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HUMAN MACHINE INTERFACE (HMI) DEVELOPMENT FOR E-BUGGY USING RASPBERRY PI

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DEDICATION

I am dedicating this thesis to my beloved parents, Mr Zulkahar Bin Ahmad and Mrs Normala Binti Sabardin who have always be a positive role model in my life and continually provide their moral, spiritual emotional and financial support. Thank you for being my source of inspiration and giving me strength when I am on my weakest point.

ABSTRACT

A human-machine interface (HMI) refers to the point at which a human interacts with a machine, whether it be a physical device or a software program. The interface can take many forms, such as a keyboard, mouse, display, touchscreen, or voice recognition system. The goal of a machine interface is to facilitate communication between the user and the machine, allowing for efficient and effective use of technology. In recent years, there has been a shift towards more intuitive and natural interfaces, such as gesture recognition and augmented reality, which seek to make the interaction between human and machine more seamless. As technology continues to evolve, the design and development of machine interfaces will play a crucial role in shaping how humans interact with machines and ultimately impact our daily lives. Some general e-buggy problems are no information display, limited info also less automation and digitalization. Raspberry pi will be used in this project to design an interface for e-buggy. According on the responses provided by 40 survey participants, the colour choice for the metre gauge was made. In this project, the HMI is developed for the e-buggy towards engineering tools such as Pugh Method or Decision Weighted Matrix is to be used for HMI design. Information on the powertrain performance can be monitored for efficient operation. As the result, an intuitive HMI is developed based on user evaluation rating. Moreover, Altair Inspire also will be used in this project to analysis of car dashboard. In this section, results for analysis of displacement, safety of factor, and von misses stress in car dashboard can be calculated. As a result, the objective of getting a car dashboard that is safe and friendly for drivers to use can be realized. In conclusion, the project demonstrates a comprehensive approach to HMI design, utilising engineering techniques in addition to user preferences to provide a well-balanced blend of safety, practicality, and aesthetics in the dashboard of an e-buggy vehicle.

ABSTRAK

Antara ‘Human Machine Interface (HMI)’ merujuk kepada titik di mana manusia berinteraksi dengan mesin, sama ada peranti fizikal atau program perisian. System ini boleh mengambil pelbagai bentuk, seperti papan kekunci, tetikus, paparan, skrin sentuh, atau sistem pengecaman suara. Matlamat HMI ini adalah untuk memudahkan komunikasi antara pengguna dan mesin, membolehkan penggunaan teknologi yang cekap dan berkesan. Walau bagaimanapun, sistem HMI yang lemah boleh menyebabkan salah faham kepada pengguna tentang keadaan semasa untuk mengambil tindakan segera. Dari segi kenderaan, ia boleh menyebabkan kenderaan rosak, malah boleh mengakibatkan kemalangan berlaku. Kebelakangan ini, terdapat peralihan ke arah yang lebih intuitif dan system semula jadi, seperti pengecaman gerak isyarat dan realiti tambahan, yang bertujuan untuk menjadikan interaksi antara manusia dan mesin lebih lancar. Memandangkan teknologi terus berkembang, reka bentuk dan pembangunan HMI akan memainkan peranan penting dalam membentuk cara manusia berinteraksi dengan mesin dan akhirnya memberi kesan kepada kehidupan seharian kita. Beberapa masalah umum e-buggy ialah tiada paparan maklumat, maklumat terhad juga kurang automasi dan pendigitalan. Raspberry pi akan digunakan dalam projek ini untuk mereka bentuk HMI untuk e-buggy. Mengikut maklum balas yang diberikan oleh 40 peserta tinjauan, pilihan warna untuk tolok meter telah dibuat. Dalam projek ini, HMI dibangunkan untuk e-buggy ke arah alat kejuruteraan seperti Kaedah Pugh atau Decision Weighted Matrix untuk digunakan untuk reka bentuk HMI. Maklumat tentang prestasi powertrain boleh dipantau untuk operasi yang cekap. Hasilnya, HMI intuitif yang dibangunkan berdasarkan penilaian pengguna. Selain itu, Altair Inspire juga akan digunakan dalam projek ini untuk menganalisis “dashboard” kereta. Dalam bahagian ini, keputusan untuk analisis “displacement, safety of factor, dan von misses stress” pada “dashboard” kereta boleh dikira. Hasilnya, objektif untuk mendapatkan “dashboard” kereta yang selamat dan mesra untuk kegunaan pemandu dapat direalisasikan. Kesimpulannya, projek ini menunjukkan pendekatan komprehensif kepada reka bentuk HMI, menggunakan teknik kejuruteraan sebagai tambahan kepada pilihan pengguna untuk menyediakan gabungan keselamatan, kepraktisan dan estetika yang seimbang dalam papan pemuka kenderaan e-buggy.

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LIST OF SYMBOLS AND ABBREVIATIONS

HMI	-	Human-Machine Interface
CLI	-	Command-line Interface
GUIs	-	Graphical User Interfaces
QFD	-	Quality Function Deployment
TO	-	Topology Optimization
AM	-	Additive Manufacturing
DMLS	-	Direct Metal Laser Sintering
WAAM	-	Wire Arc Additive Manufacturing
FDM	-	Fused Deposition Modelling
EV	-	Electric Vehicle
R&D	-	Research & Development
NPD	-	New Product Development
AI	-	Artificial intelligence
SBC	-	Single Board Computer

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CHAPTER 1

INTRODUCTION

1.1 Background

The term Human-Machine Interface (HMI) refers to the ways in which people interact with computers or other digital devices, it includes all components that enable input, output, and meaningful interaction. The command-line interface (CLI), which relied on text-based commands for user-computer interaction, was the first example of HMI. However, because of its technological complexity and requirement that users possess a particular level of competence and familiarity with the system, this strategy presented issues.

The creation of graphical user interfaces (GUIs), a result of technological advancements, marked a dramatic change in user interaction. With the introduction of features like buttons, menus, graphical components, and icons, GUIs provided a more visually appealing and straightforward experience. Through the simplification of interaction and the removal of technological obstacles connected with previous interfaces, this progression increased the accessibility of computer systems to a wider range of users.

Figure 1.1: Example of Graphical User Interface of a Dashboard (Daniel Golson, 2022)

Today, HMI has advanced even further with the introduction of touchscreens, voice commands, gesture recognition, and other forms of natural language processing. These technologies allow users to interact with digital devices in more natural and intuitive ways, making them easier to use and more accessible to people of all ages and backgrounds.

Overall, the evolution of HMI has greatly improved the usability and accessibility of digital devices, making them an integral part of our daily lives. (Hafsa Jabeen, 2023)

1.2 Problem Statement

There are several problem statements that can be addressed in the field of Human-Machine Interface (HMI). There are some of the problems such as the usability, safety, efficiency, adaptability, and user experience.

Firstly, the usability is the one of the most significant problems in HMI is making the system easy and intuitive to use for the users. Designers need to consider the different of cognitive abilities, cultural backgrounds, and preferences of users to create interfaces that are user-friendly and accessible. All of these statements could increase the users to keep use the interface without any issues (Tan et al., 2022).

Next is safety in using the interface. In some applications, such as transportation, medical devices, and industrial control systems, the HMI needs to be designed to ensure the safety of the users and others. The applications and interfaces need to be designed to prevent error in crucial time and reduce the risk of accident.

Efficiency is also one of the problems for HMI. The interface must be created to provide accurate and effective communication between the user and the system. This includes reducing the amount of time required to execute tasks, minimizing errors, and enhancing the flow of information. (X. W. Liu et al., 2012).

In other hand, adaptability is the one of the keys to make the good interface. The HMI must be developed to accommodate adjustments in the system's functionality and enable new interaction concepts as technology advances. This entails incorporating new input and output devices, adjusting to new platforms, and enabling novel interaction.

Last but not least, user experience is another critical aspect of HMI. Good feedback from user should be engaging, enjoyable, and satisfying while also being efficient and effective. Designer need consider the emotional and psychological aspects of the user experience to create interfaces that are both functional and easy to use. Also, a long-term use of interface with no lag issue also gives good feedback from user. (W. Liu et al., 2023)

Overall, the goal of HMI is to create interfaces that are easy to use, safe, efficient, adaptable, and enjoyable for the user. Addressing these problem statements can help designers create better HMI systems that meet the needs of users and provide a more positive feedbacks.

1.3 Research Objective

a) To study and design a dashboard panel display for e-buggy.

b) To test the HMI, towards the user response and interact with the system of the car.

1.4 Scope of Research

This study focuses on the designing a simple but intuitive HMI for e-buggy using Raspberry Pi single board computer (SBC). The main priority of this focus design is at the dashboard in the e-buggy. An interface design which comprise of digital meter needs to be tested and simulated in order to collect user response on which HMI design is the best in term of usability, safety, efficiency, adaptability and user experience.

The limitations of this project are shown below.

1. To study the interface design into accessibility of the electric car.
2. The exterior and engine modification will not be included in this project.
3. Raspberry Pi will be generated to create interface to display in display screen.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter offers a concise review of the literature on the following subjects: initialization to structure automotive dashboard for HMI, automotive dashboard structural analysis, form design, material, and Quality Function Deployment (QFD). All the discussion is based on the previous study from other researchers, books, articles, and other sources.

2.2 Human Machine Interface for EV Buggy Dashboard

In any vehicle there is a set of relevant information that must be presented to the driver in a precise and comprehensible way to effectively assist the driving process, which is normally carried out using a dashboard. (Luis Marques, 2011).

The information that the driver has access to depends on the design of the automobile, but it is highly recommended employing a fully digital and adjustable interface built on a computer and a high-resolution touch screen efficiently in EV buggy. This method offers a number of advantages over the traditional dashboards with metres and gauges used in modern automobiles.

In order to fulfil the interaction aim for an EV buggy, efficiency implies optimizing the driver-interface interaction. Information directly linked to driving should be presented in the dashboard or other prominent display areas in the interface layout, whereas information of secondary relevance and unrelated to driving should be shown on the centre control panel and other areas. The layout of the interface should also be straightforward, with the most important information appearing at the top level and supporting information appearing at the school or third level or in the sub-interface. High priority information should be displayed with emphasis, while low priority information should be displayed with less emphasis. The design of HMI has proven to be improved by the appropriate use of colour. (Rozhdestvenskiy et al., 2015)

2.2.1 Automotive Dashboard Structural Design

It is well known that for automakers, reducing weight is an excellent strategy to achieve the reduction of pollutants and fuel consumption and, in the end, to manage the design and manufacturing costs. Topology Optimization (TO) tools are essential for industrial applications, particularly in the automotive and aerospace industries. In reality, they have been used to avoid failure because of their capacity to imitate and meet structural goals like stiffness, loads, and dynamic behavior. Especially for the design of mechanical components for structural applications, TO may offer helpful suggestions (Mantovani et al., 2017).

The lowering of the weighted compliance for each loading situation is the TO's goal. The stiffness and compliance have an inversely proportional relationship, with maximum stiffness being comparable to minimum compliance. Torsion and bending were the two loadcases taken into account. Four nodes one for each shock-tower at the vehicle floor were monitored for displacement in the torsional load condition. Six nodes were monitored in the bending load scenario: the four nodes that were taken into account for the torsional load case before, plus two more nodes that were situated at the bottom surface of the sills. To increase the component's real stiffness, these reference nodes' displacements have been limited. It was constrained also the maximum proportion of the mass of the component adoptable by the solver to achieve the solution, in order to obtain a design that fulfills the desired stiffness and that weights a given percentage of the overall mass of the component described by the design space. This percentage varies from the twenty to the eighty per cent. A minimum dimension of the sub-structures that the TO generates has been imposed equal to 20 mm.

For the sake of conciseness, the topology findings will only be shown for the model with limited mass at 20% and 80% of the total mass of the dashboard as given by the design space. Figure 2.1 and Figure 2.2 shows that the example results of topology optimization with 20% and 80% material density (Mantovani et al., 2017).

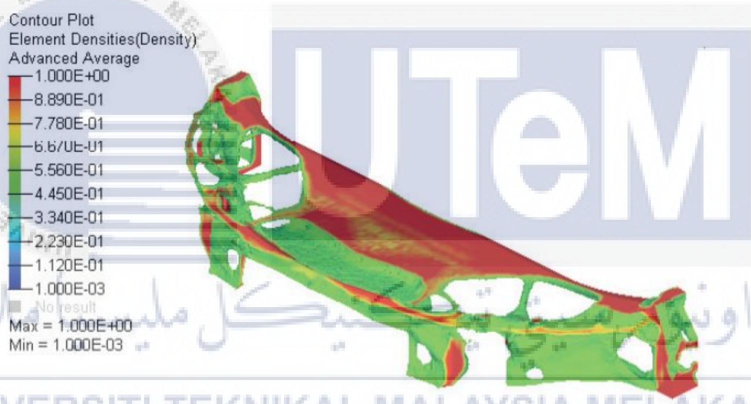

Figure 2.1: The results of Topology with 20% material density

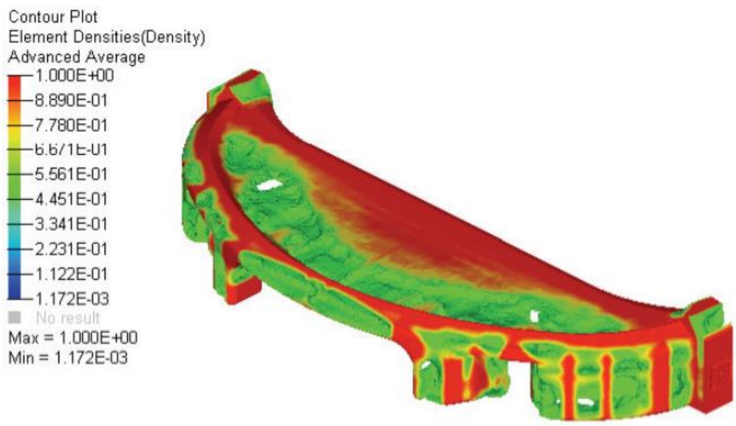

Figure 2.2: The results of topology with 80% material density

2.2.2 Implementation of Additive Manufacturing In Automotive Dashboard

The disruptive approach of additive manufacturing (AM) gives this industry a significant competitive advantage by speeding up product design and development, offering flexibility in production, and producing customized vehicle parts and optimized automotive components on demand. The use of AM on soft assembly equipment or specialized machines to create car components helps the automotive industry. The freeform capability of AM enables the design and direct manufacture of automotive components that are tailored for the performance of the vehicle as well as the creation of unique assembly tools to increase productivity. Another benefit of generative design algorithms-based additive manufacturing is the ability to create lightweight components. Last but not least, the notion of mass customisation was made possible by a dramatic reduction in the time to market for AM parts. The significant decrease in energy use creates new issues for vehicle performance, design, and regulatory compliance. (Vasco, 2021).

The application of AM also can be inherited into dashboard in EV buggy in order to give best performance and lightweight components. However, presently there exists an opportunity to produce the tooling required for these operations using AM (Jankovics & Barari, 2019). Due to the difficulty and length of time necessary to machine the strong materials utilized, conventional tooling now needs a significant investment. Due to the significantly reduced number of operations required, various AM methods including direct metal laser sintering (DMLS), wire arc additive manufacturing (WAAM), and fused deposition modeling (FDM) may be utilized to make different types of molds and dies with significantly shorter lead times and lower overall costs (Bubna et al., 2016).

A 3D object was successfully vacuum foamed around with conductive patterns printed using inkjet technology for capacitive touch applications. The published research paper demonstrated how flexible touch-sensitive sensors may be printed using inkjet technology. These sensors may be mapped onto various shapes by vacuum foaming. This might be used to include sensing capabilities to intricate geometries within or outside of a vehicle, such door handles or the car's interior. These solutions may be used for infotainment systems in automobiles as well. But with the advanced touch sensing capabilities that may be included into or printed on 3D devices like Human Machine Interfaces (HMI) (Charles et al., 2022).

