Project 0-7184: Develop an Interactive Unit Price Estimation and Visualization Tool

Background

The Texas Department of Transportation (TxDOT) invests significant amounts of budget on highway projects. TxDOT often determines unit prices of pay items using the historical bids-based estimation method and then develops an engineer's project appraisal. The engineer's estimate is used to assess the bids and select the bidder. However, the unit price of a work item is heavily affected by various project-specific and external factors, including but not limited to the project location, the quantity of the work, project complexity, time factors, and macroeconomic conditions. Therefore, accurate and reliable unit price estimation is vital for the optimum use of the available project budget.

The primary objectives of this research project were to (1) conduct an overview analysis of factors affecting unit prices, (2) identify factors affecting unit prices in Texas, (3) create a unit price estimation database, (4) create a spatio-temporal unit price estimation model considering the factors affecting unit prices, (5) develop a GIS-based visualization tool, and (6) implement, demonstrate, and validate the interactive unit price estimation and GIS-based visualization tool on six Receiving Agency's projects.

What the Researchers Did

The research project's findings were obtained through an extensive literature review, data collection, data analysis, model development, a GIS-based tool development, and the implementation of the developed tool for case studies of TxDOT projects.

• A thorough review of the literature was conducted to identify the factors that potentially affect unit prices and the unit price estimation methods used by different State Departments of Transport (State DOTs).
• A unit price estimation database was created from publicly available resources.
• Machine learning models (Deep Neural Network and Ensemble models) and statistical models (mixed-effects models) were developed for estimating unit prices of construction line items considering the factors that potentially affect unit prices.
• A GIS-based unit price estimation and visualization tool was created.

Figure 1. Map-based interface of the developed GIS-based tool

• The developed tool was implemented for estimating and visualizing the unit prices of line items for the six Texas projects provided by TxDOT.

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Project Completed:
08-31-2025

Figure 2. Location of the projects for the tool implementation in Texas

• The experience from implementing the tool was translated into an instructive and practical user manual, Educational Material (EM), and Video Training Material (VTM) to offer guidelines and tools for TxDOT staff to learn how to estimate the unit price of each work item, visualize unit prices, and analyze the results.

What They Found

• The unit price of a line item is significantly affected by various project-specific and external factors, including but not limited to the project location, the quantity of the work, time factors, and macroeconomic conditions.

• The developed machine learning models and statistical models provided reliable estimates, which could also be observed via case studies of six different projects. Deep Neural Network (DNN) models generally offered better generalization for those line-items with stable or less complex patterns, while Ensemble models might better capture temporal dependencies where such patterns exist. The mixed-effects models successfully addressed the multidimensional aspects of the heterogeneity involved in the dataset by utilizing both population-level fixed effects and group-specific random effects to produce precise predictions.

• It is critical to highlight that all the models are developed with only two years of data (March 2022 – September 2024), so certain line items and counties are underrepresented due to the limited availability of data. It is expected that the accuracy of these models could be significantly improved with more data. It is recommended that these models be fine-tuned with a larger and more diverse dataset.

• As the unit prices of line items vary with project type, county, work quantity, and time, the GIS tool could be used to visualize historical unit prices across various geographical locations (TxDOT counties) for various projects.

What This Means

• The identified (project-specific and external) factors should be considered when developing unit price estimation models.

• No single model fits all scenarios, and the predictive accuracy improves when a chosen model architecture reflects the underlying structure of the data. For example, Deep Neural Network (DNN) models work well for construction line items with stable, low-variance trends, while ensemble models are better suited for capturing irregular, time-dependent, or complex relationships. Similarly, mixed-effects models can simultaneously address multiple causes of variation within hierarchical data structure.

• The performance of the developed models can be improved with an expanded dataset covering more line items, projects, counties, and historical records.

• The GIS-based unit price visualization tool can be used for a quick retrieval of unit price values across various geographical locations. The tool helps track changes in data over time, by county, and across projects, as well as changes in the quantity of work items.