Top-Down Construction Cost Estimating Model/Guide Using a Neural Network within an Off-the-Shelf Spreadsheet and Database Programs

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PROBLEM STATEMENT

States with small populations and large amounts of highway lane miles to service must use every penny appropriated for design, construction and maintenance as wisely as possible. To do so, requires that early estimates of project costs are not overly inflated and fencing precious federal-aid funding from being obligated on other projects. Worse yet, if the budget overage is found late in the fiscal year, the incremental overage can be lost to the state by FHWA year-end reapportioning (Anderson et al. 2006). The other side of the coin is a concept called "optimism bias" where engineers deliberately underestimate project cost to keep the project "alive" (Jennings 2006; Flyvbjerg et al. 2002).

The issue is exacerbated by the fact that early costs estimates made with the least amount of design detail often become the final project budget. The result is to create a bias either toward over-estimating actual costs to provide financial room for the scope to grow as the project development process proceeds (Jennings 2006) or toward underestimating costs because of misplaced optimism (Flyvbjerg et al. 2002). Research has shown that the unintended consequence over estimating is that project managers will attempt to use all the funding available within a given project's authorization to avoid losing it rather than return the overage as soon as it is identified (Anderson et al. 2006). Thus, the efficient use of available capital is compromised (Janacek 2006). The solution is to develop a system where early estimates can be developed using rationally derived contingencies for the unknowns at the time of the estimate (Anderson et al. 2006).

This research seeks to leverage the work completed in NCHRP 15-51: *Guide for Estimating Preconstruction Services Costs*, by extending the parametric models developed for preliminary engineering, right of way, etc. to the estimating of construction project cost at the earliest stages of project planning and development. It will deliver a top-down cost estimating model that uses "stock" spreadsheet and database software without the need to purchase special software or hardware (i.e. MS Office products only).

BACKGROUND SUMMARY

The issue of accurate estimating is essentially tied to the efficient use of available public capital (Janacek 2006). Early estimates conducted during the planning phase often turn into project budgets before the final scope of project work is adequately quantified (Anderson et al. 2007; Alshanbari 2010). Additionally, since preconstruction costs are by definition a small portion of the total project delivery cost, they are typically estimated as a standard percentage of estimated construction costs. Hence, if the capital project is underestimated, preconstruction costs will be similarly underestimated. A 2002 study involving 258 transportation projects collectively valued at $90.0 billion (Flyvbjerg et al. 2002) found that 86% experienced actual costs that were on average 28% higher than initially estimated. That study concludes that "*underestimation of costs at the time of decision to build is the rule* rather than the exception for transportation infrastructure projects" (Flyvbjerg et al. 2002, italics added). Using Flyvbjerg's cost growth would mean that the agencies delivering these projects would be short $1.4 billion in the preconstruction phases of project development. The fact that project scope and quality is defined during the planning and design phases of the project development process means that an accurate estimate of construction costs will furnish sufficient funding for the early phase planning and design activities.

MDT Project FHWA/MT-08007/8189 *Highway Project Cost Estimating and Management* furnished a bottom-up conceptual estimating procedure that appears to be risk-adjusted but utilizes extremely small sample populations. The study found that MDT sees a 46% growth in construction cost from programming to construction completion. Montana's small population and its huge area makes it imperative that MDT squeeze every last penny out of its federal and state highway funding to provide as much service as it can afford. So reducing cost growth from the early estimate is a priority. To do so, requires that cost certainty be increased and that means better conceptual estimates.

NCHRP Report 574: *Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction* expresses the motivation for this MDT research project in this manner:

> "Over the time span between the initiation of a project and the completion of construction, many factors influence a project's final costs. This time span is normally several years, but for highly complex and technologically challenging projects the time span can easily exceed a decade. Over that period, numerous changes to the project scope and schedule will occur." (Anderson et. al 2007).

It is precisely because of the uncertainties present at project inception that a top-down estimate based on parametric Cost Estimating Relationships (CER) is necessary. The model will find its theoretical foundation in the fundamental parametric estimating principles used by DB to estimate construction costs (Bajaj et al. 2002; Brunsman et al. 2008). Parametric estimating is particularly effective because it permits the estimator to continuously increase the estimates level of detail as the project development increases. Figure 1 illustrates the process that is typically used to develop parametric estimating models.

