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Enhanced Fuel Efficiency via Eco-Driving Training in Freight Transport

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ABSTRACT

A training program aimed at augmenting energy efficiency in freight transportation through the cultivation of eco-driving skills was systematically developed and evaluated. The emphasis of this program was on harnessing the potential of drivers to reduce fuel consumption via eco-driving techniques. The study employed a methodical 5-step approach, with energy consumption assessments conducted both prior to and subsequent to the training to determine its efficacy. The process entailed: (1) an initial evaluation of driver proficiency in energy-conserving practices using eco-trucks, (2) the establishment of precise training objectives, (3) the enrichment of drivers' knowledge with advanced eco-driving information and techniques, (4) the selection of suitable pedagogical methods for imparting eco-truck driving skills, and (5) a comprehensive analysis of the outcomes derived from the eco-driving training. Through a comparative analysis of fuel usage before and after the intervention, the study revealed a marked reduction in energy consumption. Post-training data demonstrated a significant decrease in fuel usage by 17.57%, affirming the training's effectiveness. These findings suggest that the implementation of eco-driving training programs can substantially elevate energy efficiency among truck drivers. The resultant decrease in fuel expenditure, alongside the reduction in carbon emissions, contributes to both economic and environmental sustainability, with profound implications for the freight logistics sector.

1. INTRODUCTION

The development of transportation infrastructure is recognized as a cornerstone of national competitiveness in the global economy and a key enhancer of citizenry quality of life. As an integral facet of economic expansion, transportation systems facilitate extensive mobility and ensure the smooth distribution of market goods, reflecting the growing demand for such services [1]. However, the environmental ramifications of transportation, especially greenhouse gas emissions stemming from fossil fuel combustion, are non-negligible. Vehicular exhaust, suboptimal driving practices, and traffic-related pollution are significant contributors to urban environmental degradation [2]. Given that all transportation modalities are inherently energy-dependent, the escalation of renewable energy adoption is paramount in curtailing environmental detriments. The global energy paradigm, notably the pivot towards sustainable resources, has profound implications for national policy formulation, influencing how countries, exemplified by Thailand, strategize their energy resource management. Within the ambit of transportation and communication development, the judicious use of finite non-renewable resources is of critical consideration. Emphasis should be placed on renewable energies, such as solar and wind power, to foster energy conservation and underpin a sustainable societal framework [3].

Oil, as a predominant energy source today, is a non-renewable commodity with a finite horizon of availability. Its efficacious management and strategic deployment are essential to optimize the utility derived from extant reserves. Domestic economic expansion, coupled with demographic growth, has precipitated an escalation in oil demand. Ensuring an adequate energy supply is thus vital to uphold socio-economic and political equilibrium. In the procurement of oil energy, it is imperative to prioritize sources that are economical and pose minimal risk to ensure sustained economic and social stability. Concurrently, climate change imperatives and the urgency of energy conservation necessitate an expedited transition from non-renewable to renewable energy sources, a shift that has become increasingly critical. This transition strategy, particularly within the transportation sector, involves elevating energy efficiency and migrating towards renewable energies, thereby directly aligning with the salient research objectives of this study.

In this vein, the role of truck drivers is pivotal; their proficiency in eco-driving is crucial for diminishing the energy footprint of the transportation sector. This underscores the necessity for specialized training programs that enhance drivers' skills in energy-efficient practices, forming the basis

for the research presented herein.

Thailand's burgeoning economy and swelling population have necessitated the importation of energy, a trend that has not only catalyzed growth but also imposed an economic burden due to escalating energy costs. Recognizing the pivotal role of energy in multiple developmental dimensions, the Thai government has been confronted with the dual challenge of bolstering national growth and addressing environmental repercussions. The 20-year National Strategy (2017-2036), underpinned by the Sufficiency Economy philosophy, articulates clear concepts and mechanisms for driving and monitoring national development, emphasizing direction-oriented and efficient progress for the long-term prosperity of Thai society [4].

Within the scope of national infrastructure and logistics system development, road transportation emerges as both a principal facilitator and a significant environmental contributor, predominantly through greenhouse gas emissions. The road sector, underscored by the preeminence of truck-based freight movement, offers unrivaled convenience, speed, multiple routing options, and comprehensive access, thereby commanding the highest demand in the transportation matrix. Truck drivers, pivotal to the market economy, exert a direct influence on fuel consumption management and efficiency, rendering their expertise critical for energy conservation efforts.

