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Article

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An Analysis of Effect on Energy Saving of Trucks in Transport and Logistics Business

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ABSTRACT

This research aimed to analyze the effect on energy saving of trucks in the transport and logistics business by monitoring and evaluating truck drivers. A sample of seventy-four 10-wheel trucks was selected. Fuel consumption data was collected from drivers as they operated their vehicles using GPS systems. The results suggested a total reduction of fuel consumption with improved fuel consumption rates. Annual mileage affected better energy saving: trucks with high annual mileage were more capable of reducing fuel consumption than those with low mileage. The effect on energy-saving was 0.16 ktoe per year, suggesting a cost saving of 5.8 million baht per year.

Keywords: Energy Saving, Trucks, Transport and Logistics Business
JEL Classifications: Q43, Q48, R41, L91

1. INTRODUCTION

Thailand's transportation system is an essential national resource connecting manufacturers, businesses, and consumers. The transportation infrastructure is responsible for facilitating the delivery goods from manufacturers to wherever there is customer demand. Modes of freight transportation are characterized as motor carriers, railroads, airlines, and water carriers (Walton, 2014; Rodrigue et al., 2006). Among these, road transport by motor carriers is most common because it typically requires relatively low-cost outlays while being convenient and fast. Road transport offers wide range of routes for a carrier to choose from, with access more locations than any other mode of transport. At present, transport and logistics businesses offer the transport of raw materials from their sources to manufacturing plants to pass through the production process to become products and then finally to markets for further distribution to reach consumers. With steadily increasing demand for consumer goods, the number of freight forwarding businesses in Thailand burdening the road transport system has exploded, causing significant traffic congestion and ultimately less efficient product transportation and higher product costs. The growth of freight volume is due to the complexity of the economic system and the rapid development of the service economy (Lu et al., 2021). Transport and logistics trucks are crucial for the transportation of goods and for the processes of the logistics system that involves involved planning and management. Less energy consumption per round and maximally efficient and cost-effective management of transportation is therefore an urgent priority in order. Ongoing and rapid changes in the road freight business demands changing and updating the way technology is used to reduce the cost of transporting goods. The reduction of overall costs in transport and logistics will then have a positive effect on key businesses which serve as a mechanism to drive overall economy of Thailand (Wijitkulsawarat, 2018). Therefore, increased understanding of the role of the road for freight distribution is necessary to increase the sustainability of the freight transport system (Rikard, 2016).

All modes of transportation require energy for constant movement. Transport is the second largest and the fastest growing energy end-use sector and accounts for 28% of total final energy demand (Figueroa et al., 2014). Fossil fuels like oil are manufactured from non-renewable sources which are likely to be exhausted within the next few decades. Therefore, excellent allocation and planning of energy use is needed to ensure maximum benefits in this sector. Currently, many countries are experiencing acceleration in their domestic economic development. However, as populations grow, the demand for oil energy increases accordingly. In Thailand, the transport sector is a major consumer of fossil and all fuels as it uses a higher percentage of energy than other branches which accounts for 36.8% of the total final energy consumption. It is also a major cause of air pollution and greenhouse gases in Thailand. The CO_2 emissions from the transport sector accounted for 25.6% of all emissions, higher than that of the industrial sector with 23% of CO_2 emissions (Office of Policy and Planning, 2015). Transport emissions comprise 26% of the overall CO_2 emissions produced in Thailand. To limit and reduce the negative impacts, many air pollution control initiatives have been undertaken in the transport sector (Alam et al., 2014).

Demand for crude oil and fuel for energy tends to increase gradually in line with economic growth. One factor that has received less attention is the impact of uncertainty raised from the global energy market on oil prices (Van Robays, 2016). Oil price adjustments will have a direct impact on product prices and consumers will find that the price of the product may be more expensive than they expected. This may be partially caused by the freight forwarder. However, there is insufficient data to perform an analysis of true freight costs. Diesel fuel is used in large quantities in the transport sector making product price and various service charges within the country increase with some frequency. Without controls or allowances, the energy use of the road transport sector is potentially unlimited and could profoundly affect the country's energy security in the long run. Uncertainty in the real price of oil in the global energy market is affected the most under unexpected strong demand for alternative energy sources scenario (Xu et al., 2021).