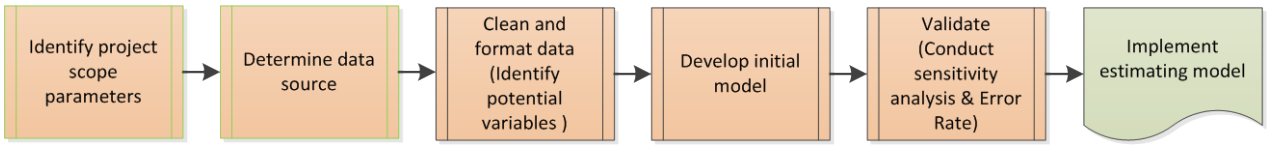

Figure 1. Basic Steps to Develop a Parametric Estimating Model

The parametric models require protocols to be developed to mine existing sources of construction cost data, to assemble relevant cost, time, and scope risk information, and to develop appropriate parametric sets for each component of the project development process. The mechanics of developing CERs at the agency level are relatively simple and can be easily adapted to cost source data like the MDT bid tabulation database. The spreadsheet macros built into the model will calculate CERs from the database, but the estimator must evaluate each one and track its ability to predict the cost item. The following are the elements of a CER protocol:

- Definition of CER
- Developing CERs in hours, sheets, percent of estimated construction, etc.
- Developing CERs to quantify scope of work in cubic yards of fill, tons of steel, square yards of pavement, linear feet of culverts, etc.
- Development of stochastic range estimates for CERs
- Rolling up CERs to produce project level range estimates.
- Associating statistical measures of confidence with each CER and using those to make professional judgments for contingencies and allowances.
- Associating specific CERs with specific levels of estimating accuracy

NCHRP 15-51: Preconstruction Cost Estimating Guide has developed a stochastic parametric estimating framework that can be directly applied to the less complex problem of estimating construction costs. Preconstruction deliverables are by and large intangible assemblies of intellectual property. The abstract nature of planning and design leads to a situation where a consultant's 30% design deliverable can be whatever the consultant has ready to turn-in when the 30% design package is due. Whereas, construction deliverables are mostly tangible, measurable features of work that can be inspected for quality and function (Chelst and Canbolat 2012). Hence, one can expect to have a higher level of confidence in parametric construction estimates than one can with preconstruction parametric estimates. Figure 2 is the model in use in NCHRP 15-51 that can easily be adapted to the MDT requirement.

