Utility Relocation Phase Overruns. (continued)

upgrade in utility line not realized at time of estimate	1 [1]	1.0% [1.9%]	36
not aware of regulation which forced more expensive solution for relocation	1 [0]	1.0% [0%]	2
court decision establishing "prior rights status"	1 [0]	1.0% [0%]	17
unforeseen relocation required for contractor's staging area	1 [0]	1.0% [0%]	38
Totals =	103 [54]	100%	

*underlined numbers refer to the current biennium

Construction Phase Overruns

Overruns in the construction phase accounted for 35.7% of the total number and 61.7% of the total cost of all overruns >15%: ninety-four (94) overruns @ $72,004,123. Although these percentages have decreased somewhat from 39.5% and 66.7% respectively, 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 two leading causes for construction overruns were higher than expected unit bid prices and/or individual work item costs, and changes in project scope as a result of changes made in the design phase. These two causes were listed 55.6% of the time. Changes in project scope due to worse than assumed site conditions were also common causes for overruns, but decreased more than any other justification from 20.8% to 15.0%. Justifications added to the list were change in KyTC policy for contingency percent add-on, addition of work materials to make safe facility realized during the construction phase, and change in design due to environmental concerns. These new justifications comprised 7.9% of all construction phase overruns.

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	52 [23]	31.4% [29.9%]	12, 12, 15, 19, 20, 21, 26, 28, 34, 35, 35, 42, 43, 44, 46, 47, 54, 54, 56, 57, 57, 66,79,142,147,151,157,3,4, 7,19,20,28,29,30,33,35,36, 37,44,44,44,46,47, 60, 66,67,68,75,75,75,76
changes in project scope as a result of decisions made in design	37 [22]	24.2% [28.6%]	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, 149,150,151,155,5,7,15,33, 45,66,69
changes in scope due to worse than expected site conditions	24 [16]	15.0% [20.8%]	14, 17, 27, 32, 33, 65, 73, 74, 78, 84, 85, 92, 94, 97, 112,113,142,151,20,27,46, 47,70,75
utility work done in construction phase	12 [2]	7.2% [2.6%]	45,116,126,150,157,3,5,7, 34,60,66,76
inadvertent omission	9 [6]	5.9% [7.8%]	19, 42, 43, 85, 93, 101,19,45,69
change in KyTC policy for contingency percent add-on	8 [0]	5.2% [0%]	30, 35,36,45,46, 47,67,68
initial estimate made with very preliminary plans, maps, and generalized data: estimate updated based on more design detail	6 [4]	3.9% [5.2%]	15, 29, 57, 81,46,47
complexity of construction underestimated	4 [1]	2.6% [1.3%]	21,157,4,67
addition of work materials to make safe facility realized during the construction phase	3 [0]	2.0% [0%]	138,27,40
bonuses for minimal traffic impact given	1 [1]	0.7% [1.3%]	85

(continued on next page)

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

sporadic contractor activity led to higher than expected state supervision costs	1 [1]	0.7% [1.3%]	97
two separate construction phases combined to minimize overall cost to state	1 [1]	0.7% [1.3%]	100
change in design due to environmental concerns	1 [0]	0.7% [0%]	156
Totals =	159 [77]	100%	

*underlined numbers refer to the current biennium

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

- Design phase overruns account for only 3.55% of the total cost of all overruns reported. Design phase overruns are not a major problem.

- Based on the 257 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:
  - 68.7% of the right-of-way overrun causes would have been eliminated.
  - 62.9% of the utility relocation phase overrun causes would have been eliminated.
  - 30.7% of construction overrun causes would potentially have been eliminated.

- Changes in project scope as a result of worse than expected site conditions contributed 12.5% of the causes listed for design phase overruns; 6.0% for right-of-way overruns, 7.2% for utility relocation overruns, and 15.0% 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 almost 2/3 of the total cost of all overruns. It was stated that 30.7% of construction overrun cause occurrence could potentially be eliminated if estimates were made after design was complete. An additional 31.4% of overrun cause occurrence 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.

PRECONSTRUCTION COST-PER-MILE DATABASE

The purpose for compiling a database of historical preconstruction costs is to provide an estimator with information about past projects to use in making estimates for new projects. Relevant cost data and key project information were collected and stored in a manner that allows an estimator to efficiently select those data useful for estimating a new project, i.e. those historical unit costs from projects which have similar characteristics.

Projects in the database 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 is the cost of each preconstruction phase, by project and by mile.

An effort was made to collect all data that significantly relate to preconstruction phases of 6YP projects completed during the years 1990-1994. The search was limited to the last four years because of missing data related to the twelve key attributes.

Brief project descriptions, district, item #, county, type of work, length, authorization year, location, and preconstruction cost data were obtained from the Project Authorization System (PAS) in the KyTC Programming Office. Functional classification and number of lanes were obtained from the KyTC Planning Office. Route name and TD-10 # was obtained from the Contractor's Pay Estimate System (CPES) in the KyTC Construction Division.

