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# Mathematical Modelling of Fleet Management Evaluation for Non-Corporate Transport Organizations

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***Abstract-****The non-corporate transport organizations are the transport services, like army transport services, police transport or any fleet owned by company supporting the product momentum. The peculiarity about these fleet services is that owner has got the dual role of user as well as maintenance manager. The productivity of the fleet is non-visible; thus, efficiency of these fleets is always evaluated with respect to the attributes like emission, road worthiness, etc. The owners of this fleet always take them as liability and maintenance of this fleet takes back bench with respect to the production plants. The fleet owner(s) forgets that this fleet provides the momentum to the product in penetration of the market and helps in establishing the new markets because of sustained supply chain. As per literature review no fool proof model for evaluation of these fleets is available. Evaluation is treated with respect to the attributes and tackled as per the owner's perceptions about their fleet. This paper has tackled the problem by establishing the relationship of fleet efficiency (F) with respect to the variables as operating efficiency (O), productivity (P) and service efficiency (S). The operating efficiency is considered to be the function of vehicle utilization ($V_u$), vehicular utilization ($V_h$) and occupation ratio ($O_c$). Similarly, productivity is assumed to be function of fleet utilization ($F_u$), vehicle utilization ($V_u$), load productivity ($L_p$) and fuel productivity. And service efficiency is considered to be function of number of accidents, mean time to repair (MTTR), mean time between failures (MTBF), availability of maintenance stores, fuel consumption, holding of first line transport for momentum (product or resource), holding of drivers and maintenance craftsmen (vehicle mechanics and electricians), holding of recovery resources, availability of literature for users and maintenance craftsmen, availability of tools and special maintenance tools, number of vehicles detailed on administrative duties. The study has also tried to establish the inter–relationship among common variables. To explore the objective of finding a model of establishing the fleet efficiency of transport systems of government and non-corporate organizations, the data has been collected from three different types of fleet at international level i.e., 212 major Indian army units, units of Indian police organizations and Ethiopian Harar brewery share company. Approximately 21,220 vehicles data have been analyzed to establish values of service efficiency, productivity and operating efficiency; relationship among the variables and relationship between the variables and fleet efficiency. The hypotheses for relationship have been established and tested by statistical techniques. This model of fleet management evaluation is the pioneering step towards the evaluation with the help of variables utilizing mathematical approach instead of traditional way of evaluating with respect to the qualitative attributes. This model will be able to give a fool proof method for evaluation of transport management of non-corporate transport organizations, and also it will help in replacement policy. Further the model can be utilized with slight variation for maintenance program. Thus, it is imperative that this model will be an asset to the non-corporate transport organizations.*

***Key words-*** *Fleet management, maintenance, productivity, occupation ratio, non-corporate transport organizations.*

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## I. INTRODUCTION

The non corporate transport organizations are the transport services, like Army transport services, police transport or any fleet owned by company supporting the logistic momentum. The peculiarity about these fleet services is that owner has got the dual role of user as well as maintenance manager. The productivity of the fleet is non-visible; thus, efficiency of these fleets is always evaluated with respect to the attributes like emission, road worthiness, etc. [1].

Defence forces are one of the non-corporate organizations, which has got large resources of men and material, which has to move from one place to another place very frequently. Movement from one place to another place without any hindrance and with 100 percent reliability is an important part of Defence forces [2].

Any service that needs to be of vast scale, that effects the human beings, like the soldiers of Defence forces or the refugees waiting for relief stores, and that wholly dominates the economic world, needs to be planned, organized and controlled and most importantly to be evaluated frequently for its effectiveness and efficiency [3].

Fast speed, safety, security, cost competitive, convenient loading and unloading, flexibility, versatility, energy efficiency, environmental friendliness, etc. are hall mark attributes used for evaluation of the non-corporate fleet for sound transportation system [4]. However, all the attributes are based on qualitative analysis and no mathematical approach is available till now for evaluation.

## II. PROBLEM STATEMENT

Till now, no author has established a fool proof model for evaluation of these fleets and evaluation is treated with respect to the attributes and tackled as per the owner's perceptions about their fleet. This thesis has tackled the problem by establishing the relationship of fleet efficiency (F) with respect to the variables as operating efficiency (O), productivity (P) and service efficiency (S).

Is $F = O \times P \times S$ (1)

or $F = O^x \times P^y \times S^z$ (2)

If the later is true than how to establish the values of x, y, z?