In response to this influence, a training program aimed at reinforcing eco-truck driving competencies was conceptualized. Such a program is essential for augmenting drivers' proficiency in both theory and practice [5]. This strategic intervention is intertwined with national transportation and energy conservation goals, pursuing the reduction of energy consumption and the promotion of sustainable practices. The research objective was to design a training regimen for energy-saving eco-truck driving skills, enhancing driver performance and fostering the adoption of eco-friendly driving habits. The hypothesized outcome is a reduction in fuel consumption, contributing to measurable energy savings.

2. LITERATURE REVIEW

2.1 Development of training programs

The meaning of “program” varies. Generally, the term “program” is used in two ways: 1) a “program” refers to units that are created for special activities or to provide services as per the needs of an institution or individual, and 2) a “program” refers to a series of planned interventions for a specific objective, especially for a target group [6]. These definitions can be directly related to the context of the truck driving skills training program as it is a specialized unit of learning designed for a specific group, i.e., truck drivers.

Boone defines a program or “programming” as a collaboration between learners and non-formal educational institutions in planning learning plans, carrying out learning activities, and evaluating outcomes [7]. This definition aligns with the training program's approach, where truck drivers (learners) collaborate with the training institution to develop and evaluate their driving skills.

Somkid Promjuy suggested that a program is a group of projects, starting from two projects, aimed at achieving the same objectives, or a combination of related projects that aim to achieve the same objectives [8]. In the context of the training program, this could be interpreted as a series of instructional modules or projects aimed at collectively enhancing eco-truck driving skills.

Uunta Nopkhun defined a program as routine work that is carried out continuously. Therefore, a program is related to time, with development, evaluation, and maintaining the continuity of activities as important aspects of a program. This definition suggests that a program is a series of continuous activities consisting of planning, development, teaching, and evaluation, involving relevant parties, related to time, and must be conducted in a particular place. A program has a broader meaning than a curriculum [9]. This perspective is particularly relevant to the training program, emphasizing its ongoing nature and the continuous improvement of driver skills over time.

In conclusion, regarding the above definitions of the term, the researcher has applied the meaning of “program” as a systematic set of activities set up to allow program participants to develop eco-truck driving skills for energy saving. Each definition contributes to understanding how the training program functions as a comprehensive, continuous educational experience, specifically tailored to improve truck drivers' skills in energy-efficient driving.

2.2 Energy saving driving

To drive a vehicle in a way that saves fuel, one must understand the role in fuel saving, how to reduce driving costs, factors that impact fuel consumption, techniques to reduce the rate of fuel consumption, daily vehicle inspections, querying drivers, and effective driving practices. This involves using sufficient and necessary information in driving, coordinating with teams and relevant individuals, and keeping a record of vehicle driving. In carrying out their work, truck drivers play manifold roles in the larger system.

2.2.1 Role in energy conservation

Drivers play a crucial role here, so they should be maximally aware of their fuel consumption. Professional drivers should be able to reduce the amount of fuel used while driving to maximize the energy produced from minimal fuel consumption. However, the effectiveness of these practices can vary depending on factors such as vehicle type, driving conditions, and driver adherence to guidelines. Drivers must be able to carry out daily, weekly, and other routine vehicle inspections to achieve the highest possible efficiency in driving.

2.2.2 Role in reducing driving costs

Professional drivers need to consider costs associated with maintenance, tire wear, reduced insurance premiums, impacts on the business, and the fuel currently used. Nowadays, fuel costs can often account for more than 30% of operating expenses. Therefore, reducing fuel consumption will be beneficial for a business's bottom lines and in lessening environmental impacts simultaneously. The challenge lies in balancing cost-effective driving practices with maintaining timely deliveries and operational demands. The literature review on energy-saving driving techniques synthesizes various sources, including the Department of Land Transport [10], the Department of Alternative Energy Development and Energy Conservation [11], American Transportation Research Institute - ATRI [12], Hino Motor Japan [13], International

Road Transport Union – IRU [14]. These sources provide similar recommendations but may vary in their approach and emphasis, highlighting the need for a context-specific application of these techniques. The specific techniques recommended are as follows:

1) Smooth Acceleration: it is important to start the truck slowly and smoothly. Avoid abrupt and rapid acceleration, as seen in racing cars, as this results in high fuel consumption and faster wear and tear of the engine and various parts.

