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IT Tools Evaluation in Drivers' Monitoring: A Data Envelopment Analysis (DEA) Approach

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ABSTRACT

Control of the achievement of a process by using technology is very effective and has a positive impact on a company, in today's digital era. In the transport and logistics industry, one of the biggest challenges is to control all off-premises assets, especially for the management and supervision of heavy vehicles controlled by company drivers. The use of IT systems is very suitable to control the driver's attitude and driving style. In this study, a framework for measuring the effectiveness of IT systems in monitoring driver behavior while on the road is proposed. This framework is proposed to use the Data Envelopment Analysis (DEA) method in identifying inputs and outputs as an indication of effectiveness. The data used in this study is from a selected transportation service company that has adopted three (3) transportation management systems since 2010. Some of the systems track drivers' behaviours while driving which then allows transportation company management to evaluate the effectiveness of different routes taken by driver, which can help produce a more efficient schedule. In addition, the assessment of individual driving style can be done more easily. Management can track their efficiency and provide feedback where improvements are needed. The use of IT systems for real-time tracking also provides great safety benefits, especially in the event of an accident.

Keywords: Data Envelopment Analysis, Driver Monitoring, Effectiveness of IT tools

1 INTRODUCTION

According to the Department of Statistics Malaysia (DOSM)[1], in the second quarter of 2021, there was a decrease in revenue for the Information & Communication and Transportation & Storage segment in the income e-commerce transaction and service sector. The revenue fell to RM59.5 billion, representing a decline of 0.6 percent compared to the first quarter of 2021. The decrease in revenue was primarily driven by the Transportation & Storage sub-sector, which experienced a decrease of RM0.4 billion or 1.9 percent. However, when compared to the same quarter of the previous year, the revenue showed an expansion of 14.7 percent. In terms of employment, the number of persons engaged in the Information & Communication and Transportation & Storage segment decreased by

0.29 percent, totaling 451,340 persons compared to the previous quarter. Additionally, salaries & wages paid also saw a decline of 1.5 percent, amounting to RM4.4 billion. These reductions in employment and salaries & wages can be attributed to the impact of the Covid-19 pandemic on the national economy. As a result of the challenging economic conditions, transportation companies are facing intense competition and striving to ensure their survival and sustainability.

The widespread use of technology as a tool to enhance the effectiveness of transportation operations is common among transportation companies. However, it is important to note that the mere use of technological tools does not guarantee 100% effectiveness. The effectiveness depends on various factors such as monitoring, the type of technology tool utilized, and its inherent advantages. In some cases, despite substantial expenses incurred, the technology or tools employed may prove to be ineffective, resulting in no significant changes. For instance, in Malaysia, one of the common causes of road accidents is speeding. While the government has implemented speed trap cameras to deter drivers from exceeding speed limits and driving in hazardous conditions, this initiative alone has not been successful in curbing speeding among Malaysian drivers. To address this issue and ensure effective monitoring of driver behavior and performance, it becomes crucial to evaluate the effectiveness of transportation management systems. This evaluation helps determine if the transportation management systems utilized by transportation companies are comprehensive and efficient in reducing operational costs, enhancing driver integrity, and promoting safer driving practices [2][3][4]. In conclusion, assessing the effectiveness of transportation management systems is essential to ensure the desired outcomes in terms of cost savings, improved driver performance, and mitigating risks associated with unsafe driving practices. It requires careful evaluation of the implemented Information Technology (IT) systems to gauge their functionality and effectiveness in achieving their intended purposes.

In accordance with the reports by the Royal Malaysian Police, PDRM [5], a significant portion (90%) of road accidents can be attributed to human factors. These accidents occur due to drivers frequently disregarding traffic safety regulations, which includes behaviors such as driving under the influence of alcohol, engaging in illegal racing, driving in hazardous conditions, exhibiting aggressive emotions, driving while fatigued, and speeding [6]. In Malaysia, the primary cause of road accidents can be attributed to the attitudes and behaviors of individuals [7]. Therefore, this study aims to identify the factors that contribute to the effectiveness of IT monitoring systems in influencing driver behavior on the road, particularly in relation to attitudes such as speeding, dangerous driving, putting other road users at risk, and driving practices that increase operational costs such as fuel consumption, tire wear, and vehicle maintenance.