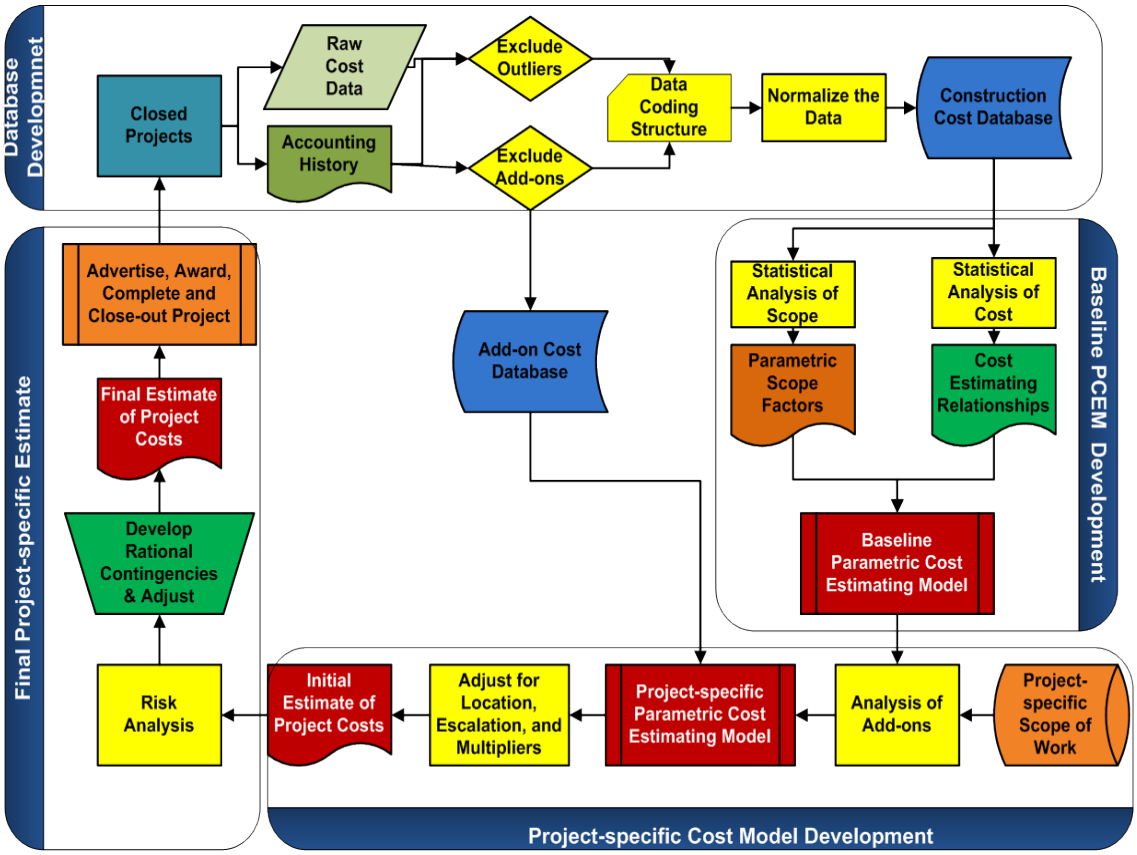

Figure 2. Parametric Estimating Model Process

BENEFITS AND BUSINESS CASE

Enhancing the accuracy of early estimates permits the state to maximize the available capital improvement funding and reduce the amount of funding that must be reserved to pay for uncertainties. The 2013 Federal-aid highway apportionment for MDT was about $400 million. If the amount of uncertainty in an annual program can be reduced by 1%, then MDT could let another $4.0 million worth of projects instead of fencing those funds against unknown requirements and potentially losing the unneeded project funding in end of fiscal year reapportioning. The incremental savings realized by better estimating and the rational development of project-specific contingencies will permit MDT to increase the number of projects it b uilds each year reducing the costs to the traveling public of structurally deficient bridges and rough roadways.

> **Said another way:** The proposed research is about *increasing cost certainty* and maximizing the efficient use of available funding.

The following benefits would be realized when the products of the research are implemented:

- Enhanced utilization of available funding.
- Increased consistency in MDT early estimates
- Ability to differentiate between project early cost estimates by project confidence levels computed by the model.
- Increased understanding of the features of the project that are driving the bottom-line cost.
- Ability to conduct sensitivity analyses to permit more knowledgeable design decisions.
- Ability to conduct “what-if” scenario evaluations during planning and design.
- The use of a neural network that learns as more data is fed into it will simplify MDT’s task of indexing construction pricing and provide the Highway Bureau with a constantly updated look at where Montana construction prices are going.

OBJECTIVES

The final product will permit MDT's project managers to prepare cost estimates for design and construction of typical MDT capital improvement and rehabilitation projects. Hence, the technical objectives of the study are as follows:

- To develop a framework for building a database from MDT bid tabulations.
- To develop a parametric estimating model that can be fed from the database using a neural network to assemble CERs and produce top-down estimates at early stages of project development.
- To develop a stochastic cost modeling system will be develop to assist MDT engineers in calculating rational contingencies for early estimates.

RESEARCH PLAN

The proposed top-down parametric estimate uses all the information available and develops several cost estimating relationships (CER) that are then used to determine the credible range of construction costs by estimating the costs in more than one way. These are easily risk-adjusted using freeware Monte Carlo simulation add-ins to MS Excel (Deis e.t al 2004). A neural network is a "black box" that uses artificial intelligence to continuously "learn" as new data is fed in and as a result becomes more accurate over time. Because the estimates are based on a system that has been trained using MDT actual cost data, it will create CERs with statistical confidence levels that portray to MDT how "good" the estimate is and when used in conjunction with the current bottom-up estimating procedure mentioned before, will allow MDT to establish a rational contingency based on project uncertainty rather than an arbitrary percentage based on empirical judgment (Mak and Picken 2000). It is proposed that one district be designated to be the subject of the development of the research and the other four districts will be added once the model for the initial district is validated. Additionally, the research will include developing training and user's guides for the products developed and delivered. The user training will be on-line and a train-the-trainer module will also be developed for face-to-face delivery.

Proposed Work Plan: The work will be divided into four phases. Note that the phases have been correlated with the academic calendar for planning purposes and the schedule has been revised to assume a contract notice to proceed date of January 1, 2015.

Phase 1: 2014 Fall and 2015 Spring Semester-**Data Development & Base Cost Model**
Phase 1 will entail collecting the necessary cost data and reducing the raw bid tabulation data into a format which can then be input into a database program to form the cost information foundation for the estimating model. It will also update the NCHRP 15-51 literature review for the Montana project delivery context.

Task 1: The phase will start with a kick-off meeting between the research team and the MDT TAP. The meeting would likely be held in Helena to permit the collection of the initial set of bid tab data to be conducted face-to-face with the MDT database manager.

Initial work accomplished by the PI and graduate research assistant (GRA) would take approximately 2.5 months and will take place during the school year. An undergraduate research assistant (URA) has been budgeted to continue this process throughout the duration of the contract. It is assumed that MDT can furnish the following data for all their projects in the most recent 5-year period:

1. Original Contract Amount
2. Final Contract Amount
3. Original Contract Period
4. Final Contract Period
5. Schedule of Values/Bid Tabulation
6. Project Type
7. Major Features of Work
8. Project Capacity (SY of pavement, bridge clear span, etc.)
9. Liquidated Damage Days and Amount
10. Atypical features of work and their value
11. Other required information

If this type of data is not readily available in digital format, then the budget allocated to data collection may need to be changed to reflect the additional effort it will take to collect that data. Our aim would be to include as many projects as possible in the database. Additionally, an inflation factor would be developed for Montana to account for time value of money and furnish an appropriate adjustment for time-related cost increases.