The operating efficiency is considered to be the function of vehicle utilization ($V_u$), vehicular utilization ($V_h$) and occupation ratio ($O_c$), ($O=f(V_u, V_h, O_c)$. Similarly, productivity is assumed to be function of fleet utilization ($F_u$), vehicle utilization ($V_u$), load productivity ($L_p$) and fuel productivity ($F_p$).

$$P = f(F_u, V_u, L_p, F_p) \quad (3)$$

And service efficiency is considered to be function of number of accidents, mean time to repair (MTTR), mean time between failures (MTBF), availability of maintenance stores, fuel consumption, holding of first line transport for momentum (logistic momentum or resource momentum), holding of drivers and maintenance craftsmen (vehicle mechanics and electricians), holding of recovery resources, availability of literature for users and maintenance craftsmen, availability of tools and SMTs, number of vehicles detailed on administrative duties [5].

It can be seen that some of the parameters of operating efficiency, productivity and service efficiency are common. Thus, the thesis has also tried to establish the inter-relationship among these variables.

### *A. Significance of the Study*

This model of fleet management evaluation is the pioneering step towards the evaluation with the help of variables utilizing mathematical approach instead of traditional way of evaluating with respect to the qualitative attributes. Thus, this model will be able to give a fool proof method for evaluation of transport management of government and non-corporate organizations.

Further, this model will help in establishing the impact of maintenance and optimization of fleet maintenance and the users can also pin point the particular part of the fleet or a particular vehicle not performing with satisfactory efficiency. Thus, it will help in replacement policy. Further, the model can be utilized with slight variation for maintenance program. Thus, it is sure that this model will be an asset to the government organizations and non-corporate transport organizations.

### *B. General and Specific Objectives*

General objective of this paper is to develop a mathematical model for evaluation of transport management of non-corporate organizations.

Specific objectives of this paper are:

- To identify the drawbacks of present system of evaluation of transport management for non-corporate organizations.
- Develop the parameters for evaluation of transport management.
- Establish the interrelationship among parameters.
- Develop the relation of parameters with fleet efficiency.
- To design and develop the final mathematical model for evaluation of transport management for specifically non-corporate organizations.
- Validate the model with available data.

## III. RESEARCH METHODOLOGY

The research paper is based on direct investigation method, analysis of present system and the indirect method. The direct method has been adopted to collect primary data. 311 defence units and federal police units were approached out of which 212 units were kind enough to disseminate the data on fleet utilization for five years.

In indirect method a questionnaire was designed separately for user, maintaining agencies and the individual officers and other employees of the federal police and defence forces.

The questionnaire was canvassed by the investigator by contacting personally the officers and other employees and by sending to 311 units by post. Apart from the primary data, secondary data, obtained from the indirect method, were used to supplement the findings based on the primary data.

## IV. DEVELOPMENT OF MODEL

*A. Concept of Efficiency in Army Transport Management*

The transport occupies a significant place in every scenario, be it economy or mobility, particularly in non-corporate organizations like defence forces and federal police organizations, where transportation is in varying terrain and availability has to be 100% and reliability cannot be compromised. Therefore, efficiency of the transport system, particularly for Army and federal police has to be very high.

The efficiency of army and federal police force fleet can be taken as fleet efficiency, which is further explained in the succeeding paragraphs.

*(i) The fleet efficiency:*

Fleet efficiency is defined as the ratio of gross load kilometerage output to the fleet input. It is the function of operating efficiency, productivity and service efficiency.

$$F = f(O, P, S) \quad (4)$$

where: F=Fleet efficiency, O=Operating efficiency, P=Productivity, S=Service efficiency

Let us discuss all the variables individually.

*(ii) Operating efficiency (O)-Capacity creation and fleet operation efficiency:*

Every organization has the capacity to produce goods or perform services. The capacity to produce is created by installing the system to produce goods or perform services. To install the capacity appropriate to organization's objective, there ought to be match between the demand and the capacity so installed, i.e., the supply. Any mismatch between the two is apt to result in wastage of material and human resources. This capacity in turn is related to the nature of the organization, the system/process of production, resources available and the policy of the organization [6].

When the organization makes use of the production capacity to produce goods or perform the services, it is termed as capacity utilization [7-9].

The organization strives to work at the optimum level. If it operates below the capacity, the cost of production/ services apt to go up or delay will take place. The reason for higher cost of services/product may be unnecessarily higher on account of higher wear and tear to the vehicles and equipments, higher fuel consumption and the wastage associated with other material and human resources. It is therefore, essential that the organization ought to estimate the demand correctly so as to utilize capacity to the full [7].