Despite fuel energy being the main cost in the transport sector, it was found that a majority of transport and logistics companies do not systematically analyze their oil consumption data and reduce oil consumption. Most of them focus instead on services, time, cost, and customer satisfaction; failing to pay enough attention to the amount of fuel and instituting no explicit guidelines or standards for managing energy use (Martulli et al., 2021). Driving behaviors with minimal fuel consumption, less pollution and reduced greenhouse gas emissions is the subject matter of "eco-driving". Eco-driving is a term used to describe the efficient use of vehicles energy (Farzaneh et al., 2012). Achieving these levels of energy output and utilisation through present technologies is not only difficult and expensive, but also environmentally unsustainable. Energy efficiency generates substantial financial savings while simultaneously improving environmental quality (Jangali and Nagesha, 2017). Additional consumption of fuel in intense traffic conditions is inevitable. However, excess fuel consumption may be avoided if an optimal driving strategy is implemented subject to the surrounding conditions of a vehicle and existing constraints (Saboohi and Farzaneh, 2009).

To promote energy conservation and savings in the service and transport sectors, the focus is on campaigns to create driving discipline and consciousness of energy saving and efficiency. In the management of energy consumption in the road transport sector, transportation systems are improved by increased energy use efficiency (Nantasang, 2020). Management of demand targets the reduction of unnecessary travel and supporting behavioral changes in the use of public transport and energy-saving transport modes (Chukwu et al., 2015). The occurrence of oil crises and shortages impacts people's cost of living, business performance, and the growth of national economy. (Naparswad, 2013) It is therefore the researcher's interest to examine the effect on energy saving of trucks in the transport and logistics business. The objective of the research was to analyze the effect on energy saving of trucks in the transport and logistics business by monitoring and evaluating truck drivers' behavior. This will be useful for entrepreneurs in terms of increased transport efficiency and reduced energy consumption and increase organizations' cost advantages and competitiveness. In addition, businesses can build trust among customers, maintain existing customers, and increase their customer base as well.

2. LITERATURE REVIEW

2.1. Principles of Energy Saving of Trucks

With the majority of transportation energy derived from petroleum sources, economical and cost-effective use of energy is of crucial importance. Many technologies such as vehicle electrification, advanced combustion, and advanced fuels can reduce transportation energy consumption by improving the efficiency of cars and trucks (Joost, 2012). Energy use needs to be planned and controlled to maximize efficiency and benefit. Ideally, there is a reduction in energy loss at every step, enhancing quality and efficiency while saving energy and reducing carbon emissions (Liu et al., 2017). Truck driving operations can be monitored and supervised at all times to reduce energy leakage and fuel efficiency as the fuel supply system increases or decreases the amount of fuel being supplied to the engine. This is the dominant factor in automobile activity operational efficiency and profitability (Oke et al., 2011).

2.2. Energy Saving Driving

Energy saving driving refers to planning your travel route in advance and adjusting your driving style and speed to suit the driving situation, thereby driving smoothy and operating efficienty (Zhou and Wang, 2019). Conscientious energy saving driving will help save and reduce expenses in many ways, especially fuel costs. Drivers have also begun to demand more efficient vehicles due to increases in fuel prices and improvements to vehicles focus on minimizing fuel consumption (Organero and Corcoba, 2014). High fuel consumption gives impact on environmental pollution, as the consequence, an environmentally friendly vehicle is required (Zainal et al., 2019). Beyond vehicles' efficiency features, it is the manner of driving that influences the lifespan and quality of a vehicle's performance. For example, fast driving for long-distances will consume more oil. And driving fast like a racing car, or harshly and quickly, will consume a lot of oil; the engine and various parts will wear a lot. Gears should be changed according to the timing and speed of use. Dragging gears for a long time will cause the engine to work harder, consume more oil. In checking and setting up the engine on schedule, the condition of the car, engine and equipment must be examined to ensure everything is in accordance with the specified standards. Optimizing decision-making in maintenance planning and executing work can result in cost reductions, improved efficiency and improved vehicle reliability (Škerlič and Sokolovskij, 2020). Overloading will cause the engine to use more oil. When masses or loads increase, fuel consumption reduction will decrease partly (Zhang et al., 2019). Having an optimized route to the destination in all travel will decrease time of trip as well as reduce oil consumption.

Driving behavior for energy savings requires drivers to be aware of their own driving behaviors. Drivers must not drive around too much, get lost, or drive too far from their destination. They should always check the tire pressure as tires that are too soft will cause the car to consume more fuel. They should always check their vehicle's air conditioning system to make the system work efficiently, adjusting the temperature appropriately. If the temperature is adjusted too low, the compressor will work harder and put more burden on the engine, resulting in higher fuel consumption rates. Finally, the cargo weight of the vehicle has an effect on fuel consumption.