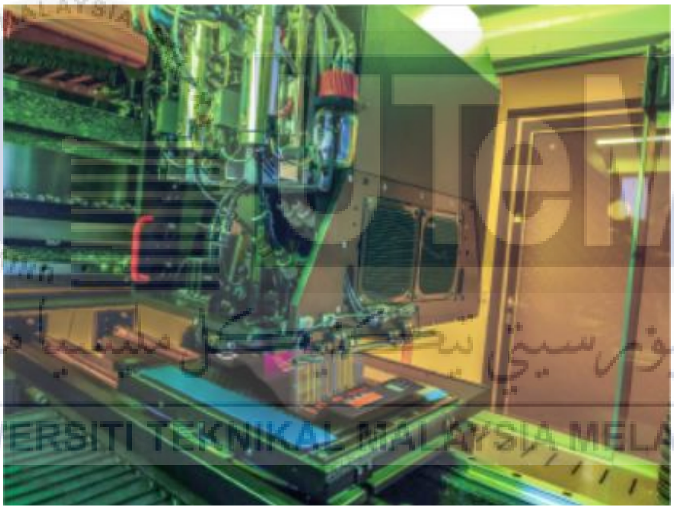

Figure 2.3: Example of Multi-Material Inkjet 3D Printing Machine.

2.3 Engineering tools for HMI Dashboard design.

2.3.1 Kansei Engineering

Comfortable and well-defined dashboard design can improve driver's attention, driving interest, driving quality and driving safety. Kansei engineering is defined as translating consumers’ affective responses to new products into ergonomic design specifications (Nagamachi, 1988, 2002). Kansei Engineering is being used to transform customers' needs and feelings into the elements of product design elements. The KJ method use to classify and analyze. The KJ-Method, named for its inventor, Jiro Kawakita (the Japanese put their last names first) (Jared M. Spool, 2016). In other hand, the key elements of design need to be defined to construct the intention space of modeling, and the shape of modeling should be extracted by morphological analysis.

Figure 2.4: Spatial Sample Image of Styling Intention (Ren et al., 2019)

Kansei engineering can be apply in designing EV buggy dashboard where we can build as driver needed and comfortable with. Although, a survey form can be created to accomplish driver desire with the most design selected. Research can be divided into four stages.

- Stage I: The collection of samples and image words. Collect the front and side view extensively, and the image words on EV buggy, generally adjectives.
- Stage II: The selection of representative samples and image words. Take morphological differences as a principle, elect representative samples for clustering experiments, use multi-scale analysis to filter representative

samples, after the initial filter of collected words, then collect the selected representative sample with a questionnaire, for further representative image words selection.

- Stage III: The establishment of the corresponding relationship between automobile styling elements of image semantics and form features. Have an investigation about the filtered image words and Morphological profile samples, to establish the relationship between the sample form elements and image words, according to which we get the mathematical model, and then we can deduce the weight among specific characteristic form elements.
- Stage IV: Analysis and verification on establishment of the corresponding relationship between automobile styling elements of image semantics and form features. (Yao et al., 2011)

2.3.2 Design Thinking Approach

Design Thinking is a methodology that imbues the full spectrum of innovation activities with a human-centered design ethos. Design thinking is a discipline that uses the designer’s sensibility and methods to match people’s needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity. Different elements of the application of Design Thinking are mentioned in literature: mindset, team diversity, process, tools and environment (Brown., 2008). The Design Thinking team, in particular, acts and thinks customer-centrically, has a high level of background diversity, adheres to a usual approach, utilizes various tools for creative thinking, and works in an inspirational setting. These elements are used to differentiate a Design Thinking team and other innovation teams such as R&D and New Product Development (NPD) teams. Applying these elements, academic literature proposes Design

Thinking to increase innovativeness. Those findings are mostly derived from describing case studies which explain examples how managers successfully implemented Design Thinking in the organization to overcome internal challenges, engage customers, develop new processes and products (Liedtka., 2014).

Thus, the characteristics of Design Thinking teams and their impact on firms' innovativeness are described in literature on the subject. The design team at UberEats frequently applies design thinking techniques to combine cutting-edge technology with the essential activity of eating. And it's reasonable to assume that their implementation was a success (Paul Clayton Smith, 2022). However, academic literature did not examine which factors influence Design Thinking teams' innovativeness. As a consequence, there is no definite understanding why some Design Thinking teams deliver highly innovative project outcomes whereas others are less innovative (Chang et al., 2013). In addition, according to there is no systematic use of Design Thinking in practice which is problematic because differences in the application do not allow a description about how Design Thinking should be applied to deliver innovative outcomes. (Simon, 2015)

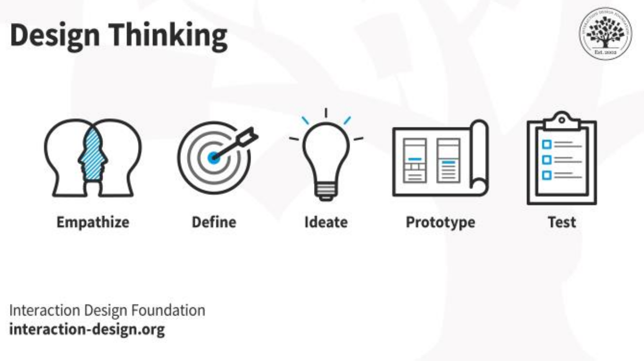

Figure 2.5: Design Thinking Process (Interaction Design Foundation, 2020)

2.3.3 Pugh Method

The purpose with a Pugh matrix is to evaluate different concepts as well as narrowing down the number of concepts. (Ulrich & Eppinger, 2000). In the matrix, the concepts are evaluated based on different criteria that are related to the performance needed for the solution. The Pugh matrix makes the evaluation and elimination more structured, since all concepts are compared with the same background and not on gut feel. (DeCarlo et. al, 2009).

Pugh's method can be applied in designing dashboard for EV buggy. It can evaluate until the desired criteria meet. The Pugh matrix is built up by various criteria in the left-hand column followed by all possible concepts. Each concept gets evaluated with a score (+), (0) or (-) for each criterion, which is decided based on a comparison with a reference concept. Based on the results, one or more concepts are further developed while some gets eliminated. (Ulrich & Eppinger, 2000)

The functions of a weighted Pugh matrix are identical to those of a conventional Pugh matrix. The key distinction is that a weighted Pugh matrix emphasises the relative weight that each criterion has. Each criterion is given a weight, ranging from 1 to 5, signifying its significance. If an idea is given a (+) evaluation and the weight is 3, the result is +3.

KEY CRITERIA	CONCEPT 1	CONCEPT 2	CONCEPT 3
EASE OF DESIGN	-	+	0
SAFETY	+	+	0
EASE OF FUNCTION	+	0	0
EASE OF MANUFACTURE	-	-	+
EASE OF USE	-	+	+
SUM OF POSITIVES(+'S)	2	3	2
SUM OF ZEROS(0'S)	0	1	3
SUM OF NEGATIVES(-'S)	3	1	0
NET SCORE	-1	3	5
RANK	3	2	1

Figure 2.6: Pugh's Method Table (Bansal, 2015)

2.4 Navigating the Art of Colour Selection

A reliable and intuitive human-machine interface will be crucial after artificial intelligence (AI) and autonomous mobility become reality. Since color adds a new dimension to our visual world and provides vital information about the surroundings, color will be significant in this context. Color helps users quickly and accurately identify items in cluttered surroundings, such as those found in busy urban environments. It also significantly increases the saliency of objects and plays a key role in directing our attention. Self-luminous color signals are used in air, rail, and road traffic because they are easy to recognize even at great distances. Indicators of color are also crucial for those with low eyesight since color can be instantly recognized regardless of their level of vision.(Werner, 2018)

Visibility is required in order to assess the color choices made in the dashboard of a car. The presence of other signals used by the vehicles and the traffic environment, such as traffic lights with the colors red, amber, yellow, and green, lights on vehicles with the colors selective yellow, yellow (amber), red, white, and signal blue, and reflections of these lights on glossy surfaces like car coating, wet pavement, and more, all affect how visible the signal colors are. Rain, fog, and snow are examples of weather conditions that can affect visibility and scatter light or lower overall light intensity.

Turquoise and Purple/Magenta are anticipated to have the most saliency due to the road environment's frequent use of yellow, orange, red, green, and white lights. This implies that both of these colors will be more noticeable against the vast majority of other lights and reflections in the field of vision, improving the identification of autonomous vehicles and their signals.

The optimal spectral ranges for human color discrimination (normal color sensitivity, center vision) are around 480–490 nm and 570–580 nm, respectively. This translates to the best discriminability in the color regions of blue-green and yellow-orange, with mint-green and purple-magenta being less preferred than turquoise and selective yellow. Both contrast sensitivity and visual acuity diminish with eccentricity, or in the peripheral field of view, due to the growing size of neuronal receptive fields from the human retina's fovea to its periphery. This is especially true for red/green contrasts. As a result, color vision becomes increasingly dichromatic, which correlates to a deutan/protan deficiency in the peripheral retina. This basically means that turquoise and purple/magenta will be easier to distinguish from other lights in the periphery than mint-green or selective yellow.

Subjective color attractiveness may play a significant role in the public's adoption of driverless vehicles. According to studies on color preferences, bluish colors are considered as the most favorable globally, with values varying slightly between cultures and genders. For instance, a study comparing the color preferences of Chinese and British Caucasians revealed that women favored reddish-purple hues, while men in the Caucasian group tended to choose blue-greens. However, there was less of a gender difference, with both sexes giving greater weight to reddish colors. US citizens showed the strongest preferences for blue, cyan, purple, and dark red in previous research that used the Berkley color set, but Japanese people favored cyan over blue, green, and mild reds. Germans, on the other hand, favored cyan, blue, and dark red colors the most. In all three civilizations, especially dark yellow or greenish yellow, appears to be the least preferred color. It is frequently connected to danger (when bright) or dirt (when dark). The most common rating for greens is neutral. Consequently, Turquoise and Purple/Magenta are more favorable than Mint-Green and especially than Selective Yellow in terms of their emotional connotations.(Hurlbert & Ling, 2007)

Selective Yellow is already employed in motor vehicles, other yellow or orange and green lights are present in street lighting, trafc lights. Turquoise, Purple/Magenta, on the other hand, are not used in the context of traffic and thus are unique in this environment. Therefore, Turquoise and Purple/Magenta possess a high recognition factor and are suitable as unique features for the identifcation of autonomous vehicles.

colour	visibility central	visibility peripheral	discriminability normal / CVD	uniqueness	attractivity	rank order
Turquoise	++	+++	+++ / ++	+++	+++	1
*Selective Yellow**	++	+	+++ / -	-	-	4
Purple/Magenta	+	+++	+++ / -	+++	+/-	3
Mint-Green	+++	+	+++ / -	++	+	2

CVD - colour vision deficiency
* already present as signal on vehicle
+/- positive/negative evaluation

Figure 2.7: Evaluation results for colours under consideration.(Werner, 2018)

Figure 2.7 provides a summary of the findings. All colors under consideration have equivalent visibility in terms of center vision, with the exception of purple/magenta. It is believed that Turquoise and Purple/Magenta will be noticeable and identifiable in peripheral vision than Selective Yellow and Mint-Green. It is reasonable to anticipate that lights emitting from other vehicles and those commonly found in the urban visual environment such as traffic lights, street lights, reflections on wet pavement surfaces, and car coating will be more difficult to discern from turquoise, purple/magenta, and mint-green. The distinct signal colors of turquoise and purple/magenta on the vehicle, along with the surrounding visual cues, make it possible to identify autonomous cars quickly and accurately. Additionally, people tend to like colors in the blue/blue-green area of color space, while yellow is often viewed less favorably. As a result, autonomous vehicles should be perceived as more appealing when they have turquoise lights.

2.5 Quality Function Development

An organized method known as "Quality Function Deployment" aids organizations in converting client requirements into design and production procedures. In order to make sure that products meet or exceed consumer expectations, it is frequently employed in the automobile sector. By obtaining the "voice of the customer" and incorporating it into the product development process, QFD promotes cross-functional collaboration.

The type of material utilized for automotive dash boards in terms of texture, look, and mass is the key issue covered in this research. Second, while the automobile is moving quickly, the dashboard should absorb vibration. Last but not least, one of the issues with Ford automobiles is the incorrect positioning of the USB port. The issues that drivers have with the materials and the incorrect placement of the USB port are the key topics of this article. Additionally, consumers require a better dashboard with new technology, material, design, and innovation that are regularly updated. The purpose of this research is to examine the advancement of the dashboard for automobiles by enhancing current features or introducing new ones to satisfy consumer demands. A good dash board may enhance revenue for the business while also meeting client demands. (Padagannavar, 2016).

Figure 2.8: Problem In Car Dashboard (Material & USB Port) (Padagannavar, 2016)**.**

Durable materials should be chosen, as should the plastic's texture and the switch substance. The plastic used for the dashboard should be safe for the environment and free from dangerous substances. The dashboard should be robust and light in bulk since this might increase fuel economy. With high speed and rough roads, the dashboard should also dampen vibration and not make noise. The USB port is one of the issues with more modern Ford automobiles. The storage space in the dashboard known as the glove compartment has a USB port. Consequently, when utilising a phone that is wired to a USB port, Because the wire is positioned between the glove compartment and glove compartment door, the door cannot be closed. In order to solve the current issues, the dashboard design must be next-generation, which has many benefits besides cost, therefore it may enhance design dashboard by employing quality function deployment. (Padagannavar, 2016)

The three sets of customer needs are structured using an affinity diagram. With the use of this affinity diagram, it can pinpoint client needs. client satisfaction is ensured through categorising client expectations. We are told what to do by the market area, and how to execute it by the engineering area.

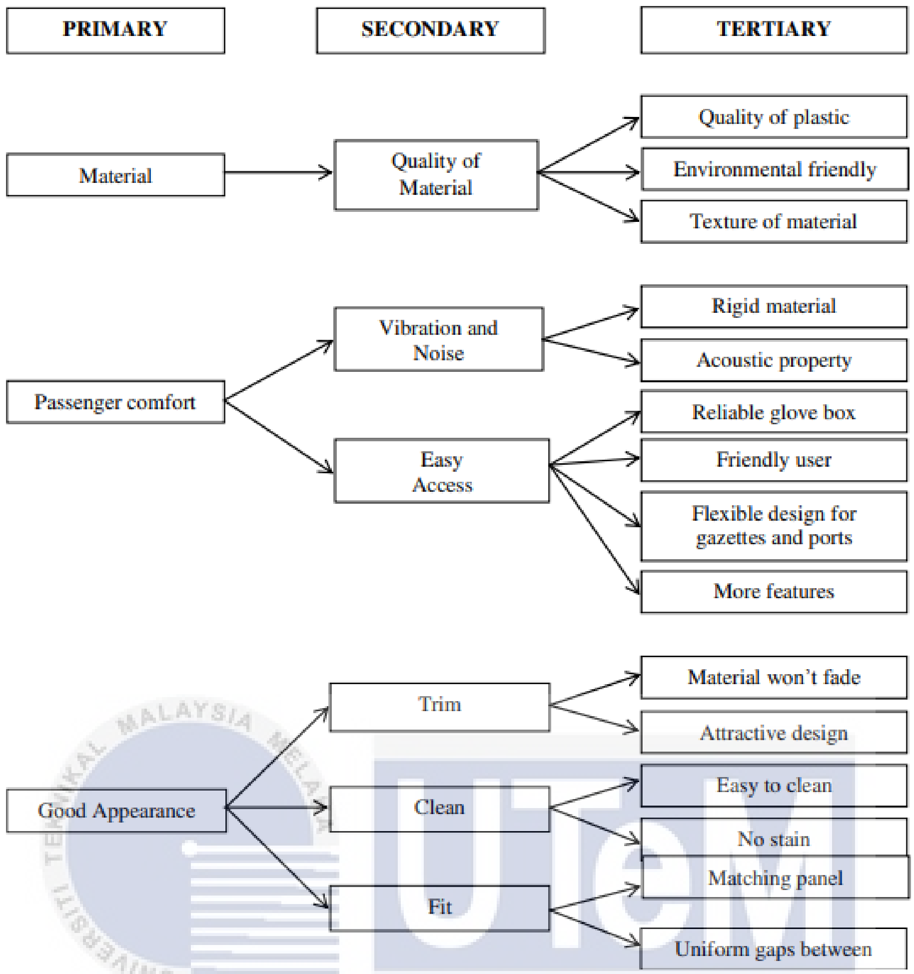

Figure 2.9: Example of Affinity Diagram (Padagannavar, 2016)

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the overall process flow of this project is discussed and visualized in Figure 3.1 beginning with defining the problem statement and conducting the literature review of Human Machine Interface (HMI) design, and the general design of HMI. Later, the questionnaire is developed to identify the customer requirement of HMI design. With the data collect from questionnaire from reviewer can conduct a design based on user needs.

