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INDICATORS TO EVALUATE SUSTAINABLE FREIGHT TRANSPORTATION STRATEGY: CASE STUDY ON GPS INSTALLATION TO FREIGHT VEHICLE

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ABSTRACT - Installation of Global Positioning System (GPS) technology on freight vehicles is a significant strategy that paves the way for sustainability in freight transportation. Hence, evaluating the outcomes of the above-mentioned strategy using appropriate indicators is paramount important. Even though fuel cost and carbon emission have been used as indicators to evaluate sustainability in freight transportation, they fail to produce meaningful comparative evaluation along with vehicle categories. The purpose of this study is to propose 'fuel cost per vehicle' and 'carbon emission per vehicle' as the indicators for evaluating sustainable freight transportation using Vehicle Miles Travelled (VMT). Secondary data on the total carbon emission of all the vehicles irrespective of GPS installed or not, VMT for both GPS installed, and GPS non-installed vehicles were collected. Methods have been proposed to define the proposed indicators using the collected data. The proposed indicators reveal that the per vehicle carbon emission and per vehicle fuel cost are lower for GPS installed vehicles over GPS non installed vehicles (6,987.64Kg versus 17,791.35Kg, LKR269,432.59 versus LKR686,008.02). The findings align with existing scholarly work and industrial application on GPS installation of freight vehicles. This research contributes to performance evaluation of sustainable freight transportation.

Keywords: Sustainability; GPS Installation; Freight Transportation

1. INTRODUCTION

Installation of GPS technology on freight vehicles helps tracking vehicles. Tracking vehicles leads to reduction of inefficiency and mismanagement in maintenance and operation of freight vehicles. At the end, GPS installation to freight vehicles leads to sustainability in freight transportation. In general, sustainability is expressed in terms of economic, environmental, and social developments. Evaluating the outcomes of the installation of GPS technology on freight vehicles for their enabling sustainability is paramount important. Indicators for economic, environmental, and social outcomes of GPS installation on freight vehicles have been developed in the literature. Indicators such as fuel cost, insurance premiums, average annual fuel consumption, operational and maintenance cost have been used to evaluate the economic sustainability. Green House Gas emission per capita and CO_2 emission savings are some of the indicators used to evaluate the environmental sustainability [1]. Existing indicators use VMT for both economic and environmental outcomes. But existing indicators fail to help evaluate the freight transport sustainability performance among the GPS installed and GPS non installed vehicles. Failure of indicators in evaluating the economic and environmental freight transport sustainability in GPS installed and non-installed vehicles results in improper performance measurements. According to the Central Limit Theorem (CLT) the probability distribution of the averaged measurements will be closer to a normal distribution than that of individual measurements, the average based or per vehicle-based indicators were used for a scenario based comparative analysis which generally mitigate the issue of improper sustainability performance measurements. The objective of this study is to propose average based or per vehicle based economic and environmental indicators that help evaluating freight transport sustainability performance.

2. MATERIALS AND METHODS

2.1. Method of Measuring

Fuel cost per vehicle and Carbon emission per vehicle are the proposed two indicators under the economic and environmental aspects respectively by using the VMT. VMT is the total distance travelled by all the vehicles of a particular fleet and an effective performance measurement use in Transportation management [2]. According to the United States Environmental Protection Agency (US EPA, 2011) Climate Leaders Guidance for Mobile Combustion Sources [3], the amount of fuel consumed by the fleet was derived along with amount of carbon emission by each type of fleet and the carbon emission factor for the unit of fuel combusted. The below mentioned equations were used to define carbon emission per vehicle and fuel cost per vehicle values for the scenario of GPS installed (*i*) and GPS non installed (*j*) respectively. It is assumed that GPS installed, and GPS non installed vehicles are at the same conditions which are falling in the same vehicle category, vehicle make and model.

$$TC_i = TC_a * VMT_i / VMT_a \quad (1)$$

$$TCV_i = TC_i / F_i \quad (2)$$

$$FCon_i = TC_i / E_f \quad (3)$$

$$FCV_i = FCon_i * FP / F_i \quad (4)$$

Where,

$TC_i = Total\ carbon\ emission\ by\ all\ the\ vehicles\ installed\ with\ GPS\ (in\ kg)$

$TC_a = Total\ carbon\ emission\ by\ all\ the\ vehicles\ (GPS\ installed\ and\ non\ installed)\ (in\ kg)$

$VMT_i = Total\ Vehicle\ Miles\ Travelled\ by\ all\ the\ vehicles\ installed\ with\ GPS\ (in\ Miles)$

$VMT_a = Vehicle\ Miles\ Travelled\ by\ all\ the\ vehicles\ (GPS\ installed\ and\ non\ installed)\ (in\ Miles)$

$TCV_i = Total\ carbon\ emission\ per\ vehicle\ of\ the\ vehicles\ installed\ with\ GPS\ (in\ kg)$

$F_i = Fleet\ size\ of\ the\ vehicle\ category\ installed\ with\ GPS$

$FCon_i = Total\ Fuel\ consumption\ by\ all\ the\ vehicles\ installed\ with\ GPS\ (in\ Liters)$

