PSAKU International Journal of Interdisciplinary Research

Original Research Article

Received: 25 May 2023 **Revised:** 24 August 2023 **Accepted:** 29 August 2023

LAYOUT DESIGN FOR DATA MANAGEMENT OF ELECTRIC VEHICLE SPEEDOMETER IN THAILAND

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(This article belongs to the Theme 2: Science and Technology for Sustainable Development)

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Abstract

The research objective is to study the layout design for data management of electric vehicle speedometer in Thailand. This survey research uses questionnaires and the Item-Objective Congruence Index as a data collection tool. The data is collected through a single measurement. The sample population consists of electric vehicle users in Thailand whose vehicles are priced at no more than 1,500,000 baht, have been used continuously for at least 6 months, are between the ages of 20 and 40 years, and travel approximately 30 to 60 kilometers per day. A specific targeted sampling approach is employed. The data is collected and summarized to analyze and draw conclusion. The research findings indicate that the layout design of model 1 which utilizes an overall area for displaying data of 75.144%, received the highest popularity score. This design is capable of displaying data on meters greater than 75% of the total area, resulting in a 25% increase in display rate when compared to electric car meters currently available in Thailand and priced at no more than 1,500,000 baht. The layout design of the meter is based on the golden ratio theory allowing the sample group to comprehend information, understand its significance, and enhance confidence in safely driving electric cars in Thailand.

Keywords: Electric Vehicle, Ordering Information, User Experience, Design, Speedometer, Golden Ratio

Citation Information: Thiparapkul, P., & Krutasaen, W. (2023). Layout Design for Data Management of Electric Vehicle Speedometer in Thailand. *PSAKU International Journal of Interdisciplinary Research, 12*(1), 18-29. https://doi.org/10.14456/psakuijir.2023.3

Introduction

The speedometer display was invented by Otto Schulze, German engineer, in 1902. He patented the equipment for displaying data (Wesner, 2002) using pointed objects similar to needles which were used to measure various parameters in vehicles with mobility capabilities. This invention quickly gained popularity across Europe, leading to developments in the automotive industry. The design of meters using pointers had a significant influence on meter design from the past to the present. During the time when horse-drawn carriages were replaced by steam-powered vehicles in 1908 (Ford, n.d.), Ford introduced the first mass-produced four-wheeled automobiles, with an engine as the driving force. It was sold as the world's first automobile. Ford was the company that produced the steam engine that revolutionized the transportation industry. The first car that Ford invented was called the Ford Model T. The Model T was a two-seater car with four wheels, a roof, and a top speed of 50 kilometers per hour. It was the first personal car that had an installed Amperes meter in the form of a small circular gauge. The Amperes meter was used to indicate the speed of the car by pointing to a number on the gauge. Additionally, it showed the total distance the car had traveled. The design of this meter followed the principle of "Keep it simple" focusing on simplicity and ease of use. As a result, the Amperes meter became a fundamental device installed in automobiles.

After World War I, the automobile industry underwent a significant leap in development. Previously, automobiles powered by internal combustion engines could reach a maximum speed of around 50 kilometers per hour. However, they were now improved to achieve speeds of 60-70 kilometers per hour. As a result, designers of meters had to adapt and create new ways to present data on the meters effectively. They divided the data into two main types; "Fast Moving" data, which rapidly changes, includes parameters like speed and engine revolutions, and "Slow Moving" data, which changes at a slower pace, includes parameters like engine temperature and remaining fuel levels. The design of both types of data on car meters emphasized aesthetics as a primary consideration. This was because, during that era, people largely purchased cars to display social status, and the appearance of the meters played a role in this.

After World War II, car meters became a significant factor in personal car purchasing decisions. Many car companies began introducing various types of car meters. Instead of using pointers to indicate values, the meters now used light bars to indicate different statuses. This change was intended to stimulate car sales and make the overall driving experience more visually appealing and user-friendly.