2) Understanding Gear Efficiency: knowing how to efficiently use truck gears to save fuel is critical. Driving in the most appropriate gear according to the vehicle's speed as recommended in the user manual can save fuel. Driving uphill, on slopes, and around sharp corners with high gears can lead to excessive fuel consumption. Frequent gear changes should be avoided.

3) Using Optimal Speed for Maximum Fuel Economy: there are techniques to maintain speeds at which maximum fuel economy is achieved.

4) Constant Speed Technique: this involves maintaining a consistent speed when driving.

5) Using Engine Brake: this technique is about using the engine brake to control the vehicle's speed without using the service brake, which can help in saving fuel.

6) Gentle Idling: this technique is about running the engine gently which can save fuel.

7) Driving Uphill and Downhill: There are specific techniques to drive efficiently when going uphill and downhill.

2.2.3 Effectiveness

In evaluating the effectiveness of the methods discussed, it is imperative to provide a balanced view that not only highlights the successes but also acknowledges the potential limitations and challenges that have been identified in the literature.

Effectiveness: Begin by summarizing the key findings that demonstrate the effectiveness of the methods or approaches. This could include statistical evidence, case studies, or notable outcomes that have been documented. It is important to be specific about what aspects have been effective and in what context.

Limitations: Despite the successes, it's crucial to discuss any limitations that have been noted. These could be inherent to the methods themselves, such as a lack of generalizability, potential biases, or limitations in scope. It's also beneficial to mention any criticisms or contrasting views that have emerged in the scholarly discourse.

Challenges: Finally, addressing the challenges provides a forward-looking perspective. This includes identifying any ongoing or future obstacles that might affect the applicability or sustainability of the methods. Challenges could arise from external factors like technological changes, societal shifts, or evolving research paradigms. Discussing these challenges can set the stage for future research directions and highlight areas where further investigation is needed.

In conclusion, providing a comprehensive analysis of the effectiveness, limitations, and challenges not only adds depth to your discussion but also positions your work within the broader academic conversation, demonstrating an awareness of the field's complexities and nuances.

3. METHODOLOGY

This research is the experimental research that involves the development of an energy-saving eco-truck driving skills training program. The research process is as follows:

3.1 Target group

The target group for this research comprises personnel within the road freight transportation profession who are members of the Thai Transportation and Logistics Association. The sample group consists of 20 people, specifically selected based on the requirement of experience in road freight transport. The rationale for choosing this sample size is based on the need for experienced professionals who can provide insightful feedback on the effectiveness of energy-saving driving techniques. However, it's important to consider whether this sample size is sufficiently representative of the larger target population. A power analysis, which helps determine the minimum sample size needed to detect an effect of a given size with a desired degree of confidence, would have been beneficial to justify the sample size chosen for this study. The training program employs blended learning concepts, combining traditional in-person training methods with online and interactive modules. This approach is chosen for its flexibility and effectiveness in catering to the diverse learning preferences of the participants. Blended learning allows participants to engage with the material at their own pace and in a manner that suits their individual learning styles, which is particularly beneficial in the context of adult learning. The use of blended learning is intended to enhance the overall efficacy of the training, ensuring that participants can effectively acquire and apply new skills in energy-efficient driving.

3.2 Research steps

3.2.1 Step 1: The creation of a draft eco-truck driving skills

Training program using the following sequence of actions:

1) Review of academic articles, textbooks, work manuals, and research related to energy-saving driving. This involves focusing on authors with relevant experience and academic roles related to energy-saving driving, such as government agencies and educational institutions. These materials are then analyzed and synthesized to define the job using job analysis techniques, thereby establishing the key skills for energy-saving truck driving. The results of this analysis are then used as guidelines for defining the job performance steps (Task/Step).

2) Design a method for developing eco-truck driving skills through a skills training program based on the model for developing energy-saving eco-truck driving skills using a 5-step training program as detailed in Figure 1.

3) Creation of a draft assessment tool for evaluating the skills of energy-saving truck driving. The validity of this assessment tool was confirmed through content validity evaluations by experts, and reliability tests like test-retest or inter-rater reliability could be considered to further validate the tool.