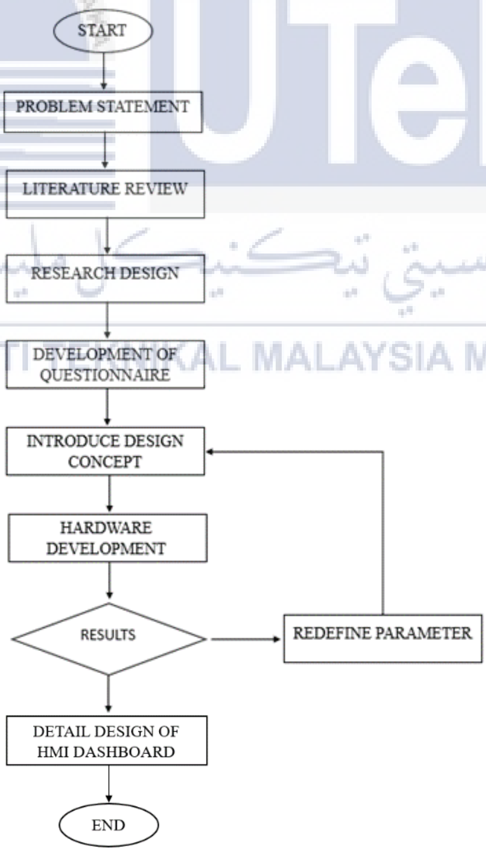

Figure 3.1: Flow Chart

Then after the first design concept have been selected from data, hardware development will be conducted with Raspberry Pi to develop interface and improvement on HMI design. Design optimization method will be conducted to identify the most desirable HMI design. After the best result achieve, detailing and finalizing the HMI design will be conducted.

3.2 Research Design

3.2.1 Aesthetic

The design of interactive user interface should be aesthetically pleasing to appeal to user and induce them to use personalized themes instead of the default one. People can become nicer on instinct if an interface is beautiful. The user interface design for the dashboard of an automobile should adhere to the standards of a harmonious image, lovely composition, and correct colour. Interfaces are made up of a variety of forms and textures that convey a range of emotions. Designers should intelligently combine and arrange visual components in such a way that the user interface's message is clear and consistent for them to instinctively understand.

In most cases, the automotive dashboard has a bilaterally symmetrical feature. The personalized theme should be designed based on the composition of the original interface, keeping a balance between the visual perception of the left side and the right side of the screen. Colour is an important component of an interface that conveys the personality of the interface and evokes people's associations of colour. Each of the three dimensions of colour; hue, saturation, and brightness play a role. Designers should use colour to accurately convey the style and atmosphere they want to express, while avoiding unpleasant colour combinations. The use of colour needs to be strictly controlled in the design of automotive user interfaces, as explained below.

Aesthetic differences exist due to the influence of various factors such as class, era, ethnicity and personal cultivation. The existence of aesthetic differences leads people to have different aesthetic standards and preferences. Users of the same car model also have aesthetic differences, and are bound to show different levels of preference for the same personalized theme, so the number and variety of themes should be increased to cover the needs of different users as much as possible. The classification criteria of themes are not uniform, but can be classified by mood, content, tone, etc. Under the premise of diversified styles, designers can refer to current popular design styles, and doing so can appeal to a wider range of consumers. Most of the popular colour among users are combination of black and white, red and black. If the color may be changed to the user's preference, that is handy.

Figure 3.2: Design 1 HMI (Menyi, 2023)

3.2.2 Usability

As it relates to driving safety, achieving the information display and interaction function for the dashboard of an automobile is crucial. It was important to take precautions not to significantly alter the original user interface throughout the design phase because the personalised interface was created after the original interface.

Generally, graphics need to be kept as simple as possible to increase the recognizability. Overly fancy graphics or overly rich colours can make information difficult to read and increase the risk of driving. The information on the dashboard reflects the operating status of the vehicle's systems and must be placed at the top of the interface without being obscured. Furthermore, this information should be displayed with emphasis and in high contrast to the background. It is important to note that some information (such as indicators and warning pop-ups) will only appeal in certain situations. So, space should be reserved for them and avoid complex design in these areas. In order to make drivers concentrated on driving information, it is advisable to use soft colours in the background to reduce the level of arousal. When drivers are driving in the dark or in tunnels, excessively bright screens can cause dazzle and make it difficult for the eyes to adjust to the light and discern the information on the screen, so low brightness colours should be used for the interface background.

Various colours each have unique symbolic connotations. Green denotes safety, yellow a caution, and red denotes restriction and danger. To prevent misinterpretation, colour usage needs to be kept to a minimum. various colours signify various alarm levels for warning lights and alert pop-ups, and these colours cannot be altered. When various states are to be expressed by different hues, colour symbols should be utilized correctly for elements like electric power and lane lines. In the event of strong power, blue or green, for instance, can represent safety, and orange or red, in the case of low power, can serve as a warning.

Figure 3.3: Design 2 HMI (Vector, 2023)

3.2.3 Experience

The excellent customized user interface of a vehicle dashboard may make consumers happy, not only because of the natural reaction prompted by aesthetics but also because of the positive dashboard-using experience.

One of the biggest features of the dashboard personalization theme is its personalized design, which is the connotation and extension of emotional design. When the design matches their personality, users feel that the product understands them and that it reflects their taste and identity. The advantage of personalized themes is that it conveys diversified personalities, and the user only has to pick the design that best fits him or her. Therefore, it is necessary to increase the number and type of themes.

Because some users like to stand out, the available personalised themes could fall short of their expectations. Because of this, specialised design services may be offered, allowing each user to have a unique user interface. To achieve participatory design, first supply pre-existing graphic pieces that users may independently mix and alter the colours. Users may only customise the interface to a certain amount, it should be highlighted, and this should not damage the interface's usefulness. Utilizing computer-aided design and interface graphics is the next step. With the help of a variety of algorithm-based image generators, users may convert album photos into a variety of interface-compatible styles and use them as background pictures or program AI to generate abstract patterns at random from a set of randomly generated images.

The user's driving process is mainly divided into several scenarios such as unlocking - starting - driving - parking - locking - charging and several other scenes. Only by connecting all the driving scenes together can closed- loop experience be completed. So, the personalized theme for the automotive dashboard should not only present the user interface in driving scenario, but also the interface under other different scenarios. Digital image achieves the interpretation of the plot through scene design (Shen, 2016). The personalized dashboard theme can become the carrier of the narrative, so that each trip becomes a story with the beginning, development, climax and the end, so that users become the protagonist of the story.

Figure 3.4: Design 3 HMI (Trevor Wernisch, 2022)

3.3 Evaluation of Design in Human Machine Interface

Putting together the data, including customer requests, technical specifications, and the connections between them, is the first stage in implementing the quality function deployment. The rankings are based on user feedback from surveys using Microsoft Forms and the Voice of the user. The table below illustrates how important each consumer demand is. The evaluation of the process and outcomes is the last step in determining customer needs. The procedure for determining client demands and the manner of data collection vary from product to product and also depend on the team responsible for product development's style of thinking. The significance of client wants is displayed in Table 1 below on a scale of 1 to 5, with 5 being the highest priority and 1 the lowest. The client preferences are shown in Table 1 below, which is sorted and rated. (Padagannavar, 2016)

Voice of the customer	Engineering characteristic	Customer needs
Dashboard and its functions should be easy to use	Structure and geometry	User friendly
Good ergonomics	Trim and finish	Good ergonomics
Superior looks	Quality of material	Attractive design
Nice looks	Structure and geometry	Aesthetic
Electronic functions and USB ports should be convenient to use	Distance to access the controls	Comfortable and convenient
It should not affect the existing features of the dash board	Dimensions and Number of components	Not interfere with vehicle operation
Attachments for gazettes and other items	Dimensions	Multipurpose
System should be durable and reliable	Operation cost	Reliable design
Labelling on screen	Structure and geometry	Informative
Attractive colour adjustment	Structure and geometry	Colour combination

Table 1: Voice of customer to customer needs.

3.3.1 Preliminary study using survey form.

Survey form is a method to interact with people by filling question. This is an effective method to obtain data to develop effective strategies and keep employees and customers happy. Example of online survey form are Microsoft Form, Google Form, and etc. so, the Microsoft was chosen because it is easy to use especially in rating requirements. At the very first question for this project need to know did user familiar with Human Machine Interface. From this question, it can gain info whether user familiar or not with this project. For the question 2 had to choose 1 out of 3 designs HMI dashboard which every design have their own criteria such as design 1 represents simplistic, design 2 represents comfortable and design 3 represents informative. For the last question which is the most important are the rating importance of dashboard requirement from user's experience. The criteria are customer needs from Table 1. User can rate up to 1 until 5 shows that 1 is very not important until 5 is very important.

Question		Requirement				
1. Do you familiar with Human Machine Interface?		Yes	No			
2. From these 3 designs, which one do you like.		Design 1 	Design 2 	Design 3 		
	Rating / Criteria	Very not important (1)	Somewhat not important (2)	Neutral (3)	Somewhat Important (4)	Very important (5)
3. Rating the importance of dashboard requirements from your experience	User friendly					
	Good ergonomics					
	Attractive design					
	Aesthetic					
	Comfortable and convenient					
	Not interfere with vehicle operation					
	Multipurpose					
	Reliable design					
	Informative					
	Colour combination					

Table 2: Shows Table of Survey Question.

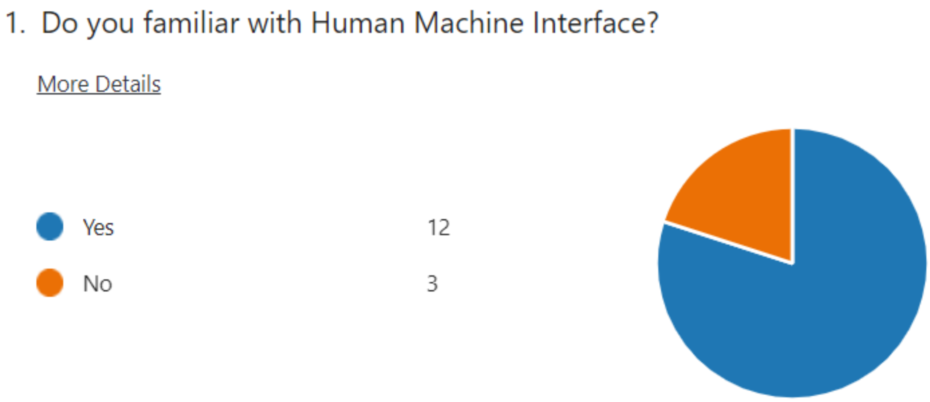

Figure 3.5: User's knowledge on HMI.

Figure 3.6:Dashboard design selection.

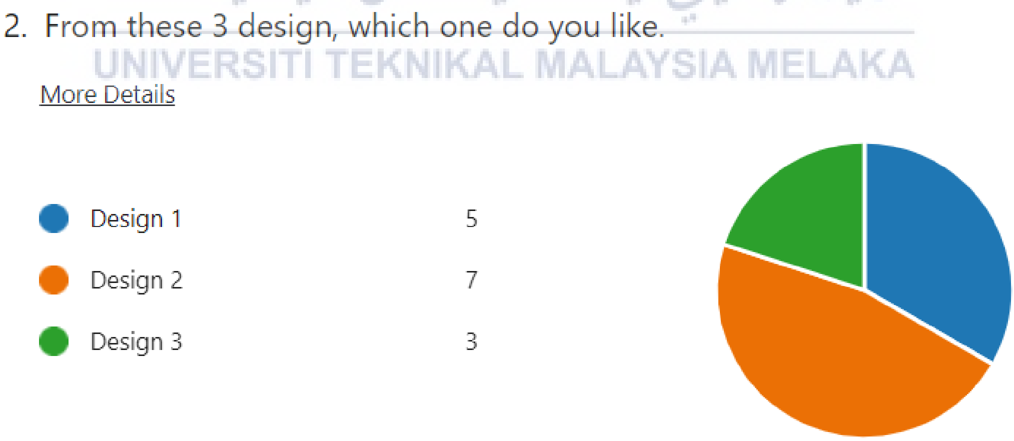

Figure 3.7: User HMI design selection.

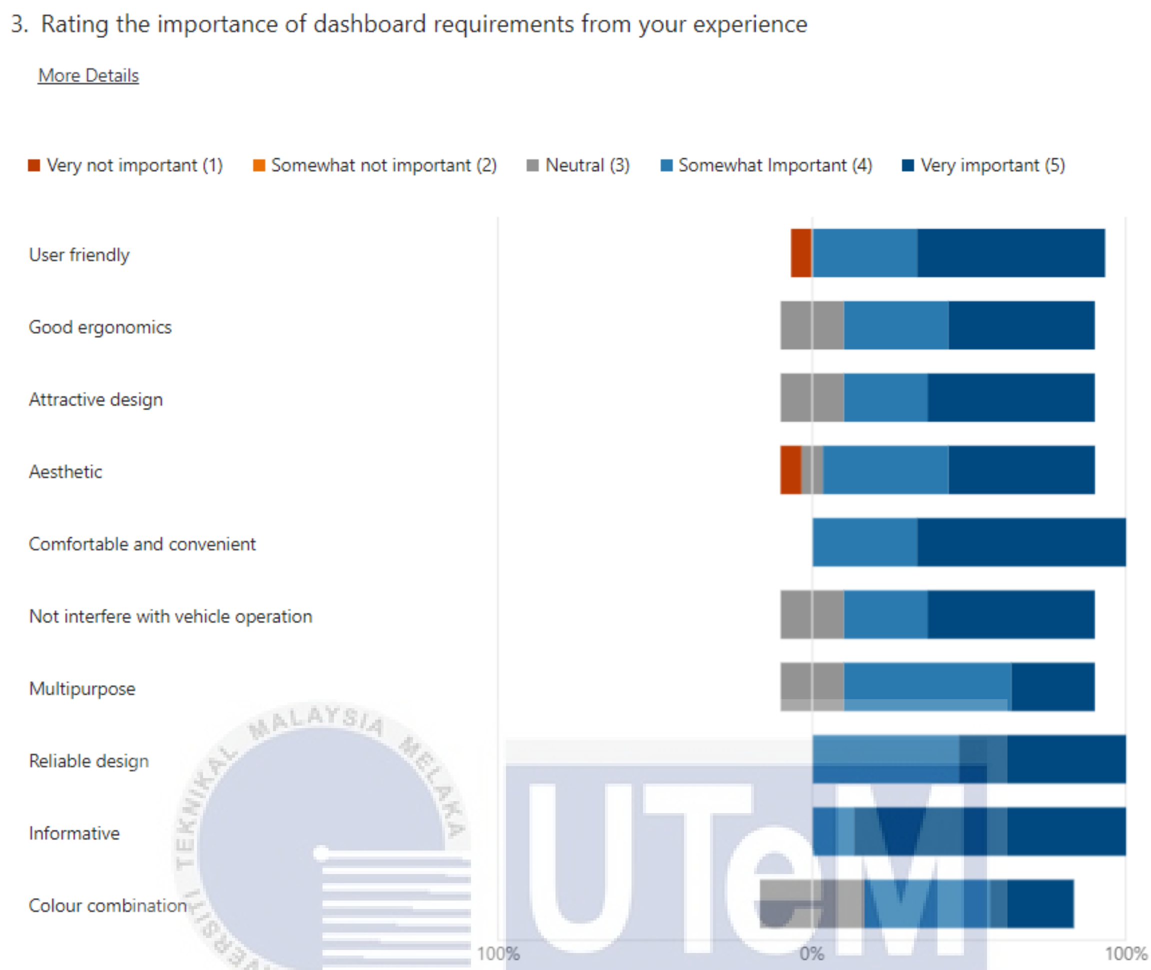

Figure 3.8: User dashboard requirement.