2.3. Energy Saving Benefits from Driving

Energy-saving driving can be effective if drivers remain conscientious when driving, aware of the organizational and efficiency goals achieved by doing so (Sayed et al., 2022). Good driver consciousness is the starting point of making driving efficient, resulting in energy and cost savings. The impact of driving behavior on a vehicle's energy consumption is significant (Rodolfo, 2020). Much of the savings come from selecting the right vehicle for the needs of an organization. Results may include a more reliable energy system, lower transmission and distribution costs, and utility insurance savings Ingrid, 2016). Beyond the benefits to organizations themselves, global warming is caused by the destruction of the atmosphere of the greenhouse effect caused by carbon dioxide (CO_2) caused by the combustion of fuel. Pollution control is achieved by reducing carbon dioxide. Global climate change mitigation goals will likely require that transportation-related greenhouse gas emissions begin to decline within the next two decades and then continue to fall (Miotti et al., 2016). This important large-scale process starts from the local act of choosing a vehicle as wisely as possible.

3. METHODOLOGY

This research evaluated the energy consumption of vehicles by using data from the TMS (transport management system) installed in them. A sample of seventy-four 10-wheel trucks was selected to measure the effect on energy-saving. Collection and measurement of fuel consumption data was performed on the actual driving of truck operators. Collection of data on driving behavior and fuel consumption employed technology to measure the driving outcome with combined use of the data and GPS data on the record to obtain accurate and reliable data. Tracking vehicles is becoming more essential in the present world of logistics market and keeping track of the vehicles to help in managing resources more efficient. Transport management systems store the complete details about all the travel of a vehicle like the route, distance travelled, driver control over the vehicle, and particular events that occurred during operation. This greatly helps in understanding the condition of vehicle as well as the driver's efficiency (Kanchana et al., 2018) To evaluate energy saving in the research project, advisors used a before and after analysis to compare effects on energy saving of trucks in the transport and logistics business by monitoring and evaluating truck drivers. The variables that effected the consumption rate of vehicles are as follows.

1. Traffic characteristics, which affected the consumption rate by 20-40%, as a result of stopping and starting.
2. Slope of roads, which affected the consumption rate by 15-20%.
3. Driving behavior, which affected the consumption rate by 20-30%.
4. Payload, increased vehicle weight by10%, which affected the consumption rate by 4-7%.

3.1. Sample Determination

This research randomly selected a sample of seventy-four 10-wheel trucks from the registration at the Department of Land Transport by means of quota sampling and selecting the trucks based on their conditions. The measuring device was installed on the truck and the driver operated the truck normally. Data was collected for a period of at least 2 weeks.

3.2. Methods of Consumption Rate Evaluation

Previously instituted economical driving training programs found a weakness in evaluating project effectiveness due to limitations in measuring the amount of fuel used before and after driving. As a number of variables effected fuel consumption, it was hence difficult to evaluate this, especially when using people to collect data in each group. At present, the lower cost of electricity and sophisticated electronic and communication technologies make it possible to apply automation technology to reduce errors from using people to collect data (Zhou et al., 2013).

Presently, new trucks all have a consumption display function on the dial. But in older trucks, operators still have to use the method of measuring fuel consumption by filling up the fuel tank and recording the mileage as a default. Every time a driver fills up the fuel tank, they record the amount of fuel added. After vehicle use, they record the current odometer value and calculate the consumption rate.

3.3. Data Collection System

IoT Telemetry, technology was applied to reduce the steps of using staff to collect data and also reduce disturbing the operation of project participants (Figure 1). The censor was connected to a communication network and data collected was automatically inputted into storage for further analysis.

Cloud computing, Using data was sent from IoT Telemetry and stored in a database. It was then processed and made ready for further analysis which include the amount of fuel, mileage, and travelling time use.