4) The draft skills for energy-saving truck driving are then revised and corrected, followed by a verification and certification process of the skill analysis results through a focus group discussion involving experts. The Item Objective Congruence (IOC) is used here, calculated as the sum of expert ratings divided by the number of experts, ensuring that the

congruence index is higher than 0.50, indicating the relevance and appropriateness of the assessment items.

5) The researcher uses the data from the focus group discussion on drafting truck driving skills for energy saving to develop these skills. The researcher also sets behavior-oriented objectives in theory and practice.

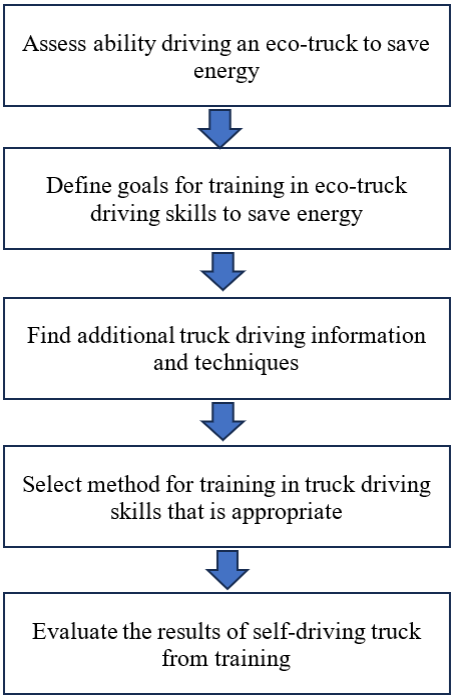

Figure 1. A model for developing an energy-saving eco-truck driving skills training program

The examination of the quality of occupational competency assessment tools using the instrument quality check is one step after the construction of the estimator is complete. The researcher used content validity. The experts must consider the consistency between the items of questions in the assessment form and the objectives of each item.

$$IOC=\frac{\sum R}{N}$$

The assessment stage with a performance appraisal tool using the Item Objective Congruence (IOC) assessment form with a criterion greater than 0.50 [15].

3.2.2 Step 2: Designing a training program to develop eco-truck driving skills

The following steps are included:

1) Study documents, textbooks, academic articles, and related research by studying blended learning concepts as a guideline. This information will be used to analyze the necessary training curriculum for the eco-truck driving skills that meet the objectives and knowledge levels of the trainees.

2) Develop the necessary topics and content for the training program. The details of topics, content, and necessary media and training equipment are described in Table 1 [16].

3) Develop content and details of teaching in the form of training documents, such as guidelines for driving trucks for energy saving.

4) Prepare evaluation tools, such as various congruence assessment forms along with supporting documents for assessment, and invite at least 10 experts to evaluate and suggest necessary skills. The evaluation results are analyzed, and improvements are made as necessary.

Table 1. Development of topics, content, media, and training equipment for an energy-saving eco-truck driving skills training program

Topics	Content	Media and Training Equipment
1. Guidelines for Energy Conservation	1.1 Energy situation, the origin of oil, current energy consumption. 1.2 Benefits to the world, the organization, and the driver. 1.3 Organizational consciousness in driving towards energy saving.	1. Document file 2. Video 3. Social media
2. Condition Inspection and Planning Before Driving	2.1 Engine characteristics, working principle, meaning of torque, maximum torque. 2.2 How to check the condition of the truck before driving according to BEWAGON principles. 2.3 Planning and studying the route before driving. 2.4 Goods arrangement, weight distribution.	1. Document file 2. Training model
3. Planning Routes and Driving for Safety	3.1 Preparing the driver for adequate rest and avoiding alcohol consumption before driving. 3.2 Attitude for safe driving. 3.3 Safe driving practices, overtaking, parking. 3.4 GPS laws, car brakes, speed limits.	1. Document file 2. Training model
4. Eco-Truck Driving Techniques for Energy Saving	4.1 How to start the truck. 4.2 How to use truck gears to save fuel. 4.3 How to maintain speed for maximum fuel efficiency. 4.4 How to maintain a constant speed. 4.5 How to use the engine brake. 4.6 How to idle the engine efficiently. 4.7 How to drive uphill and downhill.	1. Document file 2. Truck

3.2.3 Step 3: Apply the chosen eco-truck driving skills training program draft materials to an actual training

1) Conduct an initial eco-truck driving skills training with a sample group of 20 trainees as detailed in Figure 2.

