MPC-544
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Project Title:
Lifecycle Assessment Using Snowplow Trucks' Automatic Vehicle Location (AVL) Data

University:
University of Utah

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Research Needs:
Utah Department of (UDOT)'s vision is Keeping Utah Moving. The agency's ability to deliver its core mission is supported by having an optimal age fleet to ensure the delivery of its winter maintenance program at the targeted levels of service. Class 8 snowplow trucks are the primary tool for clearing snow and delivering the winter maintenance program. The state legislature has allocated an additional $6 million per year to help bring the average age of the fleet from 11+ years old, down to the 4.5 year old target. It is important to document and follow the impact of this $6 million dollar per year infusion of funds into the Class 8 truck replacement cycle. UDOT needs to ensure they are on target and demonstrates full value of the program through transparent evaluation and measurement of the impacts of the funding.

Research Objectives:
1. Evaluate and measure the impacts of the allocated fund through the snowplow trucks performance assessment during their lifecycle
2. Explore the possibility of using the Verizon's real-time automatic vehicle location (AVL) data that UDOT equipped all the snowplow trucks with to update the lifecycle model

The primary objective of this research is to evaluate and measure the impacts of the allocated fund through the snowplow trucks performance assessment during their lifecycle.

The secondary objective is to explore the possibility of using the Verizon's real-time automatic vehicle location (AVL) data that UDOT equipped all the snowplow trucks with to update the lifecycle model. Such high-resolution data can help us re-examine the replacement criteria of snowplow trucks such as age, mileage and condition score, to determine whether the replacement decision is made properly.

Research Methods:
Lifecycle is a key concept in asset management. All assets are assumed to have a finite period for which it can efficiently and effectively operate. Snowplow truck management faces several decision making challenges everyday including truck selection for service continuity/termination, truck type selection for procurement, and estimating the future maintenance and operating costs associated with each truck. Truck selection for service continuity is the process of selecting one or multiple trucks among the fleet to run extra miles due to insufficient supply (i.e. trucks). Truck selection for service termination concerns about picking one or more trucks among the fleet for retirement. The retired vehicles are replaced with newly procured ones. Currently, most of the decisions regarding truck selection for service continuity/termination are made based on planning/engineering judgment rather than data driven analytics.

Note that several inputs and outputs are jointly influential on snowplow trucks performance and lifecycle, which makes it challenging to evaluate the underlying relationship between them. To address such challenge, in the research we propose an innovative and effective application of Data Envelopment Analysis (DEA) method to measure and compare the performance across snowplow trucks. DEA is a non-parametric approach that is widely used in recent years to compare the operational efficiencies of multiple Decision Making Units (DMUs).

For the specific problem of snowplow truck performance, the trucks serve as DMUs. The miles traveled (in miles) as the amount of works produced by DMU (truck) functions as the output. Maintenance labor, parts, and overhead costs (in dollars), fuel consumptions (in gallons), oil changes (in gallons), and number of preventative maintenance associated with each DMU (truck) serve as inputs in our input-oriented DEA model. Input-oriented DEA model measures the operational efficiency of DMUs by evaluating the difference between the DMU's inputs and minimum inputs while keeping the output at their current level. Let *k* represent the index of a set of trucks (*n*), *r* and *i* represent the index of outputs (*s*) and inputs (*m*), respectively. The operational efficiency of DMU_k is determined by solving the following model:

$$Maximize\ \theta_k = \frac{\sum_{r=1}^{s} u_r\, y_{rk}}{\sum_{i=1}^{m} v_i\, x_{ik}} \tag{1}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r\, y_{rj}}{\sum_{i=1}^{m} v_i\, x_{ij}} \leq 1 \qquad \forall j = 1, \dots, n \tag{2}$$

$$u_r, v_i \geq 0 \quad \forall r = 1, \dots, s; i = 1, \dots, m \tag{3}$$

where θ_k is the relative efficiency of DMU_k, y_{rk} is the r^{th} (i.e. $r = 1$: miles traveled) output of DMU_k, x_{ik} is the i^{th} input of DMU_k (i.e. $i = 1$: labor cost, $i = 2$: parts cost, $i = 3$: overhead cost, $i = 4$: preventative maintenance, $i = 5$: oil changes, and $i = 6$: fuel consumption), and u_r, v_i are decision variables reflecting the weights associated with outputs and inputs, respectively. The objective (1), is to maximize the relative efficiency θ_k of the k^{th} truck (DMU_k). Constraints (2) ensure that each of the trucks, using the same weights, has a relative efficiency that is less than or equal to one. Constraint (3) imposes non-negativity restrictions for weights. This optimization model can be converted into a linear programming model. In order to derive relative efficiency for each of the *n* vehicles, this optimization model must be solved *n* times, once for each truck (*k* = 1, 2, …, *n*).