$E_f = Emission\ factor\ for\ the\ unit\ of\ fuel\ combusted$
$(According\ to\ the\ US\ EPA\ Climate\ Leaders\ guidance, 2011)\ (kg/Liters)$

$FCV_i = Fuel\ cost\ per\ vehicle\ for\ the\ vehicles\ installed\ with\ GPS\ (\ in\ LKR)$

$FP = Fuel\ price\ per\ Liter\ (According\ to\ the\ Ceylon\ Petroleum\ Corporation\ as\ of\ 2020)$

2.2. Data collection

This method is demonstrated to a leading ABC freight forwarding firm in Sri Lanka. This method is applied to 1467 freight vehicles installed with GPS and a set of 45 freight vehicles which are not installed with GPS. The secondary data on the total carbon emission of all the vehicles irrespective of GPS installed or not, vehicle miles travelled by both category of vehicles were collected. Value for emission factor for particular fuel type was derived from US EPA [3]. Fuel cost per liter value was derived from Ceylon Petroleum Corporation website as of 2020.

3. RESULTS AND DISCUSSION

The results were derived based on the assumptions that the vehicle capacities and engine characteristics of all the GPS installed and GPS non-installed vehicles are same. According to the derived results as shown in the figure 1; 6,987.64 kg and 17,791.35 kg of total carbon emission per vehicle were derived from equation (1) and (2), for the vehicles with GPS and without GPS respectively. Also, LKR269,432.59 and LKR686,008.02 of fuel cost per vehicle values were derived from equation (3) and (4), for the vehicles with GPS and without GPS respectively. All these values indicate that GPS installation to freight vehicles yields lower carbon emission and lower fuel cost. This leads to environmental and economic sustainability ultimately. This is due to the installation of GPS fleet

management application which helps in identifying the shortest path, providing optimal solutions to reduce fuel and capital expenditures with optimal allocation of vehicles.[4] Using these indicators, transport operators would be able to identify performance of the GPS installed freight vehicles within the fleet and take appropriate actions to reform the performance of the vehicles. With these appropriate actions, transport operators would be able to avoid future cost associated with the operational and maintenance of vehicles by prioritizing GPS installations.

Table 8. Collected Data

Variable	Value
TC_a	11,051,000.00 kg
VMT_i	14,468,767.89 Miles
VMT_j	1,129,361.68 Miles
VMT_a	15,598,129.60 Miles
F_i	1467
F_j	45
E_f	2.69 kg/Liters
FP	104.00 LKR/Liter

Reference: Authors, 2022

Table 9. Calculated Values

Variable	Value
TC_i	10,250,867.15 kg
TC_j	800,610.87 kg
TCV_i	6,987.64 kg
TCV_j	17,791.35 kg
$FCon_i$	3,800,561.70 Liters
$FCon_j$	296,830.60 Liters
FCV_i	269,432.59 LKR/Vehicle
FCV_j	686,008.02 LKR/Vehicle

Reference: Authors, 2022

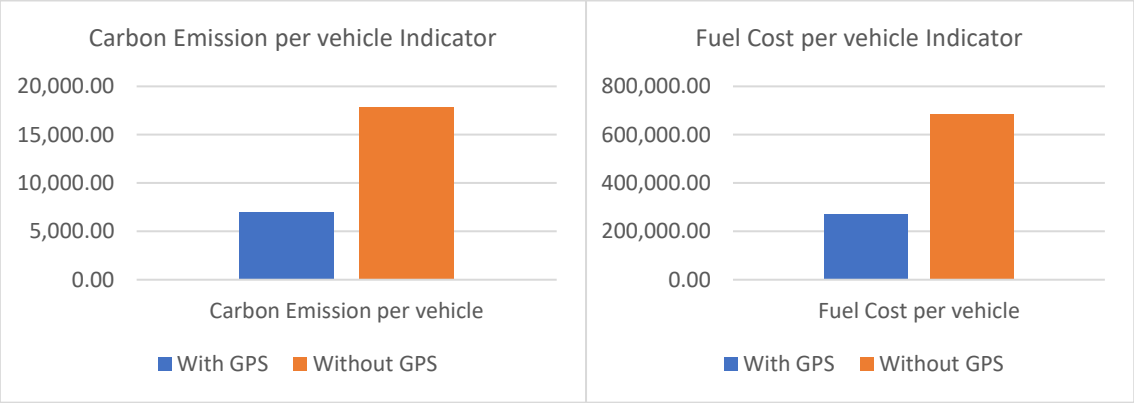

Figure 1. Scenario-based analysis of GPS installation to freight vehicles

4. CONCLUSION

According to the derived results, GPS installation on freight vehicles leads indirectly to achieve economic and environmental sustainability in freight transportation. The proposed two indicators can be used in future works to evaluate the feasibility of implementing sustainable strategies in freight transportation with respect to economic and environmental dimensions. Future works can also explore the societal impact of GPS installation to freight vehicles and expand this study into different business scales, industries and for different types of fleet and engine capacities. This research contributes to the domain of evaluation of sustainable freight transportation.

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