At present, car meters have undergone significant advancements, transitioning from the traditional needle-based or analog display to the installation of TFT (Thin Film Transistor) screens capable of displaying graphic images. This transformation can be seen as revolutionary in the automotive industry since all cars now come equipped with TFT screens as a basic component upon purchase. With the rise of electric cars and the shift from internal combustion engines to electrically powered vehicles, the data displayed on car meters has become much more diverse. Early electric car prototypes featured advanced TFT screens to give them a futuristic look. Additionally, the use of TFT screens allows for a wide range of graphic images to be displayed, enhancing the aesthetic appeal and novelty of the meter display.

However, for mass-produced electric cars targeted at the general public, car manufacturers often aim to minimize production costs. Therefore, they typically install smaller TFT screens with sizes ranging from 5 to 7 inches. As a result, the design of the data structure on car meters for different electric car brands sold in Thailand between May and September 2022 may vary significantly, as indicated in Table 1.

Table 1 Proportion of use on the electric vehicle speedometer

No.	Model	Proportion of use of the display area	Information Display			
			Speed	Remaining distance	Remaining power level	Infotainment and Sign
1	MG ZS EV 2019	50.1%	23.4%	1.1%	1.1%	24.5%
2	MG ZS EV 2020	54.2%	26.3%	0.4%	26.3%	1.2%
3	MG EP	54.2%	26.3%	0.4%	26.3%	1.2%
4	MG4	11.5%	4.2%	1.7%	2.3%	3.3%
5	Ora Good Cat	61.9%	11.6%	1%	11.1%	38.2%
6	Neta V	25.3%	9.7%	1.8%	2.6%	11.2%

In calculating the ratio of the display area on the speedometer using geometric formulas, it shows that the representation on the electric car's TFT display screen averages about 33.84% of the total area. Some electric car models use more than 50% of the display area, such as MG ZS EV 2019, MG ZS EV 2020, MG EP, and Ora Good Cat. Meanwhile, some electric car models use less than 50% of the display area, like MG 4 and Neta V. The limited size of the instrument panel restricts the area available for presenting information, lacking a proper arrangement of important data, reducing their significance and clarity necessary for driving. Furthermore, the number of electric four-wheeled vehicles registered with the Department of Land Transport since the year 2020 (Department of Land Transport, 2020) has increased to 1,056 units and is trending upward. Most of these purchases are either first-time electric car buyers or those buying their second electric cars. This highlights the speedometer as a crucial communication tool between the car and the driver, ensuring safe driving. Therefore, the design should consider the proportion of data arrangement in each section, based on driving experiences, user familiarity, and effective information delivery to the driver.

After studying the data on the design of electric car speedometer, it was found that there are no clear design works or discussions on standardized design concepts for speedometer. To address this, the researcher has introduced the Golden Ratio theory, which promotes aesthetically pleasing, proportional, and harmonious designs for various components. This theory has been applied in the design of standardized speedometer, aiming to create a design that presents necessary information in a comprehensive, clear, and adequate manner for practical use. The goal is to provide users with a better understanding of the electric car's capabilities, a better driving experience, and a reduced risk of accidents, increasing the confidence of users in using electric cars in Thailand.

Literature Review

Louise Persson and Malin Rundqvist conducted a research on Design of instrument cluster for automobiles (Persson & Rundqvist, 2007) presenting a method for designing speedometer that is suitable for technology and user groups. The variables that affect decision making are divided into male and female users. Males like to display a variety of information because it gives a sense of control with power. The colors used in the display are quite diverse than females because most of the females like the design of the meter that looks simple, elegant, uncomplicated for a good view of driving.

