DESIGN OF CAR COOLING DEVICE FOR CAR PARK IN HOT WEATHER CONDITION

CHOO HAE LING

A report is submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering (Hons)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

DECLARATION

I declare that this project report entitled “Design of Car Cooling Device for Car Park in Hot Weather Condition” is the result of my own work except as cited in the references.

Signature	:	....
Name	:	CHOO HAE LING
Date	:	....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Hons).

Signature :. ....

Name of Supervisor : Mr. Mohd Nazim bin Abdul Rahman

Date : ....

DEDICATION

To my beloved parents, Choo Ah Yoong and Chia Bak Kiau.

ABSTRACT

Car is commonly parked under exposure of sunlight directly. Increasing of air temperature in cabin vigorously due to heat trapped and transferred within the cabin causes thermal uncomfortable, heat stroke, and deformation of material within cabin. Therefore, a cooling device for car park under sunlight exposure is designed following engineering design process. Method of temperature reduction selected is the combination system of ventilation and thermoelectric Peltier cooling module. Prototype is fabricated to test the method selected and experiment is conducted from 11am to 3pm at same day and same venue by using three similar cars without tinted in three conditions: fully sealed cabin, cabin with prototype, cabin with single window gap of 4cm opened. Result showed that cabin with prototype has lowest average air temperature in cabin (41.25 ˚C), then cabin with single window gap opened (50.45 ˚C) and fully sealed cabin showed highest average air temperature in cabin (54.75 ˚C). The objective of this research is achieved with average air temperature reduction of fully sealed cabin that is 13.5 ˚C (24.66%) and cabin with window gap opened which is 9.2 ˚C (18.24%) when compared to the average temperature of cabin with prototype. Peltier module’s cooling efficiency is 25.21% and 21.74% when compared to fully sealed cabin and cabin with window gap opened respectively.

ABSTRAK

Kereta sentiasa dijemur bawah matahari semasa diletakkan di parkir yang tidak berbumbung. Kepanasan yang terperangkap di dalam kereta akan menyebabkan ketidakselesaan, kematian, dan kerosakan komponen dalam kereta. Oleh sedemikian, sebuah penyaman udara untuk kereta yang diletakkan di parkir tidak berbumbung telah direkabentuk mengikut proses rekabentuk kejuruteraan. Cara yang terpilih untuk mengurangkan suhu di dalam kereta merupakan kombinasi sistem pengudaraan dan kepingan Peltier. Sebuah prototaip dibina bagi mengkaji rekabentuk yang dicadangkan. Ujikaji dijalankan dari pukul 11 pagi hingga 3 petang pada hari dan tempat yang sama dengan menggunakan tiga kereta yang serupa dengan tingkap tidak berwarna dalam tiga keadaan iaitu kabin bertutup penuh, kabin dengan prototaip, dan kabin dengan satu tingkap terbuka sedikit dengan jarak 4cm. Keputusan menunjukkan kabin dengan prototaip mengalami purata suhu terendah (41.25 ˚C), kabin dengan satu tingkap terbuka sedikit mengalami purata suhu 50.45 ˚C, manakala kabin bertutup penuh mengalami purata suhu tertinggi (54.75 ˚C). Suhu purata yang dikurangkan sebanyak 13.5 ˚C (24.66%) dan 9.2 ˚C (18.24%) berbanding kabin tingkap bertutup penuh dan kabin dengan satu tingkap terbuka sedikit. Kecekapan kepingan Peltier merupakan 25.21% dan 21.74% berbanding kabin tingkap bertutup penuh dan kabin dengan satu tingkap terbuka sedikit.

ACKNOWLEDGEMENTS

I would like to express my outmost gratitude to Universiti Teknikal Malaysia Melaka for providing me an opportunity to conduct the research studies as a partial fulfilment of the requirement for the degree of Bachelor of Mechanical Engineering. It has gave me a chance to learn independent by handling project individually and also a chance for me to solve the problem that I never met.

Besides that, I would like to express my deepest appreciations to my supervisor, Mr. Mohd Nazim Bin Abdul Rahman for consultants and guidance throughout the studies. I am glad that Mr. Nazim willing to spend his free time always to meet with me and always provides useful and helpful information and tips for me to accomplish the project. I am sincerely thankful to the patience of him throughout the project. Other than that, I would like to thank my second examiner, Dr. Faiz Redza Bin Ramli, for giving advice during presentation.

Throughout this research studies, I am very fortunate to be blessed with the guidance and encouragement from my parents, especially the supportive and helpful during in needed. They always giving advice, support morally to make me keep going whenever I face problems. I would like to thank all the staffs and technician of the laboratory Universiti Teknikal Malaysia Melaka, who have assisted me in several small matters and also getting along with me very well. Nevertheless, I would also like to express my deepest gratitude to my friends and respondent for giving me the help and advice during the experiment, data collection, information collection and prototype manufacturing.

Last but not least, I would like to take immense pleasure of thanking who are always give me advice as well as encouragement whenever I face obstacles throughout the studies. I will never forget the help that I got from throughout the project, it would always be my motivation to fight for future.

TABLE OF CONTENTS

			PAGE
DECLARATION			
APPROVAL			
DEDICATION			
ABSTRACT			**i**
ABSTRAK			**ii**
ACKNOWLEGDEMENTS			**iii**
TABLE OF CONTENTS			**iv**
LIST OF FIGURES			**vii**
LIST OF TABLES			**x**
LIST OF ABBREVIATIONS			**xi**
LIST OF APPENDICES A			**xii**
CHAPTER			
1.	**INTRODUCTION**		**1**
	1.1	Background	1
	1.2	Problem Statement	4
	1.3	Objective	5
	1.4	Scope of Project	5
	1.5	General Methodology	5
2.	**LITERATURE REVIEW**		**8**
	2.1	Air conditioning system	8
	2.2	Ventilation	9
	2.3	Ventilation concept	9
	2.4	Cooling	11
	2.5	Solar Reflective Shell	11
	2.6	HVAC Blower	11
	2.7	Opening of Window	12
	2.8	Air Movement	13
	2.9	Heat Pipe	13
	2.10	Light Colour Exterior and Interior	14
	2.11	Infra-Red Glazing (IRG)	14
	2.12	Privacy Glazing	15
	2.13	Modified Blower	15
	2.14	Phase Change Material (PCM)	15
	2.15	Product Filled with PCM	17
	2.16	Compressed Liquid Air	17
	2.17	Thermal Comfort	19
	2.18	Power System	19
	2.19	Thermoelectrically Module	19
	2.20	Heat Sink	20
	2.21	Spray Cooling	21
	2.22	Thermal Load	21
	2.23	Cooling Device	23
3.	**METHODOLOGY**		**26**
	3.1	Define Problem	26
	3.2	Gather Information	29

	3.3	Concept Generation	29
	3.4	Concept Selection and Evaluation	30
	3.5	Product Architecture	31
	3.6	Configuration Design	32
	3.7	Parametric Design	33
	3.8	Detail Design	33
	3.9	Design Testing and Analysis	34
	3.10	Report Writing and Oral Presentation	34
	3.11	Methodology Flow Chart	35
4.	**CONCEPTUAL DESIGN**		**36**
	4.1	Survey Questionnaire Analysis	36
	4.2	House of Quality	44
	4.3	Product Design Specification	47
	4.4	Morphological Chart	48
		4.5.1 Concept Design 1	51
		4.5.2 Concept Design 2	53
		4.5.3 Concept Design 3	55
		4.5.4 Concept Design 4	57
	4.6	Weighted Decision Matrix	59
	4.7	Final Concept Design (Modified)	62
5.	**PRODUCT ARCHITECTURE**		**63**
	5.1	Arrangement of Functional Element	63
6.	**CONFIGURATION DESIGN**		**66**
	6.1	Material Selection	66
	6.2	Manufacturing Process Selection	67
	6.3	Device Operation Hour	67
7.	**PARAMETRIC DESIGN**		**69**
	7.1	Dimension and Tolerance	69
	7.2	Failure Mode and Effect Analysis (FMEA)	69
8.	**DETAIL DESIGN80**		**72**
	8.1	View of product	72
9.	**COSTING**		**77**
	9.1	Costing of Prototype	77
	9.2	Costing of Product	79
10.	**TESTING AND RESULT**		**81**
	10.1	Prototype	81
	10.2	Experiment	82
	10.3	Result	84
11.	**DISCUSSION AND ANALYSIS**		**94**
	11.1	Prototype Discussion	93
	11.2	Experiment Discussion	94
	11.3	Result Discussion	95

11.4	Peltier Module Efficiency	97
11.5	Ventilation Blower	98
11.6	Concept Design	100
11.7	Maximum Temperature Differences	100
12.	**CONCLUSION AND RECOMMENDATION**	**101**
12.1	Conclusion	101
12.2	Recommendation	103
REFERENCES		104
APPENDICES		10

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Thermal Distribution of Car Parked Under Sunlight	2
1.2(a)	Car Parked at Outdoor Exposed under Sunlight Directly	4
1.2(b)	The Indication of Temperature Inside Cabin and Outside the Car	4
1.3	Flowchart of Methodology	7
2.1(a)	Mixing Ventilation (MV)	10
2.1(b)	Cabin Displacement Ventilation (CDV)	10
2.1(c)	Low Momentum Ceiling Ventilation (LMCV)	10
2.1(d)	Hybrid Ventilation (HV)	10
2.2	Arrangement of Heat Pipe	14
2.3	Thermal Distribution in Car Cabin with PCM and without PCM	16
2.4(a)	Air Conditioning Rear Vents	18
2.4(b)	Designated Location for the CLAC	18
2.4(c)	Valve	18
2.5	Temporal Variation of Vehicle Cabin Average Temperature	18
2.6	Peltier Module	20
2.7	Thermal Distribution of Heat Sink	21
2.8	Temperature Distributions in the Car Cabin at Different Times (left) and Temperature Distribution on the Car Interiors at 3 p.m. (right).	23
2.9	Solar Powered Car Ventilator	24

2.10	The Contours of the Temperature Distribution at Different Cross Sections (left) and Contours of the Velocity Magnitude at Different Cross Sections (right)	25
2.11	Temperature Distribution inside the Car Cabin for both Systems On and Off	25
3.1	Template of House of Quality	28
3.2	Template of Schematic of Product	32
3.3	Template of Failure Mode and Effect Analysis	33
3.4	Methodology flow chart	35
4.1	Gender	37
4.2	Age Category	37
4.3	Living Place	38
4.4	Income	38
4.5	Reasonable Price	39
4.6	Durability	39
4.7	Simple and User Friendly	40
4.8	Affordable Price	40
4.9	Easy Maintenance	41
4.10	Portability	41
4.11	Reliability	41
4.12	Aesthetic Value	42
4.13	Small Size and Space Saving	42
4.14	Robustness	43
4.15	Functionality	43
4.16	Concept 1	51
4.17	Concept 2	53
4.18	Concept 3	55
4.19	Concept 4	57

4.20	Exploded View of Concept 4	57
4.21	Finalized Concept Design of Car Cooling Device and Design of Car Roof	62
5.1	Schematic of Product	64
5.2	Rough Geometric Layout	65
6.1	Electrical System of Cooling Device	68
8.1	Isometric, Top, Front, Side View of Device	73
8.2	Assembly View with Bill of Material	74
8.3	Exploded View with Balloon Generated	75
8.4	Isometric View and Exploded View	76
9.1	Prototype Costing Model	78
9.2	Product Costing Model	80
10.1	Prototype (a)Back view, (b)Front view, (c)Side view, (d)Top view, (e) (f)Isometric view	82
10.2	Similar Car with Condition (1)Fully Enclosed Cabin, (2)Cabin Installed with Prototype, (3)Cabin with Single Window Gap of 4cm Opened	83
10.3	Prototype Hanging on Window Gap Viewed from (A) External, (B)Internal	83
10.4	Position of Thermocouple Thermometer when Taking Reading Of (A)Surrounding Temperature, (B)Air Temperature in Cabin	84
10.5	Air Temperature of Different Condition (˚C) against Time (Minutes)	86
10.6	Temperature Differences (˚C) against Time (Minutes)	88
10.7	Temperature Differences (˚C) against Time (Minutes)	90
10.8	Temperature Differences (˚C) against Time (Minutes)	92
11.1	Dimension of Perodua Myvi in mm	99

LIST OF TABLE

TABLE	TITLE	PAGE
3.1	Template of Product Design Specification	29
3.2	Template of Morphological Chart	30
3.3	Template of Weighted Decision Matrix	31
4.1	House of Quality	46
4.2	Product design specification (PDS)	47
4.3	Morphological Chart	49
4.4	Weighted Decision Matrix	59
7.1	Failure mode and effect analysis (FMEA)	70
10.1	Air temperature from time to time for three kind of condition and surrounding temperature	84
10.2	Temperature differences from time to time between condition of fully enclosed cabin and cabin with prototype	87
10.3	Temperature differences from time to time between conditions of cabin with window gap opened and cabin with prototype	89
10.4	Temperature differences from time to time between conditions of cabin with prototype and surrounding temperature	91
11.1	Summarize table for Peltier cooling efficiency when different average temperature of cabin condition used as initial temperature	98
12.1	Summarize table of result specification compared to earlier specification	103

LIST OF ABBREVIATIONS

MV	Mixing Ventilation
CDV	Cabin Displacement Ventilation
LMCV	Low Momentum Ceiling Ventilation
HV	Hybrid Ventilation
IRG	IR Reflective Glazing
PCM	Phase Change Material
PV	Photovoltaic Panel
HOQ	House of Quality
PDS	Product Design Specification
DC	Direct Current

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Survey form	108
B1	Side polystyrene insulator	111
B2	Housing	112
B3	Cold side heat sink	113
B4	cold side TEC insulator	114
B5	Front polystyrene insulator	115
B6	Hot side heat sink holder	116
B7	Switch	117
B8	Hot side heat sink	118
B9	TEC Peltier module	119
B10	Fan cover	120
B11	Fan	121

CHAPTER 1

INTRODUCTION

1.0 Introduction

In this section, background regarding to the study is briefly described. The problem statement is stated and the objective and scopes of this project are listed. General methodology to conduct the project is briefly explained.

1.1 Background

Nowadays, car is one of the main transportation for human to move from one place to another. Air conditioner as built in system of car is important for thermal comfort especially during hot and sunny day (Maan Al-Zareer et al, 2017). The solar radiation from the direct exposure of sunlight caused the increasing of air temperature inside an enclosed volume or sealed car cabin. Especially for windows and windshield parts that being clear and transparent allowed the transmission of solar radiation. The solar radiation on the roof of car transmits heat via convection to the other parts in car cabin. The parts such as dashboard absorbed heat and then transmit via conduction and convection in the cabin. The heat trapped inside the sealed car cabin has increased the air temperature inside car cabin easily (C. Y. Tseng et al, 2014). The increasing of the air temperature has caused the thermal uncomfortable to human. It also destroys the materials of parts in car cabin and some of the materials might emit poisonous substances. In order to maintain the thermal comfort of human, air conditioning system is widely used to regulate and reduce the air temperature inside of car cabin. Figure below shows the thermal distribution of the car parked under sunlight.