2) Evaluating the effectiveness and the efficiency of the training program.

3) Evaluate and compare the energy usage of truck drivers before and after the training program.

A more robust assessment of the training program's effectiveness could be achieved by including a control group or employing a pre-test/post-test design.

Figure 2. An eco-truck driving skills training exercise

3.3 The tools used in the research

3.3.1 Data collection tools

1) An evaluation form for the appropriateness of the skills training program, evaluated by experts.

2) An evaluation form for the results of truck driving for energy saving, which assesses practical skills following the tasks prepared by the researcher.

3) A logbook for recording energy consumption in truck driving, which documents the driving habits of the employees participating in the truck driving skills training program.

3.3.2 A quality verification of the tools carried out by 10 experts

The relevance of the components of the skill training program. The Index of Item Objective Congruence (IOC), each item assessed by experts [17]. The analysis results show that the congruence index for various aspects obtained from the experts is higher than 0.5 in all items.

3.4 Data collection

3.4.1 Collecting data information from experts

In collecting information from experts by evaluating the appropriateness of the eco-truck driving skills to save energy with the self-skills training program, using online methods. The researcher sent the documents via email and Line.

3.4.2 Collecting data information from training

In the collection of data on the use of an eco-truck driving skills training program, a trial is conducted with a group from the Thai Transportation and Logistics Association.

3.5 Data analysis

Data analysis using basic statistical values. The data are analyzed by calculating the percentage, average, and standard deviation. The evaluation of the efficiency of the eco-truck driving skills training program has a criterion of not less than 80 percent to be consistent with the performance evaluation results. The effectiveness of the self-skill training program is evaluated according to the single-group posttest-only control group design [18].

4. RESEARCH RESULTS

4.1 Results of developing the truck driving eco-truck driving skills training program

Table 2. Developing the truck driving eco-truck driving skills training program

Evaluation Items	Evaluation Results		Meaning
	$\bar{X}$	S.D.	
1. The content corresponds to the objective of the skills training program.	4.80	0.45	Very High
2. The content is appropriate for the trainees	4.80	0.45	Very High
3. The sequence of content is appropriate and continuous	4.80	0.45	Very High
4. The exercises at the end of each unit align with the content	5.00	0.00	Very High
5. The self-directed training activities can develop truck driving skills for promoting energy-saving	4.40	0.89	High
Overall	**4.76**	**0.32**	**Very High**

From Table 2, in developing the eco-truck driving skills training program, it is found that all aspects of the initiative are appropriate and congruent. The high congruence indices suggest that the program is well-aligned with its objectives, potentially leading to effective skill development and energy savings. These findings imply that the program could be successful in enhancing eco-friendly driving practices among truck drivers.

4.2 Results of evaluating the effectiveness of the eco-truck driving skills training program

From Figure 3, in evaluating the effectiveness of the truck driving self-directed training program for energy saving, it was found that the experimental group who participated in the program had an average score of 89.07 percent, surpassing the 80 percent criterion for everyone, accounting for 100 percent of the participants. The highest score was 98.57 percent, obtained by 2 individuals, and the lowest score was 81.43 percent, obtained by 1 individual. The criterion of 80 percent was set to ensure a substantial level of competency and skill acquisition in eco-truck driving, which is considered satisfactory for this type of training.

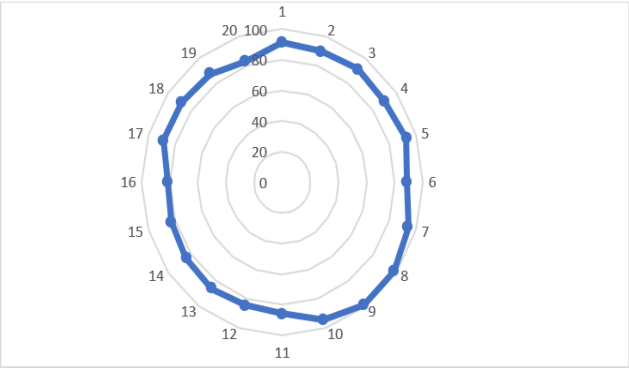

Figure 3. Results of evaluating the effectiveness of the eco-truck driving skills training program

4.3 Results of evaluating the efficiency of the eco-truck driving skills training program

From Table 3, the results of the evaluation of the program's efficiency showed that the efficiency of the eco-truck driving skills training program (E1/E2) was 86.30%/81.70%, with efficiency surpassing the specified criteria of 80%/80%.

