Developing Predictive Models for Fuel Consumption and Maintenance Cost using Equipment Fleet Data

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Abstract

- For DOT, equipment management is the most important task as it runs several heavy civil maintenance and construction projects that require a large number of equipment.
- This research develops the predictive model for fuel consumption and maintenance cost utilizing the construction equipment data provided by the ODOT.
- The predictive model will help
  - DOT to allocate budget optimally.
  - Facilitate the equipment rental rate update process.

Objectives

- To develop the predictive models, using regression analysis, of:
  - The annual fuel consumption per equipment type
  - The cumulative maintenance cost associated with the equipment

Data and Methodology

- Data Source: ODOT
- Data Preparation and Processing
- MySQL Workbench was used to analyze and compile the data received from Agile Assets equipment inventory database together.
- Data set was divided into two categories:
  - Equipment charged by dollar/mile (trucks, pick-up trucks, cabs, etc.)
  - Equipment charged by dollar/hour (Heavy civil equipment)

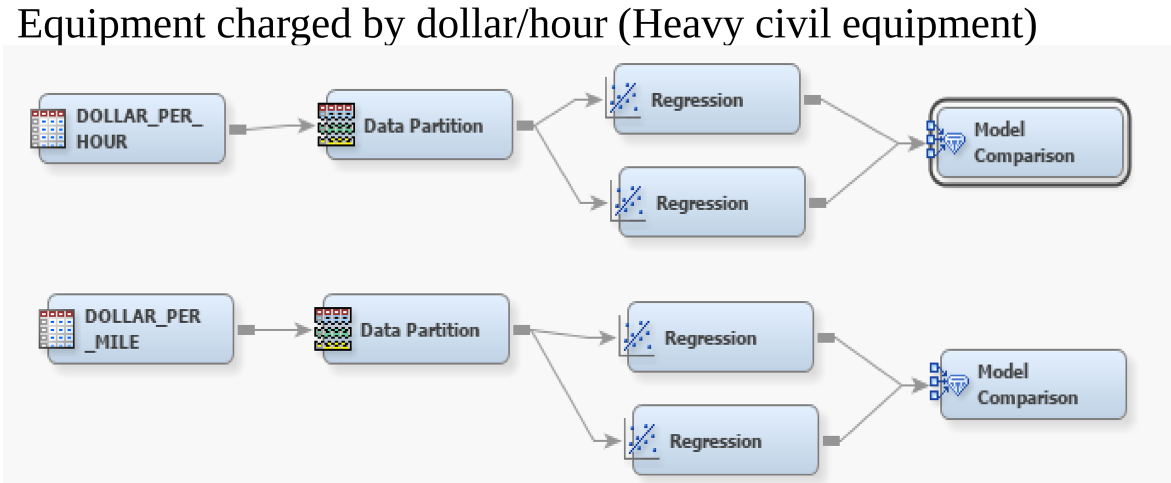

Figure 1. Fuel consumption prediction model flow chart

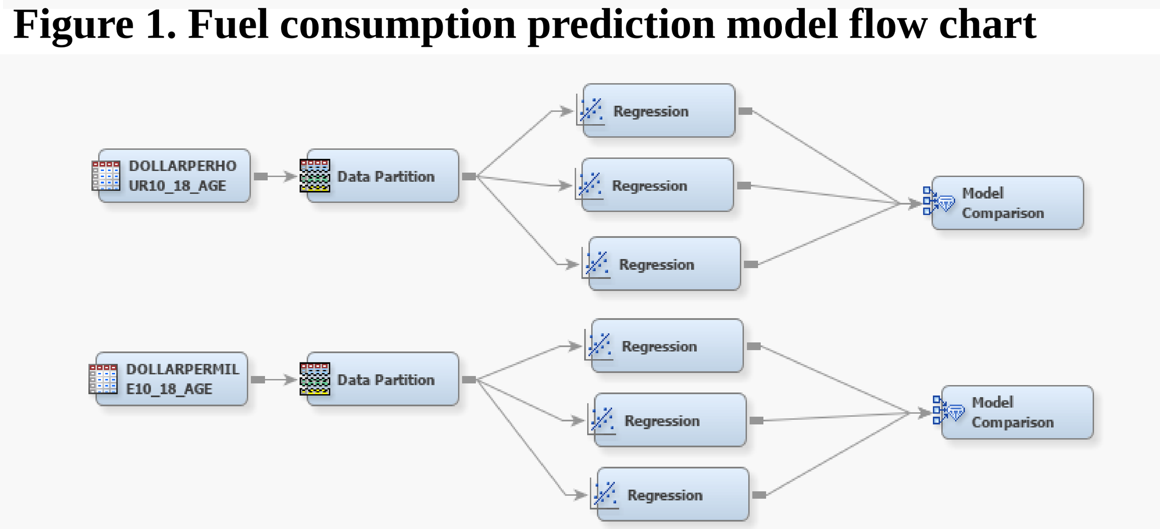

Figure 2. Maintenance cost prediction model flow chart

- Multiple Regression analysis was chosen to create the models

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots + \beta_n X_n$$

Y = Fuel Consumption – for fuel consumption models

Y = Cumulative Maintenance cost – for maintenance cost models

$\beta_0, \beta_1, \beta_2, \beta_3, \ldots\ldots \beta_n$ = Coefficients

$X_1, X_2, X_3, \ldots\ldots X_n$ = Input Variables (Table 1)

Table 1. Input Variables used for Multiple Regression Analysis

Input Variables	Description