Previous researchers have employed various methods to measure the effectiveness of IT systems, one of which is Data Envelopment Analysis (DEA). The DEA approach was initially proposed by Charnes, Cooper, and Rhodes (CCR) in 1978 [8]. Their research interpreted productivity as the ratio of a single output to effort, when there are multiple outputs and inputs involved, the DEA method is utilized. DEA focuses on analyzing the interdependence between multiple input and output levels. It calculates the technical efficiency score without prior knowledge of the initial weights. The DEA approach aims to find the optimal weights that maximize the output of each entity. Additionally, the DEA method enables the determination of the efficiency frontier curve. DEA models can be utilized not only for performance evaluation but also for benchmarking, assessing economies of scale, ranking entities, and identifying ways to improve efficiency and optimal technology structures for inefficient entities [9]. In this study, DEA is employed as the method for performance measurement.

In order to ensure good discriminatory power in the CCR and BCC models, [10] suggested that the minimum number of Decision-Making Units (DMUs) should be a multiple of the number of inputs and outputs. This is because the selection of weights assigned to the input and output values in assessing the efficiency of each DMU allows for flexibility. A DMU can allocate all its weight to a single input or output in an attempt to appear efficient. If a DMU has the highest output-to-input ratio, it will assign all its weight to that specific input and output, thus creating the appearance of efficiency. Therefore, the number of potential inputs is determined by multiplying the number of inputs by the number of outputs.

[11] suggested that the number of units should be at least twice the number of inputs and outputs. However, [12] argued that three times the number of DMUs is necessary due to the presence of both input and output variables. [13] recommended a double sum of the number of input and output variables. For example, if there are 3 inputs and 4 outputs, [11] recommended using 14 DMUs, [12] suggested 21 DMUs, and [13] recommended 24 DMUs. Therefore, in this study, the efficiency impact of both inputs and outputs on the implementation of IT tools in business monitoring is analyzed, taking into account the recommended number of DMUs based on the number of inputs and outputs.

2 MATERIAL AND METHODS

In order to measure the key performance effectiveness, the contribution factors are to be proposed and summarized in Figure 1. Factors for independent variables are fuel consumption, tire cost, maintenance cost, number of accident and driver integrity. These independent variables are the key factors to measure the effectiveness of dependent variables, which is transportation management system. The contribution from the effectiveness of transportation management system can be seen in driver performance (in terms of an increase in driver's trips, a reduction in driver's integrity cases, lower number of fatal accidents and lower in number of speeding cases).

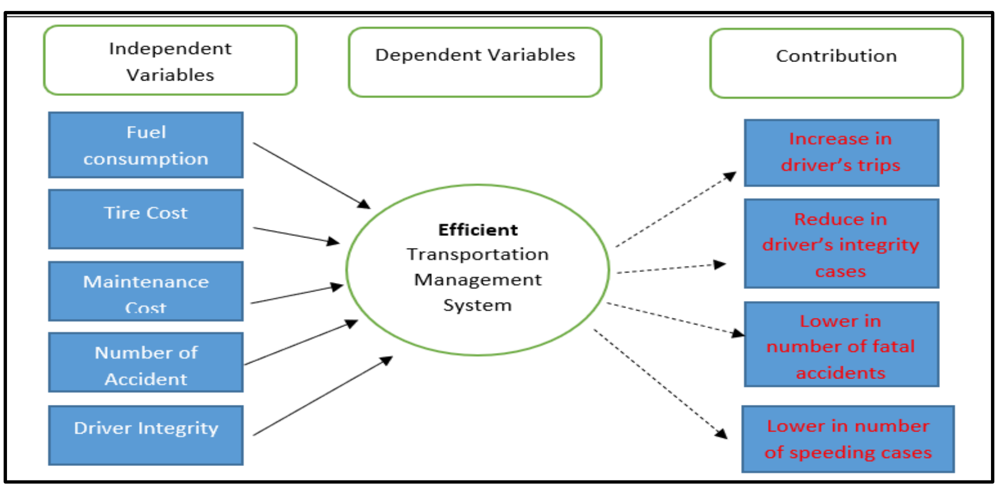

Figure 1: Model Framework of effectiveness IT system in monitoring driver behaviour.