3.4 Hardware Development

In this section, describe how to convert information such as speed, battery status, and indicators. The Arduino Uno and Raspberry Pi are two of the most well-known microcontroller versions, and we compared their characteristics. Both the Raspberry Pi and the Arduino are well-liked and reasonably priced boards for learning programming and enabling user code to communicate with actual systems using a variety of sensors and actuators. Raspberry Pi and Arduino are similar in size and price, however they serve quite distinct purposes and have very different functions. (Krauss, 2016).

A tiny microcontroller board called an Arduino may be linked to external electronics like motors, relays, light sensors, laser diodes, loudspeakers, microphones, and more via a variety of connection ports on the board. According to Monk (2012), Arduino may be powered by a 9-V battery, a USB connection from a computer, or by any other power source. Numerous pins on the Arduino can be used as analog or digital inputs or outputs. When an output pin's "HIGH" setting is selected, the pin will generate a 5 V voltage in relation to its ground and can source up to 40 microamps of current. Half of the maximum current, or 20 microamps, is a safer amount to utilize when designing circuits (McRoberts, 2010). One of the advantages of Arduinos is the ability to save the experimental script in the board's memory and let it to run without interacting with computers or outside software, providing total independence, mobility, and precision.

The Raspberry Pi does not have any analog inputs, in contrast to the Arduino. Therefore, it has to connect the Pi to an interface board or utilize an external analog-to-digital converter (ADC) (Jindarat and Wuttidittachotti, 2015). The GPU performance is comparable to the original Xbox, while the CPU performance is comparable to a Pentium II 300 MHz processor. Intriguingly, it also contains a GPIO connector for expansion. It also has a USB port, HDMI port, 512MB of RAM, and SD Card storage. Raspberry Pi may be used as a desktop computer by connecting a monitor, keyboard, and mouse through HDMI and USB ports. It supports a variety of operating systems, including Raspbian, which is what our design runs on, and a Linux distribution based on Debian. Through the use of an Ethernet cable or USB Wi-Fi adapter, Raspberry Pi may be connected to a local area network and accessed remotely using SSH (Ferdoush and Li, 2014). A touch screen may be connected to using the display serial interface (DSI), and images or videos can be recorded using the camera serial interface (CSI).

It might be necessary to connect an Arduino and a Raspberry Pi for this project. Connecting sensors, actuators, and motors to the Arduino will allow it to send and receive data to and from the Raspberry Pi. The Raspberry Pi's computationally heavy activities may be separated from the Arduino's controlling tasks in this way.

Figure 3.9: An Arduino Uno

Figure 3.10: A Raspberry Pi

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The result will be categorized into 3 sections, the first section is the outomes of data from survey analysis. The participant's colour of car dashboard meter gauge in enhancing the overall driving experience. The survey divided by 6 section, each section represents colour elements in the gauge meter which is colour section for scale, inner circle, needle circle, needle section, font, value, big and small scale. Respondent needs to choose designated colour from Colour 1 to Colour 3 in each section. The second section will be focus on structure analysis of car dashboard using Altair Inspire. This section, 2 design provide to be analyze to see which design are the best in term of Safety Factor, Von Mises Stress, Displacement, and Max Shear Stress. As result, design 2 were the best selection based on all factor requirements. Lastly, the interface of gauge meter that interact using keyboard accelerate and decelerate by pressing and release 'w' button. The button 'w' acting as pedal in car as the button 'w' press and hold, the meter show the value accelerating while release it, the meter show value decelerating. Also the colour theme can be adjust in python coding freely.

4.2 Survey Analysis

4.2.1 Importance of Colour Implement in Car Dashboard Results

This survey was conducted via Microsoft Forms to obtain data from analysis of car dashboard meter gauge colour selection. The total individuals that participate in comprehensive survey on car dashboard meter gauges colour selection is 40 respondents.

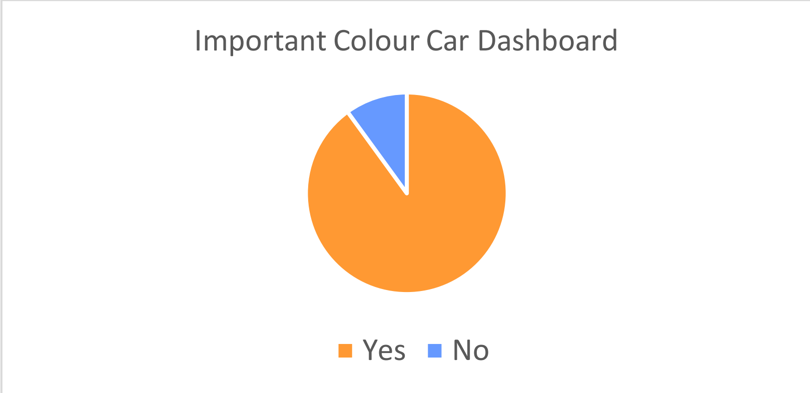

Figure 4.1: Pie Chart Important to Choose Colour of Car Dashboard

According to Figure 4.1, it shows the importance of choosing colour in car dashboard. The orange color will be preferred by “Yes” respondent participants, whereas the blue color will be preferred by “No” respondent participants. “Yes” makes up most respondents (36), while “No” makes up the minority (4). A notable tendency is revealed by the survey results on how important it is to choose the colour of a vehicle's dashboard. A total of 36 respondents, or a significant portion of the participants, strongly believed in the importance of this aesthetic aspect. This group probably believes that the colour of the vehicle dashboard plays a major role in the entire driving experience and the driver's level of pleasure with the vehicle (Li et al., 2017). Conversely, a mere minimum of 4 respondents downplayed the significance of choosing a particular colour for the dashboard of an automobile. The difference between the two groups' replies highlights the general agreement that most people's tastes are significantly influenced by the dashboard's colour.

4.2.2 Colour Selection for Scale Car Dashboard

Figure 4.2: Choosing Colour for Scale Section

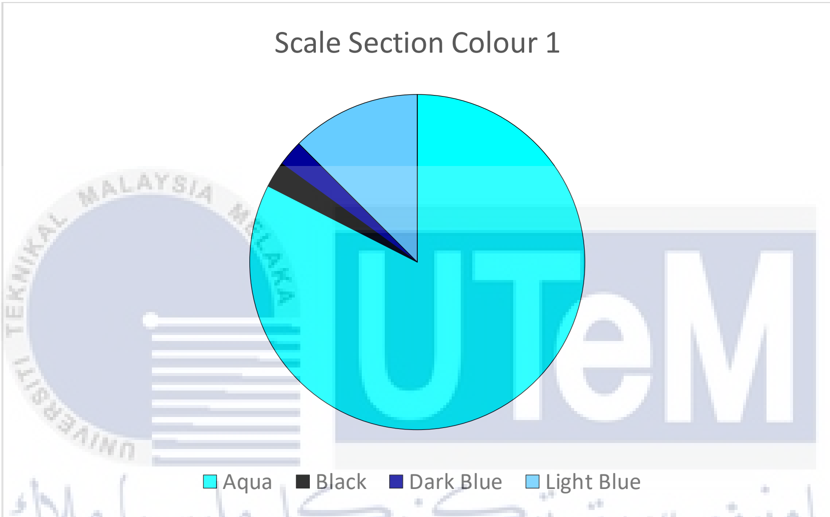

Figure 4.3: Pie Chart Choosing Scale Section Colour 1

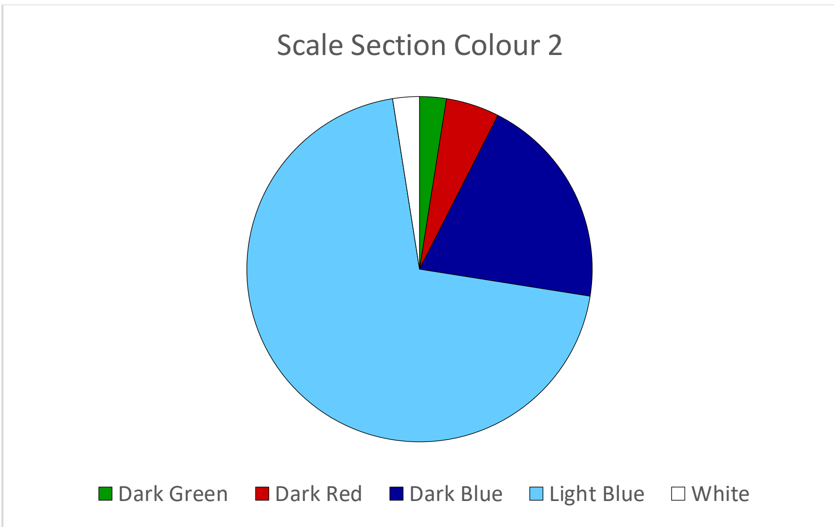

Figure 4.4: Pie Chart Choosing Scale Section Colour 2

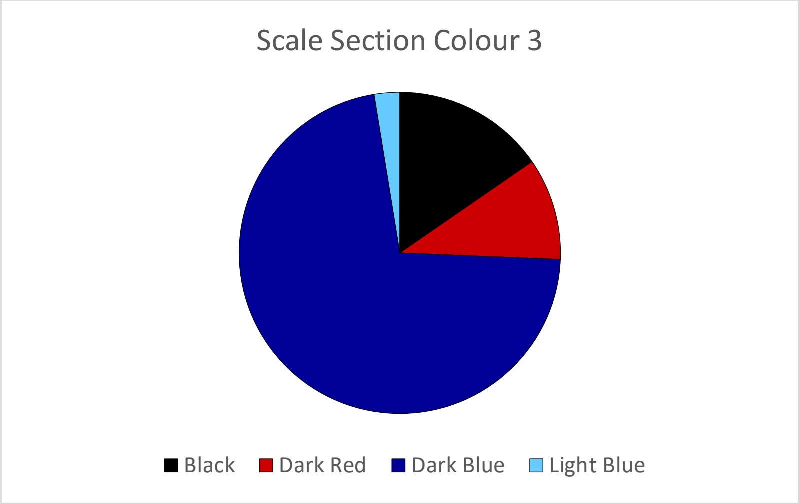

Figure 4.5: Pie Chart Choosing Scale Section Colour 3

Based on Figure 4.2, the respondents should make the decision to choose colour for scale section in car dashboard. The results of the survey about colour choices for an automobile dashboard's scale area offer fascinating new perspectives on user preferences. Derived from the insights presented in Figure 4.3, 33 respondents chose aqua as their preferred colour 1 for the scale section, with a sizable majority supporting this option. This overwhelming predilection for aqua reveals a distinct propensity towards a colour that is generally connected with tranquilly and a sense of calmness (Werner, 2018). The fact that aqua emerged as the most popular option may indicate that drivers generally want a visually relaxing and beautiful driving environment.

In accordance with figure 4.3, light blue is clearly the colour 2 of choice for the scale portion of a car dashboard, as indicated by the survey's results, which saw 28 respondents rank it as their favourite option. This preference for light blue can be explained by its connections to peace, tranquillity, and an open feeling. Light blue is frequently associated with tranquil waters and clean skies, which may improve the driving experience by fostering a pleasant mood. The psychological influence of this colour on encouraging a calm and concentrated mood may be the main reason for its appeal.

The results of the survey about the colour 3 of a car dashboard's scale area reveal that dark blue is the colour that most people like, with 28 out of 40 respondents choosing it. There are various reasons for this propensity for deep blue. First of all, dark blue is frequently connected to refinement, formality, and dependability. People looking for a sophisticated and elegant interior for their cars may find the deep and rich colour to have a timeless and classic aesthetic. Second, compared to lighter blue hues, dark blue is thought to evoke feelings of serenity and calmness along with a hint of profundity and gravity. Due to its psychological connotation of serenity, dark blue may be a desirable colour for a location where drivers spend a lot of time, which could enhance the tranquilly of the driving environment. Furthermore, dark blue may be seamlessly incorporated into a variety of car models due to its versatility and tendency to go well with varied interior design aspects.