Osiurak François, a researcher who conducted the study titled 'Digital, analogue, or redundant speedometers for truck driving: Impact on visual distraction, efficiency and usability' (François et al., 2017), described speedometer design that the safety of the user should be the main consideration. The display requires simple information whether it is a display in analog format that uses a needle pointer or the display in digital format that has similar performance features. The display must show clear information. The location of the defragmentation must be at a reasonable distance in order to reduce confusion in reading the data. François also mentions

the speed of the display on the meter that the data must be accurate to reduce the rate of taking your eyes off the road as much as possible to reduce the risk of unforeseen events. In 2021, Osiurak François and François Mathilde conducted a study titled Usability and acceptance of truck dashboards designed by drivers: Two participatory design approaches compared to a user-centered design. International Journal of Industrial Ergonomics (François et al., 2021). In collaboration with the car manufacturer Volvo, a user-centered meter design study was conducted. The data were collected from truck drivers and general motorists. It has been applied in the design of a variety of speedometer such as allowing test participants to customize the display of oil delivery data to the truck's hydraulic system. The data were then tested with a truck driving simulator to collect satisfaction and user experience data from questionnaires and interviews. According to the results of the study, it was found that user-centered speedometer designs outperform technology-based designs. This agrees with Volvo's 2009 research (Distner et al., 2009) on displaying warning messages to drivers via meter. It can significantly reduce the accident rate and can reduce the rate of rear-end collisions at a speed of 30 kilometers per hour in France by up to 60% due to driving in big cities with heavy traffic. That the cars move slowly and the driving environment places a huge burden on the driver to make decisions make decisions during driving in a stressful state.

In 2015, the researchers Jia-Sheng Hu and Chien-Chu Yeh (Hu & Yeh, 2015) discussed how to design electric vehicle speedometer and provides information on essential technologies such as the Battery Management System (BSM), Power Consumption Management (PCM), Motor Control Unit (MCU), and Tire Pressure Monitoring System (TPMS). Each set of information is important for the use of electric vehicles. If one of the systems is malfunctioning or unable to function normally, it may cause problems that affect driving safety. Jia-Sheng Hu and Chien-Chu Yeh therefore proposed a design approach for electric vehicle speedometer as shown in Figure 1 for presenting information in accordance with the aforementioned system.

Figure 1 Electric vehicle speedometer
Source: Hu & Yeh (2015)

The results of the speedometer design by simulation of Jia-Sheng Hu and Chien-Chu Yeh showed that the test participants were able to understand the current display of electric vehicle data. In 2019, Young-Jin Kwon, Jin-Kyu Choi, Juil Jeon, Kyongho Kim, and Byungtae Jang researched Design of Automotive Digital Instrument Cluster Adjustable to Driver's Cognitive Characteristics (Kwon et al., 2019) to present a concept of how to design the electric vehicle speedometer that adapts to users, experience, age and gender as variables involved in the design. Each group of samples presented different learning outcomes and methods of use. Designing digital speedometer to suit users is necessary to take into account the target audience. The design of digital electric vehicle speedometer has more information that needs to be displayed on the speedometer than conventional combustion engine vehicles.

In designing the current electric vehicle speedometer, the car manufacturers have put their functionality up to date in accordance with the needs of use to arouse interest and boost sales

of electric cars. According to a study conducted by the Swedish news agency Vibilagare, a car designed for speedometer using digital screens was put to the test on the design of digital speedometer and cabins to verify safety during the use of electric vehicles including BMW iX, Dacia Sandero, Hyundai Ioniq 5, Mercedes GLB, MG Marvel R, Nissan Qashqai, Seat Leon, Subaru Outback, Tesla Model. 3, Volkswagen ID.3, Volvo C40, Volvo V70 (2005). The test was conducted by creating more than 15 scenarios that required the driver to look at the information on the digital speedometer and dashboard of the car, timed each scenario compared to the distance traveled in driving. The results show that drivers take their eyes off the road for an average of 24.3 seconds per drive. If a car runs at a speed of 100 kilometers per hour, the driver's eyes will be lost as the car moves forward uncontrollably no less than 500 meters (Söderholm, 2022). This directly affects the safety of the driver and passengers inside the vehicle.

Zarith Zaffryna (n.d.), a researcher at Cognition & Design, says good design should meet the needs of the user. A good meter design should focus on enhancing the understanding of user needs. It pays attention to explaining the meaning and function of the meter so that it can be used comfortably by the user. Dealing with user needs and transforming them into products that are easy to use, suitable, useful, can respond the user's use. 5 TFT screens are used as a measure to display data. Users can freely customize the information displayed on each screen. The display on each screen does not affect driving or the driver's aesthetics during high-performance vehicle operation.