Table 3. Results of evaluating the efficiency of the eco-truck driving skills training program

Items	Number of Participants	Full Score	Total Score	Efficiency
E1: Process Efficiency	20	80	69.05	86.30
E2: Results Efficiency	20	50	40.85	81.70

Table 4. Results of comparing the energy used in truck driving before and after the skills training program

Oil Consumption	Number of Trainees	Average Volume (Liters Per Kilometer)	S.D.	t	P
Before Training	20	0.2401	0.16	7.646	.000*
After Training	20	0.1979	0.21		

*Statistically significant at the .05 level

4.4 Results of comparing the energy used in truck driving before and after the eco-truck driving skills training program

From Table 4, in the comparison of energy usage in truck driving before and after the training for eco-truck driving skills, it was found that the average fuel consumption before the training was 0.2401 liters per kilometer, and after the training, it was 0.1979 liters per kilometer. This indicates a reduction in energy usage of 0.0422 liters per kilometer. Therefore, it can be concluded that trainees had a higher oil consumption rate before training than after training, which is statistically significant at the 0.05 level. A t-test was used to compare pre-and post-training oil consumption. The significant p-value at the 0.05 level indicates a statistically significant reduction in fuel consumption. The effect size, as indicated by the reduction in fuel consumption, is practically significant, suggesting that the training had a meaningful impact on reducing energy usage among participants.

5. DISCUSSION

5.1 Development of an eco-truck driving skills training program

The eco-truck driving skills training program developed to save energy can be effectively used to train truck drivers for increased efficiency, climate change mitigation, and savings. The researcher applied key curricular concepts [19-24], including 1) curriculum principles, 2) curriculum objectives, 3) curriculum structure, 4) unit objectives, 5) curriculum content, instructional management, and activities, and 6) curriculum and evaluation results. The selection of the training model was based on these curricular concepts, with the qualifications of the experts involved ensuring the relevance of the curriculum to the trainees' practical needs. The results of the evaluation of the experts' content suitability for the training were found to be highly appropriate. This could be due to the content being comprehensive and appropriate for the learners' needs, having an essential and on-point curriculum design about vehicle inspection before usage for safety and energy saving, and driving techniques for energy saving, which allows learners to effectively apply the knowledge. The use of technology in teaching aids in knowledge enhancement for learners aligns with Satawat et al. [25], who developed a supplementary curriculum to cultivate civic consciousness based on social service learning and community-based learning for undergraduate students. Their findings showed that the curriculum consisted of 10 components, including 1) the rationale and significance of the curriculum, 2) the basic concept, 3) curriculum principles, 4) curriculum goals, 5) learning outcomes, 6) curriculum structure, 7) the structure of civic consciousness components, 8) the concept of organizing learning activities, 9) teaching media, and 10) assessment and evaluation of learning outcomes. The curriculum evaluation results showed that it was highly appropriate, and the trial usage of the curriculum showed that the students' civic consciousness after studying was higher than before by 70 percent. This also aligns with the idea of Saowaros et al. [26], stating that important curriculum components consist of 6 aspects, namely 1) curriculum principles, 2) curriculum objectives, 3) curriculum content, 4) teacher development process, 5) instructional media, and 6) assessment and evaluation. Furthermore, this is in line with Kunaporn et al. [27], who studied the development of a blended teacher training curriculum on classroom research, finding that the quality assessment of the training program was highly suitable in all components, and the trial usage results showed that trainees' abilities in classroom research achieved the criterion by 80 percent with an average score of 85.17 percent.

