

**Research Report
KTC 97-13**

**COST ESTIMATING AND FORECASTING
FOR HIGHWAY WORK IN KENTUCKY**

by
William F. Maloney
Raymond-Shaver Chair Professor of Construction Engineering and Management

and
Jennifer R. Walton and Adam Ross
Graduate Research Assistants

**Kentucky Transportation Center
College of Engineering
University of Kentucky**

in cooperation with Kentucky Transportation Cabinet

and

**Federal Highway Administration
U.S. Department of Transportation**

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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%. Estimates developed using current methods are not sufficiently accurate to preclude cost overruns in excess of 15%. Estimates are prepared before design is begun so that a project may be included in the six year plan. The estimates are not revised after a more detailed scope of the project is developed during design and after design is completed. Consequently, there have been 455 overruns since 1992. All have been approved for the necessary additional funding. Causes of cost overruns for the 455 overruns during the past five years were studied. The development of a conceptual estimating model, KYEstimate, was continued and reported on. Recommendations and conclusions are presented.					
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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 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 four 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 funds projects for the coming biennium. Reasonable cost forecasts for new and ongoing projects are required to ensure that funding is available and projects can be undertaken on an orderly schedule.

KRS45.245, effective July 1, 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 - 6/30/97), 455 overruns totaling over \$213 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, do not statistically support a $\pm 15\%$ confidence level. In light of the high variability of estimates based on little information and the lack of resources dedicated to estimating, a reasonable approach is to base estimates on actual costs of past projects. For the conceptual estimate, the one used for initial authorization of a project, a cost-per-mile figure based on similar past projects can be used. After the design is completed on a new project, estimates for the remaining phases--right-of-way, utility relocation, and construction--can be updated to reflect design decisions such as route, grade and drain, etc.

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

Emphasis for Year 5 of the study will be to collect cost data for overruns, refine and enlarge the construction and preconstruction databases, establish a standard for the storage of the data in the databases, change KYEstimate from an Excel program to an executable program, provide a manual for KYEstimate, and provide assistance and/or additional training to estimators involving the program.

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 Kentucky 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 fourth interim report, discusses the findings of the first four 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.
- Summary of Third Year's Findings - reviews the research findings presented in the third interim report, July 1996.
- 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 fifth year of the research.

SUMMARY OF FIRST YEAR'S FINDINGS

This 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 has not been 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.

Relevant cost data for both preconstruction and construction phases was 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	7 Length
2 Item #	8 Percent bridge length
3 County	9 Number of bridges or major culverts
4 Type of work	10 Award year
5 Functional classification	11 Route Name
6 Number of lanes	12 TD-10 Number

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

Item # - district identifier number

County - county or counties; by name

Type of work - FHWA Order M5600.1A, 12/87 (see appendix)

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 in 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.

SUMMARY OF THIRD YEAR'S FINDINGS

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

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

The current oversight requirement has resulted in 362 overruns worth over \$162 million being presented to the IJCT for approval since the law became effective (7/1/92 - 7/1/96). All of these overruns have been approved for additional funding. No concerted effort was made by the IJCT to track cost underruns.

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

The databases used for the model were enlarged and transferred into the database program DBASE IV. Microsoft QUERY was used to pull the data from DBASE IV into KYEstimate for use. This modification protects the data from being changed during the running of the cost estimate model and allows for easy addition of new projects to the database. The

primary identifier for the data was changed from the TD-10 number to the Item number. These changes were made to make the data easier for estimators to find and use.

ESTIMATES DURING THE PERIOD OF STUDY

Estimates developed using the current method have not proven to be significantly accurate to preclude cost overruns in excess of 15%. Since the law became effective, 7/1/92, 455 overruns, totaling \$213,840,516 have been submitted to the IJCT for approval. All have subsequently been approved for 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 study, is submitted by the KyTC to the IJCT for a phase overrun > 15% and is identified by a tracking number.

Figure 1 shows a breakdown of the number of overrun occurrences by phase. Figure 2 shows a breakdown of overrun costs by phase. These graphs illustrate the percentage of the occurrences and costs all of the causes of overruns collected to date. The construction phase produces the most occurrences (almost two in five) and costs (two thirds) of all overruns. The Utility relocation phase and Right-of-way phase each contribute approximately 1/4 of the overrun occurrences and approximately 1/8 of the total cost attributed to overruns. The Design phase accounts for approximately 1/8 of the occurrences but only 1/20 of the total cost.