An interview with Mr.Pansawat Paitoonpong, a car expert in Thailand, former editor of automobile-related magazines and books in Thailand, and founder of the Day Dream Drive and Headlightmag channel, a well-established automobile-related social media in Thailand, said the car speedometer will develop based on the technology installed inside the car. The design of speedometer needs to consider technology, features of use and familiarity of users mainly.

'The Effect of Dynamic (Fisheye) Feature in a Speedometer on Driver's Speed Reading Performance' (Manna et al., 2015) is a research studying the speedometer design in round shape or semicircle shape whether or not the data in the meter moves or changes the way it is presented. It will not affect vision for communication between driver and vehicle and does not affect decisions during driving.

Prioritizing the Importance of Data Displayed on Dashboards for Electric Vehicle Driving Experience in Thailand (Thiparpakul & Krutasaen, 2023), the research results revealed that prioritizing the information displayed on the meter for the electric vehicle driving experience in the country is important and essential to driving. Six types of data can be categorized; speed, battery status, system faults, symbols, indicators and Infotainment.

The golden ratio was invented by Leonardo Fibonacci, an Italian mathematician. The golden ratio is a mathematical formula for designing elements. There is a beautiful, proportional ratio that looks more perfect. It is the theory of art that is closest to human life. The golden ratio theory can be used to study the design of speedometer with limited space on a rectangular area or applied in various design elements on the interface (Interface). There is a variety of useful for new image designers. The designers who want to increase their skills can use the following mathematical formula.

$$Golden\ ratio = \frac{a}{b} = \frac{(a+b)}{a}$$

Golden ratio calculation formula

a is always longer than b at 1.618033. For example, to find the area of a rectangle, if b has a width of 1 meter, a will have a width of 1.618 meters as shown in the figure.

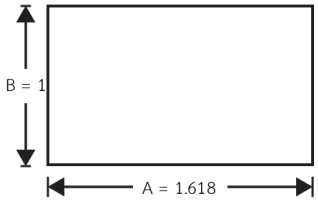

Figure 2 An example of finding the area of a rectangle using the golden ratio.

Referring to the topic Golden Ratio in UI Design on the website of Nielsen Norman Group (Gordon, 2021), the author details the design of the font size for aesthetics suitable for the golden ratio. If the font on the website is 16px (px means Font-Size in Pixel), the size of the heading on the website must be 26px, which is a theory derived from a mathematical formula.

$$\text{Font Size} = 16\ x\ 1.618$$

From the aforementioned calculation formula, it is equal to 25.88, so the font size 26 that is close to the calculated result is suitable for the size of the font in the display. This inspired designers to use the golden ratio in their designs to create or modify elements of the interface widely.

Research Methodology

The researcher conducted the research from May to September 2022 using a qualitative research method in the form of questionnaire-based survey research. It can be used as evidence to confirm the research findings and conclusions as follows.

Population and Sampling

The objective of this research is to study the layout design used to arrange data on a battery electric vehicle for users in Thailand by using an online questionnaire from a specific sampling of electric car users in Thailand with a selling price of no more than 1,500,000 baht, have used cars continuously for at least 6 months, aged between 20-40 years, have bachelor's degrees or higher, are YouTubers, pilots, business owners, chefs and most businessmen, have an average monthly income of 20,000-160,000 baht, use cars to travel about 30-60 kilometers per day. The samples are divided into 17 car-owning users and 3 non-car users. The sample group was from areas with a high number of electric car drivers including Bangkok, Pathum Thani Province, Nonthaburi Province, Samut Prakan Province, Samut Sakhon Province and Nakhon Pathom Province. The data were collected from the sample by making an appointment for the date and time of questionnaire submission and collected data from 6 provinces until reaching the total number of 20 people.