ORIGINAL_VALUE	Purchase price of the equipment
Yearly_hours	Yearly hours worked by the equipment
_CLASS_CODE_ID	Put integer value 1, it includes a number of similar kind of equipment.
YEARLY_MILES	Yearly miles are driven
Age	The current age of the equipment
CURRENT_ODOMETER	Current odometer value of the equipment
Useful_life_eq	Probable life of equipment given by the manufacturer

Results

Table 2. R-Square and Adjusted R-Square values of the models

MODEL	R-Square	Adjusted R-Square
Fuel consumption for dollar/hour equipment	0.7701	0.7690
Fuel consumption for dollar/mile equipment	0.7851	0.7835
Maintenance Cost for dollar/hour equipment	0.6182	0.5999
Maintenance cost for dollar/mile equipment	0.4864	0.4246

Table 3. Example of analysis of maximum likelihood estimates of fuel consumption predictive model for the equipment charged by dollar/hour.

Parameter	DF	Standard Estimate	Error	t Value	Pr > |t|
Intercept	1	-47.5636	17.8232	-2.67	0.0077
ORIGINAL_VALUE	1	0.00110	0.000231	4.74	< .0001
Yearly_hours	1	1.9703	0.0257	76.54	< .0001
_CLASS_CODE 5120	1	-62.7692	20.7491	-3.03	0.0025
_CLASS_CODE 5121	1	-92.1433	25.6897	-3.59	0.0003
_CLASS_CODE 5123	1	-132.5	24.1089	-5.50	< .0001
_CLASS_CODE 5189	1	-56.0303	17.0892	-3.28	0.0011
……	…	…	…	…	…

-47.5636(Intercept) + ORIGINAL_VALUE * (.00110) + Yearly_hours * (1.9703) + _CLASS_CODE 5120 * (-62.7692) + _CLASS_CODE 5121 * (-92.1433) + _CLASS_CODE 5123 *(-132.5) + _CLASS_CODE 5189 * (-56.0303) + _CLASS_CODE 5191 *(53.9059) + _CLASS_CODE 5236 * (62.4718) + _CLASS_CODE 5237 * (260.2)+ _CLASS_CODE 5238 * (75.4559) + _CLASS_CODE 5355 * (-70.8765) + _CLASS_CODE 5357 * (-97.7508)+ _CLASS_CODE 5360 *(-64.3132) + _CLASS_CODE 5362 * (71.7761)+_CLASS_CODE 5371 * (-17.2746) + _CLASS_CODE 5375 * (179.5) + _CLASS_CODE 5378 *(-70.5771)

Equation 1. Fuel consumption predictive model for the equipment charged by dollar/hour