4.2.3 Colour Selection for Inner Circle Car Dashboard

Figure 4.6: Choosing Colour for Inner Circle Section

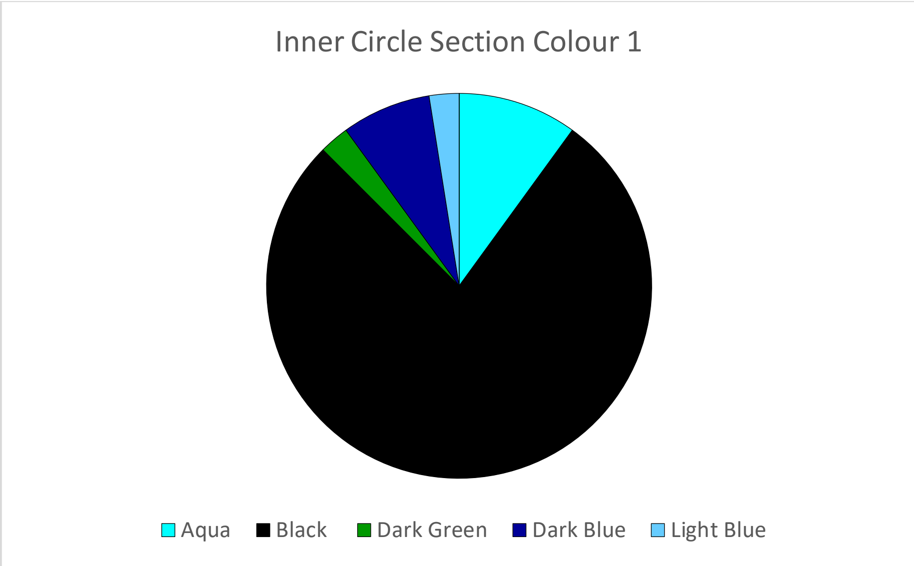

Figure 4.7: Pie Chart Choosing Inner Circle Section Colour 1

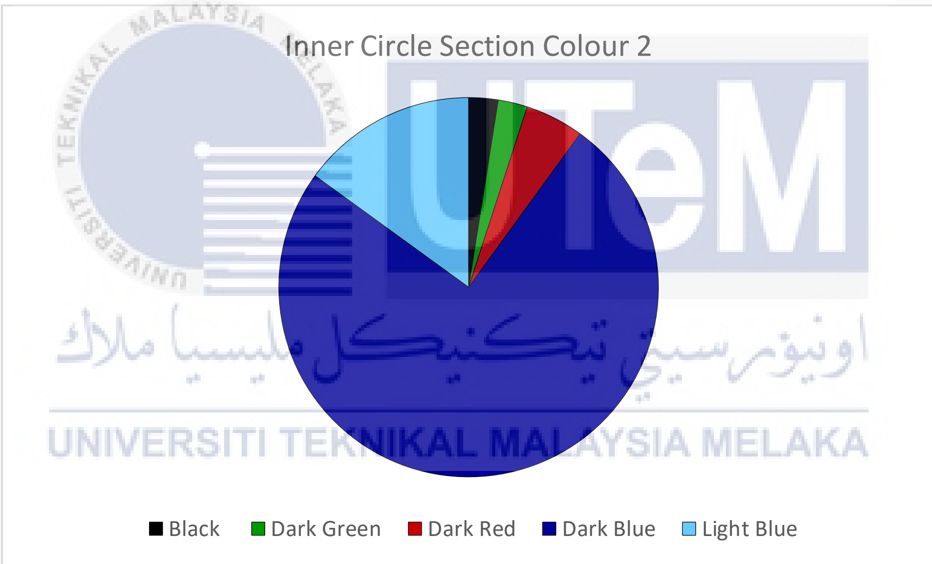

Figure 4.8: Pie Chart Choosing Inner Circle Section Colour 2

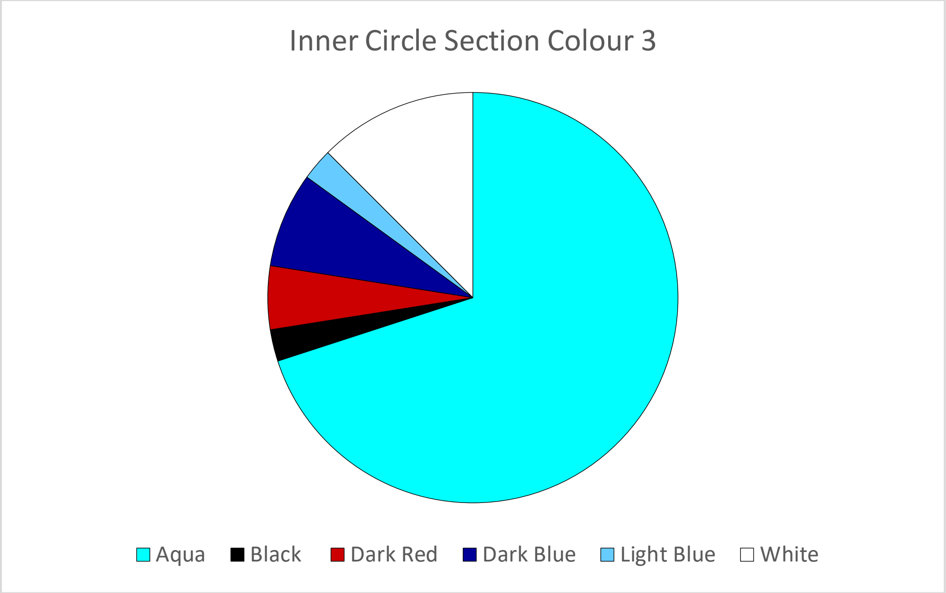

Figure 4.9: Pie Chart Choosing Inner Circle Section Colour 3

Based on Figure 4.6, the respondents should make the decision to choose colour for inner circle section in car dashboard. In Figure 4.7, which asked participants to indicate their favourite colour 1 for the inner circle region of a car dashboard, black was chosen by 31 respondents as their top preference, making it the clear winner among the participants. The prominence of black in this particular section of the dashboard is influenced by multiple variables. First of all, people that value a sleek and fashionable appearance in their cars like to favour black because it is frequently connected to refinement and classic elegance. Additionally, black is thought to be able to hide dust, fingerprints, and scratches, which is useful for a high-touch region like the dashboard's inner circular part.

Based on Figure 4.8, dark blue was chosen as the most popular colour by 30 respondents in a survey carried out that targeted to identify the ideal colour 2 for the inner circle part of a car dashboard. This is due to dark blue surfaces which can make driving more enjoyable by reducing glare from the sun or artificial light sources. This is especially crucial for parts like the dashboard, which the driver frequently looks at. Then, dark blue is frequently used because it offers high contrast and visibility for things like the dashboard's inner circle. It is readable and easily observable against lighter backgrounds, especially in low light.

As shown in Figure 4.9, the results of a recent survey regarding the choice of colour 3 for the inner circle part of the dashboard of an automobile are quite impressive. Aqua received the most votes out of all the colour possibilities, with 28 respondents selecting it, making it the clearest choice. This is as a consequence of considering it's a relatively bright and distinct colour, aqua helps improve contrast and visibility within the car. Some vital gauges, such fuel indications, and speedometers, are in the inner circle of the dashboard. These components can be made to stand out and be simpler to read and understand by using a colour like aqua.

4.2.4 Colour Selection for Needle Circle Car Dashboard

Figure 4.10: Choosing Colour for Needle Circle Section

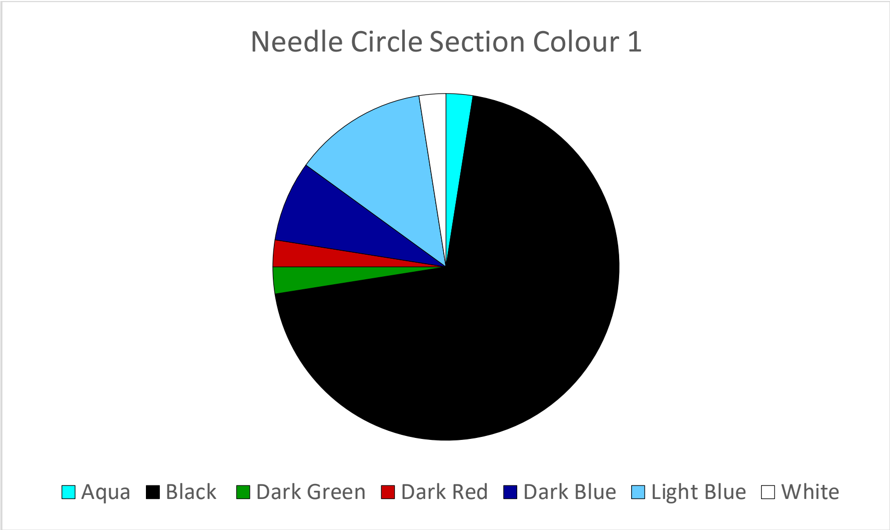

Figure 4.11: Pie Chart Choosing Needle Circle Section Colour 1

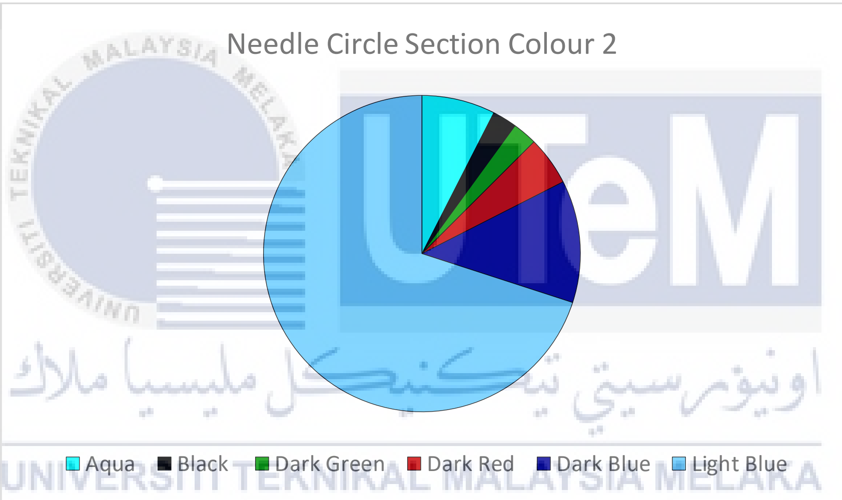

Figure 4.12: Pie Chart Choosing Needle Circle Section Colour 2

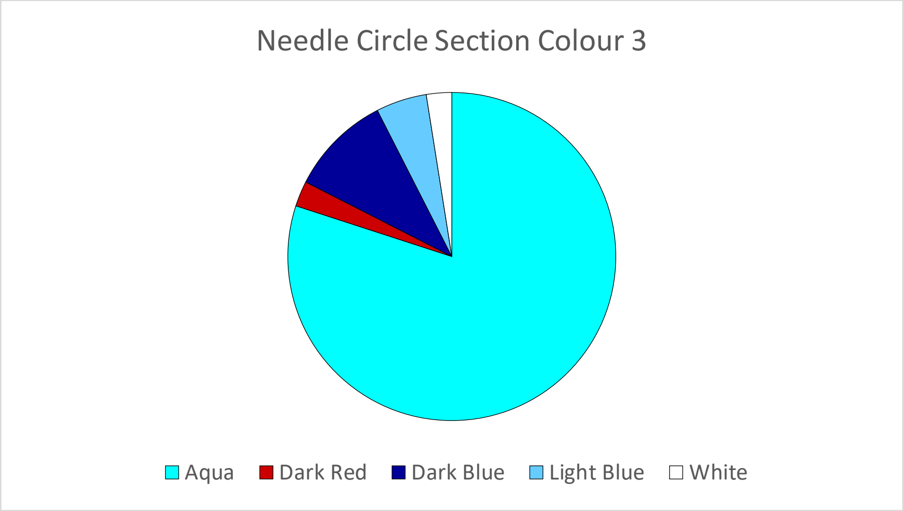

Figure 4.13: Pie Chart Choosing Needle Circle Section Colour 3

In compliance with Figure 4.10, the respondents should make the decision to choose colour for needle circle section in car dashboard. Gleaned from Figure 4.11, the results showed a definite preference, with respondents favoring black above all other options. Of the 28 participants, a sizable majority chose the colour black. The inside of cars can quickly develop wear and tear due to the exposure to different environmental conditions. The needle circular section's choice of black helps conceals small flaws, guaranteeing that the part will remain well-maintained and aesthetically beautiful even after prolonged use. Black automobile interiors are attractive overall because this practical feature supports the demand for a clean, well-presented driving environment.

Based on Figure 4.12, interesting results came from a study asking respondents what colour 2 they would most like to see for the needle circle portion on a dashboard; light blue was clearly the most popular choice. Of the participants, a significant 28 said that they preferred this specific shade. Light blue is known for its high visibility and contrast, especially in well-lit conditions. This makes it easier for drivers to quickly and accurately gauge the information displayed on the dashboard, such as speed or RPM, without straining their eyes.

According to Figure 4.13, a substantial preference for aqua was found in the results of a survey about colour preferences for the needle circular section of the dashboard of an automobile. A fantastic 32 respondents chose aqua as their colour of choice. This is because although everyone reacts differently to colours, aqua is typically thought of as a colour that encourages emotions of peace and relaxation. A soothing tone like aqua may contribute to a favourable mental state when drivers glance at the dashboard, which may enhance focus and concentration while driving.

4.2.5 Colour Selection for Needle Car Dashboard

Figure 4.14: Choosing Colour for Needle Section

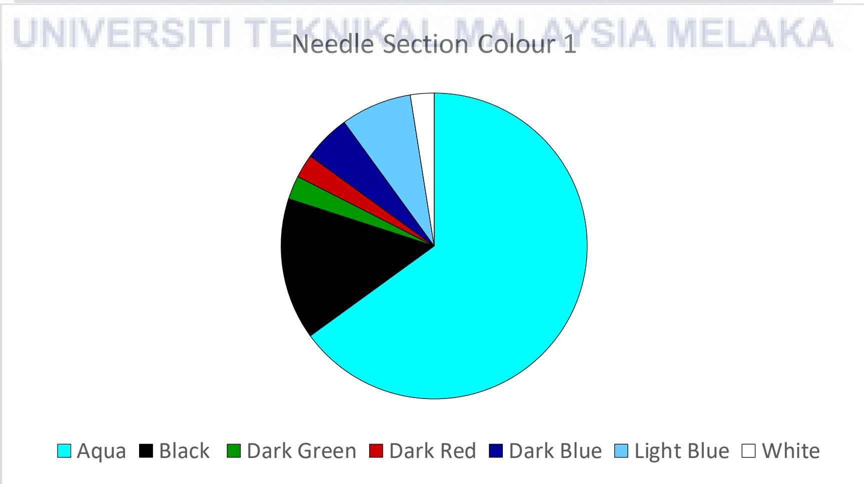

Figure 4.15: Pie Chart Choosing Needle Section

Based on Figure 4.14 and Figure 4.15, a recent survey asking participants to choose their favorite colour for the needle section of vehicle dashboards revealed a clear preference for aqua, as 26 out of the participants selected this shade. This is due to aqua can also be used for nighttime driving in order to preserve visibility. The backlit screens or ambient lighting seen in many modern automobile dashboards ensure that the needle is always visible in low light thanks to aqua's brightness. This enhances the entire driving experience by making it easier to navigate and keep an eye on important information at night.