2.1 Study Setting

FGV Transport Sdn Bhd is a leading logistics company in Malaysia that operates a supply chain for Malaysian palm oil products. It is operating throughout Peninsular Malaysia including Sabah and

Sarawak and FGV Transport has a total of 509 personnel among truck drivers [14]. It is the driver's responsibility to carry assets worth almost RM500,000 on the road with cargo worth almost RM200,000 in a safe condition, various actions and controls must be provided and monitored by the company to ensure the goods reach the destination in a safe condition.

Control over drivers on the road while driving depends only on the attitude and integrity of the individual himself. They are exposed to the dangers of road accident risk, the desire to commit irregularities, skipping work, stopping at prohibited places, selling carry-on items and so on. The company had to spend high costs to curb these symptoms from being prevalent among drivers. These symptoms if not controlled can lead to huge losses to the company which in turn impacts the company's bad image in the market.

In this study, the data are on three main depots, namely Pasir Gudang depot, Kuantan Depot and Port Klang Depot. Total number of staffs from these three main depots are 495 staff, which include 102 persons from administrative office, 340 persons are drivers, and 53 persons are mechanics. From these three main depots, data was selected from two main operations, cargo operation and tanker operation. In order to ensure that the collected data collected are reflecting the use of the transportation monitoring system, only drivers that serve from 2010 to 2019, are considered in this study.

FGV Transport are using the following monitoring IT systems which were implemented in different years.

1. Integrated Logistics Distribution System (ILDS) - ILDS is a system developed internally by one of FGV's subsidiaries, FGV Prodata. This system is integrated with other systems in FGV subsidiaries to facilitate operational and financial matters. in this system there will be information such as distance travelled, number of trips, driver details, vehicle details, travel records and trip patterns taken by the driver. The first version of this system was implemented in 2012 and enhanced to version 2.0 in 2018.

2. Vehicle Maintenance System (VMS) -VMS is a system used to record all cost variables such as diesel usage, tire usage and replacement records, repair and maintenance records, and lubricating oil records. The system also records the history of accidents that occur to the vehicle. Through this record, the effectiveness of cost control will be studied through comparison with previous records each year, targets and budgets from the company, recurring costs or repairs as well as accident records. VMS was implemented in 2008 and also being enhanced in 2018.

3. Vehicle Tracking System (VTS) - All vehicles travel information are recorded through the VTS system. This system will display the real time situation throughout the movement of the vehicle starting the engine is started. Every movement will be recorded such as speed, travel route, and so on. The system was implemented in 2004 and enhanced in 2018.

All these three systems installed by the FGV Transport to monitor their vehicles and drivers' behaviours. For example, with a 3 input, 4 output model, 14 DMUs were used as recommended in [11,12,13]. In any circumstance, these numbers should probably be used as minimums for the basic productivity models.

2.2 Method Of Analysis

In this study, DEA formula [15] is used to measure the effectiveness of transportation management system used by FGV Transport. The effectiveness of transport management systems can be measured as follows:

$$\text{Efficiency}=\frac{\text{sum of weighted outputs}}{\text{sum of weighted inputs}} \tag{1}$$

And the equation can be rewritten as:

$$\text{Efficiency}=\frac{\sum_{r=1}^{n} u_r * y_r}{\sum_{i=1}^{m} v_i * x_i} \tag{2}$$

Where n is the number of outputs for each dimension, m is the number of inputs for each dimension, y_r is benefit (or additional profit) gained from the usage of the system r, u_r is the weight of output for benefit (or additional profit) r, x_i is the quantity used by input, i and v_i is the weight of input used, i.

The Data Envelopment Analysis (DEA) approach is used to evaluate the efficiency of various types of business operations for various years [15]. DEA is a non-parametric method that compares the performance of the business before and after the implementation of the IT tools for monitoring the drivers based on their input and output variables. The goal of DEA is to identify the most efficient years that achieve the highest level of output with the least amount of input [15]. In the analysis, each year is assessed based on its efficiency score, which is calculated by comparing its input-output ratio to that of other years in the dataset. Years that achieve an efficiency score of 1 are considered fully efficient, as they operate on the efficient frontier and no other year can achieve higher output with the same level of input. Years with scores less than 1 are deemed inefficient and can potentially be improved by optimizing their input-output ratios.

Table 1 summarises the potential input and output used as the indicators for this study.