8.5127 (intercept) + Age * (-18.2660) + YEARLY_MILES * (0.1075) +ORIGINAL_VALUE * (.00614) + CURRENT_ODOMETER* (.00115) + CLASS_CODE_ID 5085 * (752.4) +CLASS_CODE_ID 5086 * (-638.8) +CLASS_CODE_ID 5089 * (-411.9) +CLASS_CODE_ID 5090 * (-364.9) +CLASS_CODE_ID 5385 * (-619) +CLASS_CODE_ID 5386 * (-525.5) +CLASS_CODE_ID 5388 * (-819.1) +CLASS_CODE_ID 5392 * (-191.3) +CLASS_CODE_ID 5393 * (-172.2) +CLASS_CODE_ID 5394 * (-213.8) +CLASS_CODE_ID 5395 * (-780.9) +CLASS_CODE_ID 5398 * (-332) +CLASS_CODE_ID 5399 * (59.6537) +CLASS_CODE_ID 5401 * (-100.9) +CLASS_CODE_ID 5402 * (-39.3478) +CLASS_CODE_ID 5404 * (99.8479) +CLASS_CODE_ID 5407 * (-46.6372) + CLASS_CODE_ID 5418 * (247.9) +CLASS_CODE_ID 5419 * (232.5) + CLASS_CODE_ID 5420 * (164.2) +CLASS_CODE_ID 5421 * (142.1) + CLASS_CODE_ID 5425 * (436.7) +CLASS_CODE_ID 5427 * (148.1) +CLASS_CODE_ID 5428 * (701.7) +CLASS_CODE_ID 5429 * (403.4) +CLASS_CODE_ID 5430 * (337.3) +CLASS_CODE_ID 5431 * (339.5) +CLASS_CODE_ID 5433 * (634.4) +CLASS_CODE_ID 5434 * (136.4) +CLASS_CODE_ID 5435 * (429.5) + CLASS_CODE_ID 5441 * (846) + CLASS_CODE_ID 5442 * (-596.3)

Equation 2. Fuel consumption predictive model for the equipment charged by dollar/mile

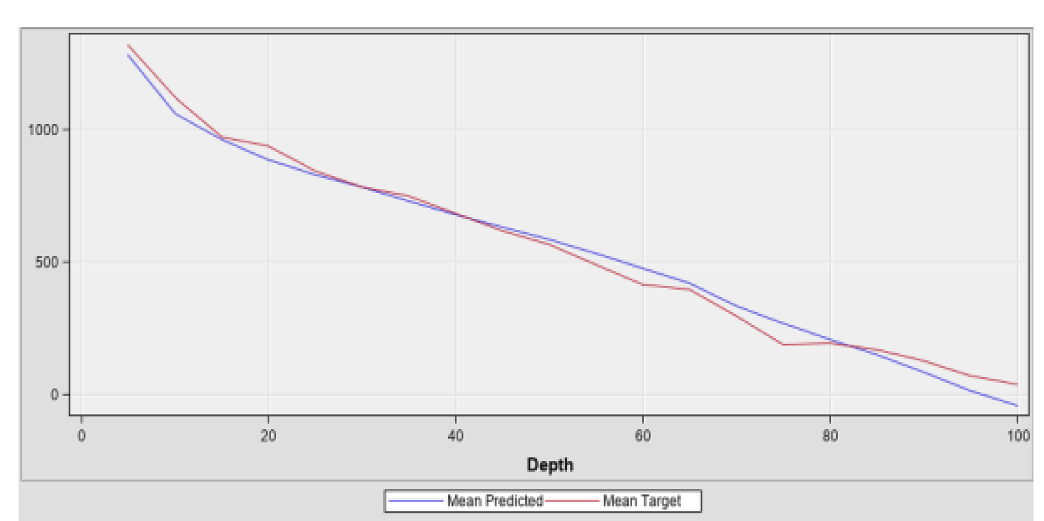

Figure 3: Validation data model for fuel consumption for equipment charged by dollar per hour

