Malaya Journal of Matematik, Vol. S, No. 2, 1385-1387, 2020
https://doi.org/10.26637/MJM0S20/0376

Age replacement optimization of various types of buses using integer programming model

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Abstract
Now a day it is very hard to manage the transport agencies with their group of vehicle in an optimal way with the recent budget and taxes. The vehicle data shows that the operating and maintenance cost of buses per kilometer increases as bus age increases. In the economic point of view between the lower cost of existing buses and maintenance cost of newer vehicles are analyzed in this paper.

Keywords
Bus fleet, Age Replacement Model, Optimization, Cost elasticity.

AMS Subject Classification
05C82, 68M12.

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Article History: Received **01** October **2020**; Accepted **10** December **2020**

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1. Introduction

Many transport agencies own huge number of buses serving different routes. Large fleets initial and operating cost are significant prices for transport agencies. In particular, high initial (or) purchase costs have forced some transport agencies to delay bus replacement decision. The main aim is to present a model and verify the factors affecting the bus replacement age and total fleet cost. Bus fleet price can be broken into following cost factors, vehicle operating cost, purchase cost, fuel, general administration cost, facility maintenance cost, etc. we restrict our attention to the factor that affect total cost and replacement age of bus such as cost of maintenance that vary with bus ages. Bus requires diesel fuel for engine, salary to pay the driver and make sure that the buses are in good running condition.Further bus cost changes as they become older and have many other problems. Bus costs are attributed to numerous cost factor capital purchase cost, vehicle operating and maintenance, fuel, general administration. The pie chart represents an average proportion of total bus operating cost based on XYZ private transport cooperation. The vehicle operating cost consists of large components.Each of these cost changes depend on fuel cost, bus fleet age, agency size, labor cost and many other factors.

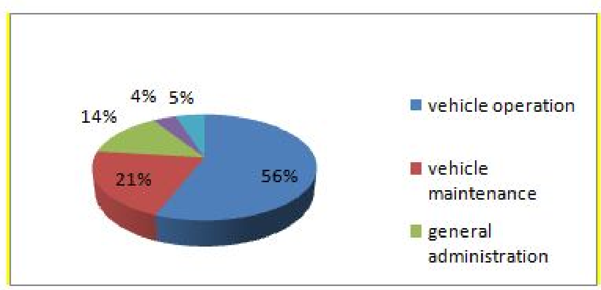

Figure 1. Overall cost for transport operations

2. Preliminaries

Integer Programming
An integer programming model is one where one or more of the decision variable has to take on an integer value in the final solution. The various types of integer programs are Pure integer programming(All values have integer values), Mixed integer programming (Not all of the values will have integer

values), Zero-one integer programming (It's a special case in which all the decision variables must have integer solution values of 0 or 1).

2.1 Model formulation

The make use of this model is to decide the replacement age and cost. The objective of this model is to decrease cost of bus over the planning period: including operating, purchasing, maintenance, emission, utilization and road call cost. The decision variable is at what time buses replace over the planning period.

Indexes

Age of the bus in years: $m \in A = \{0, 1, 2, 3, \ldots\ldots A\}$

Time period is made at the end of each year: $n \in T = \{0, 1, 2, \ldots, T\}$

Binary decision variable

R_{mn}= the m-year old bus in use from the end of year n to the end of year $n+1$

SY_n= whether a bus is salvaged at the end of year n

Parameters

(a) Constraints

M = maximum or forced salvage age (if this age is reached then the bus must be salvaged),

U_m = utilization (Kilometers traveled by m- year old bus),

Feo_m = fuel economy of m-year old bus,

(b) Costs

C = cost of purchasing a new bus,

OC_m = maintenance cost per km for m-year old bus,

rC_m = road call cost of an m-year old bus

s = salvage revenue from selling an old bus when replaced by a new bus,

sf_{mT} = final salvage revenue from selling an m-year old bus at time T,

ce = emission cost per ton of co_2 emission,

p = price of diesel fuel per liter and

ds = rate of discount

(c) Emission

Pse = salvage emission and production in co_2 tons,

em_m = utilization emission in co_2 tons per km for m-year old bus

Objective function, minimize:

$$\sum_{m=0}^{A-1}\sum_{n=0}^{T-1} SY_n(C+Ce-PSe-S-Sf_{mT})(1+ds)^{-n} + \sum_{m=0}^{A-1}\sum_{n=0}^{T-1} R_{mn}(U_mOC_m+U_mFeo_mP+U_mem_mCe+rC_m)(1+ds)^{-n} \quad (2.1)$$