Table 1 shows the cost and frequency breakdown, by phase, of the 455 overruns to date. Percentage of total occurring and percentage of total cost for the two previous bienniums are listed for comparison purposes. Total cost and total number of occurrences are not compared because the current biennium is only half completed. Tables 2-5 show specific overrun causes for each phase and the number of occurrences of each. Because overruns may have more than one cause listed, the total number of cause occurrences may be higher than the total number of overruns for a phase. Entries in the column, **Contributing Track Numbers**, refer to the specific documents where a cause is used as justification for an overrun, and the biennium that the justifications was included in. The format for this is the 1996 biennium is first, 1994 biennium second, and 1992 biennium last. Also the previous two bienniums are enclosed in brackets. A brief synopsis of the impact of the overruns in each phase is also provided.

Overrun Occurrences By Phase: '92 - '97

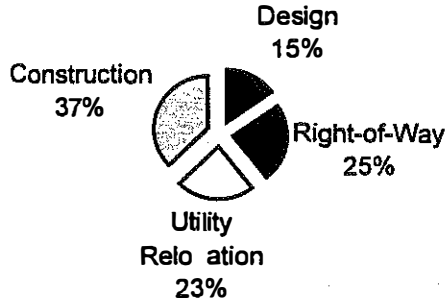


Figure 1 - Overrun Occurrences by Phase

Overruns Costs By Phase: '92 - '97

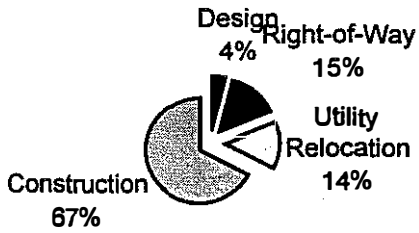


Figure 2 - Overrun Cost by Phase

Phase	Number of Occurrences	% Occurring*	Total Cost of Phase Overruns	% Cost**
Design	69	15.2 [13.0] {11.0}	\$8,553,750	4.0 [4.3] {2.3}
Right-of-way	112	24.6 [24.3] {23.6}	\$31,960,153	15.0 [13.9] {11.2}
Utility Relocation	103	22.6 [24.9] {29.7}	\$30,396,168	14.2 [17.2] {22.9}
Construction	171	37.6 [37.8] {35.7}	\$142,930,445	66.8 [64.6] {63.6}
Totals	455	100.0	\$213,840,516	100.0

* percent of the 455 overruns that occurred in each phase

** percent of total costs of the 455 overruns (\$213,840,516) attributable to each phase

Table 1: Breakdown of Highway Cost Estimate Overruns by Phase

Design Phase Overruns

Overruns occurring in the design phase accounted for 15.2% of the total number and 4.0% of the total cost of all overruns: sixty-nine (69) overruns @ \$8,553,759. Table 2 contains a breakdown of causes of overruns for the design phase. Underestimation of the complexity of the project, underestimation because consultant fees were higher than the *in-house* design costs, initial estimate based on preliminary data, scope changes due to worse than expected site conditions were the main causes of design phase overruns. These causes accounted for nearly 80% of the of all of the design phase overruns. 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, accounting for 8.9% of the total design. Due to the low percentage of cost, 4.0%, the Design phase is not considered a major factor of overruns.

Cause/Justification of Overrun	Number of Occurrences as Causes for Design Phase Overruns	% Occurrence (% of All Design Phase Overruns)	Contributing Track Numbers
Underestimation of complexity of project necessitating further design effort over what was originally envisioned	23	31.1	6,26,50,88,90,94,95 [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	17	23.0	5,42,43,50,76,77,96,97 [71,77,79]{98,99,106, 128,139,140}
Initial estimate based on preliminary plans, maps, and data	13	17.6	7,8,9,60,61,62,63 [49,159, 163,169] {25,37}
Scope changes due to site conditions being worse than expected	9	12.2	3 [48,164,169,172,173] {53,96,109}
Underestimation of cost of bridge inspection effort	3	4.1	[25,42,43]
Part of design inadvertently omitted	3	4.1	[111,121,172]
Scope changes due to local and public pressure and involvement	3	4.1	26 [79] {67}
Shift in alignment necessitating a greater design effort than what was initially estimated	2	2.7	[174] {2}
Additional administration costs	1	1.3	[77]
Totals	74	100.0	

Table 2: Breakdown of Design Phase Overruns

Right-of-way Overruns

Overruns in the right-of-way phase accounted for 24.6% of the total number and 15.2% of the total cost of all overruns: One hundred and twelve (112) overruns @ \$31,960,153. Table 3 shows the individual causes of overruns for the right-of-way phase. Initial estimate made with very preliminary plans, maps, and generalized data and changes in project scope as a result of decisions made in design were the two major causes of overruns. These two causes contributed to over half of the total overruns. Two other major causes are unusually high jury award and land values increased in vicinity of proposed right-of-way, causing 26.4% of the overruns.