3.4. Effects on Energy Saving

Evaluating the effect on energy-saving was performed by evaluating the annual reduction in diesel fuel consumption (*Vd*), number of trucks (*N*), average annual mileage of trucks (*D*), truck fuel consumption rate (*CR*), and average economy efficiency (E) (Thitipatanapong and Dechanupaprittha, 2013).

$$Vd = N \times D \times CR \times E$$

The unit of measurement of the amount of energy corresponds to the energy released by burning 1 ton of crude oil (kilo ton of oil equivalent: ktoe). On average 1 ton of crude oil is equal to 41.868 gigajoules (GJ) or 11.630 megawatt-hours (MWh), with the amount of energy in ktoe per year and the number of liters of diesel fuel is $ktoe_{diesel}$.

$$ktoe_{diesel} = 0.98 \times 10^{-6} \frac{ktoe}{l}$$

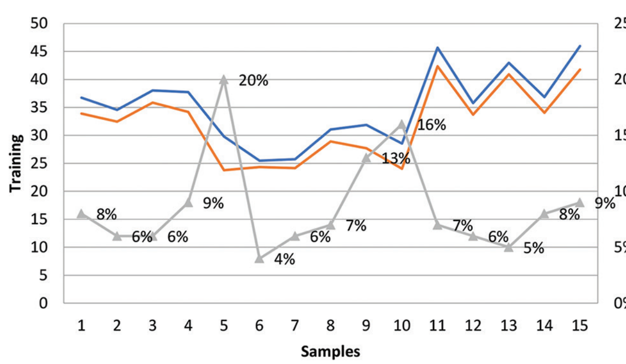
The value of effect on truck's energy-saving ($ktoe_s$)

$$ktoe_s = Vd \times ktoe_{diesel}$$

4. RESULTS

4.1. Result on Average Economic Efficiency (E)

The average economic efficiency was determined by analyzing the fuel consumption rate in the driver's truck driving with data collection before and after the training. Before training, the fuel consumption of drivers in the sample was 35.11 L/100 km. After the training, the average fuel consumption drivers in the sample was 32.14 L/100 km. The drivers who have been trained in the energy-saving truck driver training course has a net positive effect on energy savings. This is consistent with the Efficiency Study of Efficiency Driving Program (Alam and McNabola, 2014), which studied an driver training project's impact. It was found that economical driving training can reduce fuel consumption by about 5-30% depending on the environment and data collection. Results revealed that after the training, drivers were likely to use less fuel by 4-20% or 8.28% on average.

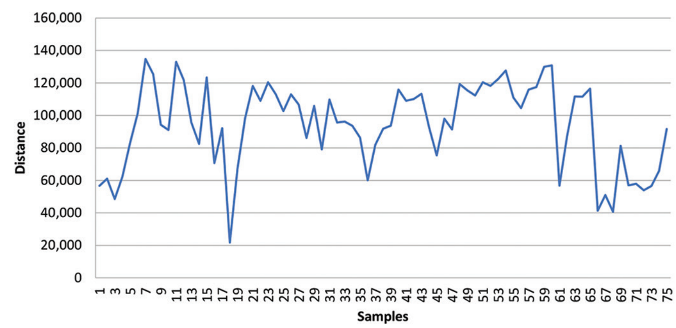


(Source: Results of data processing)

4.2. Result on Truck's Average Annual Mileage (D)

Arranging delivery by truck starts from finding the order of delivery points by identifying the closest location onwards before calculating the cost of transporting goods. This minimizes fuel costs and maximizes efficiency.

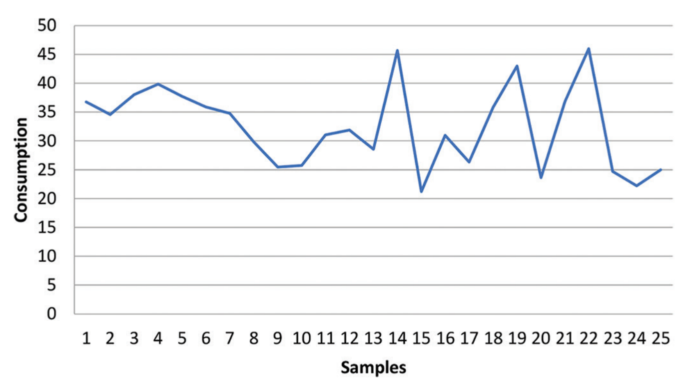
The average annual mileage of tracks in the sample was obtained by collecting data from GPS systems and evaluating the distance as annual mileage (D). The result suggested average mileage of 96,872 km/year.



(Source: Results of data processing)

4.3. Result on Truck's Fuel Consumption Rate (CR)

The fuel consumption rate for road transport represents the nominal value of the measurement of fuel consumption during operation. The calculated standard value of fuel consumption takes into account the distance traveled on the road and the amount of fuel used. It is used to calculate the required amount of fuel and the required cost. The fuel consumption rate of trucks in the sample calculated from a fuel consumption rate per 100 km. distance was 32.76 L/100 km.



