0-6412: Equipment Replacement Optimization

Background

Due to equipment deterioration and technological changes, public and private agencies that maintain fleets of vehicles and/or specialized equipment must periodically decide when to replace vehicles composing their fleet in order to minimize their fleet costs. The equipment replacement optimization (ERO) effort is also extremely important and can be effectively used as part of a long-range fleet replacement plan that can estimate the future budget required to meet predicted replacement needs for all future years. Any methodology that can improve TxDOT's replacement procedures can potentially save millions of dollars. To accomplish this task, a theoretically sound and practically feasible equipment replacement optimization methodology must be developed to accommodate specific TxDOT needs.

What the Researchers Did

To accomplish this project, researchers: 1. Conducted an extensive review of the state-of-the-art/practices concerning the ERO problem; 2. Formulated the ERO problem using both deterministic dynamic programming (DDP) and stochastic dynamic programming (SDP) with uncertainty in vehicle utilization; 3. Designed an ERO solution framework which consists of three main components: a) A Java based GUI; b) A SAS Macro based Data Cleaner and Analyzer; and c) A DP-based optimization engine; 4. Implemented the DDP and SDP approaches using both Bellman's and Wagner's formulations and conducted effective scenario reduction treatments for the SDP approach to resolve the "curse of dimensionality" issue; 5. Developed and Validated SAS and Java software codes to solve the ERO for both brand-new and used vehicles both with and without annual budget considerations.

The developed ERO software contains many features and options that can accommodate the fleet manager's different needs. Optimization can be run on a single classcode or all classcodes and for a specific brand new or used equipment unit, or all equipment units. The software allows the user to specify budget constraints, the time window, the inflation rate, the cost of money, and the desired number of years to delay the replacement of the selected equipment. The user can choose between two different cost forecasting approaches, cost current trend or cost equal mileage; and several different solution approaches; DDP, SDP 2-Level (high/low annual mileage usage), or SDP 3-Level (high/medium/low annual mileage usage), and Bellman or Wagner. The user can choose to run the software using SAS automatically generated cost data or use the Editable cost data and manually make any necessary changes. Finally, users can add new annual TERM data at the beginning of each year and make dynamic keep/replacement decisions for any chosen classcode or equipment units.

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What They Found

Comprehensive statistical analyses and optimization numerical results have been provided and show several trends that are consistent across classcodes for the majority of the TERM data. Firstly, as model year increases, the non-adjusted original total purchase cost increases noticeably and the adjusted total purchase cost seems to stay relatively flat. Secondly, as equipment age increases; the equipment utilization decreases, the commit hours decrease, the total O&M cost per mile/hour increases, and the down time seems to stay flat (due to the canceling effects of decreasing equipment utilization and increasing risk of equipment being down). As for the cost estimation and forecasting model performance, nonlinear models seem to outperform linear models for most classcodes.

The developed DP-based optimization engine seems to perform very efficiently and effectively. The computational time is very uniform for both the DDP and the SDP 2-Level solution approaches, which takes an average of 10 seconds for the ERO software to provide the best optimized decision for each classcode. The SDP 3-Level solution approach, however, is less uniform and takes approximately 30 seconds per classcode. Numerical results also indicate that all three approaches have produced promising results and each can yield significant cost savings (over two million dollars) compared to the current TxDOT benchmark decisions. Furthermore, DDP is generally more stable and reliable in terms of its cost forecasting quality because of the relatively abundant aggregate data for each classcode, while SDP is set up to allow the user to obtain more realistic/reliable results when sufficient data is available. A significant amount of cost savings can also be estimated by using the developed solution when considering an annual budget for the current TERM data.

What This Means

This research is the first of its kind implemented to accommodate specific needs of TxDOT. The developed ERO solution system is very general, user-friendly, and can be used effectively and efficiently to help TxDOT personnel make optimal decisions on whether to retain or replace a unit of equipment based on the equipment classcode, age, and mileage, both with and without budget consideration. Specifically, it can 1) Provide a general guide on ERO and develop optimal aggregate classcode replacement cycles for a particular classcode starting with brand-new equipment without considering budget; 2) Select the equipment units for annual replacement from a solution space that is composed of all the candidate equipment units that are eligible for replacement based on the annual budget and other constraints. A significant amount of cost savings can be realized by using the developed solution for the current TERM data.

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