Cause/Justification of Overrun	Number of Occurrences as Causes for ROW Phase Overruns	% Occurrences (% 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	42	29.2	6,26,50,88,90,94,95[8,26,41,50,56,57,58,61,89,91,92,93,94,96,103,118,135,138] {3,6,7,9,10,16,40,59,69,71,102,105,117,124,139,152,154,159}
Changes in project scope as a result of decisions made in design	35	24.3	73,87,89 [10,11,16,21,23,39,51,52,58,62,89,116] {3,24,51,55,62,63,70,71,76,83,86,95,108,117,118,127,139,140,141,158}
Unusually high jury award	20	13.9	1,2,3,25,48,53,71,83 [58,88,90,102,116,118,139,153,154,160,161] {132}
Land values increased in vicinity of proposed right-of-way	18	12.5	14,59,69,74,75,84,86,87,89 [10,56,85,93,112,138,144] {16,158}
Changes in project scope as a result of worse than expected site conditions	9	6.3	59 [38,57,61,93,132] {38,59,136}
Inadvertent omission	7	4.9	84 [50] {1,58,70,76,158}
Improvement made to right-of-way after initial estimate was made	6	4.2	[57,123,145,158] {72,133}
New or modified legislation enacted after initial estimate made	3	2.1	{16,51,64}
Acquisition of utility easements (usually part of the utility phase)	3	2.1	49,65 [10]
Settling of ROW parcel to speed up process	1	0.1	[24]
Totals	144	100.0	

Table 3: Breakdown of Right-of-Way Overruns

Utility Relocation Phase Overruns

Overruns in the utility phase have decreased during both the 1994 biennium and the 1996 biennium, no other phase has shown this decrease. This phase accounts for 22.6% of the total number and 14.2% of the total cost of all overruns: one-hundred and three (103) overruns @ \$30,396,168. Table 4 shows that the three most common causes were initial estimate made with

very preliminary plans, maps, and generalized data, changes in scope from design changes, and increased relocation costs. These three causes contributed in 72% of the total causes.

Cause/Justification of Overrun	Number of Occurrences as Causes for Utility Relocation Phase Overruns	% Occurrence (% of All Utility Relocation Phase Overruns)	Contributing Track Number
Initial estimate made with very preliminary plans, maps, and generalized data. Estimate updated based on more design detail	43	29.5	13,27,33,34,41,72 [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	36	24.7	33,51,52 [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	26	17.8	27,33,44,52,68 [1,2,13,17,31,57,63, 72,95,96,97,117,133,155,162] {48,49,51,62,120,129}
Inadvertent omission	15	10.3	13,27,33,44,72 [31,119] {8,11,49,52,82,91,135,159}
Changes in scope due to worse than expected site conditions	13	8.9	64,92 [13,22,38,61,72,110,122,133] {38,71,82}
Underestimation of state force involvement cost	9	6.2	27,52 [31,72,110,117,133] {120,129}
New installation in proposed ROW after estimate made	3	2.1	[1] {48,120}
Greater complexity than previously experienced	1	0.1	40
Totals	146	100.0	

Table 4: Breakdown of Utility Relocation Phase Overruns

Construction Phase Overruns

Overruns in the construction phase account for 37.6% of the total number and 66.8% of the total cost of all overruns: one-hundred and seventy-one (171) overruns @ \$142,930,445. The majority of the overruns still occur in the construction phase. In addition, the construction phase still comprises the largest total overrun cost, much greater than the three other phases. Table 5

shows that the leading cause for construction overruns was higher than expected unit bid prices and/or individual work item costs. This one cause contributes one third (1/3) of the total causes for construction overruns. Two other major causes were changes in project scope as a result of decisions made in design and changes in scope due to worse than expected site conditions, contributing a combined 31% of the overruns.

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	99	32.8	12,16,17,18,19,20,21,22,23,24,29,30,31,36,39,45,46,47,54,66,78,79,80,81,82,85,93 [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	53	17.5	16,21,29,37,38,45,57,58,82 [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	38	12.6	11,30,39,56 [20,27,46,47,70,75,82,114,124,148,149,150,151,156] {14,17,27,32,33,65,73,74,78,82,84,85,92,94,97,112,113,142,151,156}
Utility work done in construction phase	25	8.3	12,17,21,24,30,31,57,58,85 [3,5,7,34,60,66,76,81,113,156,168] {45,116,126,150,157}
Inadvertent omission	21	7.0	18,21,55 [19,45,69,100,105,106,131,137,150,151,156,168] {19,42,43,85,93,101}
Initial estimate made with very preliminary plans, maps, and generalized data: estimate updated based on more design detail	21	7.0	19,23,35,36,56 [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	4.3	[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	10	3.0	16,36,37 [27,40,113,131,147,151] {138}
Complexity of construction underestimated	7	2.3	78 [4,67,81,86] {21,157}
Poor initial estimate	7	2.3	20,45 [98,101,107,142,168]
Higher than expected inspection costs	4	1.3	47,93 [114] {97}
Bonuses for minimal traffic impact given	3	1.0	[124,156] {85}
Two separate construction phases combined to minimize overall cost to state	2	0.6	[80] {100}
Totals	303	100.0	