5.2 Evaluating the effectiveness of the eco-truck driving skills training program

The effectiveness of the training program was found to be high. In the sample group, the average score was 96.40 out of 100, which is significantly higher than the set standard of 85%. This high effectiveness can be attributed to the careful consideration of the training model by experts in energy-efficient driving, making the content interesting, applicable, and thereby enhancing learner engagement and skill

acquisition. Therefore, this training program is deemed more effective than the defined standard. This is due to the training model being carefully considered by experts in energy-efficient driving, including both scholars in the field of energy saving and related individuals such as truck driving instructors and fleet managers. If implemented, this program can genuinely lead to energy saving. The developed training model consists of a curriculum, a training plan, course content, practical tasks, both theoretical and practical assessments, training media, and an online learning management system. These components were verified for their appropriateness by training experts and were found to be highly suitable, thereby ensuring that the developed training model and curriculum can be truly implemented. Moreover, it's a blended learning model that uses technology for learning, focuses on the learners' needs, and features appropriate and comprehensive teaching plans covering essential content. This makes the teaching content interesting and applicable to daily life, enhancing interest and persistence in learners for understanding energy-efficient driving theory. Appropriate learning outcome assessments help learners understand their success and encourage their continuous self-development. Feedback and additional information provided to learners during and after training help them improve their driving skills continuously. The emphasis of their organizations on continuous training motivates employees to enhance their driving skills and promote energy saving. This accords with Pathummasak et al. [28], who conducted a study on the development of a teacher training model for action research with participation in the classroom, in line with the Sujipuli approach. The experts assessed the suitability of the model at the highest level. Moreover, it is in accordance with Krishda et al. [29], who conducted a study on the development of a vocational skills training model for technical teachers, applying knowledge management systems for industrial education students. It was found that the developed model was highly suitable according to the experts. Additionally, Kritphon et al. [30] developed a vocational training model for communication technicians. The results of using the training model with a sample group of 30 people achieved knowledge and skills passing the 80% criteria. All trainees were able to pass the competency assessment. In addition, a study by Islam et al. [31] examined blended learning focusing on learner-centeredness at the tertiary level to promote learner interaction and collaboration in aeronautical studies. The study indicated that a learner-centered blended learning model improved the relationships between learners and teachers in both synchronous and asynchronous teaching. This aligns with Phuangphan et al. [32], who studied the development of a training curriculum for out-of-school education curriculum developers with a blended learning approach. The study found that the blended training model consisting of online and face-to-face methods was highly suitable according to the experts. Finally, these findings are consistent with the concepts of Joyce et al. [33] and Saylor et al. [34], who stated that a good training model must be systematically designed and must correspond with theories, learning principles, ideas, or beliefs. It includes learning and teaching processes, teaching methods, and various teaching techniques that conform to the theories, principles, or concepts they hold. The media used in teaching and learning may be digital, such as computer programs and multimedia, which help trainees learn according to the set objectives [35]. The research can deal more thoroughly with the advantages and potentials of adaptivity regarding students.

5.3 Results obtained from eco-truck driving skills training program

To obtain results about how the training in eco-truck driving skills affected drivers' upgraded efficiency behind the wheel, the researchers followed and evaluated the trainees tracking their application of knowledge and skills from the training program in energy saving one month later. The reduction in energy use by 0.0422 liters per kilometer is significant, translating into substantial fuel savings and environmental benefits over time, especially considering the scale of road freight transportation. It was found that the average amount of fuel used before the training was 0.2401 liters per kilometer. After training, the average was 0.1979 liters per kilometer, indicating a decrease in energy use by 0.0422 liters. These findings have practical implications for truck drivers, fleet managers, and policymakers, suggesting that wide-scale implementation of such training could lead to significant energy savings and contribute to climate change mitigation efforts. However, limitations of the study include the small sample size and the short duration of the follow-up period. These factors might affect the generalizability and the long-term impact assessment of the training program. Further research with a larger sample and a longer tracking period would provide more comprehensive insights into the sustained effectiveness of the training. Considering the t-value calculated as 7.646, which is statistically significant at the 0.05 level, it means that if a truck driver travels 100 kilometers, they would save 4.22 liters of energy. In terms of energy efficiency, the use of fuel energy decreased by 17.57 percent, equal to a reduction of 0.0422 liters. If a truck is used to travel 100 kilometers, 4.22 liters of energy would be saved, equivalent to 126.60 Thai Baht when considering oil prices at 30 Thai Baht per liter. Only one truck did not show an increase in fuel saving of up to 10 percent, which may be because the truck used in the experiment was 15 years old, resulting in engine wear and an outdated engine system, leading to less fuel saving than other trucks. It could nevertheless still be said that all the drivers' developed skills via the specific training format had a higher efficiency than before the training, statistically significant at the 0.05 level. This may be because the truck drivers who participated in the training gained the necessary knowledge and techniques for energy-saving driving, such as how to change gears, effective use of brakes, constant speed driving, driving a truck on a flat road, and driving a truck on a sloping road. This improved driving skills, control of speed, and adjusting driving to suit road conditions. Furthermore, effective training helps truck drivers to have a higher standard of work, which results in better energy efficiency. This aligns with the study by Saboohi et al. [36] in which a model of eco-driving strategies for the least fuel-consuming passenger cars was developed. The research found that the car speed and gear ratio affect fuel consumption, which results from the three-stage engine operation process: idling, partial load, and wide-open throttle. This is also in line with the study by Mark et al. [37] on saving-oriented driving training for professional bus drivers. The study found that bus drivers significantly save energy in simulations. Furthermore, the bus company reported that trained bus drivers immediately started saving fuel after the training, and this effect persisted for six months after the training. Moreover, the study by Jenny Diaz-R. et al. [38] on the primary factors in eco-friendly driving affecting fuel consumption in the group of heavy trucks in Colombia, found that the experience of the drivers, errors in driving, average