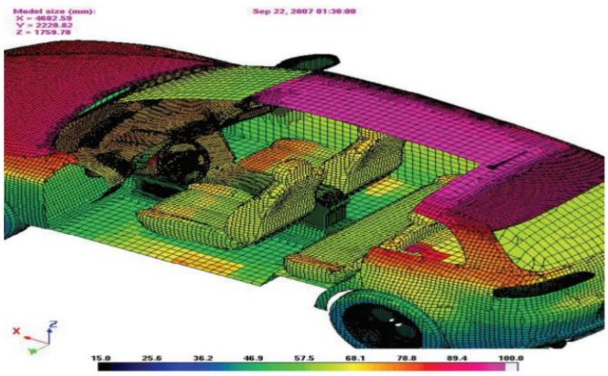


Figure 1.1: Thermal Distribution of Car Parked Under Sunlight (C. Y. Tseng et al, 2014).

Whilst the car parked statically under sunlight exposure directly without shading is unable to initiate and maintain the air conditioning system. The air temperature inside car cabin increased tremendously and heat being trapped until the re-entry of drivers and the initiation of ventilation and air conditioning system. Immediate cooling requirement needed more fuel consumption and also promoted the emission of harmful substances. The solar radiation and the increasing of air temperature inside the car cabin can be described as the greenhouse effect. The extremely high temperature inside the car has raised some issues such as the thermal comfort, colour fading and seat upholstery wear and tear, death of children and animals that unintended left inside the car and so on. The number of children in USA left unintended in car cabin parked under sunlight and died of heat stroke in 2003 and 2004 was 42 and 35 respectively (Sudhir, Jalal, 2015). It shows the importance of air ventilation system and reduction of temperature inside car cabin.

In order to reduce the transmission of solar radiation into the car cabin, variety of external methods such as tinted, sunscreen, sunshade, curtain, car ventilator has been implemented mostly to the car. The shading is used to prevent the solar radiation as much as possible. The Road Transport Department Malaysia stated that the visible light transmission of front windshield is at least 70%, rear and side windows at least 50% (Jabatan Pengangkutan Jalan Malaysia, 2017). The control of the translucence level makes restriction to the prevention of solar radiation transmission. The heat transferred via convection and conduction through the solar radiation onto the roof of cabin still existed even though all cars' windows are shaded.

Somehow the window is rolled down to a gap distance for ventilation purpose. The ventilation system is done by movement of air in and out of the car where hot air escaped to the surrounding meanwhile ambient air is introduced into the car cabin (Tobias D. et. al, 2017). Subsequently, the air temperature inside of the car cabin can be reduced due to the ambient air has lower air temperature than the air temperature inside meanwhile increased the indoor air quality. However, there is no cooling or reduction of temperature inside car cabin when the ambient air temperature is higher than the air temperature inside. The ventilation system is not effective enough due to the natural ventilation and small gap opening available. The window gap opening is limit due to the security issue.

Sometimes, driver and passengers are forced to enter the car cabin that higher in temperature or forced to wait outside the car and open the door while initiate the air conditioning system to wait for the cooling of car cabin. As a result of solar radiation to the car that parked under direct sunlight exposure, it is very important to remove and minimize the unwanted temperature rise inside the car cabin. Solution is required not only to reduce the air temperature inside the car cabin anytime but also convenient and secure the car and passengers.

1.2 Problem Statement

Car is frequently used to be the transportation vehicle that assists human from moving one place to another. During hot and sunny day, the solar radiation from sunlight transmitted to the unshaded object is unavoidable. Parking lot inside the building or parking lot with cover roof is rarely found and does not in demand due to its costly development fees. Most of the car drivers are forced to park their car at outdoor parking lot. The outdoor parking lot does not prepare covered place where the entire car parked under direct exposure of sunlight without any shelter. The heat transmitted to the car and trapped inside the car cabin has increased the air temperature inside car cabin tremendously. The air temperature inside car cabin is higher than outside temperature. Driver felt uncomfortable and hot once they entered into the car parked under the sunlight exposure. They are forced to open windows, initiated air conditioning system and wait outside the car for cooling of cabin before re-entry of car. The air conditioning runs at high energy and fuel consumption in order to cool rapidly. The hotness of the cabin also been found that destroy the materials of the car cabin and even emit poisonous substances.

(a)

(b)

Figure 1.2: (a) Car Parked at Outdoor Exposed under Sunlight Directly (b): The Indication of Temperature inside Cabin and Outside the Car (Eduard et al, 2016)

1.3 Objective

The objective of this project is shown as follow:

1) To design a cooling device for car that parked in hot weather condition.

1.4 Scopes

This project is subjected to focus mainly on:

1) Only passenger car type is used to implement the cooling device

2) Reduction of the temperature in cabin of car installed with cooling device for at least 5 ^{o}C compared to car without cooling device

3) Prototype is fabricated to test the function of the method selected

1.5 General Methodology

1. Define problem

Problem given according to the topic. Problem details will be inspected via survey questionnaire. The result of survey questionnaire will be analysed. The product design specification will be listed. Customer requirements and engineering characteristics will be generated and grouped into house of quality. The importance of customer requirements will be given based on the result of survey questionnaire. Relationships among engineering characteristics and customer requirements will be rated. The rank of engineering characteristic will be rated for further development of conceptual design.

2. Gather information

Reviews, journals, articles, internet, consultant, products regarding to the project will be referred and read through to gather the information. Previous result will be reviewed as to further understanding and guideline of the topic.

3. Concept generation

Design of functional models will be generated via brainstorming and creativity. The alternative design of the functional parts will be classified into morphological chart. Conceptual design will be generated from the combination of different type of alternative functional parts in morphological chart.

4. Concept selection and evaluation

Weighted decision matrix will be conducted to select the most concern criteria and to select the most suitable concept of design. The conceptual design generated will be evaluated based on each of the criteria. The rank of the conceptual design will be rated to proceed for further development. Redesign and design modification will be carried out to confirm last design concept.

5. Product architecture

Physical elements will be arranged in blocks to decide the arrangement of the parts in the assembly of the product.

6. Design configuration

Materials will be selected and the manufacturing process will be decided. The size and dimension of parts will be generated according to real vehicles dimension.

7. Design parametric

Tolerance of dimension will be set. Design robustness, assembly, manufacturing will be explained.

8. Detail design

Engineering drawing for every part design will be produced by using software Catia in real dimension. Assemblies of parts will be produced with material applied. The drafting of every parts and assembly of product will be generated.

9. Design testing and analysis

The prototype will be fabricated and experiment will be carried out to show the function of the method selected. Result will be analysed and discussed.

10. Report writing and oral presentation

A report on this study will be written in the end of project. Presentation slides will be prepared for oral presentation.

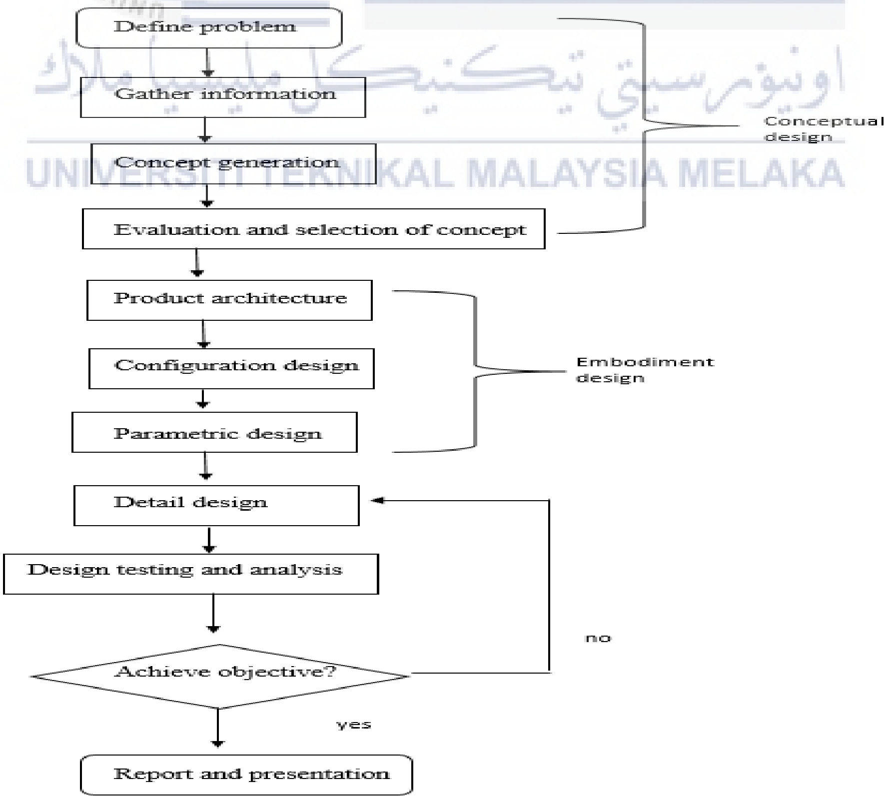


Figure 1.3: Flowchart of Methodology (Ertas and Jones, 1996)

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

A literature review is defined as an evaluative report of information found in the literature related to selected area of study. It did not include the primary sources where all are secondary sources. All of the literature has been reviewed, evaluated, analysed and summarized which give theoretical base for the research and help in determine the nature of research. The literature established gives ideas and knowledge on the research topic selected. As the problem met is the higher temperature of car cabin when the car is parked under direct sun exposed without shading, the objective is to resolve this problem by design a cooling device. Hence, the literature reviewed is regarded more to cooling or method that would assisted in reduction of temperature. Other related information also reviewed.

2.1 Air conditioning System

Air conditioning system is used to alter and remain the temperature, relative humidity, the velocity of air flow, and so on inside the car cabin effectively as well as to build better thermal comfort environment inside the car cabin. The air conditioning system required 70% of overall train energy and up to 15% of petrol consumption. (Jianghong Wu et al., 2017, Abbas Z. Kouzani et al, 2011). The usage of air conditioning system depleted battery which leads to the cruising range reduced up to 33% (Tobias D, 2017). The air conditioning system is said that energy was used to cool down the vehicles more than to the passengers. The emission and fuel consumption of air conditioning system is affected by the temperature, humidity and solar load. The air conditioning system consists of refrigerant that used to absorb heat, condenser to reject heat, evaporator to cool, and compressor which regulate the heat removed from cabin((D. Bridge, 2011). It was used to cool the cabin air from hot condition. The air conditioning is operated if only the engine was started and the vehicles were in operation. The continuous operation of the air conditioning required the consumption of energy. While car parked statically is under steady mode and under the exposure to the surrounding.

2.2 Ventilation

A good ventilation system will affect in both thermal comfort and also air quality. The ventilation at the front seat of the car shows a better ventilation effect compared to back seat due to the introducing of fresh air from the surrounding via the front air conditioning duct. Better ventilation not only improved the air quality and thermal comfort but also improved cooling and heating. Ventilation installed on top of the aircraft cabin reduced 75% of heat meanwhile provided thermal comfort. (Tobias D, 2017) Forced ventilation by using the fan to absorb exterior air into cabin and replaced hot air out of the cabin build good ventilation for cooling purpose when there was not operation of air conditioning system (D. Bridge, 2011). Forced and natural ventilation gave almost same effect.

2.3 Ventilation Concept

There were three vertical ventilation concept generated and analysed experimentally by using tracer gas and numerically by using CFD. The results were compared to the traditional ventilation of car from dashboard which also called as mixing ventilation (MV). The ventilation of car from dashboard allowed the inflow of outside air came in from the dashboard and dissipated at the luggage compartment. The first concept of the ventilation concept was the cabin displacement ventilation (CDV) where the air is distributed at the foot area slowly to be heated up and rise to upward then leave via the inversely operated low momentum ceiling ventilation (LMCV). Second concept is the LMCV provided the inflow of the surrounding air into the car cabin and outlet for the outflow of inside air. Third concept was the combination of first and second concept which was known as hybrid ventilation (HV). HV allowed both provision of fresh air from foot area and from the ceiling of car cabin while also allowed outflow of inside air. Results show that MV and CDV have better cooling effect during summer. CDV has better ventilation effect at both upper and lower area (Tobias D. et. al., 2017).

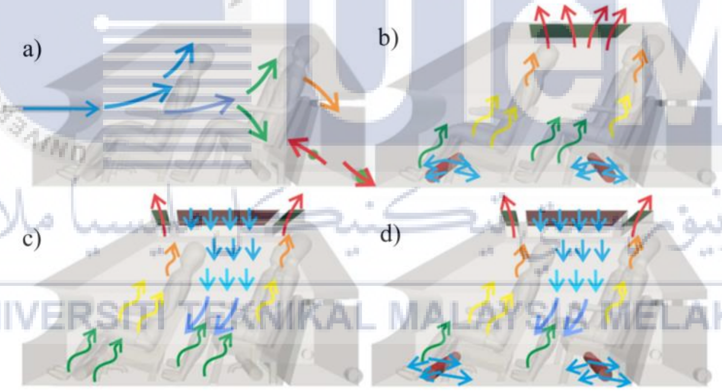


Figure 2.1: a)Mixing Ventilation (MV); b)Cabin Displacement Ventilation (CDV); c)Low Momentum Ceiling Ventilation (LMCV); d)Hybrid Ventilation (HV) (Tobias D. et. al., 2017).

Radiant cooling ceiling system which consists of cooling panel and circulatory coils that used to make water as an agent of being cooled, absorb heat, and repeated to be cooled. It has been claimed that with mechanically ventilation of cooled air passed through the system make the reduction of room temperature significantly (W.H. Chiang et al, 2012).

2.4 Cooling

The cooling of the car cabin is clarified that limitation of the heat penetration to the car help to reduce the thermal load which corresponding to cooling effect when compared to car without limitation of heat penetration. During the car park directly under exposure of sunlight, the cooling load required is extremely high. Materials of the car were changed to reduce the thermal load of car cabin. It was suggested that the light colour of exterior, IR Reflective Glazing (IRG) all around glazing surface, light colour of interior trim, and the installation of HVAC blower. Cooling is achieved when the thermal load is reduced and the final temperature of cabin is reduced. (D. Bridge, 2011). Solar reflective glazing is claimed that the ability of reducing 70% of heat gained in cabin. There were reduction of temperature of cabin, windshield, instrument panel (Ronnen Levinsn et al, 2011).

2.5 Solar reflective shell

White colour of coating has better reflective effect than black colour. Higher solar reflectance facilitates more temperature reduction of cabin. Light colour has higher solar reflectance while dark colour could not reflect much as light colour (Ronnen Levinsn et al, 2011).

2.6 HVAC blower

It is usually consists of fan and commonly known as cooler fan that help to introduce outside air into the car cabin while hot air inside the cabin as replacement is expelled out of the cabin. This induced a better ventilation of the cabin. (D. Bridge, 2011). Rotated fan designed with concave and convex surface was a portable cooling system that withdraws heat out of the cabin. (Ronnen Levinsn et al, 2011). Normally in most of the industries, there is implementation of fan as the ventilation system. The fans used are axial and radial type fan. The fan with more blades has less flow pulsation and higher vibration. Fan blade frequency must be preventing from reaching natural frequency of fan. Therefore the design of rotor, shape, frequency of fan, blade and rotor is always considered to prevent failure in industries (E. Rusinski et al, 2017). Axial fan was designed specifically for cooling of CSP power plant. The fan forced the air to the air-cooled condenser for further provision of fresh air. Optimization of the design of the fan increase the fan performance (G. Angelini et al, 2017).