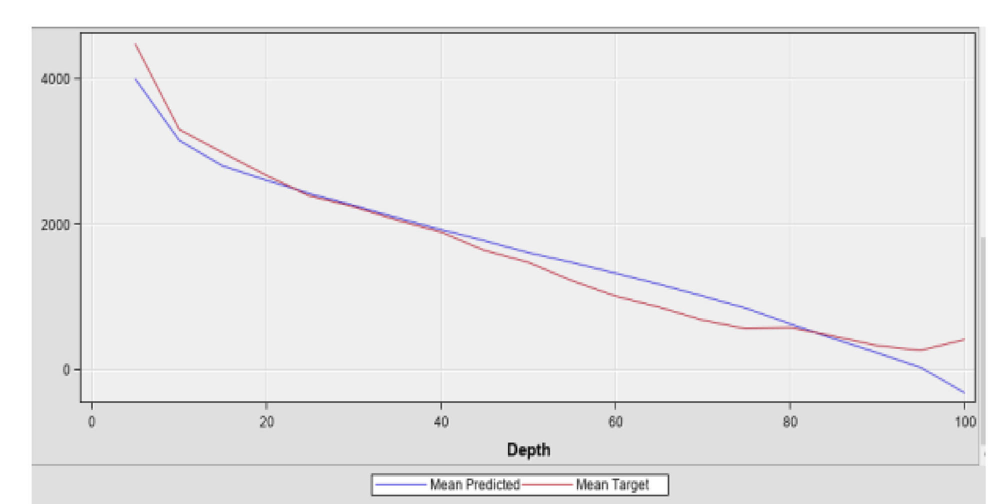

Figure 4: Validation data model for fuel consumption for equipment charged by dollar per mile

3417.1 (intercept) + EQUIPMENT_CLASS_CODE_ID 5121 * (-2788.3) +EQUIPMENT_CLASS_CODE_ID 5123 * (-2581.6) +EQUIPMENT_CLASS_CODE_ID 5189 * (-1691.9) +EQUIPMENT_CLASS_CODE_ID 5237 * (14100.3) +EQUIPMENT_CLASS_CODE_ID 5238 * (3729.5) +EQUIPMENT_CLASS_CODE_ID 5355 * (-1947.3) +EQUIPMENT_CLASS_CODE_ID 5357 * (-1175.3) +EQUIPMENT_CLASS_CODE_ID 5360 * (-3356.9) +EQUIPMENT_CLASS_CODE_ID 5375 * (-1911.4) +CURRENT_ODOMETER*CURRENT_ODOMETER* CURRENT_ODOMETER * (1.318E-6) + CURRENT_ODOMETER*CURRENT_ODOMETER*Useful_life_eq * (-0.00025) +CURRENT_ODOMETER*CURRENT_ODOMETER*age * (-0.00080) + CURRENT_ODOMETER* Useful_life_eq *age * (0.2577)ORIGINAL_VALUE*ORIGINAL_VALUE*age* (-1.11E-7)

Equation 3. Maintenance Cost predictive model for the equipment charged by dollar/hour

42546.4 (intercept) + age (-27877.2) + age *age (6797.3) + CURRENT_ODOMETER*CURRENT_ODOMETER*age (8.214E-8) + CURRENT_ODOMETER*ORIGINAL_VALUE*age (-2.78E-7) +age * age *age (-457.5) +EQUIPMENT_CLASS_CODE_ID 5085 * (-7795.5) + EQUIPMENT_CLASS_CODE_ID 5086 * (39985.8) +EQUIPMENT_CLASS_CODE_ID 5089 * (1102.8) +EQUIPMENT_CLASS_CODE_ID 5090 * (966.8) + EQUIPMENT_CLASS_CODE_ID 5385 * (-2335.7) +EQUIPMENT_CLASS_CODE_ID 5386 * (4278.2) +EQUIPMENT_CLASS_CODE_ID 5393 * (-13391.5) +EQUIPMENT_CLASS_CODE_ID 5394 * (-2197.4) +EQUIPMENT_CLASS_CODE_ID 5395 * (2516.3) +EQUIPMENT_CLASS_CODE_ID 5399 * (-15484.2) +EQUIPMENT_CLASS_CODE_ID 5401 * (-6417.6) +EQUIPMENT_CLASS_CODE_ID 5407 * (-1275.4) +EQUIPMENT_CLASS_CODE_ID 5418 * (-4730.4) +EQUIPMENT_CLASS_CODE_ID 5419 * (-5336.9) +EQUIPMENT_CLASS_CODE_ID 5420 * (474.1) +EQUIPMENT_CLASS_CODE_ID 5428 * (6079) +EQUIPMENT_CLASS_CODE_ID 5429 * (20515.4) +EQUIPMENT_CLASS_CODE_ID 5431 * (253.3) +EQUIPMENT_CLASS_CODE_ID 5434 * (-3502.7) +EQUIPMENT_CLASS_CODE_ID 5435 * (-918.8) +EQUIPMENT_CLASS_CODE_ID 5441 * (-2680.5) +EQUIPMENT_CLASS_CODE_ID 5442 * (-6956.4)