Research Tool

The instrument used in this research was an online questionnaire. The operation was conducted by answering multiple measurement questionnaires. The Item-Objective Congruence Index, or IOC, was used to score from "Agree with the data" (1), "Undecided" (0), and "Disagree" (-1). The researcher conducted a quality check of the research tools by testing the validity of the questionnaire from consulting for advice from car experts with more than 10 years of experience. There is clear information about the design of electric vehicle functions. It is accepted by various institutions in Thailand and seeks advice from an advisor to consider the contents of the questionnaire to be accurate, clear and consistent with the research objectives. After that, validated questionnaires were used to ask specific and anonymous samples by sending a link to the questionnaire directly to the sample via Microsoft Form package program.

Research Results

Layout designing to place data on a user experience speedometer which the drivers have used the cars continuously for at least 6 months, aged between 20-40 years old, most of whom use

cars to travel to the destination with an average distance about 30-60 kilometers per day is the design to develop the display ratio of the information in each section for the display on the speedometer of electric cars sold in Thailand from May to September, 2022, at a price not exceeding 1,500,000 baht. The researcher created the model of electric car speedometer for displaying on TFT screen in 3 formats. The layout design of data frame in squares and circles do not affect decision making in choosing certain actions during driving. The size of the screen was determined from the average screen size in the current display of electric cars. It is the model for testing the ability to perceive information from the speedometer by referring to the design pattern from the golden ratio theory as shown in Figure 3.

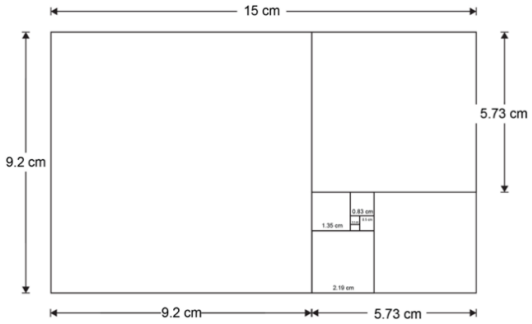

Figure 3 Main structure of general electric vehicle speedometer and the size of the display area

According to the main structure of the speedometer, there is a rectangular area with a length of 15 centimeters, a height of 9.2 centimeters, and a total area of 138 square centimeters representing a ratio of 100%. The layout of the data takes up the display area within the region of the rectangle or circle. From the calculation of the area from the geometry of the 3 model structures, the circle from Model 1 has a radius of 5.73 centimeters or 25.774 square centimeters representing 18.876% display ratio. The circle from model 2 has a radius of 2.865 centimeters or 6.443 square centimeters representing 4.668% display ratio. The third model has a radius of 9.2 centimeters or 66.442 square centimeters. This represents a 48.146% display ratio. Each model has different usage features.

Model structure No.1, the overall display area of 75.144% shows information related to speed, 48.146% of system symbols and indicators, 18.876% of information related to battery status, 4.668% of information related to system faults, and 3.454% customizable general information display with 25% increase in display rate approximately. When being compared to electric car speedometer sold in Thailand at a price not exceeding $1,500,000$ baht, the shape, color and size of the fonts will be adjusted according to the style of driving.

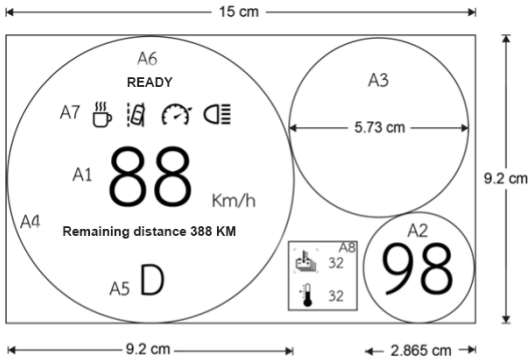

Figure 4 Example of model structure No.1, ratio of area and displayed data

Model structure No.2, the overall display area of 57.483% shows information related to speed, 48.146% of system symbols and light signals, 4.668% of information related to battery status, and 4.668% of information related to system faults, approximately 7% increase in display rate. When being compared to electric car speedometer sold in Thailand at a price not exceeding 1,500,000 baht, the shape, color and size of the fonts will be partially modified according to the style of driving.

