Abstract
Transit operators are gradually incorporating hybrid and electric vehicles in existing conventional-diesel and natural gas fleets, in an effort to improve carbon-footprint of transit services. The objective of this study is to provide an ex-ante evaluation of bus fleet management plans in cases of fleets with mixed propulsion technologies. An integer programming model is exploited, seeking to minimize the total cost of purchasing, operating and selling buses, under various fiscal and operational constraints. A realistic data set from various sources is collected and a thorough scenario analysis is performed to assess the various trade-offs between different propulsion technologies. Results show that the largest reduction in the fleet management cost stems from favorable conditions for the purchase of more fuel-efficient types of buses, such as electric and natural gas buses.

Model
\[ X_{ik} \] the number of type-1 buses of age \( j \) in operation at year \( t \)
\[ X_{ik}^o \] the number of type-1 buses of age \( j \) sold at year \( t \)
\[ x_{ik} \] the number of type-1 buses purchased at year \( t \)
\[ \alpha \] consumption rate \( \alpha \frac{X_{ik}^o X_{ik} + x_{ik} X_{ik}^{o1}}{X_{ik} + x_{ik} + X_{ik}^o} \]
\[ \beta \] salvage revenue \( \beta X_{ik} \)
\[ \gamma \] operation, maintenance, emissions’ cost \( \gamma X_{ik} \)

Subject to:
\[ \sum_{ik} x_{ik} \leq B \] Budget constraint
\[ \sum_{ik} X_{ik} + X_{ik}^o - x_{ik} \geq 0 \] Distance constraint
\[ X_{ik}^o + \frac{x_{ik} - X_{ik}}{k} \geq 0 \] Fleet size limits
\[ \sum_{ik} X_{ik}^o \leq M \] New vehicles must be used right away
\[ \sum_{ik} x_{ik} \leq R \] Compensation of vehicles
\[ \sum_{ik} X_{ik} \leq A \] A vehicle must be used or sold the following year
\[ X_{ik}^o \leq A \] Maximum age constraint
\[ X_{ik} \geq 0 \] \( \forall \ i, j, k \) A new vehicle (of age \( i \) cannot be sold
\[ x_{ik} \geq 0 \] \( \forall \ i, j, k \) Form of decision variables

Data Collection
* Determination of optimal fleet management plan for a transit operator
  * Consideration of different fuel types:
    * Diesel
    * Compressed Natural Gas
    * Hybrid-Electric
    * Electric
  * Thorough data collection:
    * Transit agencies
    * Literature
    * Online-databases
  * Application for transit operator in a large urban area:
    * Solution by Integer Programming
    * Scenario analysis to estimate effect of economic parameters
  * Assist transit operators in management decisions during transition from conventional to alternative fuel buses

Objectives
* Determination of optimal fleet management plan for a transit operator
  * Consideration of different fuel types:
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Results

Conclusions
* Hybrid and electric vehicles are advantageous in terms of operation and maintenance costs
* High purchase costs for hybrid and electric buses limit vehicle purchases
* A 30% increase in fuel price prohibits new bus purchases regardless of vehicle type
* An emissions’ tax would bring about a drastic reduction in conventional and NG vehicles, as well as in average fleet age
* Lower prices of non-diesel vehicles and energy sources produce favorable solutions in terms of cost