Equation 4. Maintenance Cost predictive model for the equipment charged by dollar/mile

Results

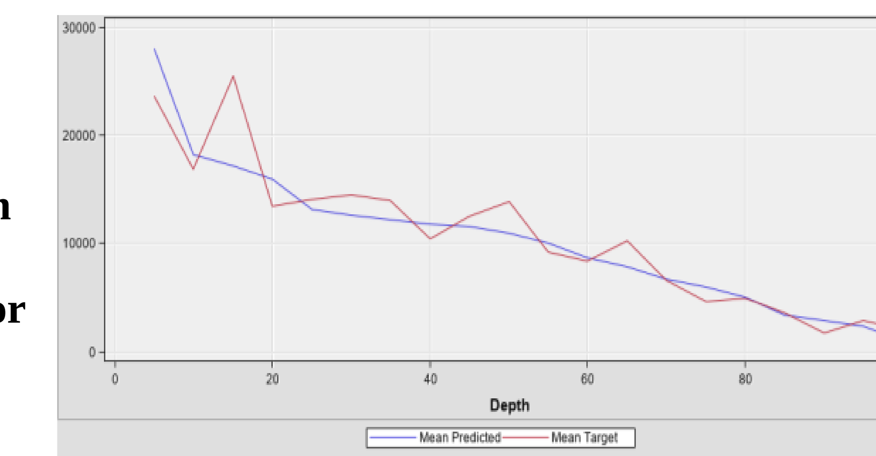

Figure 5: Validation data model for maintenance cost for equipment charged by dollar per hour

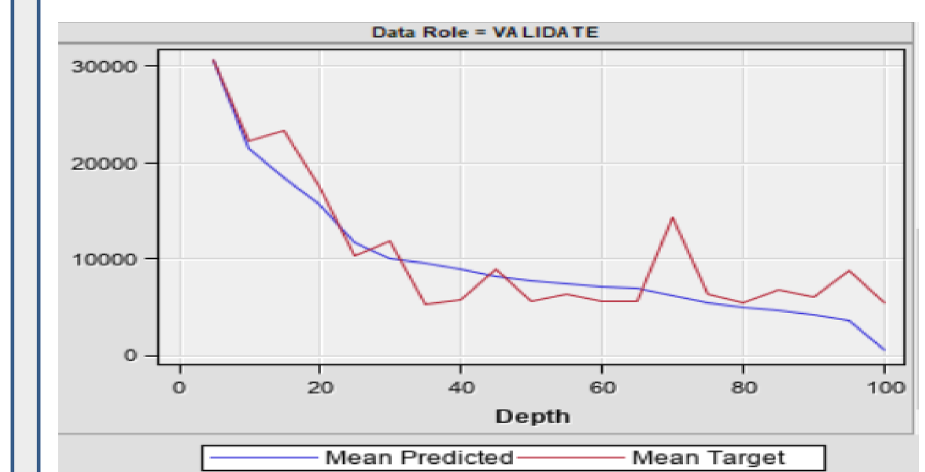

Figure 6: Validation data model for maintenance cost for equipment charged by dollar per mile

Conclusion and Contribution

- The predictive model developed in this study accounts for the prediction of fuel consumption and maintenance cost of the equipment
- The result could be taken into account for budget estimation, rental rate calculations and equipment maintenance related decisions.
  - Good Predictor to forecast:

Fuel Consumption	Maintenance Cost
○ Purchase price of the equipment ○ Yearly hours worked by the equipment ○ Present age of the equipment ○ Current odometer reading of the equipment	○ Current odometer reading of the equipment ○ Useful life of the equipment ○ Present age of the equipment ○ Purchase price of the equipment

- The predictive accuracy of the developed model depends upon the number of data available for the equipment.

Recommendation

- Similar study to be carried out to develop maintenance cost model using parameters like engine size, number of axles, etc.
- Another study to be performed by distinguishing equipment based on the type of the fuel consumed and developing predictive models for a particular type of fuel consumption.
- Separate maintenance cost predictive models to be developed for preventive and scheduled maintenance, and repairs and breakdowns.

Acknowledgement

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