Dc fan was implemented to one of the open end of the roof chimney which composed of double layer space imperforated with small air gap. And another open end is installed at interior side. The dc fan is used to create ventilation where hot air inside room is sucked out and improve air circulation inside the room. In fact, it also subsequently reduces the air temperature of room (Preeda Chantawong, 2017). Exhaust fan for roof ventilation layer shows that 60 degree Celsius without the exhaust fan functioning while temperature dropped to 40 degree Celsius with exhaust fan functioning (Haksung Lee et al, 2017)

The ventilation of a blower to the car with raises of temperature inside the car has proved obvious result of ventilation flow on the cooling effect. The flowrate of ventilation blower claimed that the temperature and cooling effect might differ where it was not higher flowrate can achieved cooling effect significantly (Du Yingmeng et al, 2014).

2.7 Opening of window

It was revealed that the car parked under hot weather with window fully closed shows a faster rate of temperature increasing inside the car cabin. While if the window was leave with a small opening, the temperature rise slower than the car fully enclosed (Sudhir, Jalal, 2015). Experiment conducted to show the temperature difference of inside and outside of car cabin. Results shows that the car parked under sunlight with opening gap of window produced temperature difference up to 8 degree Celsius (Chunling Qi et al, 2017).

2.8 Air movement

During hot and warm time, the air movement within a volume has good effect on the thermal comfortability of the environment. It has been included in ASHRAE55. Air velocity moved within the environment is one of the matter concerns to the thermal comfortability (Francesco Babich et al, 2017). Previous research shows that the increasing of air flow rate is important to decrease the cabin temperature.

2.9 Heat pipe

It is a simple common passive cooling system that applied only with the difference of heat source and heat sink. It was easy to embed in car seat as it does not compose of the moving part. Heat pipe was in contact with an aluminium plate which responsible to absorb the heat from the heat source and then transfer it to the evaporator part in order to cause the boiling of refrigerant. The other side of heat pipe which is not in contact with aluminium side was in contact with insulated side. The more heat pipe used, the higher the efficiency of temperature reduction. It was more suitable for small difference of temperature among heat source and heat sink (Omar Hatoum et al., 2017). **Figure 2.2** shows the arrangement of heat pipe.

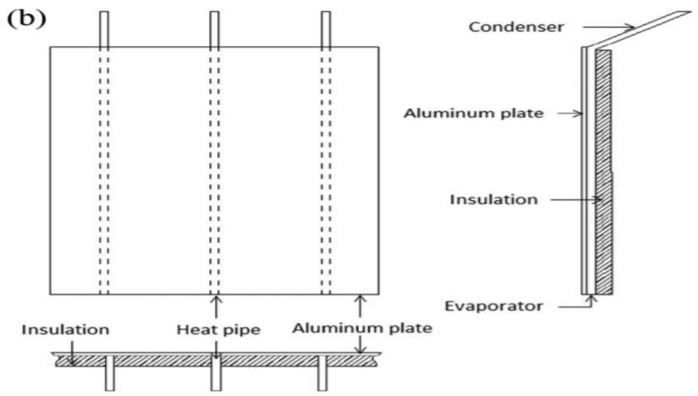


Figure 2.2: Arrangement of Heat Pipe (Omar Hatoum et al., 2017)

Implementation of phase change materials to the heat pipe connected to both heat source and heat sink prevented the heat went to surrounding. Heat pipe has higher efficiency of heat thermal conduction.

2.10 Light colour exterior and interior

It can effectively reflect visible electromagnetic spectrum and reflect heat. However, heat reflected also would likely to be trapped by other surface (D. Bridge, 2011).

2.11 Infra-Red Glazing (IRG)

It is a laminated based product that allows transmission of light while the silver doped interlayer would likely reflect the Infra-Red Light. Thus, it can eliminate the heat transfer into the cabin and reduce the solar radiation. However, it unable to electromagnetic signals therefore GPS and a phone is not available to use. (D. Bridge, 2011). Film of the car glasses is claimed to be able to reduce glass transmittance of solar radiation (Du Yingmeng et al, 2014). Window film and sun screen can reduce the rise of temperature in car cabin (C.Y. Tseng et al, 2014).

2.12 Privacy Glazing

It is used to absorb heat but the heat would then retransmit into car (D. Bridge, 2011).

2.13 Modified blower

The blower used to blow cooled air that cooled by the air conditioning system in the car was modified by changing its polarity. The direction of the blower changed to suck the hot air inside the car cabin out to the surrounding without any ventilation. The blower was initiated by solar powered system. The temperature inside car cabin was successfully reduced up to 14% (N.S. Hamdan et al, 2017).

2.14 Phase Change Material (PCM)

It is a special material with high heat of fusion that provided large storage for latent heat of fusion even the temperature is varies by changing state between melting and solidifying at certain temperature. As a thermal storage, it has used to conserve energy. PCM is affordable and economical which can be installed easily inside car cabin for thermal comfort purpose. It has be claimed that car parked under sunlight with the installation of PCM would helped to store the thermal energy which consequently make the temperature constant meanwhile reduce the greenhouse effect that would likely increase the cabin temperature. There are few parameters that kindly judge the PCM by its phase change temperature, latent heat capacity, density for solid phase, specific heat capacity, and thermal conductivity. From the Analytic Hierarchy Process method used, results shown SavEnrg PCM-Hs01P is the most suitable PCM for car parked under sunlight (Lavinia Socaciu et al, 2015).

The experiment carried out shows the PCM used in car parked under sunlight has greatly helped in reduction of air temperature and temperature on the steering surface. The refrigerated truck replaced with PCM shows 16.3% of daily heat flow reduction. The PCM were encapsulated right under the roof of car cabin and at the steering wheel where the car cabin initial temperature is set around 20 degree Celsius. Figure below shows the thermal distribution in car cabin with PCM and without PCM.

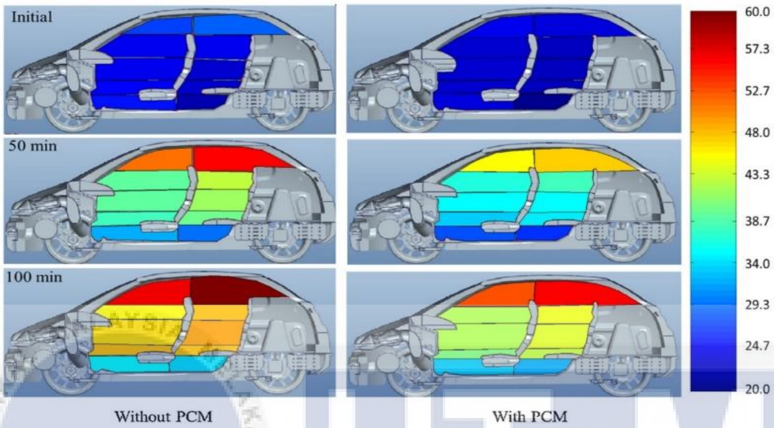


Figure 2.3: Thermal Distribution in Car Cabin with PCM and without PCM

(Lavinia Socaciu et al, 2015)

Results show that the PCM reduced significantly the temperature inside car cabin after two hour of sun exposure. (Eduard et al, 2016). Research carried out few studies for better thermal buffering implementation by PCM (Nicholas R. Jankowski, F. Patrick McCluskey, 2014). Rotatable shutter is used to solidify the PCM by releasing the absorbed heat during non-sunshine hours. It is also attached on and used to absorb the heat on conventional photovoltaic panel which reduced the temperature from 64 degree Celsius to 42 degree Celsius (Adeel Waqas, Jie Ji, 2017). The heat from the photovoltaic panel is prevented from escape to the surrounding. The cell temperature increased while the efficiency of the conversion from solar energy to electric energy would decrease. The PCM is claimed has high efficiency of heat absorption with no moving component, no electric required, and low maintenance cost which has better effect than convection (Xiaojiao Yang et al, 2017). Heat storage and released has been verified throughout the experiment to the air circulation of housing in Japan (Haksung Lee et al, 2017).

2.15 Product filled with PCM

Glazed unit such as window is vital parts of buildings which provide vision, ventilation, solar gain, and so on. The poor performance of thermal affect greatly on the energy demand of buildings. Triple pane building window with the injection of PCM into the glasses cavity shows greater effect on heat insulation (Changyu Liu et al 2017). Bricks also filled with PCM due to its latent heat of fusion can be used to reduce energy consumption for cooling and in turns reducing greenhouse gas emission. for long period and reused of the PCM, it required detail process to choose the right PCM, P116 has better reduction in heat flux and save more energy when filled in bricks (Emad Elnajjar, 2017). The glazed unit which can match with the window of car would be more likely to be applied to the car.

2.16 Compressed liquid air

An insulated container filled with 1 litre of compressed liquid air which is portable could allow fast cooling of car cabin that parked under sunlight without shading. The compressed liquid air container would require the modification of rear vent system of the air conditioner. The compressed liquid air enable car to cool down up to 15.2 degree Celsius in 60 seconds. The rear vent system is modified with implementation of a valve which acts as stopper to prevent the compress liquid air vapour from escape to outside via the vent duct meanwhile also prevent the escape of cooling air to other directions during air conditioner functioning.

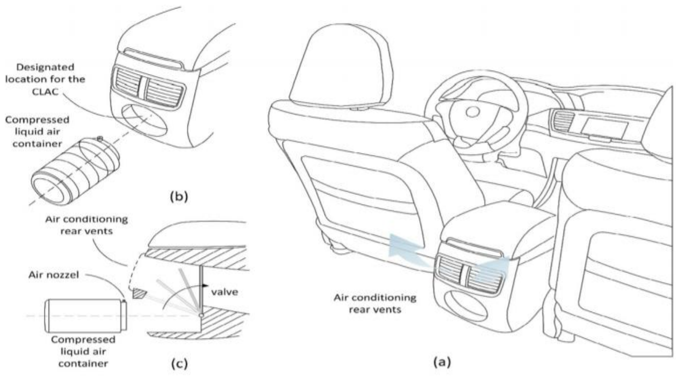


Figure 2.4: a) Air Conditioning Rear Vents, b) Designated Location for the CLAC, c) valve (Maan Al-Zareer et al., 2017)

The compressed liquid air container was designed with injection port functioned as pressure relief valve. It helped to release part of the air when it is found that heat leak into the container and make the pressure increase. This is used as to control the constant pressure inside the container. The container is opened and put in the rear vent system and the window is opened to a small gap. The pressure dropped make the compressed liquid air changed into vapour which consequently cooled down the cabin. Higher pressure inside the container makes a greater reduction of air temperature inside cabin (Maan Al-Zareer et al., 2017). Figure below shows the temporal variation of vehicle cabin average temperature.

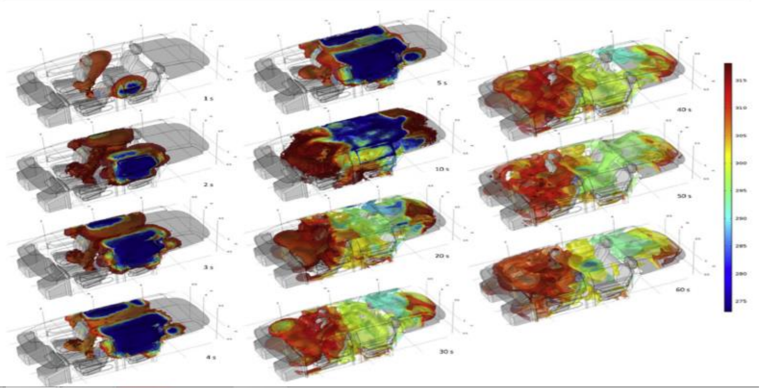


Figure 2.5: Temporal Variation of Vehicle Cabin Average Temperature (Maan Al-Zareer et al., 2017)

2.17 Thermal comfort

It has become more and more important when people spend more time inside the car. It has been commissioned that during daytime, the human comfort is most necessary; the air conditioning system is a must to ensure thermal comfort. The factors that influent thermal comfort is air temperature, relative humidity, mean radiant temperature, and relative air velocity (Eduard et al, 2016).

2.18 Power system

Photovoltaic panels have the main function of converting solar energy to electrical energy (Xiaojiao Yang et al, 2017). The used of photovoltaic panel (PV) is commonly applied due to its free electrical energy generation under sunlight. Rechargeable battery is used as alternative storage and electrical power supply which frequently installed together with photovoltaic panel for free recharge purpose during sunny day and as alternative power supply when there is weaker supply from photovoltaic panel. During sunny day, photovoltaic produced highest power and provide highest air flow rate. (Ronnen Levinsn et al, 2011).

2.19 Thermoelectrically module

Thermoelectric module is a piece of square shape module that consists of two thin ceramic wafers. One of the ceramic is the p-type semiconductor materials while another ceramic is the n-type thermocouples. It has two ways whether electric used to generate heating and cooling or temperature differences that induced the electrical energy. One of its examples is Peltier cell. It is used as cooling system such as cooler vaccines. The temperature difference between the outside and inside of car is not enough big to generate higher electric voltage, therefore it was not suitable to use as thermoelectric generator in car. While it can be used as cooling system in car with the battery charged by supply of solar power (A Sunawar, I Garniwa, 2017).

It was claimed that the thermoelectric unit is lightweight, portable, cheaper, ease to maintain, and do not wear out with use. Therefore, it is the best choice for portable car cabin cooling system (DR. Pushpendra Singh, 2015). Figure below shows the Peltier module

Figure 2.6: Peltier Module (DR. Pushpendra Singh, 2015).

2.20 Heat sink

It is a kind of heat exchanger that commonly used to cool down the electronics and prevent over heating of the electronic. It has many discrete surface where it shows the larger surface area that it had. The fin can be variety in shape such as rectangular, base plate, triangular and trapezoid. The heat sink is cooled by transfer heat via convection (Kaj Lampio, Reijo Karvinen, 2017). The heat transferred from the object to the heat sink by conduction and the heat transferred to the surrounding by convection. Heat sink with porous media and perforated fins shows better heat transfer (Hamdi. E Ahmed et al 2017). Figure below shows the thermal distribution of heat sink.

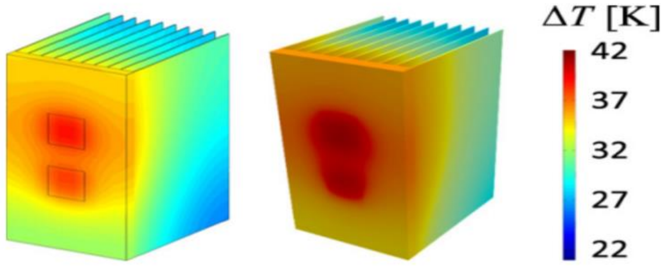


Figure 2.7: Thermal Distribution of Heat Sink (Hamdi. E Ahmed et al 2017).

Besides that, the heat sink also sometimes used to absorb the heat from the thermoelectric module. The heat transfer throughout the fin by conduction is greatly affected by based thickness, fin thickness, length, number and area. While the removal of heat via convection from the fins to the surrounding depends on the mass flow, temperature and the area (Yong Min Seo et al 2017).