The data would be reduced and included in the database in a manner that would permit data queries to sort both vertically and horizontally through the database to create the most applicable set of data for each new project estimate. An input routine would be developed and documented to permit new project information to be placed in the database to keep it current. Additionally, depending on the amount of available data, a five-year moving average algorithm would be used to eliminate old projects and keep the foundation for estimates fresh. Finally, a control algorithm would be developed to test new projects for excessive variation and eliminate those that are atypical. An example of this type of project would be one where a previously unknown costly environmental remediation effort was encountered and caused the project to be substantially over budget through no fault of MDT or its contractor. Once this phase is complete, the researchers will have a base of MDT cost information on which to build the next phase of study.

Task 2: Phase 1 will also involve the creation of a parametric estimating cost model that is specific to the needs and requirements of MDT. This work will require direct knowledge of MDT's cost estimating policy operations. This is to be gained by the researchers interviewing engineers at the Highway Bureau as well as a knowledgeable individual in each of MDT's five districts. Structured interviews will be developed and completed using the Government Accountability Office (1991) protocol, following rigorous qualitative research design and analysis methodologies based on Eisenhardt 1989, 1991; Yin 2008; Miles and Huberman 1994; and others. The interview will seek to ascertain the following items of information:

1. Level of estimating confidence required
2. Allowable tolerances – both theoretical and practical
3. Number of estimates done each year
4. Internal project cost/budget control system requirements
5. Time available to do estimates and update database
6. Management culture
7. External demands of cost information
8. Other information as appropriate

The proposed model will be based on parametric estimating theory similar to that used by several federal public works agencies and successfully implemented in 2010 by Dr. Gransberg at the San Antonio Water System and by Dr. Jeong in 2012 with the Oklahoma DOT. Figure 3 shows the team's current thinking of a five-level Cost Breakdown Structure where CERs are developed by drilling down to the activity level if the information is available.

The base cost model will be developed to generate an estimate on the design information available at any given moment in a project's design development. The model will be robust enough to permit varying levels of estimating accuracy to be accomplished within a project's inventory of known requirements and unknown factors. The final estimate output will include a level of confidence to