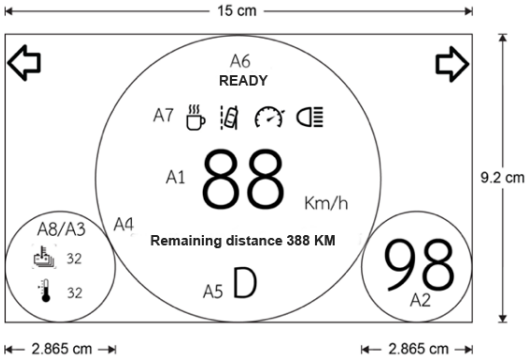

Figure 5 Example of model structure No.2, ratio of area and displayed data

Model structure No.3, the overall display area of 57.483% shows information related to speed, 48.146%, of system symbols and indicators, 4.668% of information related to battery status, 4.668% of information related to system faults, approximately 7% increase in display rate. When being compared to electric car speedometer sold in Thailand at a price not exceeding 1,500,000 baht, the shape, color and size of the fonts will be partially modified according to the style of driving.

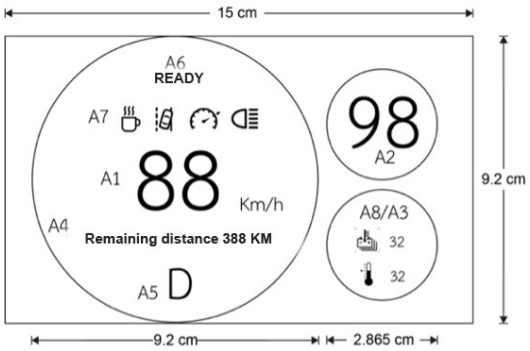

Figure 6 Example of model structure No.3, ratio of area and displayed data

In the three model structures, positions A1 to A8 are designated to present information that users need during driving, as shown in Table 2.

From answering the structural design questionnaire to placing data on user experience metrics by a specific sample group who are users of electric cars sold in Thailand with a price not exceeding 1,500,000 baht, having behaviors of using the car continuously for at least 6 months, 20 people are divided into 17 car owners. 3 people who do not own a car are male, aged between 20-40 years old, graduated with a bachelor's degree or higher, are YouTubers, pilots, business owners, chefs and businessmen. Most of them have a monthly income averagely 20,000-160,000 baht, use a car to travel about 30-60 kilometers per day. They are tech savvy and have no bias towards electric cars. Three models were tested with 50-75% of the total area displayed compared to the current electric vehicle meter design. A three-item questionnaire on the golden ratio was used for composition. The display order of data with shape, color and font size is shown in Table 3.

Table 2 Data presentation table

Position	Types of information displayed when the vehicle is moving.	Types of information displayed when the vehicle is stationary.
A1	Speed status	Charging status (when power is being charged)
A2	Battery status and driving style	Battery status and graphics
A3	Warning messages from the vehicle system	Warning messages from the vehicle system
A4	Remaining distance	-
A5	Drive gear	-
A6	Current car status	-
A7	Driving aid system functionality status	-
A8	Various temperature states	-

Table 3 The results of the spatial structure test on the gauge with data from the sample population.

Components	Golden ratio for composition			Sorting the display of information			Shape, color and font size		
	Model No.1	Model No.2	Model No.3	Model No.1	Model No.2	Model No.3	Model No.1	Model No.2	Model No.3
Total scores	16	15	15	18	14	15	19	13	14
Mean	0.8	0.75	0.75	0.9	0.7	0.75	0.95	0.65	0.7

The structure used to organize the data to display on the survey meter from the sample required candidates to vote from 1, 0, -1 per person per topic per model. It was found that the overall model structure that received the most popularity was Model No.1, using the overall display area of 75.144%, followed by Model No.3, using the overall display area of 57.483%. The second place uses the overall area to display 57.483%, respectively, as follows.