With optimal utilization of capacity, the fixed cost gets distributed over a larger number of units of production which brings down cost of services. In the absence of fuller utilization of the capacity, the cost of production goes up because of the higher pursuit component fixed cost [9].

*(a) Factors affecting the capacity creation and utilization:*

Capacity development in non-corporate transport system depends on the requirements of units and installations for mobilization, availability of type of transports in the transport markets at the national and international level, policy of the government, technological advancement, shifting of staff preferences at defence forces head quarter and ministry of defence level, demand for better facilities and operational efficiency. All these factors have to be taken into consideration while making capacity development decisions [10].

The aspect of capacity utilization of non-corporate transport system may be viewed from a quantitative horizon and mathematical approach as: vehicular utilization, vehicle utilization, and occupation ratio

- *Vehicular utilization (Fleet utilization):* Vehicular utilization is a ratio of number of vehicles on road to the fleet held by the organization. The vehicular utilization gives the idea of the share of the services performing kilometer performed by the vehicles on road [10].

$$\text{Vehicular utilization} = \text{Vehicles on road} \div \text{Total number of vehicles in the fleet} \quad (5)$$

Vehicular utilization is always $\leq 1.00$

- *Vehicle utilization:* It refers to the number of kilometers run per vehicle on road per day. Vehicle utilization indicates the extent of the use of vehicle per day. Higher vehicle utilization distributes the fixed cost over a large number of kilometers thereby reducing the unit cost of operation, which leads to better margin [10].

Required vehicle utilization of army transport:

Maximum service kilometrage offered during the year per vehicle: 12000km

Number of service days: 365days

Average of service days: $12000 \div 365 = 32.88$km/day

Required vehicle utilization: $32.88 \times 0.9 = 29.6$km/vehicle/day

- *Occupation ratio:* Occupation ratio studies the extent of actual utilization of service kilometers viz., the available kilometers, consequently the size of the service performed as against the service expected. Occupation ratio refers to the success with which the organization provides what it possesses [10].

Required occupation ratio of army transports:
(i) Considering vehicular utilization:
Excellent: > 80%, Desired: > 70%
Satisfactory: > 60%, Poor: < 60%
(ii) Vehicle utilization: 90%
(iii) Occupation ratio:
Excellent: $0.8 \times 0.9=0.72$ or 72%
Desired: $0.7 \times 0.9=0.63$ or 63%
Satisfactory: $0.6 \times 0.9=0.54$ or 54%
All these variables determine the level of capacity utilization. Its effect on operating efficiency is examined in subsequent paragraphs.

*(b) Capacity utilization and fleet operating efficiency:*
Vehicular utilization is the percentage of vehicles on road to that of vehicles held by the organization. It is regarded as the "acid test" of efficiency of the army transport system. If vehicular utilization is higher, it means more vehicles are put to use which leads ultimately to higher operating efficiency [10]. Thus, fleet utilization α fleet operating efficiency.
Occupation ratio indicates the percentage of service capacity used to the service capacity available. When this ratio is higher, the capacity is properly utilized resulting in higher efficiency of the vehicle and vice versa [7, 10]. Thus,
Operating efficiency (O)=Vehicular utilization ($V_u$) × Vehicle utilization ($V_h$) × Occupation ratio ($O_c$) (6)

*(iii) Productivity analysis:*
The term "productivity" means the overall net yield of goods and services during a specified period, achieved within a given volume of resources. Productivity of army transport system can be measured as the ratio of output to input. In army transport system the indicators of productivity are fleet utilization, vehicle utilization, load productivity, and fuel productivity [10, 11].

*(a) Load productivity:* Tonnage kilometer per vehicle per day is also an indicator of operating efficiency is called load productivity. If we convert the services of transports into revenue earnings, it is tonnage carried which gives the revenue [10, 11].
Load productivity (LP)=Vehicular utilization ($V_h$) × Number of vehicles offered (N) × Vehicle utilization ($V_u$) × Loading capacity (L) (7)