CONSTRUCTION COST PER MILE DATABASE

Like the database of preconstruction costs, a database of historical costs was created to provide an estimator with information about past construction costs. The databases were created separately for two primary reasons. First, preconstruction phases for a project usually involve the same scope of work, whereas the construction phase often involves change orders and claims. Secondly, the construction phase is usually broken into segments and let at different times, so correlation between the preconstruction costs for the entire project and the construction cost of a single segment of the project is difficult.

Projects in the database were defined by the same twelve key attributes as in the preconstruction database. Along with the above attributes is the cost of each construction segment, by project and by mile.

As with the preconstruction data, key attributes were missing from many projects, precluding their inclusion in the databases.

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,

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) 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 predicts.

The model, called KYEstimate, is very user-friendly. Since it is still under development, the following example represents neither the total capability nor the final format, but simply shows how KYEstimate is used.

EXAMPLE

A new estimate is needed for the preconstruction phases of a 4-lane major widening project in Clark County on a principal arterial. The road length is five miles with one 400' bridge.

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 preconstruction 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

ESTIMATE SUMMARY SHEET

ESTIMATE IDENTIFICATION

PROJECT ID #	
ROAD NAME	US60 Clark Co.
DISTRICT	7
ESTIMATOR	J. Stevens
DATE OF ESTIMATE	1 July 1995

KYEstimate

STATISTICAL ANALYSIS - (COMPUTER RESULTS)

	DESIGN	ROW	UTILITY	CONSTR	TOTAL
MEAN $/MILE	121,073	166,482	120,747	725,000	1,133,302
STANDARD DEVIATION	67,804	277,278	148,009	175,300	
HISTORICAL MAX $/MILE	227,540	645,833	333,333	1,234,500	2,441,206
HISTORICAL MIN $/MILE	41,237	1,915	8,996	674,300	726,448
SIZE OF DATABASE	5	5	5	10	

USER ESTIMATE

	DESIGN	ROW	UTILITY	CONSTR	TOTAL
USER ESTIMATE ($/MILE)	125,000	350,000	120,000	725,000	1,320,000
PROB OF EXCEEDANCE (%)	0.46	0.24	0.50	0.50	
Z= # OF STD DEVS AWAY	0.06	0.66	-0.01	0	
% UNDER/OVER MEAN $/MILE	3.24	110.23	-0.62	0	16.47

6 YP ESTIMATE

APPROXIMATE PROJECT LENGTH (MILES) = 5.00

	DESIGN	ROW	UTILITY	CONSTR	TOTAL
MEAN ESTIMATE ($)	605,363	832,412	603,737	3,625,000	5,666,512
USER ESTIMATE ($)	625,000	1,750,000	600,000	3,625,000	6,600,000
6 YP ESTIMATE ($)	625,000	1,750,000	600,000	3,625,000	6,600,000

SUMMARY OF DATABASE SEARCH CRITERIA

DISTRICT	7
COUNTY1	Clark
COUNTY2	
WORK TYPE	40
#LANES1	4
%LANES1	100
#LANES2	
%LANES2	
FCLASS1	RPAO
%FCLASS1	100
FCLASS2	
%FCLASS2	
LENGTH	5.00
BLPID	0.015
NOB	1
AUTH YR	95

ESTIMATE JUSTIFICATION/SPECIAL CONDITIONS:

This project is similar to others on this road. ROW will be higher because of development along this corridor.

Figure 3. Estimate Summary Sheet

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.

In this case, after trying various combinations, the estimator selects the following: Preconstruction Phases, District 7 and Work Type 40. In the other fields All items are automatically selected. The search of the preconstruction database using these criteria finds the projects data shown in Table 7.

Table 7. Search Results

P/C	DISTRICT	COUNTY1	COUNTY2	WORK TYPE	#LANES1	%LANES1
PRE	7	fayette	scott	40	4	100
PRE	7	fayette		40	6	100
PRE	7	boyle		40	4	100
PRE	7	anderson		40	4	100
PRE	7	fayette		40	2	100

#LANES2	%LANES2	FCLASS1	%FCLASS1	FCLASS2	%FCLASS2	LENGTH
		RPAI	100			20.107
		UOPA	100			1
		UOPA	100			5.27
		RPAO	66	UOPA	33	8.879
		UMA	100			2.4

NOB	BLPID	AUTH YR
12	0.0204	86
1	0.04	86
2	0.0093	88
3	0.0116	88
1	0.0088	83

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.

RIGHT-OF-WAY COST-PER-PARCEL DATABASE

The Cost-per-mile Model is used for conceptual estimating only and is based on actual total costs of past projects. Once a route is established for a new project, parameters other than number of miles may provide a better basis for an estimate. The Right-of-way Database contains projects defined by twelve key attributes:

1 District
2 Item #
3 County
4 Parcel #
5 Owner's Name
6 Parcel Type
7 Cost of Parcel
8 Area of Parcel
9 Building to be Purchased
10 Litigation on Parcel
11 Right-of-way Estimate
12 TD-10 #

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

Item # - district identifier number

County - county or counties; by name

Parcel # - number assigned to parcel by the right-of-way division

Owner's Name - last name of the owner of a particular parcel

Parcel Type - categorizes parcel according to highest and best use: residential, commercial, industrial, and agricultural

Cost of Parcel - final cost of the parcel

Area of Parcel - size of parcel in acres

Purchase of a Building - indicates if an existing building has been condemned

Litigation - indicates litigation required to obtain a parcel

Right-of-way Estimate - conceptual estimate made prior to project authorization

A Cost-per-parcel Model, similar to the Cost-per-mile Model, is under development.