2.21 Spray cooling

It is a technology that characterized with high heat transfer, uniform heat removal, little fluid inventory and low droplet impact velocity. The cooling medium is usually forced to the dispersion into droplets which then sprayed onto the heat surface in order to reduce the heat on the surface. The heat is reduced by the evaporation of latent heat (Jungho Kim, 2007). Spray system reduce the condensation temperature effectively by pressurized the water through the nozzle into fine droplets. It is not only humidify but well absorb the latent heat of vaporization (Shuo Feng et al, 2017).

2.22 Thermal load

The water put in a car cabin tends to absorb the heat surrounded and rises due to the buoyancy caused by heat source. The heat transferred to the dashboard and roof of car by direct solar radiation exposure. The heat from the dashboard were then transferred to windshield in both radiation and convection heat transfer. The roof conduct the heat to the ceiling of the car cabin. Ceiling also received the radiation of heat by radiation from windshield and dashboard. Most of the head in cabin came from the cabin surface (Ronnen Levinsn et al, 2011). The heat inside the cabin is affected by three parameters which are air temperature, the solar radiation and wind velocity (Eduard et al, 2016). Solar radiation striking on surface and caused the accumulation of heat. The heat transfer via convection, conduction and distribute to object in the room and air inside the room. The heat accumulated increased the air inside of the room (Preeda Chantawong, 2017).

The highest thermal load is found that to be during the period of direct sunlight exposure. Thermal load increased also would likely increased the energy consumption for air conditioning system. There were up to 50% of thermal load were contributed by the visible electromagnetic spectrum. The enclosed car would likely trapped air inside and heated easily by the solar radiation on both external and internal surface. The coldest part would be door. (Ronnen Levinsn et al, 2011). Refer figure 1.1.

The glazing directly of the solar radiation has caused higher thermal load. The heat energy from the solar radiation would likely transfer by using convection and conduction throughout the car. Thermal load is different at different opacity of window and is affected by the ratio of window to shell area. The smaller the ratio, the little the thermal load inside cabin (Ronnen Levinsn et al, 2011). The thermal situation inside car cabin is highly sensitive to the climatic condition. It was claimed that the car parked under sunlight would likely raise up to 20 degree Celsius compared to ambient temperature (Eduard et al, 2016).

Experiment is carried out to verify the effect of blower flow and solar radiation intensity. The results concluded that when car parked under hot surrounding without shaded and direct exposed to the sunlight, the air inside cabin would increase and achieve its equilibrium. The larger the intensity of the radiation caused a higher equilibrium of temperature inside cabin (Du Yingmeng et al, 2014).

The solar radiation heat that coming from side window is claimed to be larger than the front windshield due to its transparency of glass. Radiative heart entered the car cabin was conducted via roof of car. The radiation strike on the interior of car cabin would re-radiate the heat again which make the radiation heating obviously (C. Y. Tseng et al, 2014). Figure below shows the temperature distributions in the car cabin at different times (left) and temperature distribution on the car interiors at 3 p.m. (right).

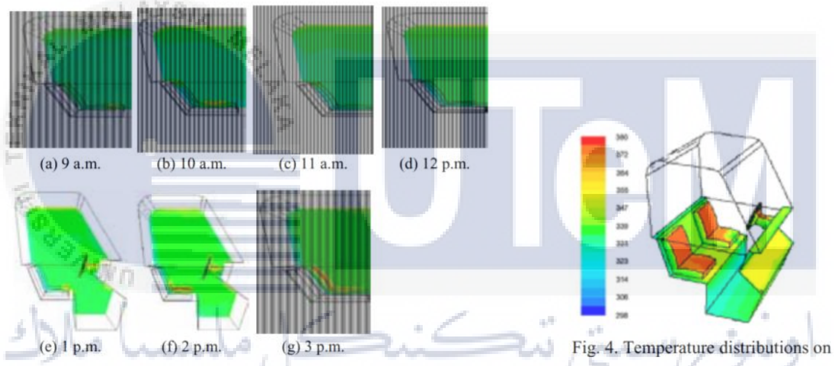


Figure 2.8: Temperature Distributions in the Car Cabin at Different Times (left) and Temperature Distribution on the Car Interiors at 3 p.m. (right). (C. Y. Tseng et al, 2014)

2.23 Cooling device

The solar radiation exposed directly to the car parked at unshaded area increased the temperature inside cabin significantly. In order to increase the exchange of air in and out of the vehicles without using of fuel energy, solar powered car ventilator is invented and experiment is conducted to shows reduction of temperature inside car cabin. The research claimed that the thermal distribution at front and rear zone of car is highest due to the larger surface of front and rear window that allowed more radiation of solar. It was also claimed that seat would likely trapped most heat. The ventilator composed of fan, pipes and solar panel. The pipes were used to direct hot air inside the cabin out of the car and introduced cooler ambient air into the cabin. The ventilator was installed at the rear side of car which controlled by circuit timer where 3 minutes per cycle. The temperature inside cabin successfully reduced (Sudhir, Jalal, 2015). Figure below shows the solar powered car ventilator.

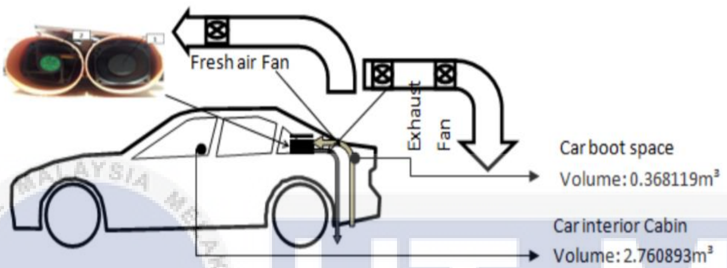


Figure 2.9: Solar Powered Car Ventilator (Sudhir, Jalal, 2015)

Additional car cooling device which also implemented with solar panel and four axial fan for higher flowrate purpose. The fan created static pressure gradient when operating. The pressure difference lead to the removal and replacement of hot air with cooler surrounding air. As an alternative to the solar power, rechargeable battery is also implemented. The battery is charged by using solar power and is used only if the solar radiation is not strong enough to initiate the operation of fan. However, low solar irradiation do mean with the less requirement to remove heat inside the cabin. The device was installed right below the ceiling of car, the removal of heat inside the cabin were replaced with the ambient air came from the vent duct of front air conditioning system (Y. A. Yan et al, 2012). Figure below shows the contours of the temperature distribution at different cross sections (left) and contours of the velocity magnitude at different cross sections (right).

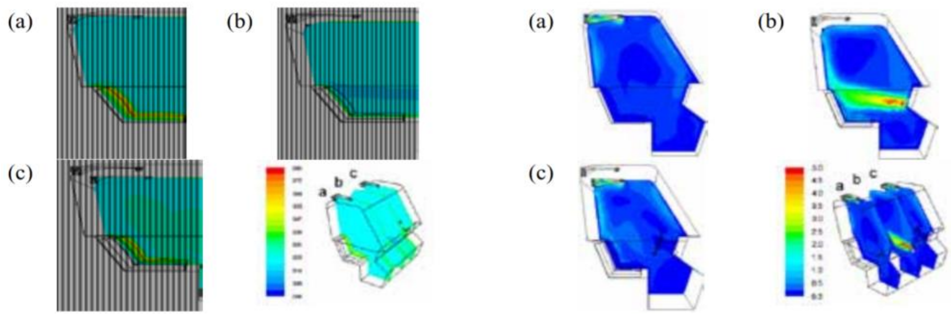


Figure 2.10: The Contours of the Temperature Distribution at Different Cross Sections (left) and Contours of the Velocity Magnitude at Different Cross Sections (right) (Y. A. Yan et al, 2012).

A wireless portable solar powered cooling system that consists of four main parts is introduced. The parts are solar collector mechanism, energy conduit, temperature controller and cooling module. The solar panel was foldable and opened when system operating. The solar energy converted into electrical energy would store in supercapacitor that supply electrical energy to the cooling system without making any modification on the vehicles. The cooling module is implemented with small fan for cooling purpose (Hongye Pan et al. 2017).

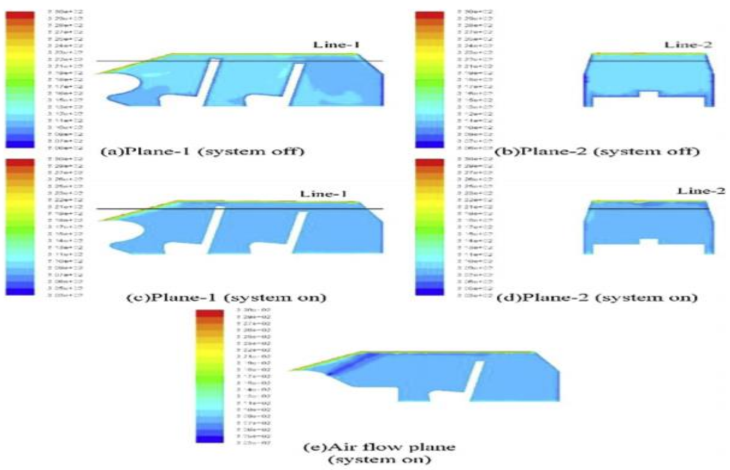


Figure 2.11: Temperature Distribution inside the Car Cabin for both Systems On and Off (Hongye Pan et al. 2017).

CHAPTER 3

METHODOLOGY

3.0 Introduction

This section introduced the steps from defining the problem to its solution. The steps to design and to generate the concept design for a car cooling device is briefly explained in this section. Survey questionnaire and interview is given to collect the data to generate the customer requirements. Further reviews assisted further understanding and as a guideline to the topic. House of quality is used to generate the rank of engineering characteristic in designing the concepts. Alternative of sub functional parts is generated in morphological chart where the combination of alternatives gave four conceptual design. Conceptual design is evaluated by using weighted decision matrix for the selection of best concept design.

3.1 Define problem

First of all, problem is required to define in details for deep understanding in order to generate a suitable solution for the problem. In order to know more about the problem raised, background study is done from online sources and also journal articles. News is also given focus to know the severity that caused by the problem. The references are cited right after the statements in chapter one.

According to the solution that figured out, survey questionnaire is conducted to gather the feedbacks of customers on the desired car cooling device design. Online survey questionnaire is conducted and feedback from 50 respondents is collected. Basic information about the respondents and questions regarding to the properties of car cooling devices is given in the survey questionnaire form. The result collected is gathered in pie chart and bar graph form for each of the questions. Then, the result is analysed based on each question with briefly explanation. Refer to **Appendix A** for the online survey questionnaire form.

After that, House of Quality which is a matrix of customer requirements and engineering characteristic is conducted by using the result of survey questionnaire. It is used to shows the relationships among engineering characteristic and customer requirements for the priorities of designing system. The designation of the car cooling device required the customer requirements and also its corresponding engineering characteristics. The customer requirements is then generated from the result of customer feedback. Its corresponding engineering characteristic also listed into the x-axis of House of Quality. The customer requirements is listed into y-axis of the table of House of Quality. The weightage percentage of customer requirements is rated according to the voice of customers. The level of correlation among engineering characteristics and customer requirements is represented by filling empty, 3 and 9 where level of correlation increased respectively. Weight importance of each of the engineering characteristics is calculated by summing up the product of level of correlation to correspond weightage percentage of each of the customer requirements. Relative weight is calculated by dividing the weight importance by the sum of weightage importance. Then, the rank is rated according to the relative weight. The equations below show the equation for calculating weightage importance and relative weight.

$$\text{weightage importance} = \sum \begin{array}{l}(the\ level\ of\ correlation\ of\ certain\ column \\ \times\ weightage\ percentage\ of\ correspond\ row)\end{array} \tag{3.1}$$

$$\text{relative weight} = \frac{weightage\ importance\ of\ certain\ column}{\sum weightage\ importance} \tag{3.2}$$

The correlation among engineering characteristic is also rated by empty, 3 and 9 where increasing in level of correlation at the top side of the house of quality. Figure below shows the template of House of Quality.

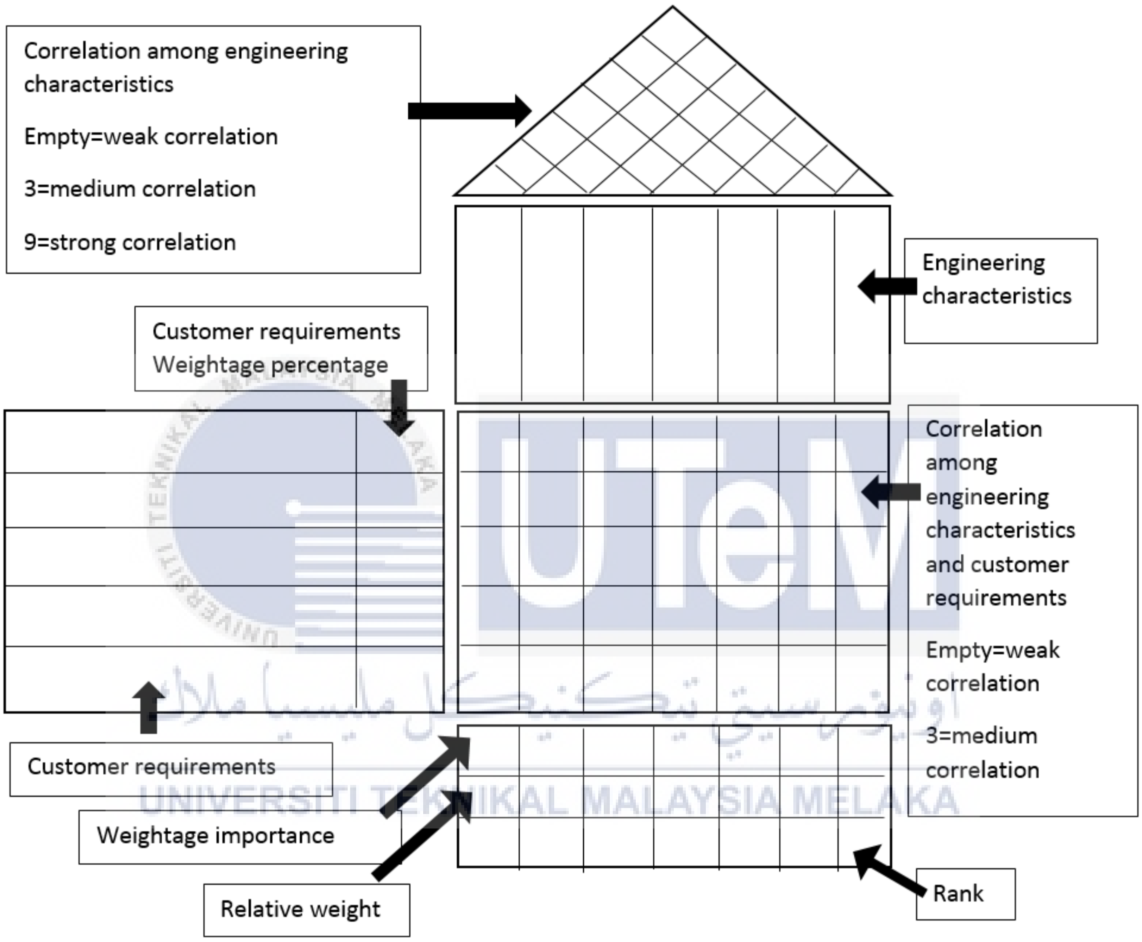


Figure 3.1: Template of House of Quality (Ertas and Jones, 1996)

Then, product design specification which is a list of the specification intended of each of the engineering characteristics. The value is referred to the design standard of each of the engineering characteristic of the design. It is used to ensure that the product designed is highly meet the customer requirements and within constraint. Briefly explanation is included in the product design specification.