Table 1: Indicators of input and output

Composition of indicators	Description	Unit	References
Inputs (4 items)			
Capital	1. Fuel Consumption	(km/litre)	C. L. Ross (1983)[16].
Workforce	2. Maintenance Cost	(RM)	
Energy	3. Tire Cost	(RM)	Z., Yang, J. Peng, L. Wu, C. Ma, C. Zou, N. Wei, & H. Mao (2020) [17].
	4. Number of trips	(units)	

Outputs (3 items)			
Social Output	1. Total distance travelled.	(KM)	
Economic Output	2. Number of summonses	(units)	
Environmental Output	3. Number of accidents involved.	(units)	

Based on Table 1, the data for each driver at the selected ports is collected and summarized. However, due to the complexity of drivers' information, instead of drivers, number of lorries is used to replace number of drivers. Table 2 shows the details of the relevant data based on the three depots, Pasir Gudang, Kuantan and Port Klang. The three depots are selected due to their huge volume of cargo being handled by the depots. Kuantan depot has the highest number of lorries as well as handled the largest volume of cargo at revenue amounting to RM43,371, 160. The highest number of trips is also seen at Kuantan depot as well as the number of kilometres travelled by the lorries amounting to 14,081,334 km.

Table 2: Data profile for selection of sample and data collection

Depots	**Descriptions**	**Pasir Gudang**	**Kuantan**	**Port Klang**
Input	Number of Lorries	132	140	92
	Volume of Cargo	1,214,040	1,224,154	685,683
Output	Revenue (RM)	43,177,539	43,371,160	26,268,785
	Number of trips	29,267	29,428	17,147
	Number of kilometres	11,008,574	14,081,334	8,432,200

(Data: 2019; FGV Transport Services Sdn Bhd)

All three depots are managed by dedicated and experienced Site Managers who are well verse in monitoring the business operation and maintaining facility and asset for smooth daily operation. Based on the ten years record, from 2010 to 2019, the average business contribution for both Tanker and Cargoes in three depots are summarised in Table 3.

Table 3: Data Profile for Volume by business types

Depoh	Tanker / year			Cargoes / year		
	Average Truck - unit	**Average Load (MT)**	**Average Income - RM**	**Average Truck - unit**	**Average Load (MT)**	**Average Income - RM**
Port Klang	664	515,223.6	19.39mill	440	285,038.1	10.71mill
Pasir Gudang	887	810,631.4	26.06mill	774	475,261.2	18mill
Kuantan	973	830,154.7	27.17mill	666	380,258.5	14.85mill

The IT tools were implemented in three different years based on depot readiness, system testing completion and certification and approval from the management to proceed with the implementation after the benefit and risk identification. Based on the data of total volume by each business type, Tanker and Cargoes for the three depots in the past ten years, the analysis is done using DEAP Ver. 2.1 [18].

3 RESULTS AND DISCUSSION

The analysis is done using both input data (BCC-I) and output data (BCC-O) based for both types of business. On top of analysing the performance of each depot, the performance for each year is scrutinised in order to see the efficiency impact of IT tools implementation in running the business.

3.1 Dea Result for Tanker Business

Table 4 shows the results for Tanker business. The Kuantan Depot is not efficient in 2011, 2013 and 2017 for both Input Oriented and Output Oriented. In 2011, the result of input oriented and output oriented for both depot Port Klang and Pasir Gudang is not efficient. Details analysis shows that it was due to a smaller number of lorries which caused the insufficient truck availability to carry out the load, hence resulted in reduction of total Kilometres and higher technical expenses incurred. Pasir Gudang Depot on the other hand was not efficient for both Input Oriented and Output Oriented in 2014 while Port Klang was not efficient in the input Oriented and Output Oriented in 2017.