speed, and the weight-to-capacity ratio affect the basic average fuel consumption rate. Driving errors, such as accelerating, braking, and overspeeding, affect the basic average fuel consumption rate. In the study [39], it was found that the fuel-saving driving skills of truck drivers are a significant factor in reducing fuel usage. And according to Wang et al. [40], the fuel consumption of aggressive driving styles affects the average fuel consumption by 10%.

6. CONCLUSIONS

In conclusion, this research has highlighted the significant role of eco-truck driving training programs in reducing fuel consumption and driving errors on fuel consumption. The study found that the training led to a reduction in fuel consumption by 0.0422 liters per kilometer, equating to a decrease in energy use by 17.57%. Moreover, the importance of eco-driving skills for professional bus and truck drivers was underscored, with significant savings achieved through these training programs benefiting the organizations financially and contributing to environmental savings.

Furthermore, the research findings suggest that integrating eco-driving training into standard driving education programs could be highly beneficial. This approach would ensure that all drivers, not just professional bus and truck drivers, are equipped with the skills and knowledge necessary to drive in a manner that minimizes fuel consumption. This wider adoption of eco-driving techniques could significantly reduce overall emissions from vehicles, contributing to global efforts to mitigate climate change.

To effectively implement these findings in policy and practice, it is recommended that transportation departments and driving schools incorporate eco-driving modules into their curriculums. Policy changes could include incentives for transportation companies that implement eco-driving training and adhere to fuel-efficient practices. Additionally, educational reforms should focus on integrating these skills into driver education programs at all levels.

In conclusion, the promotion and adoption of eco-driving practices by truck drivers is a key element in achieving sustainable transportation. By equipping drivers with the necessary skills and knowledge, we can reduce fuel consumption, decrease carbon emissions, and make a significant contribution to environmental saving efforts. It is hoped that this research will inspire further exploration into effective eco-driving training methods and foster a culture of environmental responsibility among drivers.

Future research should focus on the long-term effects of eco-driving training, examining its sustained impact on driving behavior and fuel consumption. Additionally, exploring the integration of new technologies, such as telematics and advanced driving analytics, into eco-driving practices could provide valuable insights into further enhancing training effectiveness and monitoring driver performance.

7. RECOMMENDATIONS

Based on the research findings, here are some suggestions for future application and research:

1. **Policy Implementation:** Governments in Thailand and Southeast Asian countries should consider integrating eco-driving training programs into their national driver education programs. This would ensure all drivers, not just professionals, are equipped with eco-driving skills, leading to broader environmental and economic benefits.

2. **Educational Reforms:** Driving schools should incorporate eco-driving modules into their curriculums. These programs can be supported by incentives for transportation companies that implement eco-driving training and adhere to fuel-efficient practices.

3. **Future Research:** Further studies should explore the long-term impact of eco-driving training on driving behavior and fuel consumption. Investigating the integration of new technologies, like telematics and advanced driving analytics, into eco-driving practices could enhance training effectiveness and provide insights for continuous monitoring and improvement of driver performance.

4. **Wider Implementation:** Encouraging the adoption of eco-driving practices across various sectors, including public transportation and logistics, can significantly contribute to reducing carbon emissions and enhancing fuel efficiency in the region.

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