Subject to:

$$SY_0 = 1,\ \text{where } S=0 \quad (2.2)$$

$$SY_T = 1,\ \text{where } C=0 \quad (2.3)$$

$$R_{(m-1)(n-1)} = R_{mn} + SY_n, \forall m \in \{1, 2.....A\}, \forall n \in \{1, 2.....T\} \quad (2.4)$$

$$SY_n = R_{on},\ \forall n \in \{1, 2......T-1\} \quad (2.5)$$

$$R_{An} = 0, \forall n \in \{0, 1, 2.......T\} \quad (2.6)$$

$$X_{mT} = 0,\ \forall j \in \{0, 1, 2......T\} \quad (2.7)$$

$$SY_n, R_{mn} \in I = \{0, 1\} \quad (2.8)$$

The aim of the Objective Function:

(2.1) Reduce the total amount of maintenance, purchasing, emission, salvage and road call cost over the time period from present to the end of the planning period. At the first period of time the model start with new bus (2.2). At the end of the period the bus which is exist is sold (2.3) which equal to the value of salvage for the bus at the time T, sf_{mT}. The age of vehicle in current use increases by the year of one after each time period (2.4). A constraint makes sure that a bus obtain equal to the new bus in use (2.5). The maximum service age bus forced to be salvaged (2.6). At the last time T, the bus is not used and cost of operational are not added (2.7). At the end decision variable related to salvage and purchasing decision must be binary (2.8).

Data collection

The data in this study were collected over 20 years from the private transport corporation. The cost data contain purchase cost, maintenance cost, fuel cost, emission cost etc also contain bus ages.

2.2 Assumption and terminology

Maintenance cost per kilometer

It is the total cost which includes labor, parts, and tire costs, overhead costs to maintain the building & employee service. Maintenance cost is Rs. 6/km.

Fuel efficiency

The average fuel economy has been found to be Rs. 29.50/km.

Road call

A bus has a road call when it has a mechanical problem and a mechanic must be sent out to fix it. Road calls are detrimental to the transit agency because of the additional staff and resources required to repair a bus with mechanical problems. The transit cost of RCs is already integrated in the maintenance cost data.

Utilization

The average utilization is 12,000 per year per unit and is held constant for the time horizon of the model.

Salvage value

Decommissioning a bus is costly because equipment as well as external markings must be removed. If revenue from selling a bus exceeds Rs.880000 the difference must be reimbursed to the capital assistance funds were employed. A salvage value s=Rs.220000 is assumed. However, on year T when the bus is compiled to be sold, a salvage value of Rs.220000 may not be realistic especially if a relatively new bus is sold. The final salvage value is determined by the following equation.

$$sf_{mT} = C - M_n * (C - S)/20$$

Emissions output

Life cycle analysis studies have estimated a passenger vehicle's production and salvage emissions. There is no equivalent bus production and salvage emissions study; a bus CO_2tons estimation is production based on a ratio of vehicle weight and the CO_2 released to manufacture and scrap a vehicle. The emissions associated to the production and salvage of a bus is estimated at 100 tons of CO_2. In addition, there are CO_2 emissions associated with bus usage; this value equals the CO_2 released when a gallon of diesel is burned, which is well known.

3. Additional data inputs and assumptions

Transit buses are replaced at year 10 and bus ages rarely exceed 20 years. Hence, the bus maximum age is set to 20 years. For reference, after year 11 of the model, the nominal discount rate is fixed at 9%. Bus cost is assumed to be $V = 4000000$ based on real data including equipment, manuals and contingency.

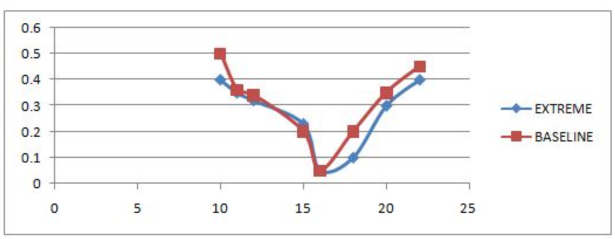

Figure 2. Impact of age replacement

4. Conclusion

From the above result we conclude that the fuel cost, purchase cost, operation and maintenance cost are contributed to 21%, 13%, 66%of the total bus cost .The optimal replacement age of the bus is 15.8 years..

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ISSN(P):2319 − 3786
Malaya Journal of Matematik
ISSN(O):2321 − 5666
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