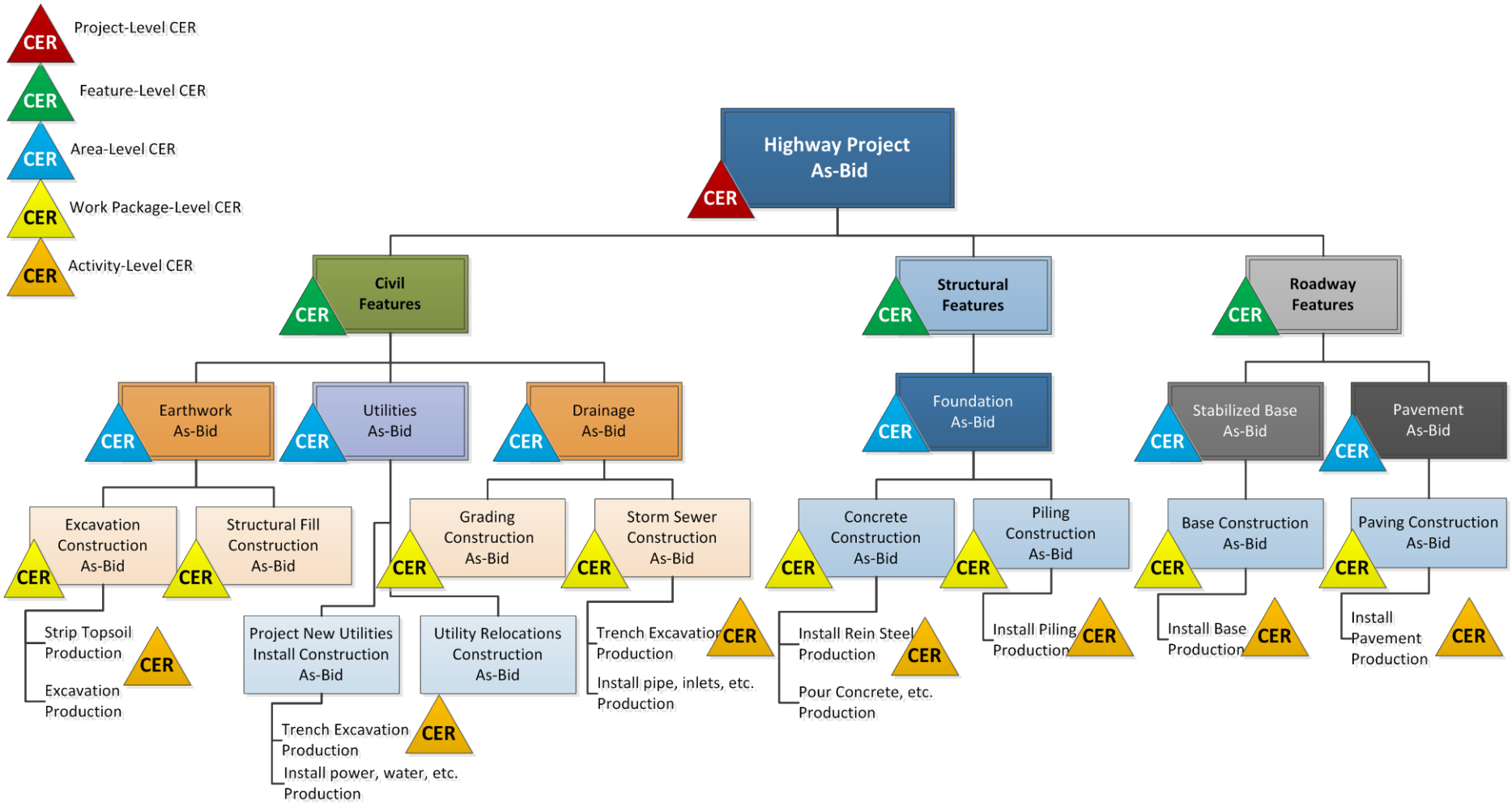

Figure 3: Conceptual Parametric Cost Breakdown Structure Showing Cost Estimating Relationship Levels.

assist MDT decision-makers in understanding the accuracy of the estimate. Thus, an estimate that is being performed early in a project's life will have a lower level of confidence indicated than one that is being performed later in the design process. Additionally, the model will be developed in form of a commercial spreadsheet that will make it exportable to MDT design consultants if that might be of functional use. This will work will likely extend through the Spring 2015 semester.

Phase 2: 2015 Summer Semester-**Base Cost Model Calibration**

Phase 2 will run in parallel with the final portion of Phase 1.

Task 3: The initial portion of Phase 2 will be to gather a set of known data for use in testing and calibrating the base cost model. During this phase MDT will permit the ISU Graduate Research Assistant to collect the detailed data necessary for the parametric cost database at the MDT headquarters in Helena. A period of about 8 weeks is estimated and will permit the student to work on a daily basis with MDT project managers and calibrate the database and parametric estimating model to fit typical MDT projects. Once the Phase 1 model is completed to a point where it can be tested in Phase 2, the test set of known data will be run. A series of statistical tests will be conducted on both the input and the output to calibrate its accuracy and to verify calculated confidence levels. During this period, MDT is encouraged to involve the student data collector in other activities, such as project development meetings and site visits that will furnish the student with the necessary insight to customize the model to MDT's requirements.

In mid-August 2015, Drs. Gransberg and Jeong will review the resultant model and independently analyze its accuracy. This allows the reviewer will assess changes in its performance in relation to test data set to ensure that a technically correct methodology is contained in the spreadsheet and that the spreadsheet is properly reading the database. Next, an independent estimate will be made using an available database (perhaps Iowa DOT from the NCHRP 15-51 project with a calculated regional adjustment factor) for each of the test projects. This is necessary to verify that the estimate produced by the model is superior to those that are currently being done.

Phase 3: 2015 Fall – 2016 Spring Semester: **Base Cost Model Validation – Final Cost Model Development.**

Phase 3 will consist of the pilot testing of the base cost model to validate it both internally and externally.

Task 4: Several small and at least one large project for two project types (roadway and bridge/structure) with data available down to the Work Package-Level shown in Figure 3 that have been recently completed will be nominated by MDT for pilot testing. At this writing the procedure will be to collect historical project cost estimate information at each milestone in the MDT project development process for each project. Once this is complete, the base model using parametric scope and cost data appropriate for the period will be run and the output will be compared to actual outcomes. Adjustments and revisions to the base model will be made until it produces a reasonably accurate of actual costs. This is a particularly tedious process involving an intense amount of statistical analysis and data sampling analysis, as well as multiple iterations for each project type. Thus, it is expected to take approximately 9-months.

During the same period the MDT Guide for Parametric Estimating will be developed and it will include typical user's manual instructions for the use of the spreadsheet and the care, operation, and maintenance of the database. It will also cover the primary concepts of parametric estimating and

any MDT policies for its application that were created during the first three phases of this research

Task 5: Phase 3 will conclude with a final presentation to MDT consisting of an overview of the project with detailed discussions on the findings and recommendations. This presentation will focus on the technical components of the deliverables and permit in-depth discussions focusing primarily on the research and implementation. The implementation plan will also be presented and discussions held to fine-tune its content for execution in Phase 4.

Phase 4: 2016 Summer- Fall Semesters: **Documentation and Technology Transfer/Implementation**

Phase 4 will involve technology transfer to MDT personnel and will occur during the final two academic semesters of the project.