*(b) Fuel productivity:* The fuel consumption of the fleet is already established. Based on fuel consumption and load kilometrage achieved, "fleet specific fuel consumption" in terms of ton kilometer per 1000INR of fuel expenditure can be calculated. It is independent of the vehicle utilization and vehicular utilization. It gives the fuel cost of the service providing load kilometers (ton km/1000 INR of fuel expenditure) [11].
Fleet specific fuel consumption (FSFC)=Load kilometrage × 100 ÷ Fuel consumption × Price of fuel (8)
Fuel productivity=Vehicular utilization × Number of vehicles offered × Vehicle utilization × Loading capacity × 1000 ÷ Fuel cost × Vehicular utilization × Vehicle utilization × KPL (9)
FP=Loading capacity × 1000 ÷ (Fuel cost × KPL) (10)
Fuel productivity (FP)=1000L ÷ ($F_c$ × KPL) (11)
Thus, Productivity (P)=Vehicular utilization ($V_u$) × Load productivity (LP) × Fuel productivity (FP) (12)
But then productivity and operating efficiency are both derivative of vehicular utilization. To make productivity independent, we have to separate the effect of vehicular utilization. Hence, we introduce new variable as productivity per unit of vehicular utilization

$$P^* = P \div V_u = LP \times FP \quad (13)$$

*(iv) Service efficiency:*
Though there are several criterions to judge service efficiency of Army transport organizations, the criteria adopted in the present thesis focuses attention on the following parameters [10]:

- Number of accidents.
- Mean time to repair.
- Availability of maintenance stores.
- Fuel consumption.
- Holding of first line transport.

- Holding of recovery resources.
- Holding of drivers and maintenance craftsmen (vehicle mechanics and electricians).
- Availability of literature for users and maintenance craftsmen.
- Availability of tools and SMTs.
- Number of vehicles detailed on administrative duties [7-10].

Service efficiency=Accident score + MTTR score + Fuel supply score + Main supply items score + First line transport score + Fuel efficiency $\div 6$ (14)

It is seen that service efficiency is independent parameter. Thus,

Fleet efficiency (F) = $O \times P^* \times S$ (15)

## V. DATA ANALYSIS, DISCUSSION AND VALIDATION OF MODEL

The army transport system has got various types of vehicles. For validation of model, particularly for this paper covers only heavy vehicles. The actual research work covers the complete fleet.

There are several types of heavy commercial vehicles in the army. However, we have selected only one vehicle for our study; truck 5/7.5 ton Stallion Mk II.

Operating efficiency (O)=Vehicular utilization ($V_u$) $\times$ Vehicle utilization ($V_h$) $\times$ Occupation ratio ($O_c$)

$V_u = 0.9054$; $V_h = 0.8915$; $O_c = 0.8346$

Thus, $O=0.9054 \times 0.8915 \times 0.8346=0.6736=67.36\%$

The specific productivity,

$P^*=P \div V_u=LP \times FP$ (16)

$LP=0.8443$, $FP = 0.9215$

Thus, $P^*=0.8443 \times 0.9215=0.7780=77.8\%$

The service efficiency works out to be 0.6463.

Thus, the fleet efficiency=$O \times P^* \times S=0.6736 \times 0.7780 \times 0.6463=0.34=34\%$

On enquiring with defence forces headquarter, it has been revealed that the fleet efficiency is about one third of the capacity. Thus, our model is suitably validated. Considering the hypothesis; "Are the parameters operating efficiency, productivity and service efficiency independent?" is rejected. The productivity has to be modified as productivity per unit vehicular utilization (P* or specific productivity) to make it independent. The degree of accuracy of the model is 96%.

## VI. CONCLUSION AND RECOMMENDATIONS

This model of fleet management evaluation is the pioneering step towards the evaluation with the help of variables utilizing mathematical approach instead of traditional way of evaluating with respect to the qualitative attributes. Thus, this model will be able to give a fool proof method for evaluation of transport management of government and non-corporate organizations. Further, this model will help in establishing the impact of maintenance and optimization of fleet maintenance and the users can also pin point the particular part of the fleet or a particular vehicle not performing with satisfactory efficiency. Thus, it will help in replacement policy. Further the model can be utilized with slight variation for maintenance program.

The following recommendations are solicited:

The non-corporate organizations should utilize this model extensively for evaluation of their transport management.

The organizations can utilize the operating efficiency, productivity and service efficiency independently to identify the gaps in utilization, productivity analysis, replacement policy, inventory management and maintenance/repair and adopt corrective measures to improve the individual parameters.

The effect of any extraneous factor must be avoided to get the accurate results.

With slight modification in the model, it can be utilized for predicting the fleet efficiency and replacement policy.

The basis of vehicle utilization and vehicular utilization can be utilized for establishment of maintenance program.

In case of any other very important parameter affecting the fleet efficiency, same can be included and model can be modified suitably.

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