PERFORMANCE MEASUREMENTS

Improving the estimating process requires performance measurements with which to benchmark progress. Questionnaires and interviews with KyTC district office personnel, and a study of measurements used by Florida's Highway Department, were conducted in an effort to determine what performance measurements were appropriate.

A questionnaire was sent to the twelve district highway offices asking about the current process of developing conceptual estimates and 70% of them were returned. Responses indicate that estimators are comfortable with their conceptual estimates and understand what they are used for, but are not certain what constitutes a good conceptual estimate because of a lack of feedback. There is no standard statewide procedure with clear guidelines on how conceptual estimates should be developed.

Comments on recommended improvements to the conceptual estimating process are shown on the Pareto diagram in Figure 4.

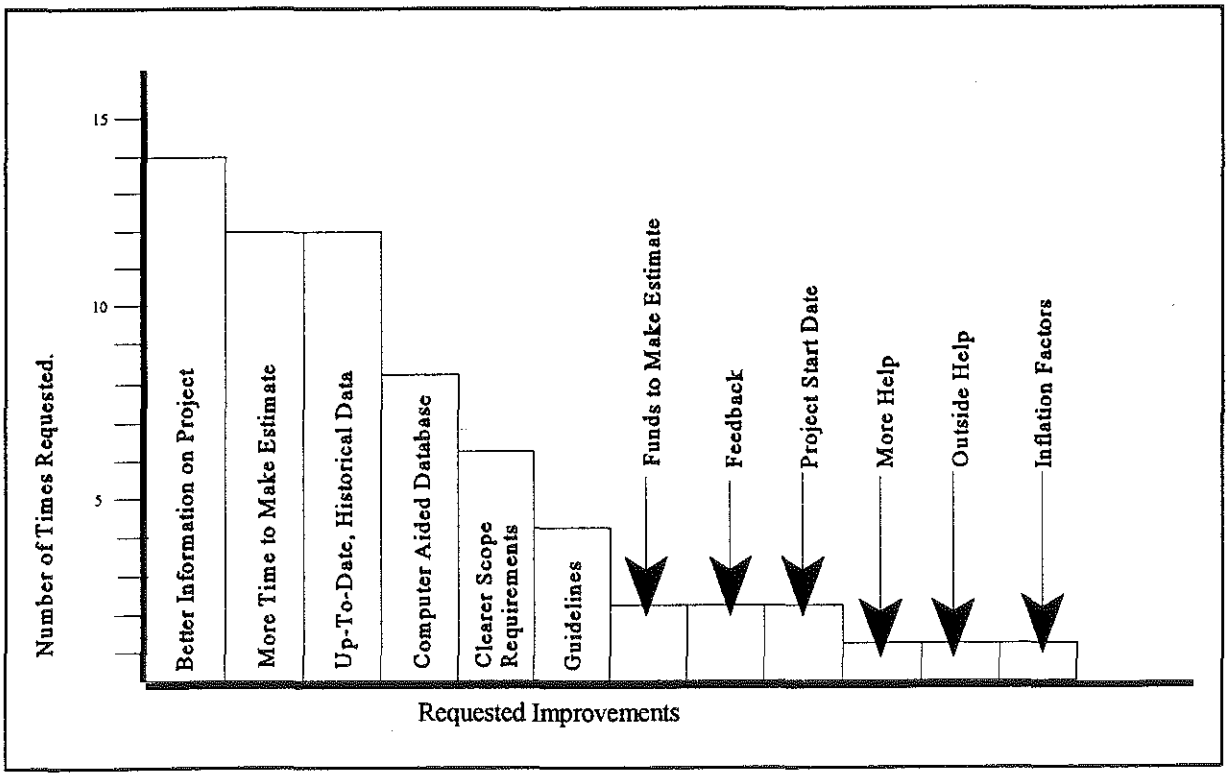

Figure 4. Recommended Improvements

The Florida Transportation Cabinet (FTC) developed performance measurements which are used by an appointed oversight committee to access the department's performance annually. This process has improved accountability and the public's perception of the department.

Performance measurements currently being investigated include:

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
Number of projects certified for construction vs. Number scheduled to certify
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

These and other performance measurements will be studied during the next year.

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 263 overruns worth nearly $117 million being presented to the Interim Joint Committee on Transportation for review to date (7/1/92 - 7/1/95). 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 statistically 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 can be improved by using actual costs of past projects. The cost-per-parcel database under development will assist estimators in preparing estimates when information is available about the route and the parcels needed to be acquired.

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. 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 two years of this three-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 3 are:

- to finish development of on the Cost-per-Mile Database and Model,
- to finish development of the Right-of-Way, Cost-per-Parcel Database and Model,
- 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 develop a set of performance measurements that will allow the KyTC and the Legislature to assess improvement in the estimating process,
- 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.