Leveraging the real-time AVL data that UDOT has, we will be able to collect truck usage information as mentioned in the DEA model and identify the usage variations across trucks spatiotemporally. More importantly, we will be able to compute the operational efficiency of each truck θ_k, ranges from 0 to 1. Efficiency score of 1 indicates that truck is performing the best compared to other trucks based on inputs and outputs. In other words, these trucks are minimizing resource consumption (i.e. inputs) given their miles traveled (i.e. outputs). The DEA analysis is able to determine trucks efficiency and reliability, and further guide truck fleet procurement. We will conduct truck efficiency time series analysis for predicting future maintenance and operational costs associated with each truck. The trucks can then be ranked based on the predicted operational efficiency for service continuity/termination.

Expected Outcomes:

1. DEA model that can be used by UDOT to evaluate the lifecycle of snowplow trucks and compare the operational efficiency across all trucks for service continuity/termination evaluation
2. Recommended strategy for the number of trucks and dollar value that would need to be replaced in each year
3. A compilation of the AVL data that can be used for future lifecycle analysis and truck deployment optimization

Relevance to Strategic Goals:

- State of Good Repair
- Economic Competitiveness

With USDOT's emphasis on improving the conditions of the aging infrastructure, this project establishes a data-driven framework to document and follow the impact of a $6 million dollar per year infusion of funds into the Class 8 truck replacement cycle. The analysis leveraging high-resolution AVL data will assist UDOT to ensure that they are on target and demonstrating full value of the program through transparent evaluation and measurement of the impacts of the funding. The results of project will also assist UDOT to modify the program as needed and ensure the ability to respond to stakeholders (senior leadership, legislature, public) about the value and impact the funding is having in achieving the objectives and providing value to the transportation system and traveling public.

Educational Benefits:

One graduate student will be heavily involved in this research. He/she will lead the preparation of journal publications resulting from the work, and in most cases, deliver conference presentations. The project will serve as a basis for his/her dissertation work. The graduate course CVEEN 7545 Transportation Network Modeling is the ideal platform to introduce the analytics of truck AVL data, and the DEA modeling approach. The truck lifecycle analysis and operational efficiency modeling developed in this research will lead to new material included in the course to teach the students practical skills on infrastructure asset management.

Tech Transfer:
The potential audiences for this research are individuals involved in the traffic operations and transportation asset management, including traffic engineers, planners, and senior leaders at FHWA and at individual state DOTs. The following agencies, offices, and committees are those most likely to take a leadership role in implementing the research results:

- Utah Department of Transportation
- FHWA Office of Operations
- TRB Maintenance and Operations Management
- TRB Highway Capacity and Quality of Service Committee

The proposed principal investigator routinely interacts with UDOT, FHWA, SHRP 2 Reliability Program, and the listed TRB Committees. The 2018 Midyear Meetings of TRB Highway Capacity and Quality of Service Committee, TRB Managed Lane Committee, and TRB Maintenance and Operations Management will be an opportunity to share early results and future directions of the research project. The proposed principal investigator will work with the committee chairs to possibly get a presentation on the project added to the agenda. The proposed principal investigator and her graduate students routinely attend TRB's annual meeting as well. At least one TRB paper on this work will be submitted for presentation and publication.

Work Plan:

1. Steering committee assembly
2. Research synthesis
3. Data collection and compilation
4. Lifecycle analysis and DEA modeling
5. Final report

Task 1 – Steering committee assembly (1 month)
Assemble steering committee and set up meeting/communication protocols for the duration of the research project

Task 2 – Research synthesis (2 months)
Identify best practices for the lifecycle analysis of Class 8 snowplow trucks

Task 3 – Data collection and compilation (4 months)
Integrate heterogeneous data sources such as truck AVL, vehicle costs, vehicle usage into a spatial database

Task 4 – Lifecycle analysis and DEA modeling (6 months)
Through the analysis of lifecycle modeling, recommend strategy for the number of trucks and dollar value that would need to be replaced in each year and report the impact of the state funds in the program

Task 5 – Final report (1 month)
Summarize the findings of the research

Project Cost:

Total Project Costs:	$65,000
MPC Funds Requested:	$30,000
Matching Funds:	$35,000
Source of Matching Funds:	Utah Department of Transportation