Table 3.1: Template of Product Design Specification (Ertas and Jones, 1996)

NO.	ENGINEERING CHARACTERISTICS	UNIT	VALUE
1			
2			
3			
4			
5			

3.2 Gather Information

After the product design specification, further information regarding to the engineering characteristic, customer requirements, science theories is referred via journal articles, patents, websites, and so on. The information gathered is grouped and categorized into chapter two and the references are cited right after the statements. The main focus of the searching is on cooling and ventilation. This is due to the main purpose of car cooling device is to achieve cooling purpose and also reduce the temperature. Cooling agent and cooling method is categorized and reviewed to show each of the application, benefits, mechanism, efficiency, and limitation. The previous result of research and study is also referred to further improve and inspire new development. The thermal distribution and the heat transfer method have been studied. This helped in understanding of the hotspot in car cabin and root caused to come up with better solution to reduce temperature.

3.3 Concept Generation

Based on the research study on engineering characteristics and customer requirements, sub functional parts are generated to carry out the function. Morphological chart which is a table that used to list down the alternative way of each of the sub functional parts in order to carry out the same functions. It is a visual chart that used to illustrate the alternative sub functional parts. The combination of any one of the alternatives from each of the sub functional parts to become a product that can achieve the function wanted. Figure below shows the template of morphological chart. All the optional alternative form is represented by graphic.

Table 3.2: Template of Morphological Chart (Ertas and Jones, 1996)

Sub functional part	Alternative form			
	Option 1	Option 2	Option 3	Option 4

Then, any option of the sub functional part is assembled to be a product that can perform a function. The sub functional parts of a car cooling device consisted of cooling agent, frame, mounting part, heat sink, ventilation blower, power supply. All of the sub functional part assembled to be car cooling device in order to reduce the temperature of car cabin that parked under hot weather. Every conceptual design generated is briefly described in its mechanism and advantages.

3.4 Concept Selection and Evaluation

The total four conceptual designs generated are then evaluated by using weighted decision matrix. It is a tool in table form that used to evaluate alternative concept design of product based on its score on the criteria concerned. Every criterion has different weight factor according to its importance. Each of the concepts is evaluated one by one to each of the criteria by rating. 0, 1, 2, 3, and 4 is used to rate the alternative concept design among each other based on its performance on the criteria concerned from unsatisfactory to very good. The rating is then multiply with its corresponding weight factor of criteria. The total weighted rating of every criterion is summed up which then compared between alternative concept designs. The concept design with highest score of total weighted rating is selected for further development. The equation below shows the calculation of weighted rating and total weighted rating.

$$\text{weighted rating} = \text{rating} \times \text{weight factor} \tag{3.3}$$

$$\text{total weighted rating} = \sum weighted\ rating\ of\ each\ criteria \tag{3.4}$$

The table below shows the template of weighted decision matrix.

Table 3.3: Template of Weighted Decision Matrix (Ertas and Jones, 1996)

		Alternative concepts							
		Concept 1		Concept 2		Concept 3		Concept 4	
Criteria	Weight factor	Rating	Weighted rating	Rating	Weighted rating	Rating	Weighted rating	Rating	Weighted rating
Total									
Ranking									

3.5 Product Architecture

The functional elements is first arranged into a schematic of product. The flow of material, forces or energy, signal or data is also shown by solid line, bolded solid line and dash line respectively among the functional elements. Then, it is clustered into physical chunks. A rough geometric layout shows each of the components or functional element arranged in an assembled view by using kinds of geometry. It decided the position of functional elements in the product. Figure below shows the template of schematic of product.

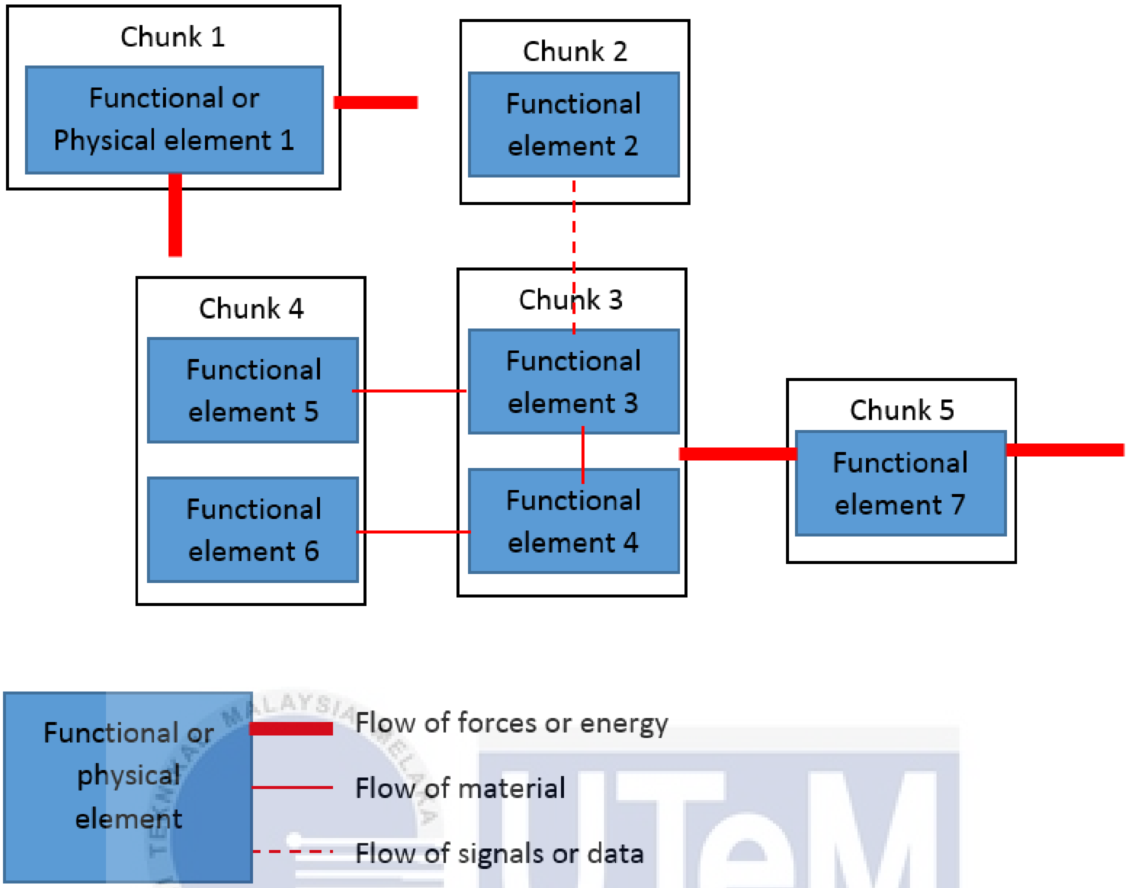


Figure 3.2: Template of schematic of product (Ertas and Jones, 1996)

3.6 Configuration Design

Configuration design is strongly related to the availability of the materials and manufacturing process in order to create the form of the parts and to perform the function in assembly of product. Requirements to the parts of product and elements is stated and constraint is also given to the product. It is highly related to the relationship and interaction between user and product, the physical constraint, lifespan of product, and other related to the access for maintenance. Therefore, the selection of materials and manufacturing process is also stated based on the suitability of the materials to perform the function and its suitable process. Parts which can be eliminated and combined are preferable to reduce the parts quantity and thus ease the assembly.

3.7 Parametric Design

Parametric design is related to the specific values and various design elements that are found in the configuration design. It included the dimension of the parts, material used, shape, manufacturing process and also assembly in order to manufacture the part. The setting is variety so that best design is produced as to maximize the quality and performance while minimize the cost of the product and variability of the product. Failure mode and Effects Analysis (FMEA) is conducted to determine the failure and effect of possible ways so that product can be improved further to ensure robust design.

Part	Function	Failure Mode	Effect	Root Cause	Severity	Occurrence	Detectability	Risk Priority Number	Critical Value

Figure 3.3: Template of Failure mode and Effects Analysis (FMEA) (Ertas and Jones, 1996)

3.8 Detail Design

Catia V5R20 which is one of the CAD software is used to produce the detail design of the device. From the dimension and arrangement of component generated from embodiment design, each component part is drawn via the workbench of part design in mechanical design with dimension applied in millimetre (mm). The drafting workbench is used to generate the drafting of all components. Title block is placed with each of its name and date generated. Then, all of the existing component is then assembled by using assembly design workbench where constraint is put to assembly all of the components such as offset, coincidence, surface contact and so on. The material is applied to produce a more realistic look of the device. To do the drafting of assembled product, exploded view is first done to show each of the components separately from the product. The balloon is generated and bill of material is listed to clearly show the component part, part name, quantity.

3.9 Design Testing and Analysis

Prototype is manufactured under the budget cost of RM200. The materials and manufacturing process selected is different where alternative way is used to fabricate the prototype in order to test the function of the method decided. Three similar car which is Myvi without tinted is placed at same venue at same time from 11am to 3pm. The car is set as fully enclosed cabin, cabin installed with prototype, cabin with right side rear window opened with 4cm gap respectively. Three thermocouple is placed at the right side back seat of each car. The data is recorded every 5 minutes start from 12pm to 3pm. Data is tabulated into three table and plot in one graph. The graph is analysed and discussion is made based on the background theory stated in chapter 1 and chapter 2. The result is compared with similar established work and judgement is also included in discussion. The research is then concluded and recommendation is given for further development of the research.

3.10 Report writing and oral presentation

Report is written technically with the format stated and arranged neatly according to the chapter with suitable content. PowerPoints is prepared for oral presentation purpose.

3.11 Methodology Flow Chart

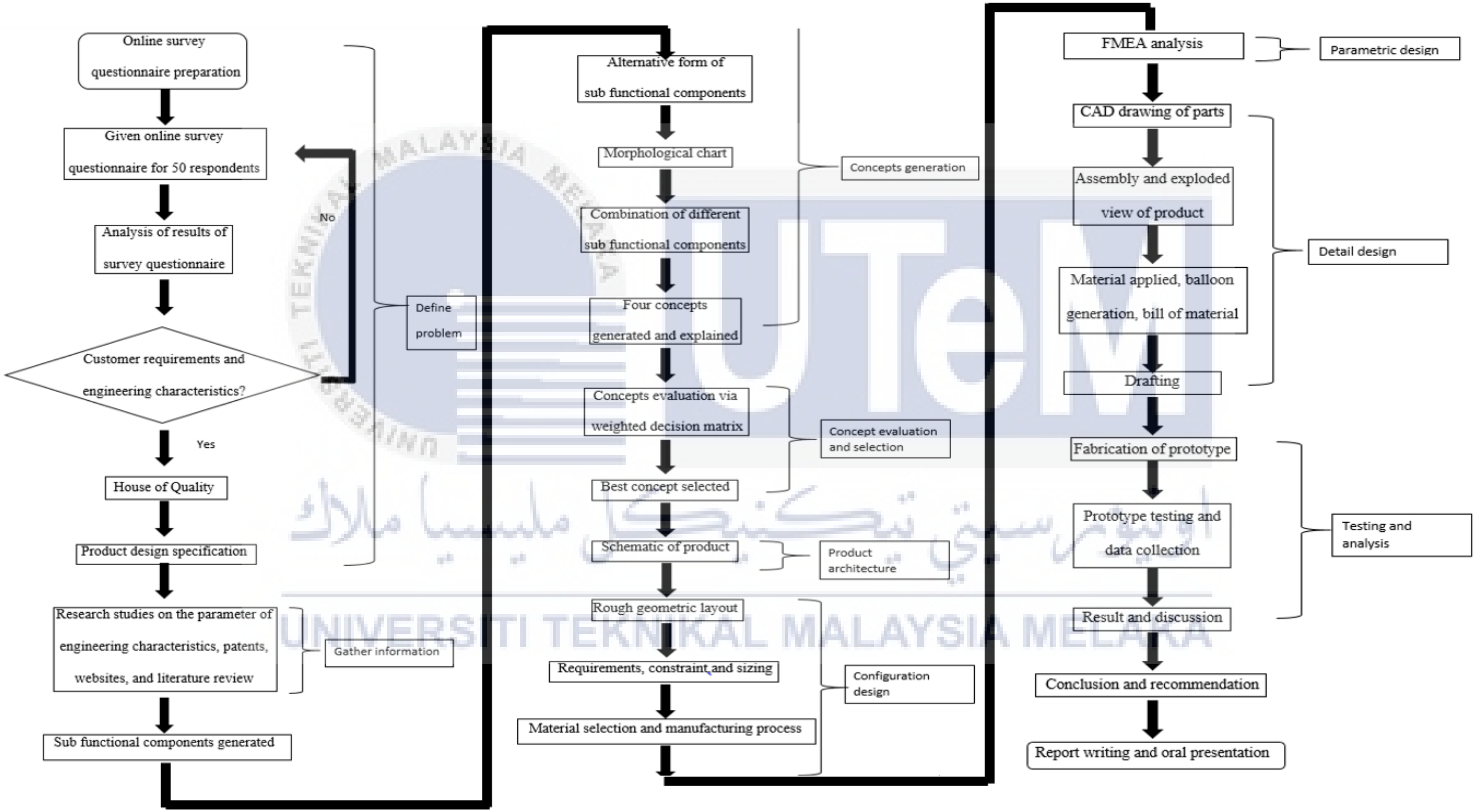


Figure 3.4: Methodology flow chart

CHAPTER 4

CONCEPTUAL DESIGN

4.0 Introduction

The conceptual design included the generation of ideas, benefits and disadvantages of the ideas in order to increase the success ability of the concept design idea. The idea of concept is generated via the techniques such as brainstorming, synthesizing, morphological analysis, and word triggering. This section consists of the analysis of survey questionnaire to get the customer requirements, analysis of House of Quality that used to correlate engineering characteristics and customer requirements, analysis of product design specification, analysis of morphological chart for alternative options of sub functional parts, analysis of conceptual design generations and evaluation by weighted decision matrix to generate best concept design.

4.1 Survey questionnaire analysis

The first part of the survey questionnaire is regarding to the personal information about respondents. Figure below shows that most of the respondents are male which 54% is and only 46% of respondents are female.