Conclusions

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

- While design phase overruns account for 15.2% of all overruns, they only account for 4.0% of the total cost reported. Design overruns are not a major problem.
- Based on the 455 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:
 - 53.5% of the right-of-way overrun causes would have been eliminated.
 - 54.2% of the utility overrun causes would have been eliminated.
 - 24.5% of the construction overrun causes would have been eliminated.
- Changes in project scope as a result of worse than expected site conditions contributed 12.2% of the design phase overruns, 6.3% of the right-of-way phase overruns, 8.9% of the utility relocation phase overruns, and 12.6% of the construction phase overruns. This cause provided fewer overruns than in the previous bienniums, but increased site investigation by designers and estimators might reduce these overruns further. However, some soil conditions and contamination will always present a problem.

- The construction phase accounted for 2/3 of the total cost of all overruns, but only 38% of the occurrences. Reducing the construction overruns will have a major impact on the cost to the state. 32.8% of overrun causes could be reduced if accurate unit bid price data was used.
- Causes for overruns resulting from omissions in the estimate, transposing numbers, or switching of work between phases cannot be avoided unless estimates are updated periodically.

COST PER MILE MODEL

The Cost-per-mile Model 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. 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. The updated copy of KYEstimate was released during February 1997.

Since the last interim report, the size of the construction database has increased by several hundred projects. The preconstruction database has been enlarged but not to the extent of the construction database. 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 cost 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. Estimators can change the inflation factor if they believe the 3% is not accurate. Also the inflation factor is now projected to the approximate time the project will be used, 2 years for preconstruction and 4 years for construction projects.

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

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

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

Construction Fiscal Year - year the construction phase took place

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

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

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

Number of lanes - number of lanes involved

Functional classification - KyTC classification system (see appendix)

Length - length in miles to three decimal points

Lane Width - the width of the particular route

EXAMPLE

A new estimate is needed for the construction 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.

ESTIMATE SUMMARY SHEET

ESTIMATE IDENTIFICATION

PROJECT ID # ROAD NAME DISTRICT ESTIMATOR UNITS(ENG/METRIC) DATE OF ESTIMATE	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> US 60 7 J. Walton ENG 6/26/97 </div>	<div style="border: 1px solid black; padding: 2px; display: inline-block; margin-top: 5px;"> KYEstimate </div>
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STATISTICAL ANALYSIS - (COMPUTER RESULTS)

	DESIGN	ROW	UTILITY	CONSTR	TOTAL
MEAN UNIT COST				50,528	50,528
STANDARD DEVIATION				31,067	31,067
HISTORICAL MAX UNIT COST				137,080	137,080
HISTORICAL MIN UNIT COST				23,859	23,859
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 (\$)				151,584	151,584
USER ESTIMATE (\$)					
6 YP ESTIMATE (\$)				170,609	\$170,609

SUMMARY OF DATABASE SEARCH CRITERION

DIST CONST_FY CON_TYPE ROUTE WORK_TYPE # LNS1 FCLASS1 LENGTH LN_WDTH	SEARCH1 SEARCH2 SEARCH3 SEARCH4 SEARCH5 SEARCH6 SEARCH7
--	---

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 useless in estimating a project of this type.

Figure 3 - Estimate Summary Sheet

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 Figure 3, summary of database criterion. 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.

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.

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

Table 6: Search Results

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 455 overruns worth over \$213 million being presented to the Interim Joint Committee on Transportation for review to date (7/1/92 – 6/30/97). All of these overruns have been approved. The IJCT makes no concerted effort to track cost underruns which demonstrate a poor estimate as much as an overrun.

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 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

researchers, 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 four 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 revise the oversight requirements 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 5 are:

- to convert KYEstimate from an Excel file into an executable file, for more practical and efficient use,
- to convert the database files to Microsoft Access,
- to continue work with the KyTC to get project data recorded in a State wide standard format for use with KYEstimate,
- to improve the size and quality of both the preconstruction and construction databases with newly completed projects,
- to conduct a seminar to train KyTC personnel on the new estimating tools and procedures,
- to incorporate any ideas and suggestions from estimators to KYEstimate,
- to produce and distribute a manual for KYEstimate to all district offices, 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/W |
| 4. Construction phase | U |
| a. Grade, drain, and surfacing | C |
| b. Grade and drain | G |
| c. Surfacing on new route or reconstruction | S |
| d. Bridge construction | B |
| e. Roadside improvement | I |
| f. Traffic Services | T |
| g. Service facilities | F |
| h. Resurfacing | H |

Work Type Classification

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

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