(Source: Results of data processing)

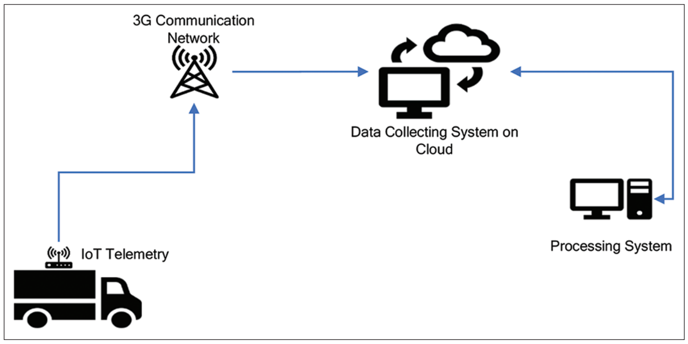
4.4. Result on Energy Saving of Trucks in Transport and Logistics Business

To determine the value of energy saving of trucks in the transport and logistics business from a sample of seventy-four 10-wheel trucks, data was collected from the training of drivers, and the monitoring of drivers during driving operation from GPS data. The result on truck's energy saving (1 L of diesel weights 0.83 kg) is summarized as in the following Table 1.

4.5. Effect on Truck's Energy Saving ($ktoe_s$)

A determination of the effect on energy saving among the seventy-four 10-wheel trucks in the sample reported an economic efficiency

Figure 1: Operation of Data Collecting System



(Source: creations of the Authors)

Table 1: Results of energy Consumption per truck

Analysis of energy consumption/truck	Results	Unit
Average annual mileage of truck (D)	96,872	km/year
Fuel consumption rate of truck (CR)	32.76	l/100 km
Estimates of oil use per truck	31,735	l/year
Average economic efficiency (E)	8.28	Percentage
Estimates of oil saving per truck	2627.68	l/year
Reduced cost of oil per truck	78,830.40	Baht/year
Energy saving per truck	2.180	Toe/year

Source: Author's computation

Table 2: Results of truck energy savings

Analysis of effect on truck's energy saving	Results	Unit
Number of trainees (n)	74	Trucks
Average economic efficiency (E)	8.28	Percentage
Effect on oil saving	194,457.2	l/year
Effect on energy-saving (toe_{10})	161.39	Toe/year
Cost of energy-saving	5,833,716	Baht/year

Source: Author's computation

(E) between 4 and 20% or 8.28% on average. The figures were obtained from the estimates of oil saving per truck (2,627.68) × the number of trucks (74), suggesting fuel saving for 194,457.2 L/year or 161.39 toe per year in the amount of 5.8 million baht (refer to the price of diesel fuel of 30 baht/L). A summary result is shown Table 2.

5. CONCLUSION AND RECOMMENDATION

This analysis of the effects of energy-saving driving among the study's sample of seventy-four 10-wheel trucks in the transport and logistics business was based on data collected from the training of truck drivers and mileage monitoring using GPS data. Results showed energy saving at an average economic efficiency of 8.28%, an average mileage of 96,872 km/year, and a fuel consumption rate of 32.76 L/100 km. The value of the effect on energy saving for trucks was calculated from the estimates of oil saving of 2,627.68 L/year/truck, suggesting a fuel savings of 194,457.2 L/year or 161.39 toe/year. Efficient driving behaviors could reduce fuel use by 20% on aggressively driven trips and by 5-10% on more moderately driven trips (Gonder et al., 2012). The results of monitoring and evaluation concluded showing a total reduction of oil consumption, an improved fuel consumption rate, an increased amount of fuel saving, and showed that trucks with high mileages/year were more capable of reducing fuel consumption than those with short mileages. The analysis result also suggested fuel saving of 0.16 ktoe/year or cost saving of 5.8 million baht per year (Rattanasuwan, 2018). Training in energy saving driving to upgrade and control the standard of employee driving, including checking the condition of trucks in operation, can reduce excessive fuel consumption.

Further research should define the mileage/year of over 100,000 km. as it will offer the break-even point in a short period of time. Other variables should also be examined for their effects on fuel saving, for example, tire pressure, air resistance, traffic condition, weight of goods, and backhaul since they provide detailed information and affect fuel consumption rate. Truck drivers in the freight sector should be encouraged and/or required to take training courses in energy-saving driving. By putting various techniques into practice until they become operational habits of work, including route planning and use of GPS to control driving and avoid congested areas, truck drivers can directly benefit the economically paramount logistics business while also positively impacting the world at large.

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