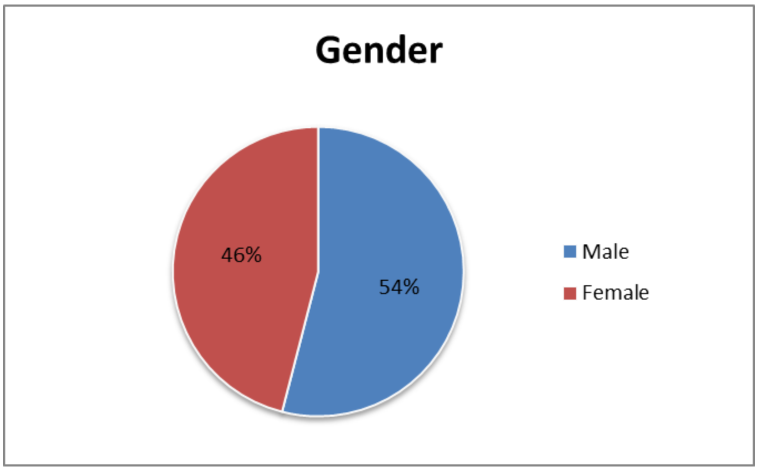


Figure 4.1: Gender

While figure below shows most of the respondents are between 21 to 30 years old (36%), then is 31 to 40 year-olds (32%) and 22% of them is between 41 to 50 years old. Respondents above 50 years old is the least (4%) and 6% of the respondents is between 17 to 20 years old. It might because of people 50years old and above has less active online and most of the respondents concerned about the issues.

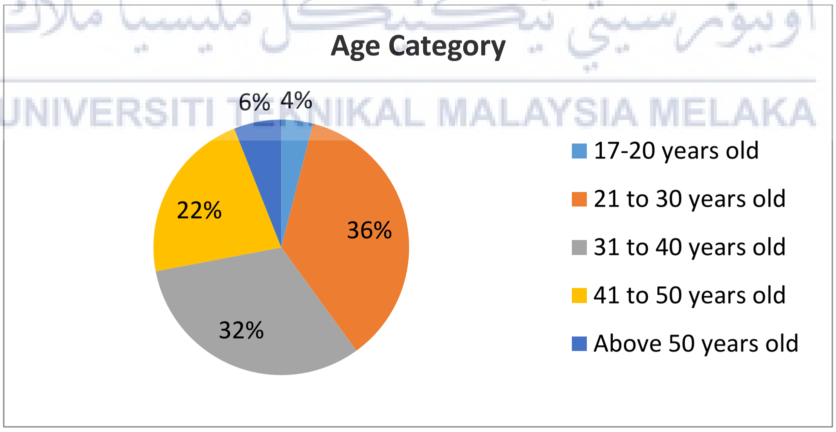


Figure 4.2: Age Category

Figure 4.3 shows that most of the respondents which over half of the respondents live in city areas (66%), while there are 34% of them live at outskirts. It might because of people live in city spend more time in their car, so they are more concern to the car issues.

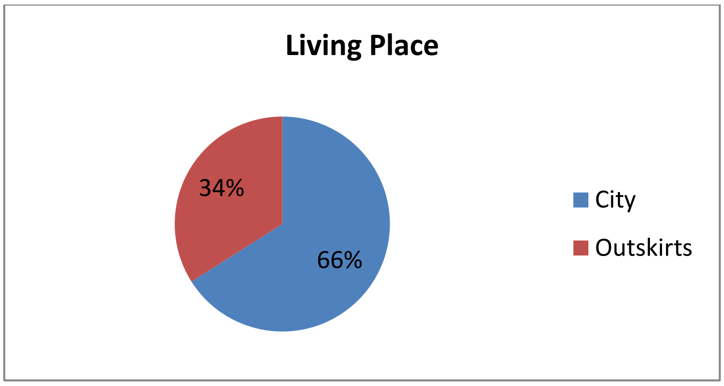


Figure 4.3: Living Place

Figure below shows that most of them has income above RM1000 where 34% for RM1001 to RM3000, 32% for RM3001 to RM5000, 22% for RM5001 to RM8000 and 10% for RM8000 and above. Only 2% of the respondents have income less than RM1000. This might because of most of the respondents are 20 years old and above which has a job with income at least RM1000.

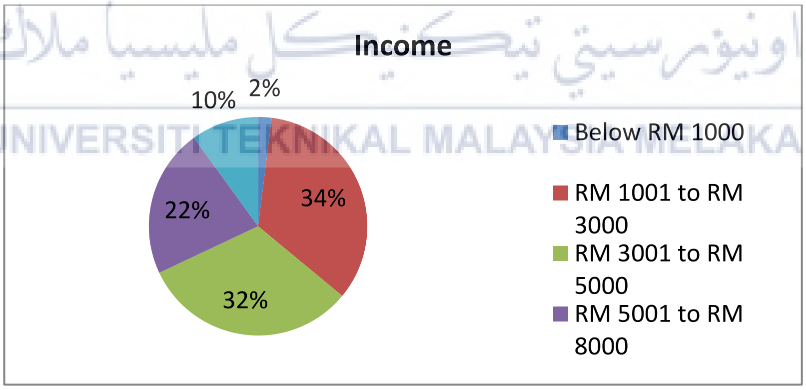


Figure 4.4: Income

The next part of the survey questionnaire focused on the aspects of car cooling device preferable in order to know more about customer requirements on the device. Customer requirements are generated from the result of this part of survey. Figure below shows that they are most of them preferred cheaper cooling device which able to function well below RM100 (52%). However, they are still 42% of them willing to spend more around RM101 to RM300 for better quality of product. Only 6% willing spend more than RM300 for a cooling device with high specification.

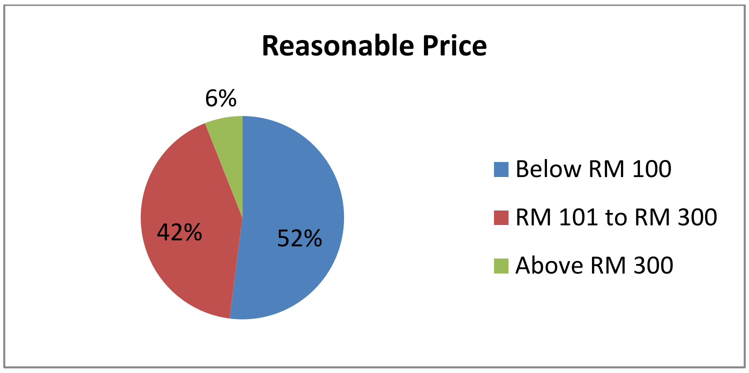


Figure 4.5: Reasonable Price

There are 76% of them agree with a durable car cooling device which has long life span of sustainability. While same 12% for both slightly agree and disagree.

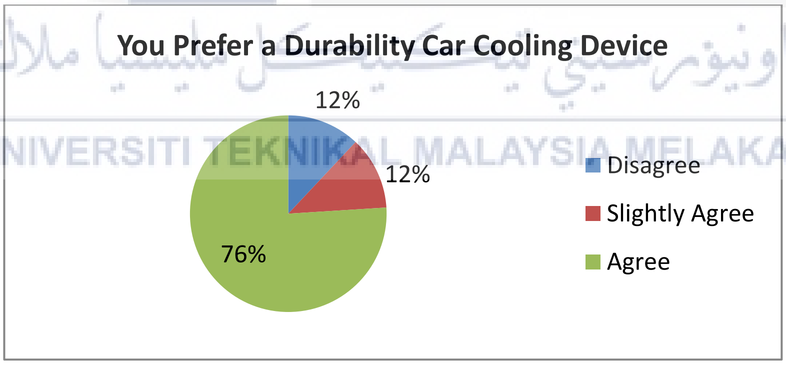


Figure 4.6: Durability

Figure below shows that 86% of them preferred a simple and user friendly car cooling device. This might because of simple mechanism make them convenient and ease of use for every respondent from all age category. There are only 8% and 6% disagreeing and slightly agree.

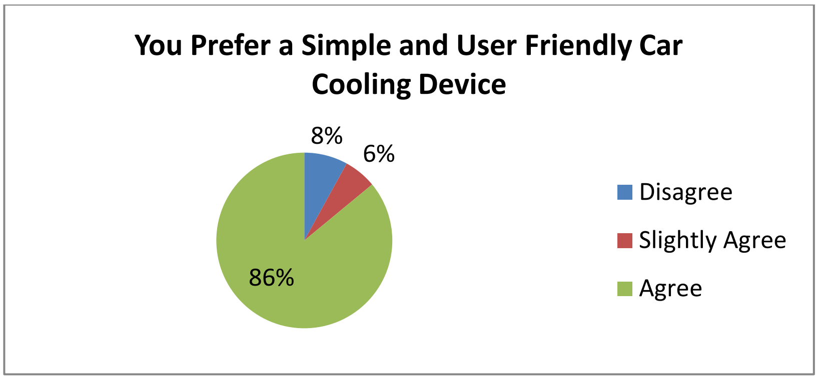


Figure 4.7: Simple and User Friendly

From the above questions that shows most of the respondents agreed with economical and9 affordable car cooling device (76%), while same amount of them agree and disagree with it (12% respectively).

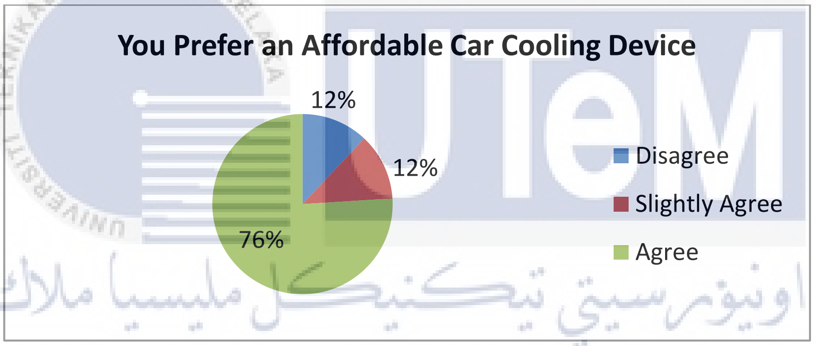


Figure 4.8: Affordable Price

Figure below shows that 84% of the respondent agreed with an easy maintenance car cooling device. While 12% of them disagree with it and only 4% of them slightly agree with it. It might because a cheaper car cooling device could be replaced anytime with a new one so that respondents vote for slightly agree and disagree to prevent the trouble of maintenance.

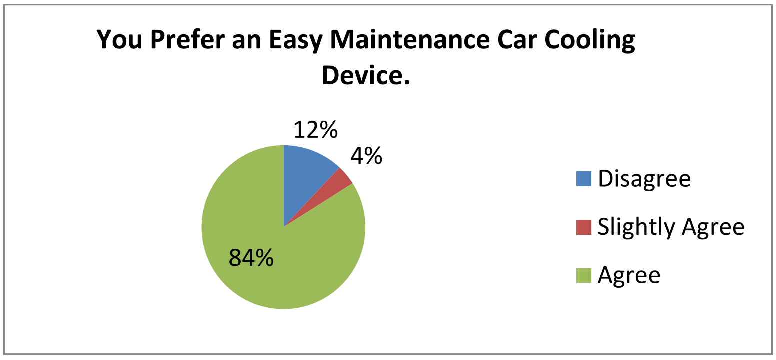


Figure 4.9: Easy Maintenance

There are also mostly 84% of respondents would love to have a portable car cooling device. Only 8% is disagreeing and slightly agree with it respectively. A portable cooling device makes them convenient when the car device is required to travel along.

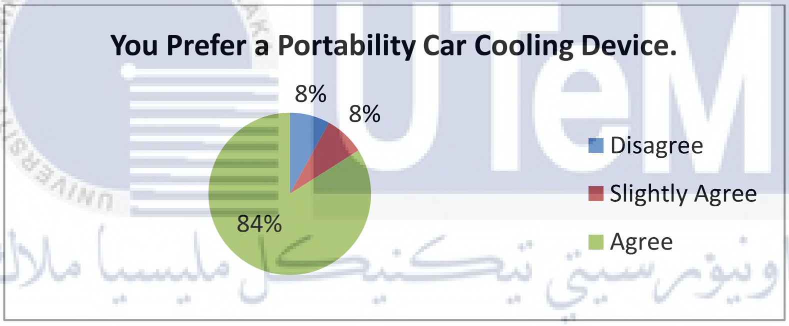


Figure 4.10: Portability

Figure below shows that high reliability device is the first choice of 74% of respondents. There are 16% respondents disagreeing and 10% of them slightly agree.

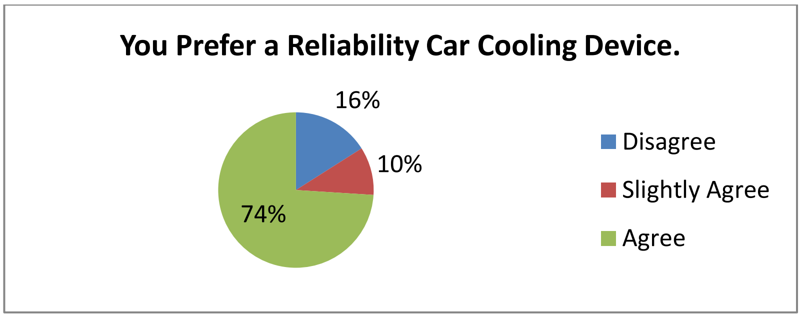


Figure 4.11: Reliability

In the aspect of aesthetic value, respondents preferred high aesthetic value car cooling device, but only 12% and 15% are disagree and slightly agree respectively.

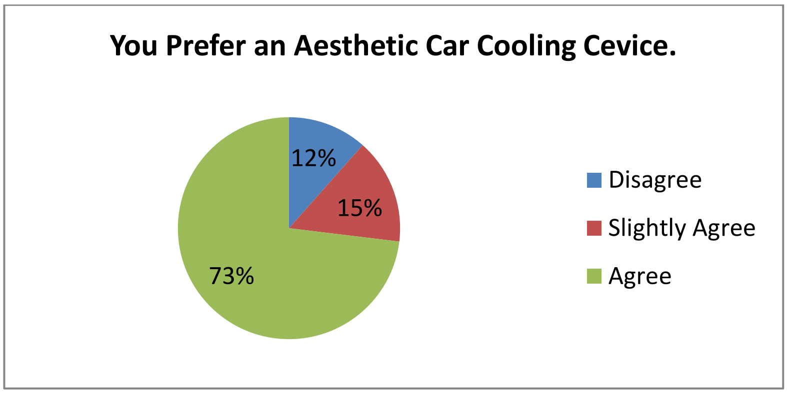


Figure 4.12: Aesthetic Value

Figure below shows there are 78% of them agreed with a smaller size which space saving car cooling device and 16% of them disagree while 6% of them slightly agree with it.

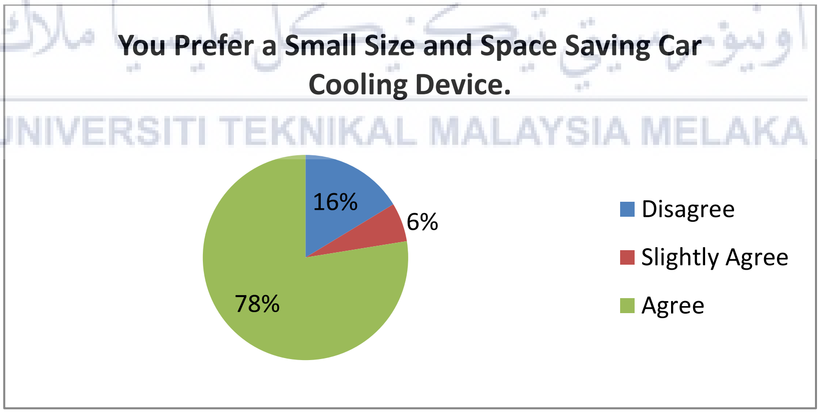


Figure 4.13: Small Size and Space Saving

Figure 4.14 shows there are 60% preferred a robust car cooling device. While there are 28% of them slightly agree with this and 12% of them disagree with it.