4.2.6 Colour Selection for Font and Value Section Car Dashboard

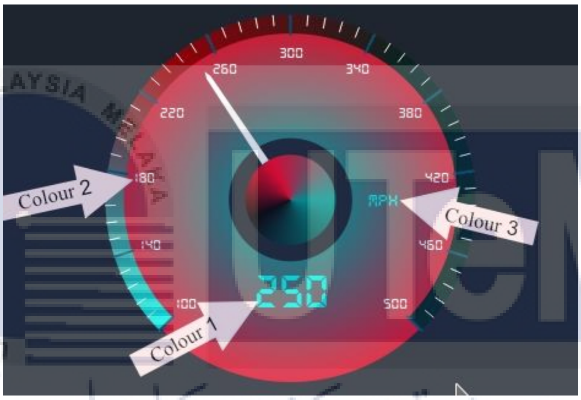

Figure 4.16: Choosing Colour for Font and Value Section

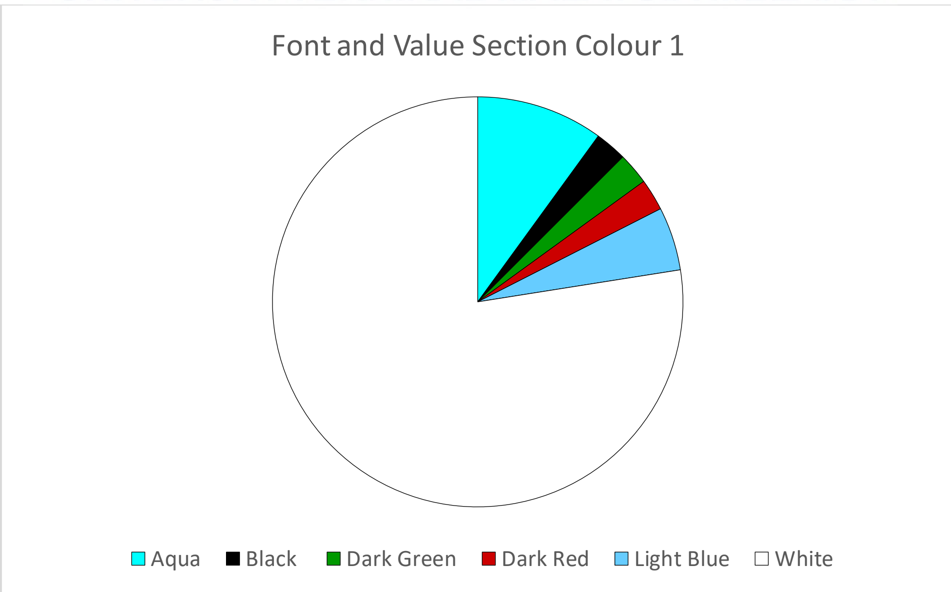

Figure 4.17: Pie Chart Choosing Font and Value Section Colour 1

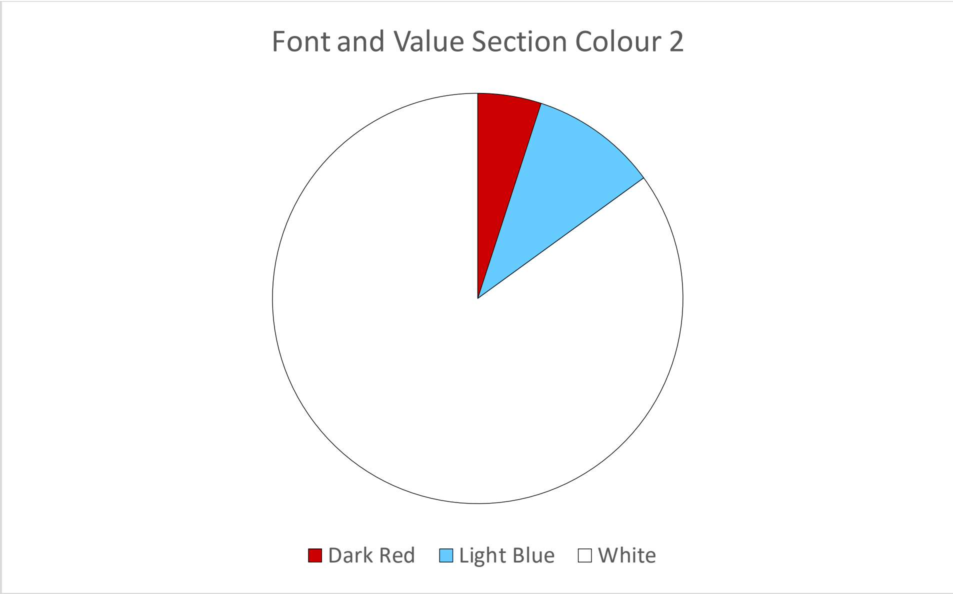

Figure 4.18: Pie Chart Choosing Font and Value Section Colour 2

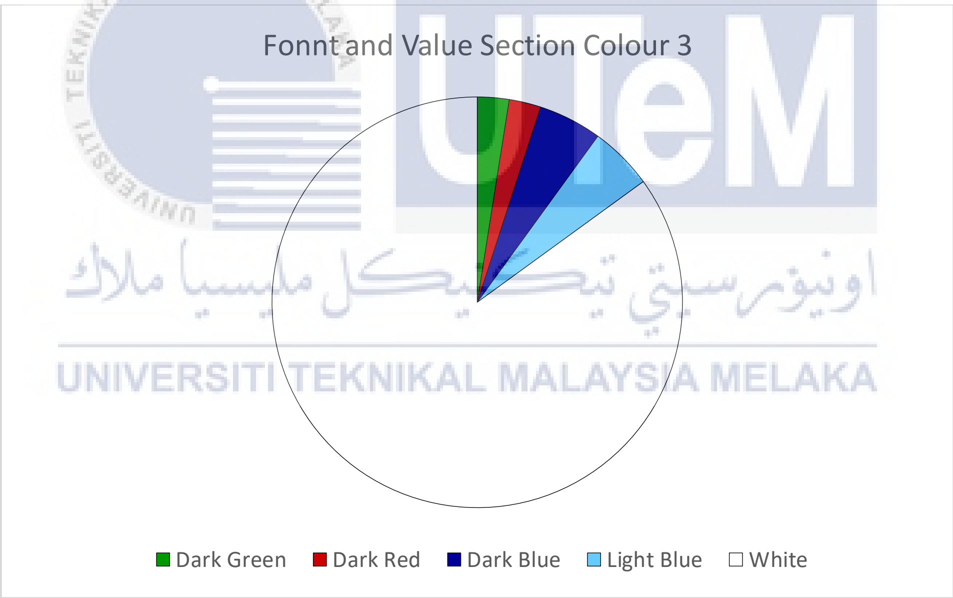

Figure 4.19: Pie Chart Choosing Font and Value Section Colour 3

Based on Figure 4.16 until Figure 4.19, white was the most popular choice across all three categories in a recent study to find preferences for the font and value areas of an automobile dashboard. A total of 31 respondents preferred white for font colour 1, and an even larger total of 34 preferred white for font colour 2 and 3. First of all, white is known for being clear and legible, making information on the dashboard easy to read even in different lighting situations. For drivers who need to understand data rapidly and precisely about fuel levels, speed, or other important indicators, this is essential. Then, White is frequently linked to a minimalist and contemporary style. The interior of the vehicle appears sleek and elegant thanks to the use of white for the text and values, which is in line with current design trends.

4.2.7 Colour Selection for Big and Small-Scale Section Car Dashboard

Figure 4.20: Choosing Colour for Big and Small-Scale Section

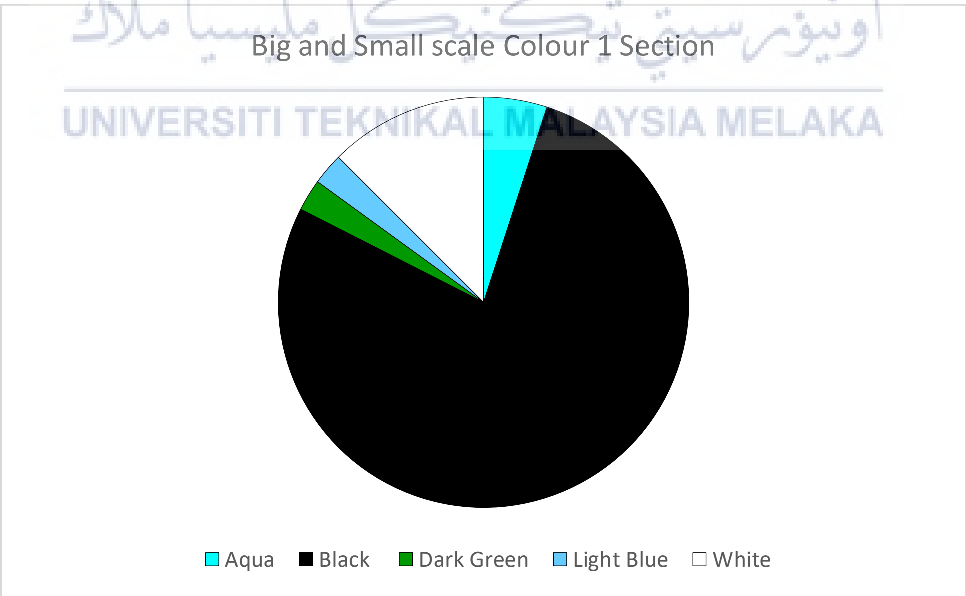

Figure 4.21: Pie Chart Choosing Big and Small-Scale Section Colour 1

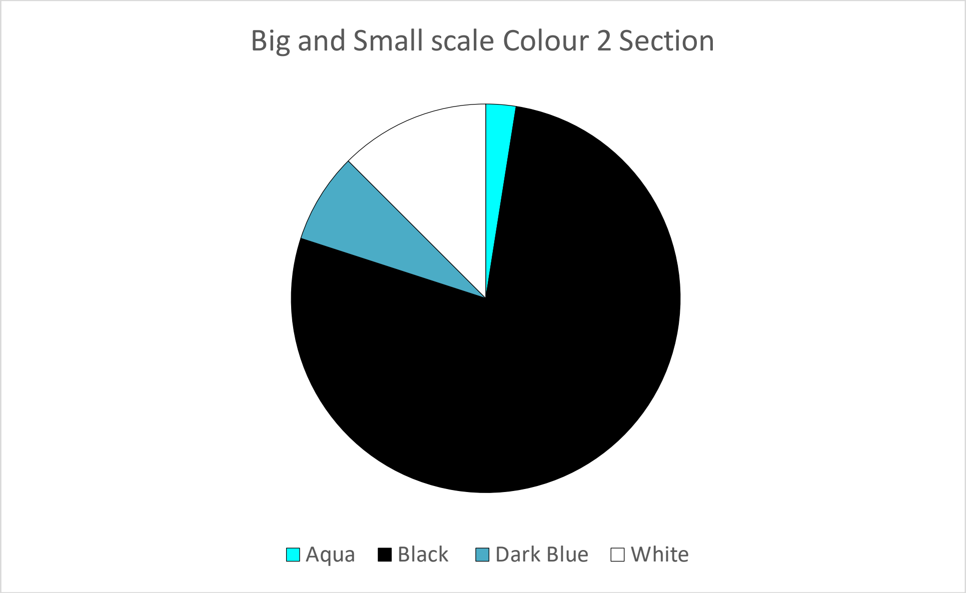

Figure 4.22: Pie Chart Choosing Big and Small-Scale Section Colour 2

Based on Figure 4.20, Figure 4.21 and Figure 4.22, a recent survey that focused on choosing colours for the large- and small-scale areas of car dashboards, black was surprisingly preferred by 31 respondents, who preferred both colour 1 and colour 2. This double consistency in desire highlights the importance of black in car design. The propensity of black to evoke a sense of refinement and modernity can be used to justify its use for both the large and small size sections. Black gives the interior of a car a sense of refinement and is frequently associated with elegance and timeless style. Because of its neutral and adaptable character, it integrates seamlessly with different dashboard designs, resulting in a unified and visually appealing overall appearance. Moreover, black also helps to minimize distractions and establish a visual hierarchy that is concentrated. It makes the numbers and scales stand out clearly, guaranteeing that the driver's attention is focused on the important information. The dashboard design is made more intuitive and user-friendly by this simple and uncluttered display, which improves the driving experience as a whole.

4.3 Structural Analysis

To carried out the result of the safety of factor, a structure analysis in Inspire was done on the two design of car dashboard. The result on each design were applied force with 50N on the top of the dashboard represents hand pressing. Both designs were applied same material which is Plastic (Nylon) with 3mm thickness.

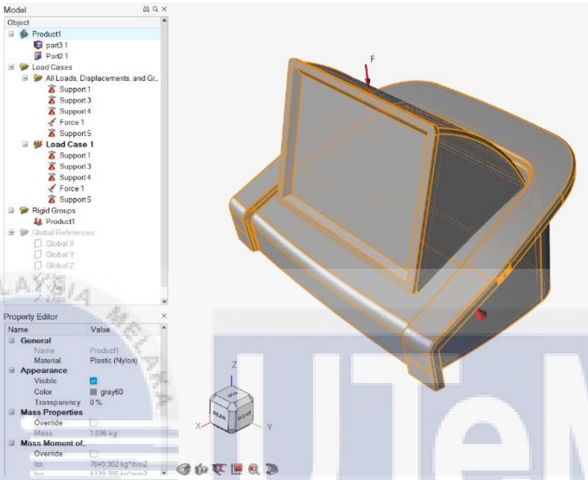

Figure 4.23: Car Dashboard Design 1

Figure 4.24: Car Dashboard Design 2

One of the huge aspect in structural analysis are safety factor. This could lead major differences in user experience in driving safety. In figure 4.25 and figure 4.26 shows the result of safety factor for both design. Design 1 with 1.2 as minimum value of safety factor and 1778.8 as value of maximum while Design 2 with 1.7 as minimum value and 1.519e+07 as maximum value. In this scenario, it shows the Design 2 have higher minimum value of safety factor than Design 1 which indicate more safetiness when force applied.

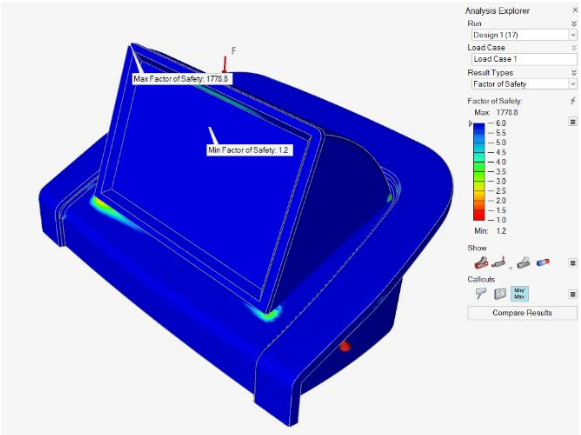

Figure 4.25: Safety Factor of Design 1

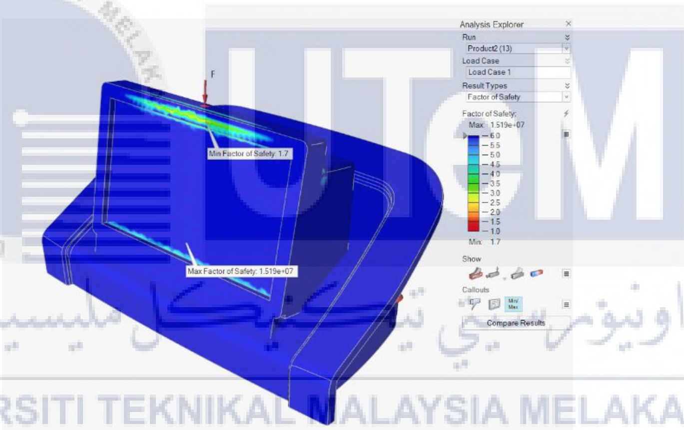

Figure 4.26: Safety Factor of Design 2

This section shows result of displacement for both designs in figure 4.27 and figure 4.28. Displacement values are paramount indicators of a structure's response to applied loads. Design 1 and design 2 showcases a minimum displacement of 0 mm, underscoring its stability under the applied conditions. Design 1's maximum displacement reaches 3.166e+00 mm, indicating the degree of structural deformation encountered throughout the analysis. With a maximum displacement of 1.079e+00 mm, Design 2's displacement is noticeably smaller, indicating a stiffer reaction to applied force.

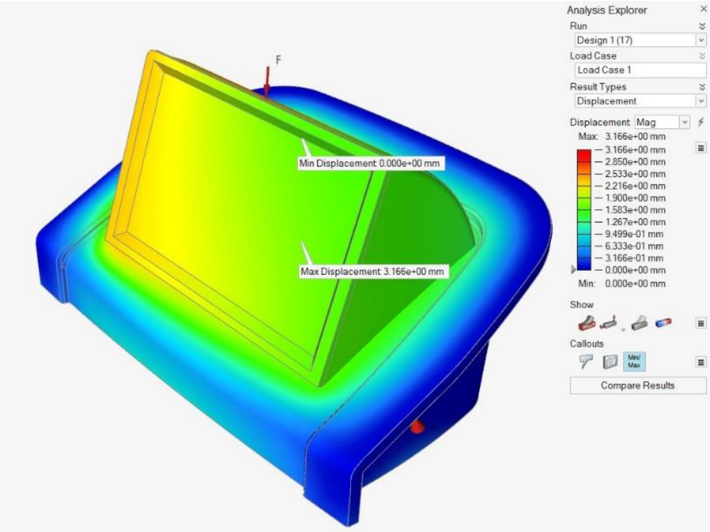

Figure 4.27: Displacement value of Design 1

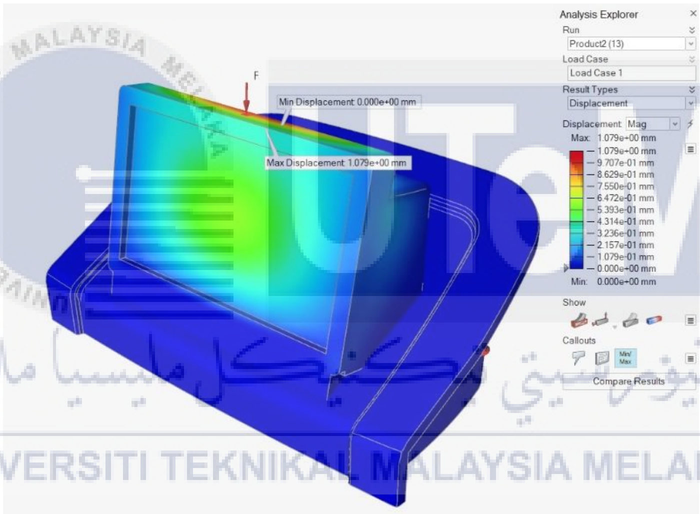

Figure 4.28: Displacement value of Design 2

This analysis conducting with a thorough investigation of structural integrity and explores the von Mises stress results for Design 1 and Design 2 in by Altair Inspire as shown in figure 4.29 and figure 4.30. A crucial factor in determining a material's vulnerability to failure under different loading scenarios is the von Mises stress. The minimum von Mises stress of 0 MPa is shown in Designs 1 and Design 2, suggesting that stress-induced issues are not present at lower loads. The maximum von Mises stress for Design 1 is impressively high at 6.521e+01 MPa, providing insight into the structure's possible critical areas and stress distribution. At 4.351e+01 MPa, the maximum von Mises stress for Design 2 is noticeably lower, indicating a more cautious stress distribution. The objective of this analysis is to explain the variations of von Mises stress in both designs, providing significant insights into their individual structural performances and identifying potential areas for optimization.