Table 4: DEA results for TANKER YEARLY

DEPOT	BCC-I									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
KUANTAN	1.000	0.971	1.000	0.950	1.000	1.000	1.000	0.966	1.000	1.000
PASIR GUDANG	1.000	1.000	1.000	1.000	0.928	1.000	1.000	1.000	1.000	1.000
PORT KLANG	1.000	0.984	1.000	1.000	1.000	0.984	1.000	0.952	1.000	1.000
DEPOT	BCC-O									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
KUANTAN	1.000	0.979	1.000	0.961	1.000	1.000	1.000	0.974	1.000	1.000
PASIR GUDANG	1.000	1.000	1.000	1.000	0.938	1.000	1.000	1.000	1.000	1.000
PORT KLANG	1.000	0.921	1.000	1.000	1.000	0.981	1.000	0.939	1.000	1.000

The performance of both Depot Kuantan and Port Klang in handling Tanker business was found to be insufficient in terms of Input Oriented and Output Oriented efficiency in 2011 and 2017. Additionally, Depot Kuantan exhibited a negative result for Input Oriented and Output Oriented efficiency in 2013, while Port Klang faced the same negative result in 2015. On the other hand, Pasir Gudang depot had only one negative result in 2014 out of the ten-year period analyzed, indicating their efficiency in managing Tanker business handling throughout the period.

Relating it to the implementation of IT tools monitoring system namely VMS that was first implemented in 2008, all depots reported efficiency in 2010 for both input and output based analysis. However, the performance was not consistent until the enhancement of ILDS system in 2018 that resulted in efficiency in both years 2018 and 2019 for all depots.

3.2 DEA Result for Cargo Business

The outcomes of DEA Analysis for another single product (refer Table 5) – Cargo has mentioned that all three depots get negative efficiency more than once. The result shows that all three depots were not efficient in handling cargo in 2013 which is 0.976 – Input 0.975 output for Kuantan, 0.963 Input and 0.977 output for Pasir Gudang and 0.911 input and 0.937 output for Port Klang. Earlier, Pasir Gudang and Port Klang were not efficient result in their cargo handling in 2011. Pasir Gudang repeated the negative results in 2014 with 0.924, lower from their previous year. In 2017, Kuantan and Port Klang both had negative results for both Input Oriented and Output oriented in 2017.

The results were similar with tanker business, in which the efficiency was seen for both input and output based analysis in all depots for year 2018 and 2019. It can be concluded that when the system has been improved, integrated and accessible, the efficiency of the operation can be maintained. The cause of inefficiency in cargo handling could be due to the outdated system, inaccurate data record and analysis report and also imperfection in smart analysis for forecasting and controlling.

Table 5: DEA Result for CARGO YEARLY

DEPOT	BCC-I									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
KUANTAN	1.000	1.000	1.000	0.976	1.000	1.000	1.000	0.969	1.000	1.000
PASIR GUDANG	1.000	0.995	1.000	0.963	0.952	1.000	1.000	1.000	1.000	1.000
PORT KLANG	1.000	0.893	1.000	0.911	1.000	1.000	1.000	0.931	1.000	1.000
DEPOT	**BCC-O**									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
KUANTAN	1.000	1.000	1.000	0.975	1.000	1.000	1.000	0.992	1.000	1.000
PASIR GUDANG	1.000	0.997	1.000	0.977	0.924	1.000	1.000	1.000	1.000	1.000
PORT KLANG	1.000	0.882	1.000	0.937	1.000	1.000	1.000	0.933	1.000	1.000

3.3 DEA Result for Combined Business (Tanker and Cargo)

Further analysis on the effect of IT tools implementation was done for combined businesses. Table 6 summarises the results of inefficiency for combined businesses for all three depots. Both input and output oriented results are the same for every depot. Details analysis shows that the results of being efficient are related to the year in which the company has implemented the new integrated system and further enhanced it in 2018.

Table 6: DEA Results for Tanker and Cargo Yearly

Type	Kuantan	Pasir Gudang	Port Klang
Input Oriented	Not Efficient (2013,2017)	Not Efficient (2011,2014)	Not Efficient (2011,2017)
Output Oriented	Not Efficient (2013,2017)	Not Efficient (2011,2014)	Not Efficient (2011,2017)

4 CONCLUSION

In the era of technological advances, IT tools are used to help transportation companies to smoothen their operations as well as monitoring the movement of their products and services. Hence, in this study, the framework for IT tools monitoring is presented and was analysed using DEA. DEA provided not only the level of efficiency but also ways to improve if there is any. Every system that is new in the industry must be trained to better understanding of the system before they can be master. Lack of understanding of the system may become the cause of the discrepancies of the system. The results show that the implementation of IT tools in monitoring the behaviour of the drivers did improve the efficiency in the business operation for a while. Close monitoring and analysis need to be done in order to maintain the effectiveness of the system.

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