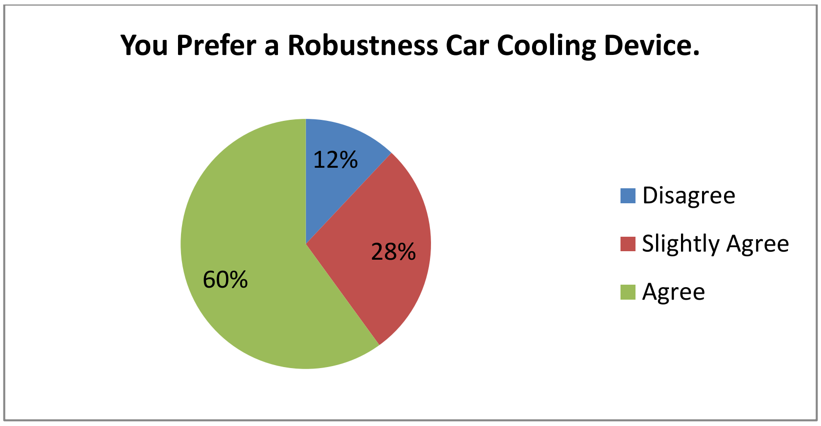


Figure 4.14: Robustness

The result shows that 76% of the respondents agreed that a car cooling device that function well is the importance that they concerned. There are 16% of them disagreeing and 8 % of them slightly agree with this.

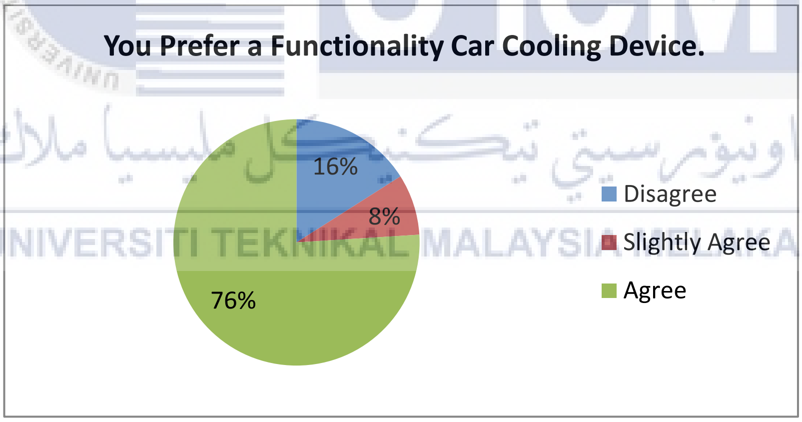


Figure 4.15: Functionality

The customer requirements generated from the survey questionnaire are functionality, robustness, small and space saving, aesthetic, reliability, portability, durability, ease of maintenance, affordable price, simple and user friendly. With the customer requirements generated, it is then grouped into House of Quality for further correlation with engineering characteristic generated.

4.2 House of Quality

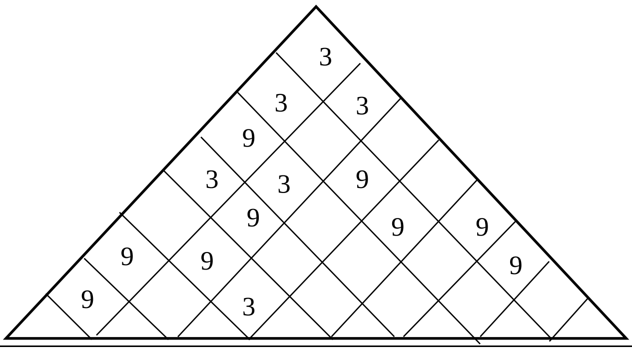
House of Quality is a central tool of Quality, Function and Deployment to assure quality. It is a systematic product planning and graphic representation of product design information organized as a matrix of rooms, roof and basement.

Based on this House of Quality, the customer requirement on (y-axis) and engineering characteristics (x-axis) is shown in the table below. Detailed understanding of the problem is required, including customer requirements, importance weights, engineering characteristics and customer satisfaction. The weightage shows that the customer importance requirement level on a car cooling device. The relationships between engineering characteristic and customer requirements are shown by the number which indicate the level of related between each other.

The weightage is categorized into three which is 0.15, 0.10 and 0.05 based on the importance and priorities that customers would want on the design of car cooling device to least importance respectively. There are ten customer requirements that generated from the survey questionnaire given. Three customer requirements that have 0.15 weightage are cost affordability, functionality and portability. This has shown that customers always seek for valuable and economical product which able to function well. The product has to be portable so that it is easier to move around and keep it somewhere. The customer requirements that has 0.10 weightage are durability and space saving. The second importance of customer requirements shows that customer would want a durable product which can sustain for life long. The product designed does not consume space so that it would make customer more convenient to keep the product. There are four customer requirements that scored 0.05 in weightage which are robustness, maintainability, reliability and aesthetic value.

The engineering characteristic generated are manufacturing cost, number of sub functional parts, material used, weight without loading, capacity of device, rotation frequency of DC motor, factor of safety and voltage input. The correlation is rated based on the relationships among customer requirements and engineering characteristics. The weightage importance calculated from the equation (1) shows that number of sub functional parts has highest value which is 6.15 among eight engineering characteristics. This has shown that the customer requirements correlated most to the number of sub functional parts. While second engineering characteristic is manufacturing costs with weightage importance 4.35. The next engineering characteristics are 3.90, 3.30, 2.40, 2.25, 1.80 and 1.35 for material used, rotation frequency of DC motor, and capacity of device, weight without loading, voltage input, and factor of safety respectively. The relative weight is calculated using equation (2). The rank is then given from highest relative weight to the lowest relative weight. The House of Quality ensured the product designed based on the customer requirements. These engineering characteristics are then transferred to precede the product design specification. Figure below shows the House of Quality.

Table 4.1: House of Quality



No	Customer Requirements	**Weightage (%)**	Manufacturing cost (RM)	Number of sub functional parts (unit)	Material used	Weight without loading (N)	Capacity of device (m^2)	Frequency of rotation of DC motor (rpm)	Factor of safety	Voltage input (V)
			Engineering characteristics							
1	Cost affordability	0.15	9	9	9		3	9	3	
2	Durability	0.10	3		9	3		3	3	3
3	Simple and ease operate mechanism	0.15	9	9			3			
4	Space saving	0.10		9			9			
5	Robustness	0.05	3		3	9		3	3	
6	Maintainability	0.05	3	3	9			3		
7	Reliability	0.05	3	9	9	3			9	3
8	Portability	0.15	3	3	3	9	3			
9	Functionality	0.15	3	9				9		9
10	Aesthetic	0.05		3	3		3			
Weight Importance			4.35	6.15	3.90	2.25	2.40	3.30	1.35	1.80
Relative Weight			0.171	0.241	0.153	0.088	0.094	0.129	0.053	0.071
Rank			2	1	3	6	5	4	8	7

Indicator

0 - weak relationship 3 - medium relationship 9 - strong relationship

4.3 Product design specification

The product design specification is done right after the completion of House of Quality. The requirements must be met to produce a successful product. It is useful for designing and implementing system on the product. With the product design specification, the related engineering characteristics and requirements are ensured within limitation. It was then turned into specification which the requirements have to be fulfilled during design of the car cooling device.

Table 4.2: Product design specification (PDS)

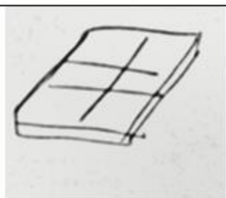
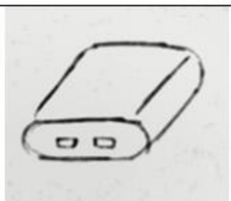
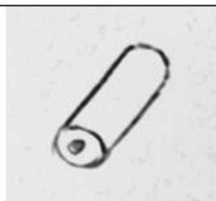
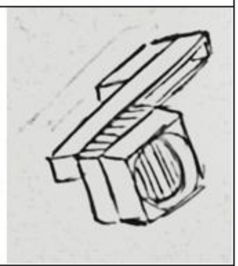
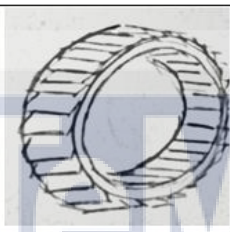
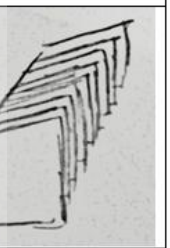
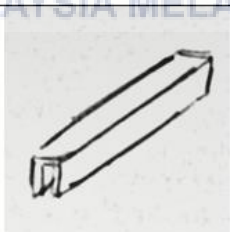
No.	Engineering Characteristic	Unit	Value
1	Manufacturing cost	Ringgit Malaysia	< RM200
2	Number of sub functional parts	unit	< 12
3	Material used	type	Plastic, metal
4	Weight without loading	kg	<10
5	Size of device	mm x mm x mm	<250mm x 250mm x 300mm
6	Rotation frequency of DC motor	rpm	1500-5000
7	Device operation hour	hour	>8hour
8	Voltage input	Voltage (V)	>5

The car cooling device designed should be affordable and is worth with the value so that it is economic friendly. The targeted manufacturing cost of the cooling device is less than RM200 with lesser sub functional components as possible. It assisted in reducing the manufacturing cost and material cost. The material used should be affordable and easy to get, recyclable, and also good heat resistance so that it produced durable cooling device and shall be replaced with cheaper and easier get part when part of the cooling device spoiled. The cooling device designed shall not be exceeded 250mm x 250mm x 300mm and 10kg so that the device is portable and less space consumed. The voltage supplied shall be more than 5kg to operate the device such as higher power consumption for higher speed rotation of fan to create more air movement and for better air circulation. The voltage supplied shall enough to supply for all times the device is required to work such as maximum of 8 hour. Voltage rechargeable and storable is preferred to prevent wastage. The rotation of DC motor should be within 1500 to 5000 rpm in order to provide suitable requirement of device and release less heat and less vibration which able to be supplied with the voltage fixed aforementioned. The device designed must be safe to use always to prevent any fatalities and causalities.

4.4 Morphological chart

After the product design specification and research regarding to the related standard requirements of components of car cooling device, five sub functional components is generated which are power supply, frame, ventilation blower, cooling agent, and device holder. The morphological is the chart that consists of alternative form of sub functional parts that can perform similar function by visual illustration. It provided simple yet powerful analysis of design requirements. It effectively reduces complexity of the rich research data, while maintaining enough accuracy for intended analysis.

Table 4.3: Morphological Chart

Sub functional parts	Option 1	Option 2	Option 3	Option 4
Power supply				
Frame/ cover				
Ventilation blower				
Cooling agent				
Device holder				

Power supply, ventilation blower and device holder consisted of three options of alternative ways to perform same sub function. While frame and cooling agent consisted of four alternative options to perform the sub function. The power supply is necessary to be included when the device used is device that possessed the use of electronic. There are three alternative options for power supply which could be solar panel, power bank, or battery which is also rechargeable. The ventilation blower could be axial fan, centrifugal fan and also mini fan. The fan is rotated by using motor so that it required electric power supply. Device holder has three optional alternative components which are the suction cups, magic sticker, and also gap type holder. The car cooling device could be mount anywhere inside car cabin therefore there are different type of device holder for car cooling device mount on different position. Frame is used to support and cover the ventilation blower and giving a good surface outlook without affect device functionality. Cooling agent also known as the tools used to reduce temperature or absorb heat or dissipate heat in this context. There are four type of alternative cooling agent which is compressed air tank, thermoelectric cell, phase change materials and also heat sink.

4.5 Concept design generation

4.5.1 Concept design 1

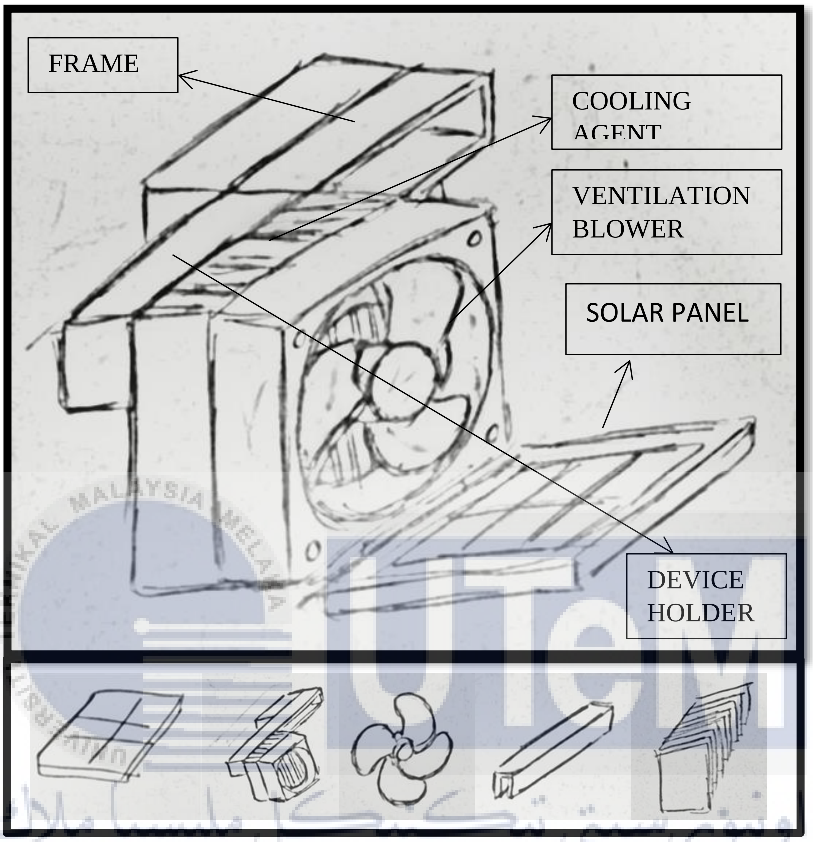


Figure 4.16: Concept 1

This concept design consisted of the combination of following options that selected from the morphological chart:

Power supply – option 1

Frame – option 4

Ventilation blower – option 1

Cooling agent – option 4

Device holder – option 3

This concept design is inspired by the computer processor unit cooling fan. The heat sink is used to attach to the heat source so that the heat can be sucked out and passed through the heat sink when axial fan rotated. The heat sink is installed to face outside of car cabin which is surrounding. The heat sink is used to dissipate heat effectively to prevent overheating of processor of computer; the concept is then applied on designation of car cooling device where car cabin is the heat source. This concept used gap type device holder so that the gap can fit the window thickness and clip the device on the window. The window of car is required to be lowered down a bit to mount the device. Smaller gap opening could assist the ventilation and reduction of temperature in car cabin while still maintains the secure of car. There are two axial fan used where one faced inside of the car to introduced cooler ambient air into the car cabin meanwhile another faced outside of the car which installed right in front of heat sink is used to suck out hot air inside the car cabin. By introducing cooler air and reduce the hot air inside car cabin, the temperature inside car cabin can be lower down.