Golden Ratio for Composition

The golden ratio for the placement of spatial structure elements on the scale in all 3 models, just the right size, in the right place easy to see and makes it possible to quickly find the information you need. The most popular model is Model No.1 which uses the overall display area of 75.144%, followed by Model No.2 occupies 57.483% of the overall display area and Model No.3 occupies 57.483% of the overall display area.

Sorting the Display of Data

Sorting the display of data by order of importance of the data displayed on the meter is an important variable in presenting information on the meter for accurate communication. The sample can get information, understand and analyze data accurately, precisely, and effectively. The most popular model structure was Model No.1 with 75.144% of the total display area, followed by Model No.3 with 57.483% of the total display area and Model No.2 with 57.483% of the total display area, respectively.

Font Shape, Color and Size

The font shape, color and size affect visibility, awareness, recognition and eye-take-off rate. Different meter construction designs all affect the use of the drivers. Comparison between model structure No.2 and model structure No.3, it can be seen that the display area is close. However, the feedback on use is different. The users under 30 years old prefer the design of Model No.2. The users over 30 years old prefer the design of Model No.1 and Model No.3 because they are easy to see. In the subjects over 30 years old, when looking at the meter and the traffic surface, it causes blurred images or blurred vision for a while making them decide to choose model structure with shape, font color and size which are easy to see and eye friendly.

In addition, the information is clear on the display. From the results of the questionnaire survey, it was found that the model structure that the sample group agreed to be very suitable and the most popular was Model No.1, using the overall area to display 75.144%, followed by Model No.3 occupying 57.483% of the overall display area and Model No.2 occupying 57.483% of the overall display area, respectively.

Conclusion

According to the study on the layout design used to place data on the Battery Electric Vehicle for users in Thailand, the results showed that Model No.1 layout design uses the overall display area of 75.144%, receiving the most popular rating. It is a design that can display information on the meter more than 75% of the total area. There is an approximately 25% increase in the display rate compared to electric car meters that are sold in Thailand at a price not exceeding 1,500,000 baht. Regarding the use of electric cars while the car is stationary or the car is moving, the users will periodically look at the information on the meter. The layout design of the meter was based on the golden ratio theory enabling the sample to receive information, able to understand the meaning of the information displayed on the meter well and clearly. This corresponds to the research of Osiurak François and François Mathilde on Usability and acceptance of truck dashboards designed by drivers: Two participatory design approaches compared to a user-centered design. International Journal of Industrial Ergonomics (François et al., 2021) studying the user-centered meter design. It was found that the user-centered meter design was more effective than the technology-based design. This agrees with Volvo's 2009 research (Distner et al., 2009) on displaying warning messages to drivers via the meter. It can significantly reduce the accident rate.

Designing a structure used to place information on electric vehicle meters for users in Thailand on the subject of the golden ratio for the composition, display order of information, shape, color and font size affect the visibility of information on the meter. The rate of taking your eyes off the road includes the time to make a decision. The design of electric vehicle meters in Thailand needs to take into account the local users. The golden ratio theory should be used as a basis for the design of the meter structure. This includes choosing to use important information to display on the meter and positioning of information in each section in a position that can be easily seen during the day and night.

Recommendations

1) For the study on the design of the structure used to place data on the Battery Electric Vehicle meter for users in Thailand, there is a weakness in installing TFT screens for use as meters in electric cars. Most of them are limited to about 5-7 inches. The display information about the car's operating system is quite detailed. This makes it difficult to design so that users can use information about electric vehicles to make travel decisions.

2) It should be encouraged to popularize the structure of the data arrangement based on the golden ratio theory in order to create standards for the design of electric vehicle meters that are safe to drive.

3) Utilization of layout design should be encouraged to arrange data on the meter by focusing on communicating knowledge, understanding and familiarity in using electric vehicle meters in order to create effective communication between drivers and electric vehicles to enhance a good driving and operating experience of electric vehicles.

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Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.