Task 6: First an operations and instruction manual documenting the use, care, and maintenance of the database and spreadsheet will be produced in this phase and submitted to MDT for review and revision

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Task 7: During the Fall semester, the manual, database and estimating model will be submitted and MDT PM's will be trained in its use. Additionally, selected personnel will be specifically trained on the operation and maintenance of the database. All final deliverables will be completed and turned over to the project sponsor. The implementation plan detailed in the subsequent section on page 14 of the proposal will be executed.

Task 8: In parallel with Task 7, a performance measures report that describes the value of costs and benefits of this project will be developed and submitted to MDT for review and revision.

Reporting: MDT will receive status reports as required by the agency throughout the life of the project. The principal investigators will travel to MDT offices during each Phase supervise data collection, identification of MDT technical requirements, and to participate in the technology transfer and training. Additional visits to make presentations can be added to the project if found to be necessary by MDT.

MDT INVOLVEMENT

Assistance required from MDT will include the following:

- Bid tabulation data in exportable spreadsheet form for all projects let during the five-year period preceding notice to proceed on this research contract (Fall 2014).
- Access to knowledgeable MDT personnel for structured interviews (Spring 2015)
- Assistance from the MDT point of contact for bid tabulation database management (entire project period).
- Assistance arranging accommodations and office space in Helena for the student during the Summer Semester 2015.

PRODUCTS

The following are the products to be produced under this contract:

- MS Access database based on the Montana Department of Transportation's (MDT) actual construction project experiences
- Parametric estimating model that operates off a MS Excel spreadsheet.
- A stochastic cost modeling system will be develop to assist MDT engineers in calculating rational contingencies for early estimates.
- MDT Guide for Parametric Estimating to support the above three products.
- Training for MDT personnel to assist in implementing and maintaining the newly created database/parametric estimating spreadsheet model.
- Quarterly progress reports
- Task reports at the end of each phase.
- Final report cover page photo (JPG format);
- Final report, including an implementation plan
- Project summary report;
- Implementation meeting and report;
- Final presentation.

All products will be prepared to meet MDT quality standards. The Institute for Transportation (InTrans) at ISU has a full-time technical writing and publications staff. All products will be reviewed and edited by an InTrans technical editor. Any figures, photographs, etc. included in each product will be ultimately prepared by a professional graphics designer. All products will be reviewed by both Drs. Gransberg and Jeong for content, form and format.

IMPLEMENTATION

The Highways Bureau would be responsible for implementation of the research product. The implementation plan is as follows:

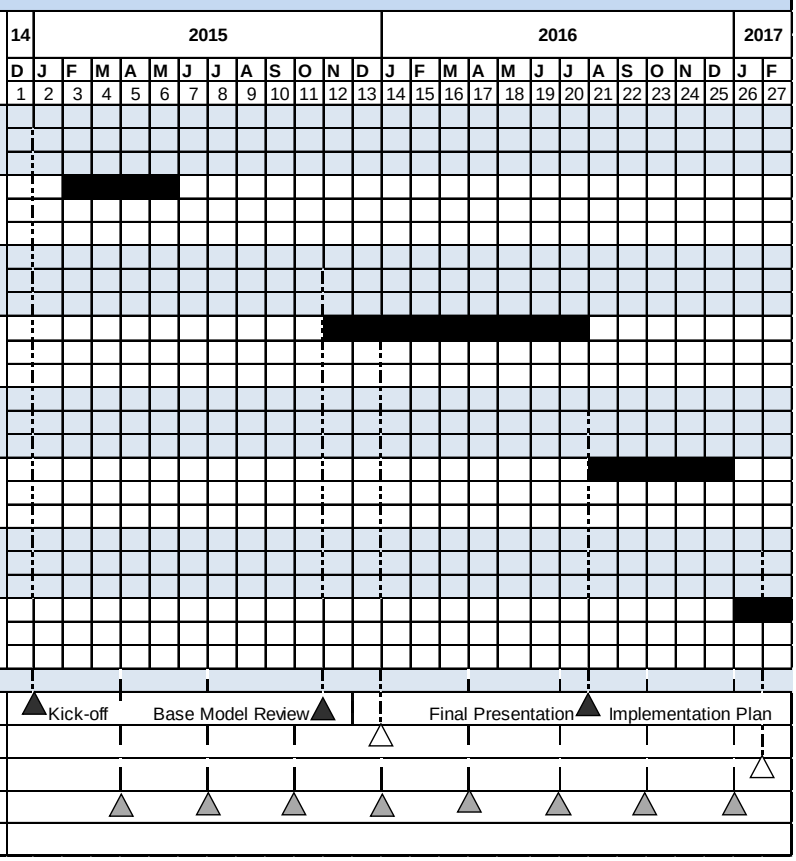
1. Research complete; final top-down estimating model and database delivered to MDT.
2. Train-the-trainer implementation training delivered on site – 1 to 2 months after Phase 4 completion.
3. User training uploaded to internet and initial trial with select group of participants – month 3
4. Projects selected for initial set of estimates selected and estimates completed. – month 3
5. Parallel estimates using current system for same projects completed.
6. Comparison of differences between the two estimates conducted – month 12.
7. Adjustments made to model – month 13.
8. Implement new system state-wide – month 18.