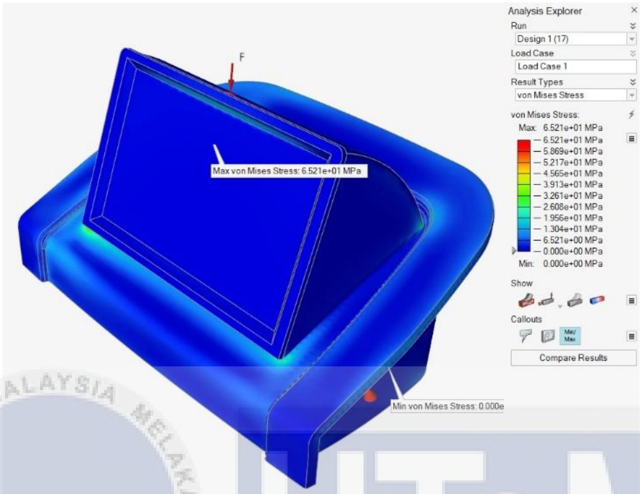

Figure 4.29: Von Mises Stress value of Design 1

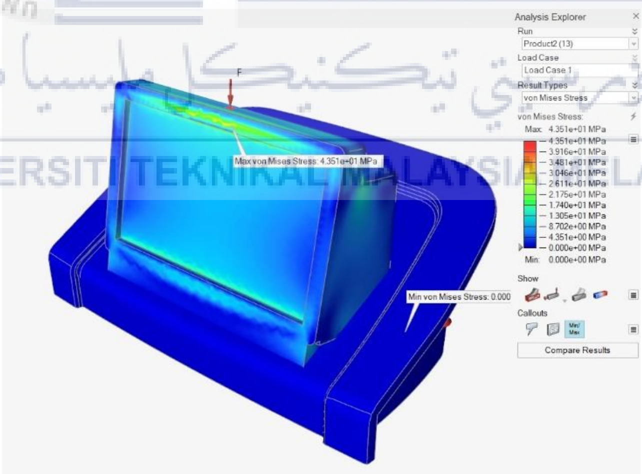

Figure 4.30: Von Mises Stress value of Design 2

Last but not least for result of max shear stress structural analysis based on figure 4.31 and figure 4.32. A critical factor in determining the likelihood of material breakdown under various loading scenarios is max shear stress. For Design 1 and Design 2, there are no shear-induced issues at lower loads, as seen by the minimum Max Shear Stress of 0 MPa, suggesting a strong shear stress resistance at reduced loading conditions. The distribution and magnitude of shear stresses for Design 1 throughout the structure are clarified by the impressively high maximum Max Shear Stress of 3.463e+01 MPa. A cautious shear stress distribution is suggested by Design 2's highest Max Shear Stress, which is noticeably lower at 2.503e+01 MPa. By examining the slight variations in Max Shear Stress between the two designs, this analysis hopes to provide light on the structural characteristics of each and identify possible areas for improvement.

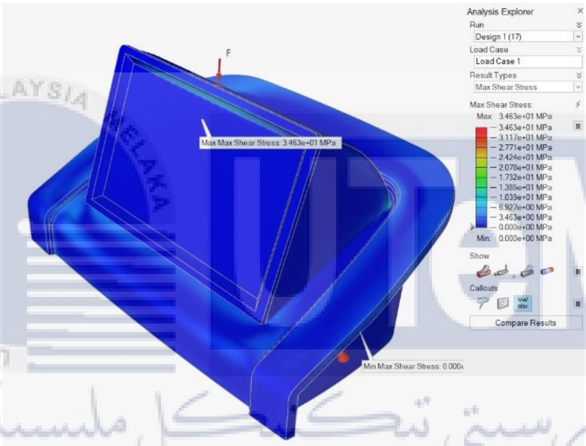

Figure 4.31: Max Shear Stress of Design 1

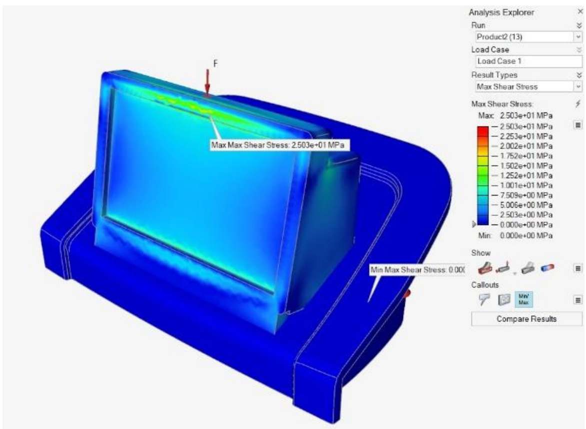

Figure 4.32: Max Shear Stress of Design 2

Finally, a detailed understanding of the structural behaviors of Designs 1 and 2 has been obtained by the extensive use of Altair Inspire to analyze Safety Factor, Displacement, Von Mises Stress, and Max Shear Stress. Both designs' strong Safety Factor values attest to their resilience and capacity to bear imposed loads with sizable safety margins. In the meantime, the displacement data provided insight into the structural deformations under different loading situations, showing that Design 1 responded more noticeably than Design 2, which exhibited more rigid behavior. By examining the material's vulnerability to failure, the Von Mises Stress analysis identified crucial stress spots inside the structures. A larger maximum Von Mises Stress was shown in Design 1, suggesting possible areas for reinforcement or improvement. On the other hand, the stress distribution in Design 2 was more cautious. The structures' reaction to shear forces was finally brought to light by the analysis of Max Shear Stress. The Max Shear Stress values for Design 1 were greater, indicating that shear-induced consequences must be carefully considered. Design 2, with lower Max Shear Stress values, exhibited a more durable reaction to shear forces.

	Design 1	Design 2
Displacement	Min: 0 mm Max: 3.155e+00 mm	Min: 0 mm Max: 1.079e+00 mm
Safety factor	Min: 1.2 Max: 1778.8	Min: 1.7 Max: 1.519e+07
Von Mises Stress	Min: 0 MPa Max: 6.521e+01 MPa	Min: 0 MPa Max: 4.351e+01 MPa
Max Shear Stress	Min: 0 MPa Max: 3.463e+01 MPa	Min: 0 MPa Max: 2.503e+01 MPa

Table 3: structural analysis result of Design 1 and Design 2.

4.4 Setup and Coding Process using Python

Using a Raspberry Pi for dashboard design in a car is an excellent option because of its adaptability, low cost, and supportive community. With the ability to run multiple operating systems, the Raspberry Pi, a tiny computer the size of a credit card, enables developers to construct personalised dashboards. Its cheap price makes it perfect for do-it-yourself projects, allowing you to experiment without having to make a big investment. There are lots of internet resources and forums for cooperation and troubleshooting available thanks to the vibrant Raspberry Pi community. The Raspberry Pi's GPIO pins make it easier to integrate electronics with the sensors and screens that are frequently found in dashboards of cars. Because of its small size, it may be easily incorporated into the dashboard of an automobile. Furthermore, minimising power usage and maintaining compatibility with the vehicle's electrical system depend heavily on the energy-efficient design. Support for open-source software gives developers access to a wide range of customisation tools and libraries. The multimedia features of the Raspberry Pi are ideal for a range of dashboard information requirements, including entertainment and navigation. In dashboard projects, safety and adherence to automotive requirements should be taken into account.

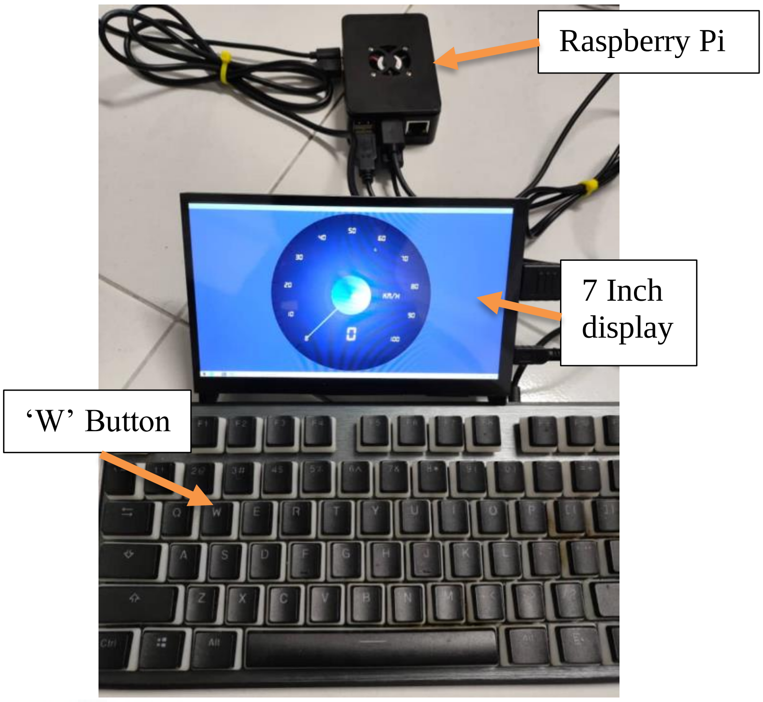

Figure 4.33: Hardware setup of Raspberry Pi and Display Screen

Figure 4.34: Increasing Meter when hold 'W' button

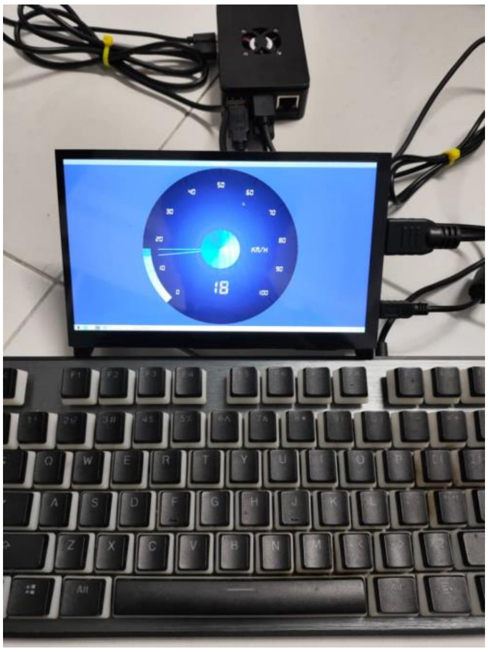

Figure 4.35: Decreasing Value when release 'W' button

To carried out the interface of development car dashboard meter using Python within Visual Studio Code was done with a design based on colour from comprehensive survey of gauge meter colour selection. The graphical user interface (GUI) for this project is constructed using the reliable Qt framework, with the aid of Qt Designer to speed up the design process. The Analog Gauge Widget, which is a notable interface element, is carefully incorporated into the widget file to dynamically display important data.

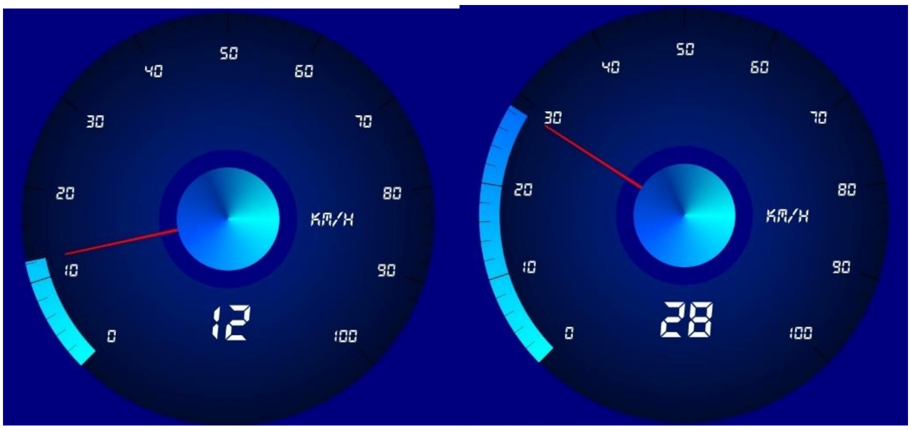

Figure 4.36: Analog Gauge Meter Interface

The project uses organized coding, splitting up its functions into different files. The graphical user interface (GUI) for PyQt5 is accessed through the ‘Dashboard.py’ file. It uses the ‘MainWindow’ class to control the configuration and personalization of the GUI as a whole. To specify the look, scale, and units of the analog gauge, this class instantiates and configures the ‘AnalogGaugeWidget’.

```
import os
import sys
import serial


from PyQt5.QtWidgets import QMainWindow, QWidget, QApplication
from PyQt5.QtGui import QFont, QFontDatabase
from PyQt5.QtCore import QTimer
from PyQt5.QtCore import QTimer, Qt, QElapsedTimer
from PyQt5.QtGui import QKeyEvent
from interface_ui import Ui_MainWindow


###############################################################
#CONVERT UI TO PyQt5 py file
####################################
os.system("pyuic5 -o interface_ui.py interface.py")

###############################################################
#Import Ui file
####################################

from interface_ui import *

###############################################################
#MAIN WINDOW CLASS
####################################
class MainWindow(QMainWindow):
    def __init__(self, parent=None):
```

Figure 4.37: Coding structure to import interface.ui and AnalogGaugeWidget.py into Dashboard.py

```python
##################################################
#MAIN WINDOW CLASS
######################################
class MainWindow(QMainWindow):
    def __init__(self, parent=None):
        QMainWindow.__init__(self)
        ##########################################
        #Setup the Ui main Window
        ######################################
        self.ui = Ui_MainWindow()
        self.ui.setupUi(self)

        ##########################################
        #Show Window
        ######################################
        self.show()

        ##########################################
        #Customize
        ######################################
        self.ui.widget.enableBarGraph = False

        ##########################################
        # Set gauge units
        ##########################################
        self.ui.widget.units = "Km/h"

        ##########################################
        # Set minimum gauge value
        ##########################################
        self.ui.widget.minValue = 0
```

Figure 4.38: ‘MainWindow’ class to show interface from Qt Designer

Various parameters, including unit, minValue, maxValue, scalaCount, gauge theme, big and small scale color, font preferences, and needle color, are specified within this class based on respondent survey of colour selection. These settings define the appearance and behavior of the analog gauge, creating a visually appealing and informative interface.


```python

        ##########################################
        # Set gauge units
        ##########################################
        self.ui.widget.units = "Km/h"

        ##########################################
        # Set minimum gauge value
        ##########################################
        self.ui.widget.minValue = 0
        ##########################################
        # Set maximum gauge value
        ##########################################
        self.ui.widget.maxValue = 100
        ##########################################
        # Set scale divisions
        ##########################################
```

Figure 4.39: Customize Element in Gauge Interface

```python
        ################################################
        # Select gauge theme
        ################################################
        self.ui.widget.setCustomGaugeTheme(
            color1="#003399",
            color2="#0055ff",
            color3="#00ffff"
        )

        self.ui.widget.setOuterCircleColor(
            color1="black",
            color2="#50E3C2",
            color3="#002080"
        )

        self.ui.widget.setBigScaleColor("#000000")
        self.ui.widget.setFineScaleColor("#000000")
```

Figure 4.40: Customize Theme in Gauge Interface

```python
        ################################################################################
        # Set custom font
        ################################################################################
        QFontDatabase.addApplicationFont(os.path.join(os.path.dirname(__file__), '/home/

        self.ui.widget.setValueFontFamily("DS-Digital")
        self.ui.widget.setScaleFontFamily("DS-Digital")

        self.ui.widget.setScaleValueColor(255, 255, 255)
        self.ui.widget.setDisplayValueColor(255, 255, 255)

        self.ui.widget.setNeedleColor(0, 255, 255)
```

Figure 4.41: Customize Font, Font Colour And Needle Colour.