SCHEDULE

Table 1: Project Time Schedule

SCHEDULE OF TASKS FOR TOP-DOWN PARAMETRIC ESTIMATING MODEL

TASK	DESCRIPTION
1	**Evaluate the State of the Practice** *Literature Review Update and Bid Tab Data Collection/ Reduction*
2	**Develop MDT Parametric Model** *Establish CERs, Statistical Analysis, Policy, etc.*
3	**Base Model Calibration** *Calibration, Adjustments, and Review*
4	**Model Validation - Final Model Development** *Pilot Testing; Guidebook Development*
5	**Final Presentation**
6	**Final Draft Guidebook and Implementation Plan**
7	**Prepare and Submit Final Guidebook, Software, and Research Report**
8	**Prepare and Submit Performance Report**



STAFFING

The research team formed for this project has sufficient experience and knowledge in cost engineering, risk management, and project management which are a required set of expertise for successful completion of the proposed project. Dr. Doug Gransberg will be the PI for this project, overseeing the entire progress of the project. Dr. Jeong will participate in this project as Co-PI and one graduate and one undergraduate research assistant from ISU's department of Civil, Construction, and Environmental Engineering will be hired throughout the project.

Dr. Doug Gransberg holds the Greenwood Endowed Chair in Construction Engineering at the ISU CCEE Department and brings over 20 years of research experience and 20 years of industry experience to the project. He is currently PI on the NCHRP 15-51 "Preconstruction Service Cost Estimating Guide." He has also served as PI/Co-PI on 53 funded research projects worth a total value of $12.0 million sponsored by National Cooperative Highway Research Program, the National Science Foundation (NSF), the Departments of Transportation in California, Minnesota, North Carolina, Oklahoma, Oregon, Texas, and Washington State, as well as, several privately funded research institutes. Several of Dr. Gransberg's past funded research projects that directly relate to this work are listed below:

- Principal Investigator, "Develop Parametric Cost Estimating System," 2010-2011, San Antonio Water System
- Co-Principal Investigator, "Project Management Strategies for Complex Projects," 2009-2014, SHRP2 Project R-10, Transportation Research Board.
- Principal Investigator, "Preconstruction Services Estimating Guidebook," 2012-2015, NCHRP Project 15-51,
- Co-Principal Investigator, "Quantification of Cost, Benefits and Risk Associated with Alternative Contracting Methods and Accelerated Performance Specifications," Federal Highway Administration, 2013-2015.
- Co-Principal Investigator, "Construction Manager General Contractor Risk Assessment," MnDOT Project 2010-077, 2010-2011

Dr. David Jeong is an associate professor of construction engineering. Most of his previous and current research projects are highly related to infrastructure asset management, highway project management, project estimating, and project scheduling. He has published more than 30 technical journal and conference papers in this area for the past ten years. He also has 6 years of industry experience in bridge and highway construction projects as project engineer and cost engineer. He has won the 2010 Construction Industry Institute (CII) outstanding researcher of the year award and he is the recipient of the 2008 Institute of Industrial Engineers (IIE) Transactions Award for Best Application Paper in Operations Engineering. Several of Dr. Jeong's past funded research projects that directly relate to this work are listed below:

- Cost Estimating Competencies Using Criticality Matrix and Factor Analysis, Oklahoma DOT
- Preliminary Engineering Cost Prediction for Reliable Highway Project Budget Allocation, Oklahoma DOT.

- Advanced Linear Scheduling Program with Varying Production Rates for Pipeline Construction Projects, Oklahoma DOT.
- Daily Work Reports Based Production Rate Estimation for Highway Projects, Mid-America Transportation Center

Mr. Philip Barutha will be the Graduate Research Assistant on the project. He is a graduate of Montana State University and has spent the past 12 years working as a project manager for the M.A. Mortenson Company, a large national general contractor.

Mr. Andy Reynolds will be the undergraduate research assistant. He is a senior in construction engineering, the president of the ISU AGC Student Chapter and brings over 10 years of construction experience to the job having worked as a heavy equipment operator before starting his undergraduate degree. He has been Dr. Gransberg's undergraduate research assistant for the past two years and recently wrote and submitted a paper to TRB on the impact of diesel fuel price volatility on economic haul distance for aggregates. His work involved the development of a stochastic cost model as well as experience in reducing Iowa DOT bid tabulation data for use in his research.

Table 2: Project Staffing

Name	Role in Study	Task									% Time vs. Total Project Hrs *	% Time - Annual Basis **
		1	2	3	4	5	6	7	8	Total		
Dr. Gransberg	Prinicipal Investigator	10	20	40	20	10	30	30	20	180	8%	9%
Dr. Jeong	Co-PI	10	0	20	20	10	10	10	0	80	3%	4%
Grad Student	Data collection, analysis, and evaluation	200	90	500	600	80	20	10	0	1500	65%	72%
Undergrad student	Data reduction	200	200	0	100	0	0	0	0	500	22%	24%
Editor***	Report Preparation, editing, and review	0	0	0	0	0	20	30	0	50	2%	2%
TOTAL		**420**	**310**	**560**	**740**	**100**	**80**	**80**		**2310**		

*Total hrs/ person/total project hrs; **Total hours/ person/2080 hr

***Editor hours included in the $5,000 lump sum for communications services per Intrans policy.

FACILITIES

The scope of work outlined in the Research Plan has very little equipment or facility needs associated with any of the tasks. For this research, the level of support services within the institutions will be more important than physical equipment and facilities, although all organizations involved in the research program have exceptional facilities.

The ISU research team is affiliated with the Institute for Transportation (InTrans), formerly the Center for Transportation Research and Education (CTRE), at ISU. Resources at InTrans include access to staff specializing in publications work, computer facilities, student resources, and professional staff. InTrans is an ISU research institute administered by the Office of the Provost for Research and Advanced Studies.

The proximity of InTrans to the university campus and the state transportation agency offers tremendous opportunities to share resources and provides an integrated knowledge community environment. Resources at InTrans also allow researchers to maintain websites for information exchange and provide access to e-mail lists, conference programs, and training calendars for federal and state highway administrations. Such access will be critical in both gathering and disseminating information, including feedback on the Guidebook and planning and delivering the workshop series.

ISU also supports a world-class library with collections totaling more than 2.2 million volumes and close to 22,000 c urrently-received journals and serial publications. The Iowa Department of Transportation (Iowa DOT) maintains a synergistic working relationship with the university, providing programmatic support for InTrans, while InTrans conducts significant research and development work for the Iowa DOT. The Iowa DOT also manages an excellent transportation library with many specialty publications and access to TRIS, which InTrans students and staff use regularly.

REFERENCES

Alshanbari, H. (2010). "Impact of Pre-Construction Project Planning on Cost Savings," Master of Science Thesis, University of Florida, 52pp.

Anderson, S.D., Molenaar, K.R. and. Schexnayder, C.J. *Final Report for NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction*. National Cooperative Highway Research Program, Transportation Research Board, (2006), 290pp.

Bajaj, A., D.D. Gransberg, and M.D. Grenz, "Parametric Estimating for Design Costs" *2002 Transactions*, AACE, Int'l, Portland, Oregon, June 2002, pp. EST.08,01 – EST.08.06.

Brunsman, A., K.F. Robson, and D.D. Gransberg, ""Parametric Estimating for Environmental Remediation Projects," *2008 Transactions*, AACE, International, Toronto, Ontario, Canada, July 2008, pp EST.06.1-EST.06.8.

Chelst, K., and Y. B. Canbolat. *Value Added Decision Makings for Managers*. CRC Press, Boca Raton, (2012).

Deis, D., Schneider, H., Wilmot, C., and Coates C. (2004). "A Simulation Approach To In-House Versus Contracted Out Cost Comparisons," J. of Public Procurement, 4(1), 43–66.

Eisenhardt, K. M. "Better Stories and Better Constructs: The Case for Rigor and Comparative Logic." Academy of Management Review, 16(3), 1991, pp.620-627.

Flyvbjerg, B., Skamris Holm, M.K., and Buhl, S.L. Underestimating costs in public works projects: error or lie?," *Journal of the American Planning Association*, Vol.68(3), (2002), pp. 279–95.

Government Accounting Office (GAO) Using Structured Interviewing Techniques, GAO/PEMD-10.1.5, Government Accounting Office, Washington, D.C., June 1991, 191pp.

Gransberg, D.D., C. Lopez del Puerto, and D. Humphrey. "Relating Cost Growth from the Initial Estimate Versus Design Fee for Transportation Projects," *Journal of Construction Engineering and Management,* ASCE, Vol. 133 (6), June 2007, pp. 404–408.

Janacek, J. "Construction Costs Going Through the Roof?" Presentation, 2006 *Public Works Officer Institute*, Los Angeles, California, (2006).

Jennings, W. "Why costs overrun: risk, optimism and uncertainty in budgeting for the London 2012 Olympic Games." *Construction Management and Economics,* Vol. 30(6), (2012), pp. 455-462.

Mak, S. and D. Picken, Using Risk Analysis to Determine Construction Project Contingencies. American Society of Civil Engineers, *Journal of Construction Engineering and Management*., Vol. 126 Issue 2, 2000, pp.130–136

Miles, M. B., and Huberman, A. M. "Qualitative Data Analysis: An Expanded Sourcebook." Sage, Thousand Oaks, CA 1994.

Yin, R. *Case Study Research: Design and Methods*. Sage, New York. 2008, 176pp.