The custom ‘AnalogGaugeWidget’ class, which is in charge of rendering the analog gauge, is stored in the ‘AnalogGaugeWidget.py’ file. This widget has functions like ‘increase_gauge_value’ to implement acceleration and ‘updateValue’ to dynamically modify the gauge value. To obtain the required visual representation, the widget's parameters unit, minValue, maxValue, scalaCount, and needle color are carefully configured. Periodic updates are guaranteed for a responsive user experience when QTimer is used.

The 'W' key in the GUI initiates the ‘increase_gauge_value’ method, which incorporates the acceleration capabilities. By enabling users to dynamically accelerate the gauge value, this feature adds a compelling and interactive element to the interface. The division of these elements into discrete components improves the readability and maintainability of the code, which adds to the project's overall structure and modularity.

```

        # Additional variables for acceleration
        self.acceleration_factor = 0.1
        self.timer = QTimer(self)
        self.timer.timeout.connect(self.update_gauge_value)

    def keyPressEvent(self, event):
        if event.key() == Qt.Key_W:
            self.acceleration_factor = 1.0
            self.timer.start(20)  # Start the timer on key press wi

    def keyReleaseEvent(self, event):
        if event.key() == Qt.Key_W:
            self.acceleration_factor = -1.5  # Set deceleration on

    def update_gauge_value(self):
        # Update the gauge value with acceleration/deceleration
        current_value = self.ui.widget.getCurrentValue()
        new_value = current_value + self.acceleration_factor
```

Figure 4.42: Coding Structure For Acceleration And Deceleration Interact With 'W' Button

Lastly for the whole coding to execute the Dashboard.py file's 'if __name__ == '__main__':' block starts the application's execution. This block creates a QApplication and instantiates an instance of the 'MainWindow' class. The GUI window is displayed by calling the 'show' function. When the user quits the interface, the program is properly terminated thanks to the 'sys.exit(app.exec_())' function.

With the 'QApplication' handling the event loop and the 'MainWindow' class coordinating the GUI configuration, this approach guarantees a smooth application launch. Enhancing the application's user experience and reliability is the neat and organized execution sequence.

```python
#######################################
#EXECUTE APP
####################################
if __name__ == '__main__':
    app = QApplication(sys.argv)

    window = MainWindow()
    window.show()
    sys.exit(app.exec_())

#######################################
#EXECUTE APP
####################################
```

Figure 4.43: Coding Structure to Execute The ‘Dashboard.Py’ File

In summary, the integrated system, provides a thorough approach to the real-time monitoring and visualization of analog sensor data. The PyQt5 GUI, microcontroller integration, and a custom analog gauge widget come together to produce a precise and eye-catching data representation. This outcome ensures a user-friendly interface and facilitates effective data interpretation.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter will conclude the overall process flow and finding result in terms of creating the Human Machine Interface (HMI) Development For E-Buggy using Raspberry Pi. Recommendations for future study are listed as well in this chapter to improving the finding in this study.

5.2 Conclusion

Generally, this study has successfully achieved the main objective of this study to design an interface of car dashboard design that interact with user. As stated in the Introduction before, the first objective of this study is to propose and design a development car dashboard interface using Raspberry Pi single board computer (SBC) for E-buggy while only considering the gauge meter interface, as mentioned in the work scope and limitation. This study started with the development of designing car dashboard in CATIA V5 and analyze to get the structural analysis in Altair Inspire considering the Safety Factor, Displacement, Von Mises Stress and Max Shear Force.

On the other hand, the second objective of this study is create an interface of car dashboard using Raspberry Pi. This objective was carried out with Python and QT Designer within Visual Studio Code. The PyQt5 GUI, microcontroller integration, and a custom analog gauge widget come together to offer a precise and eye-catching data representation. This result guarantees an interface that is easy to use and makes it easier to analyze data effectively. The gauge interface colour element were designed based on survey that have been conducted. As result, a modern looking analog gauge meter have been created that can be interact the meter by pressing ‘W’ button with represents the throttle of the development of E-buggy. On the other hand, the interface design much followed the criteria while using the hardware which is the Raspberry Pi validated the result of the interface that interact with the user to give important information as mentioned in Chapter 3, Methodology. Extra information for the design of E-buggy dashboard that have conducted with Altair Inspire, the data analysis Safety Factor, Displacement, Max Shear Force and Von Mises Stress were obtained and Design 2 were the right choice as it acceptable following the criteria of data analysis.

As a conclusion, this research has successfully achieved all the objective that mentioned early in the introduction as the proposed a design that interact with user and analyzing the needed of the user prespective of E-buggy dashboard design.

5.3 Recommendations

Since this study in just focusing on the interface design of car dashboard for E-buggy using Raspberry Pi, it is recommended to do deep study about the Raspberry Pi itself on how to mkae more informative and interative interface. For example study on how to use Python with Qt Designer in Visual Studio Code more effective way to create a complete interface of E-buggy dashboard. It is possible to test the physical dashboard arrangement in a car. The Dashboard can have further features added to it, such as map navigation. Additionally, backend work can be done to save telemetry data on the cloud for statistical analysis that could offer useful information to the user and the EV manufacturer.(Sumith et al., 2022).

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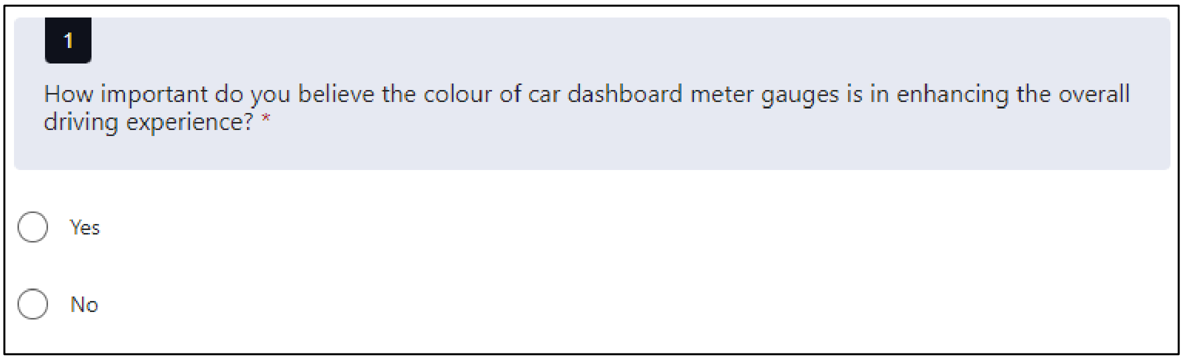
APPENDICES

APPENDIX A Gantt Chart

No.	Activities	Status	Week (March 2023 – July 2023)													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Title registration with supervisor	Plan														
		Actual														
2	Project explanation from supervisor	Plan														
		Actual														
3	Defining problem statement, objective and project scope	Plan														
		Actual														
4	Drafting & writing chapter 1	Plan														
		Actual														
5	Hardware preparation	Plan														
		Actual														
6	Defining & finding reference for literature review	Plan														
		Actual														
7	Drafting & writing chapter 2	Plan														
		Actual														
8	Defining methodology on research	Plan														
		Actual														
9	Drafting & writing chapter 3	Plan														
		Actual														
10	Revising chapter 1, 2, 3, preliminary result before submission	Plan														
		Actual														
11	Submission of full report PSM 1 to supervisor	Plan														
		Actual														
12	Conclusion	Plan														
		Actual														
13	Submission of full report PSM 1 to the panel	Plan														
		Actual														
14	Presentation PSM 1	Plan														
		Actual														

Activities	Status	Week (October 2023 – January 2024)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
PSM 2 implementation	Plan														
	Actual														
Discussion with supervisor	Plan														
	Actual														
Method used for experiment	Plan														
	Actual														
Experiment setup	Plan														
	Actual														
Hardware and equipment selection and supervisor meeting	Plan														
	Actual														
Experiments and testing	Plan														
	Actual														
Troubleshooting experiments	Plan														
	Actual														
Writing chapter 4	Plan														
	Actual														
Writing chapter 5	Plan														
	Actual														
Report checked by supervisor	Plan														
	Actual														
Poster Implementation	Plan														
	Actual														
Submission Full report to Panel 1&2 and supervisor	Plan														
	Actual														
PSM 2 presentation	Plan														
	Actual														

APPENDIX B Survey Questions



Suggestion Colour for Scale Section in the Gauge Meter

2

Suggestion for scale section Colour 1, Colour 2 and Colour 3 *

	Aqua	Light Blue	Dark Blue	Dark Green	Dark Red	White	Black
Colour 1	○	○	○	○	○	○	○
Colour 2	○	○	○	○	○	○	○
Colour 3	○	○	○	○	○	○	○

Suggestion Colour for Inner Circle Section in the Gauge Meter

3

Suggestion for Inner Circle Colour 1, Colour 2 and Colour 3 *

	Aqua	Light Blue	Dark Blue	Dark Green	Dark Red	White	Black
Colour 1	○	○	○	○	○	○	○
Colour 2	○	○	○	○	○	○	○
Colour 3	○	○	○	○	○	○	○

Suggestion Colour for Needle Circle Section in the Gauge Meter

4

Suggestion for Needle Circle Colour 1, Colour 2 and Colour 3 *

	Aqua	Light Blue	Dark Blue	Dark Green	Dark Red	White	Black
Colour 1	○	○	○	○	○	○	○
Colour 2	○	○	○	○	○	○	○
Colour 3	○	○	○	○	○	○	○

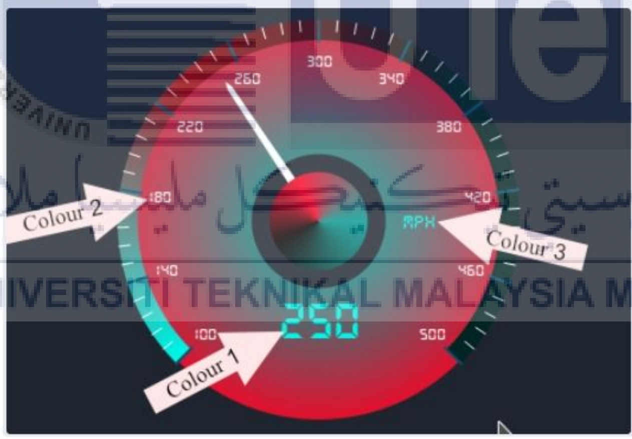
Suggestion Colour for Needle Section in the Gauge Meter

5

Suggestion for Needle section Colour 1 *

	Aqua	Light Blue	Dark Blue	Dark Green	Dark Red	White	Black
Colour 1	○	○	○	○	○	○	○

Suggestion Colour for Font and Value Section in the Gauge Meter



6

Suggestion for Font and Value Colour 1, Colour 2 and Colour 3 *

	Aqua	Light Blue	Dark Blue	Dark Green	Dark Red	White	Black
Colour 1	○	○	○	○	○	○	○
Colour 2	○	○	○	○	○	○	○
Colour 3	○	○	○	○	○	○	○

Suggestion Colour for Big and Small Scale Section in the Gauge Meter

7

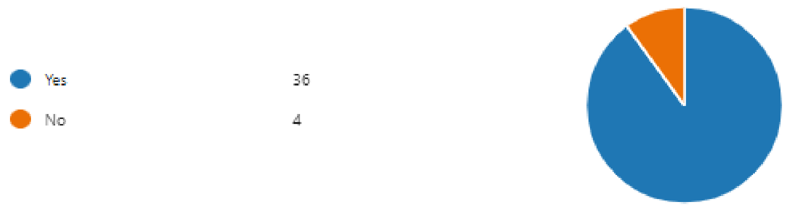
Suggestion for Big and Small Scale Colour 1 and Colour 2 *

	Aqua	Light Blue	Dark Blue	Dark Green	Dark Red	White	Black
Colour 1	○	○	○	○	○	○	○
Colour 2	○	○	○	○	○	○	○

APPENDIX C Raw Data Respondents

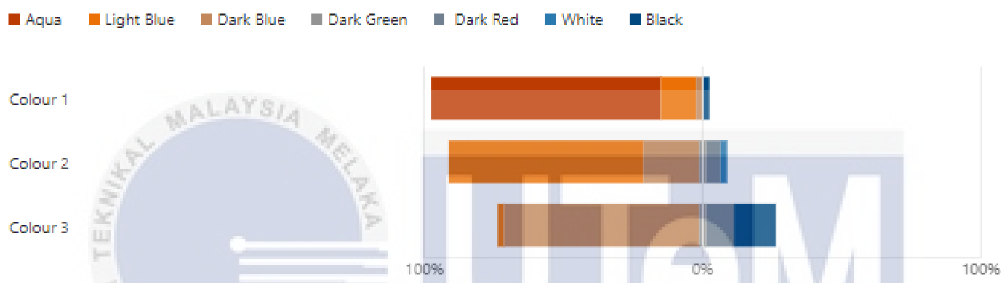
1. How important do you believe the colour of car dashboard meter gauges is in enhancing the overall driving experience?

More Details



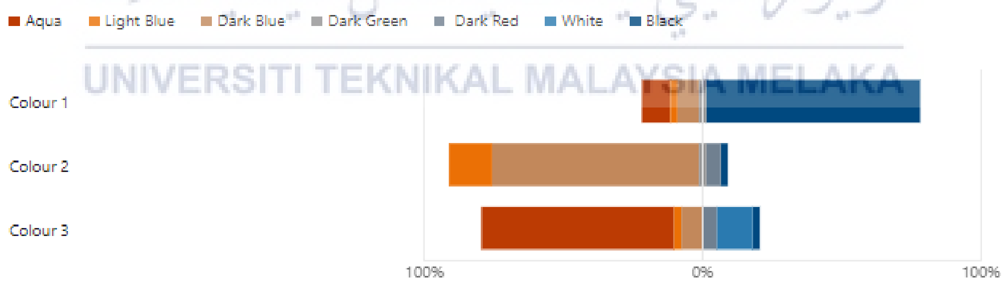
2. Suggestion for scale section Colour 1, Colour 2 and Colour 3

More Details



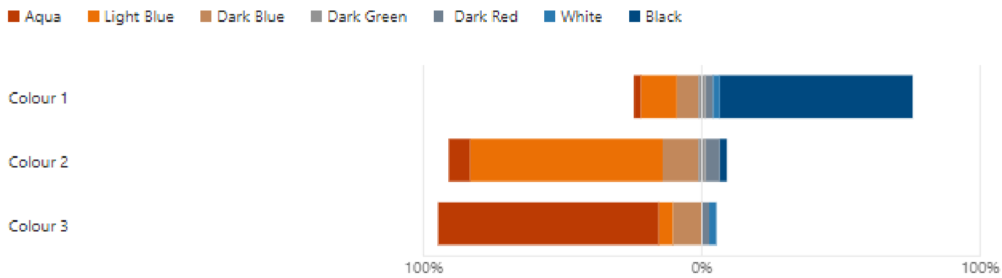
3. Suggestion for Inner Circle Colour 1, Colour 2 and Colour 3

More Details



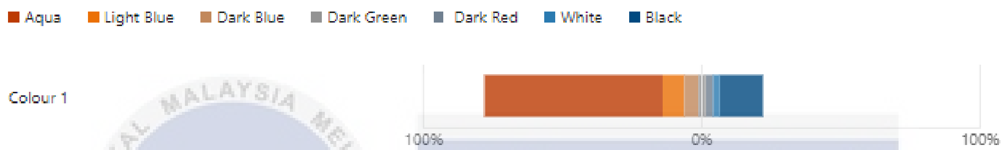
4. Suggestion for Needle Circle Colour 1, Colour 2 and Colour 3

More Details



5. Suggestion for Needle section Colour 1

More Details



6. Suggestion for Font and Value Colour 1, Colour 2 and Colour 3

More Details

7. Suggestion for Big and Small Scale Colour 1 and Colour 2

More Details