4.5.2 Concept design 2

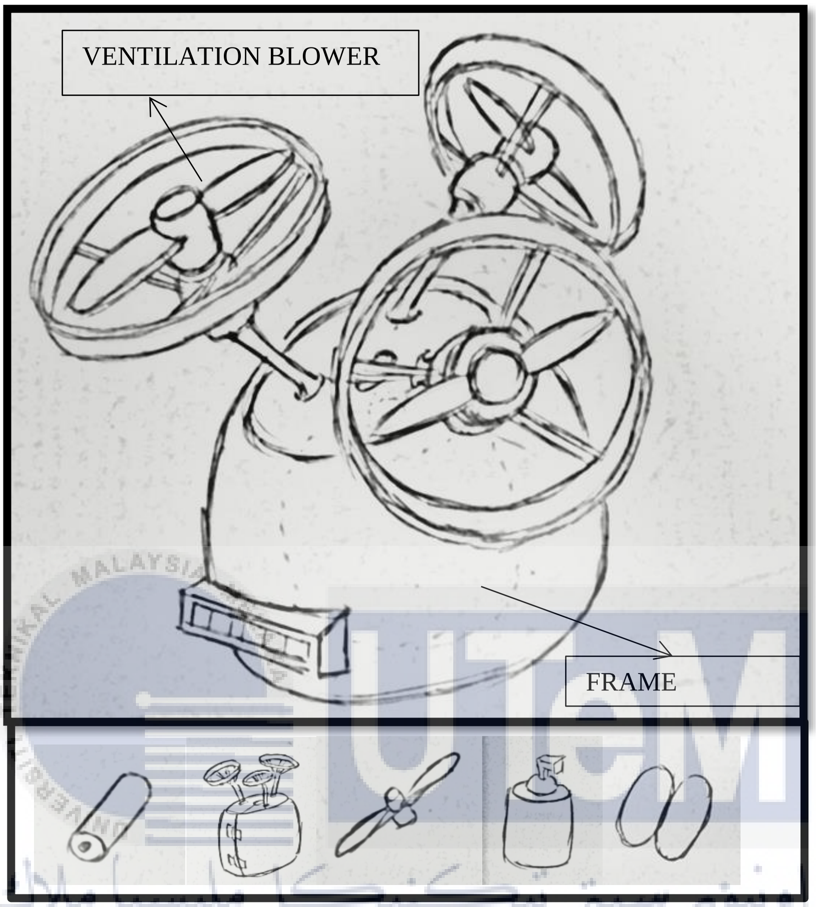


Figure 4.17: Concept 2

This concept design consisted of the combination of following options that selected from the morphological chart:

Power supply – option 3

Frame – option 3

Ventilation blower – option 2

Cooling agent – option 1

Device holder – option 2

This concept design is inspired by the combination of the handphone mini cooling fan and water spray cooling system. There are three mini cooling fan installed on the device which can be adjust in direction. The direction is set to be three different direction so that it can make create more air movement surround the device. Unlike the first concept, this concept used the magic sticker which fixed the device at anywhere inside car cabin. The magic sticker can be applied on any kind of materials and is reusable. This concept used rechargeable battery instead of solar panel to ensure its portability and mini sizing. It can be decoration of car while provide ventilation and temperature reduction inside car cabin. The high pressure compressed air tank inside the device has automatic spray controller. The compressed air sprayed become vapour due to the pressure difference is cold so that it can reduce the air temperature inside car cabin. However, the battery is limited due to there is limit power supply per charge available. The ventilation have to prevent from kids that the simple frame may not protect touching in several way. This concept is suitable to be used for short using of car that required only short period of temperature reduction.

4.5.3 Concept design 3

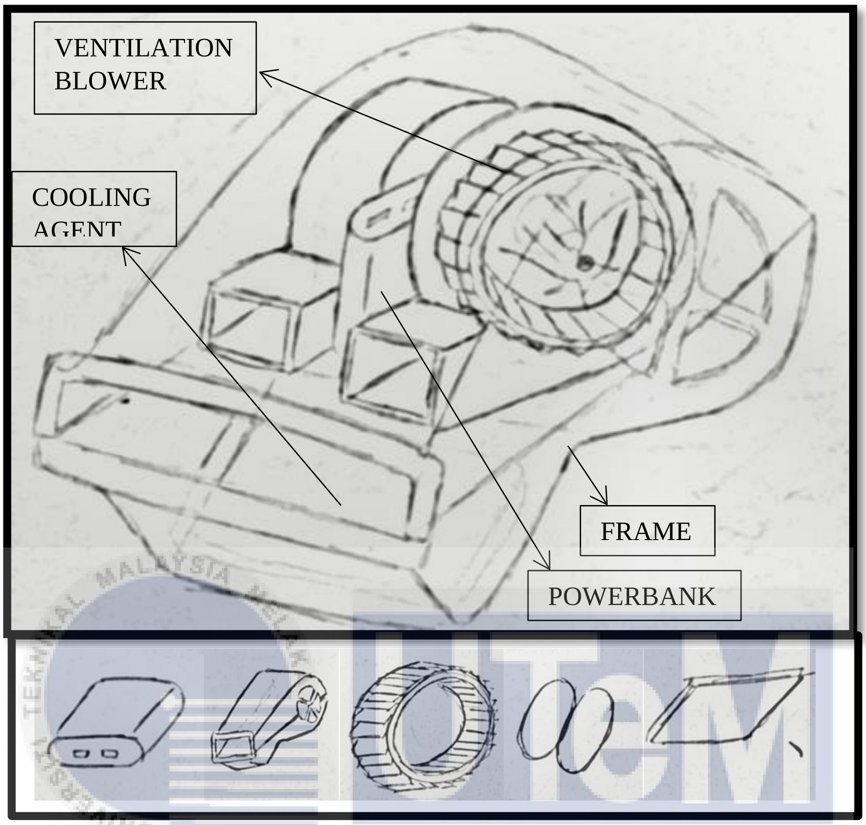


Figure 4.18: Concept 3

This concept design consisted of the combination of following options that selected from the morphological chart:

Power supply – option 2

Frame – option 2

Ventilation blower – option 3

Cooling agent – option 3

Device holder – option 2

This concept design was inspired by centrifugal portable cooler fan. The ventilation blower used in this concept is the centrifugal fan which sucked air in and out at a duct which perpendicular to the direction of air sucked in. this is different from axial fan where sucked air in and out in only one direction. This concept is designed to be put at anywhere and can be used at anywhere other than car cabin. The frame consisted of a cover which can be open in order to take out the powerbank and also put in cooling agent such as water and phase change material at the place prepared in front of the air out direction. This is because the air that released would passed through the cooling agent release the heat to the cooling agent. The air came out from the device is cooler and allowed the replacement of hot air to cooler air which subsequently reduce the temperature inside the car cabin. Phase change material such as the ice bag which freeze in freezer is used to relieve the heat during fever. This can be applied to the car cabin to relieve the heat in car cabin by absorb the heat until all of the material change to liquid phase. The deep curve for placing the cooling agent prevent water from moving to the blower side which might cause damage of the device. This cooling device can provide cooler air when cooling agent still functioning while this device stop once the powerbank is exhausted.

4.5.4 Concept design 4

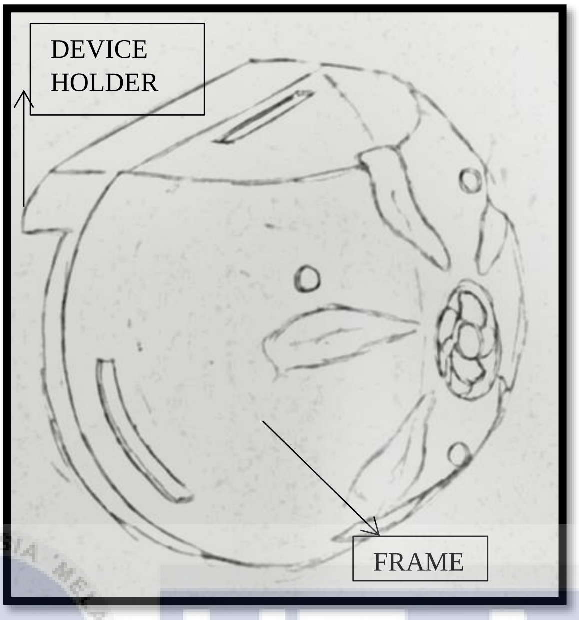


Figure 4.19: Concept 4

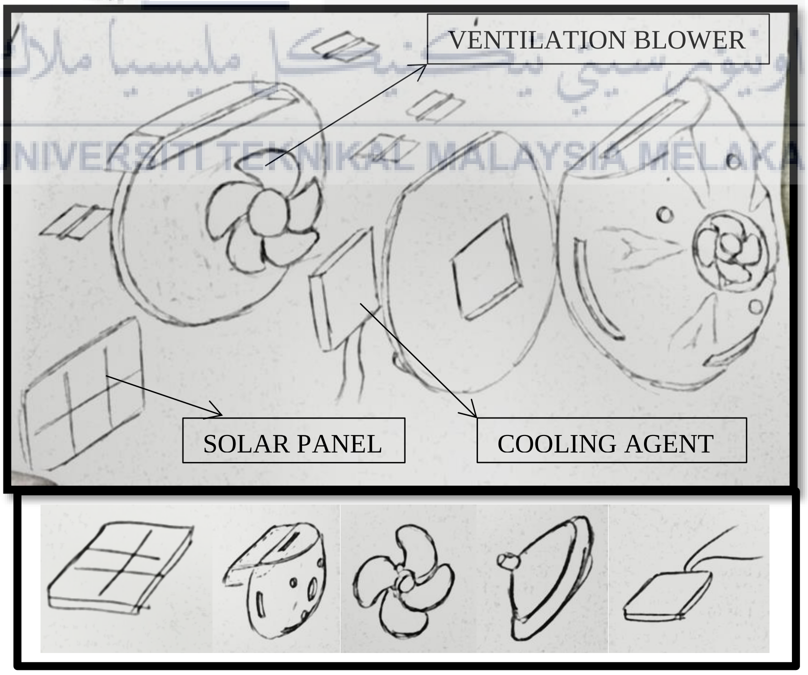


Figure 4.20: Explorer View of Concept 4

This concept design consisted of the combination of following options that selected from the morphological chart:

Power supply – option 1

Frame – option 1

Ventilation blower – option 1

Cooling agent – option 2

Device holder – option 1

This concept design was inspired by the idea of table fan. This concept used the axial fan. There are two fan used in this concept where one is large fan that put inside and smaller fan that put at outside. The larger fan which is used to create static pressure and air movement that sucked in the hot air inside the car cabin via the rectangular duct at side. The hot air is then transferred to outside. Thermoelectric cell which has two surface where one is used to generate heat and another face is used to generate cold by using the electric supply. The cold side can be used to circulate the hot air that sucked into the cold area by using the smaller fan in front via three circular holes. The hot air is then turned into cooler air and blow to the car cabin. The solar panel is put within the suction cups that fixed the device on window of car. The window is required to open a gap for the opening duct of device. The device can be disassembled and assembled easily. This concept design is suitable for the car that do not tinted their window which enabled better reception of sunlight to operate the device.

4.6 Weighted decision matrix

Decision matrix offer a formal means for declaring at the beginning of the decision process what are the most important aspects to consider in making a decision. A decision matrix evaluates and prioritizes a list of options. First, a list of weighted criteria is established and then is evaluated each option against those criteria. The measurement of the best and the reason is known from the results. Four concept of seed planter is generated to be evaluated. This is used as reference for selection of best concept for further development, modification and optimization

Table 4.4: Weighted Decision Matrix

		Concept Alternatives							
		Concept 1		Concept 2		Concept 3		Concept 4	
Criteria	Weight Factor	Rating	Weighted rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Portability	0.15	3	0.45	4	0.60	2	0.30	3	0.45
Manufacturing Cost	0.15	3	0.45	4	0.60	2	0.30	2	0.30
Size	0.10	3	0.30	3	0.30	2	0.20	3	0.30
Durability	0.15	3	0.45	0	0.45	1	0.15	3	0.45
Maintainability	0.05	2	0.10	1	0.05	3	0.15	3	0.15
Functionality & efficiency	0.15	2	0.30	4	0.30	4	0.60	3	0.45
Ease of mechanism	0.05	3	0.15	2	0.10	0	0.00	3	0.15
Reliability	0.05	3	0.15	1	0.05	2	0.10	3	0.15
Aesthetic	0.10	0	0.00	1	0.10	2	0.20	3	0.30
Manufacturing time	0.05	3	0.15	3	0.15	4	0.20	4	0.15
TOTAL	1.00	-	**2.50**	-	**2.70**	-	**2.20**	-	**2.85**
Ranking	-	-	**3**	-	**2**	-	**4**	-	**1**

Rating	**Value**
Unsatisfactory	0
Tolerable	1
Adequate	2
Good	3
Very good	4

The criteria that have been selected to make the decision on each of the concept is portability, manufacturing cost, durability, maintainability, functionality, ease of mechanism, reliability aesthetic and manufacturing cost. The weight factor is categorized into three categories which is 0.15, 0.10, and 0.05 based on the understanding of importance of the criteria selected to the car cooling device. There are four criteria has weight factor of 0.15 which is portability, manufacturing cost, durability, and functionality. There are also two weight factor of 0.10 which is size and aesthetic. Another four criteria such as maintainability, ease of mechanism, reliability and aesthetic. The more the weight factor and rating, the higher the contribution of decision making.

In the aspect of portability, concept 3 has least rate of 2, concept 1 and 4 has rating of 3 and concept 2 has highest rating of 4. This might because of concept three has more sub functional components and it has larger size which also have unsealed container for cooling agent. This make it less portability. Concept 1 and 4 is easier to move from one place to another due to its smaller size. Concept 3 has least sub functional components and simple design so that it has highest portability value.

Concept 2 has highest rating of 4 in the aspect of manufacturing cost. This might because of because of its lesser components that used lesser materials. Concept 1 has rating of 3 due to its simple outlook of the device which all is in square shape. Concept 3 and 4 which has curve on the surface and more sub functioning components has least rate of 2. In the aspect of size, rating shows that concept 1, 2, and 4 has same rate of 3. It shows that three of these device has almost same size while concept 3 that has been rated 2 has larger size. The durability of the cooling device of concept 2 is the lowest. This might because of its simple structure that has least protective components. Then, concept 3 has rated 1 which might because of its complexity and many components inside that might spoil easily. Concept 1 and 4 has same rate of 3. Concept 3 and 4 has same rate of 3 in the aspect of maintainability. Due to the more components, concept 3 and 4 has higher maintainability rating. While concept 1 with least rating of 1 required less maintenance which might because of its component is easier to carry out maintenance. Concept 1 has moderate rating of 2 due to its simple arrangement and components of concept 2.

Rating shows that concept 2 and 3 has highest functionality of 4. It might because of the compressed air tank of concept 2 that enable cooler effect to the hot air inside car cabin. It might also because of the centrifugal fans that drawn the hot air into and passed through the cooling agent which make it effective to cool down the hot air sucked. While concept 1 and concept 4 has rating of 2 and 3 respectively. The concept 1 has only heat sink that used to dissipate heat by forced and natural convection. The concept 4 has larger fan to sucked hot air out of the car cabin and small fan to suck air that cold by the cold surface of thermoelectric cell to the surrounding. However, solar panel supply allowed continuous functioning of device.

At the aspect of mechanism, concept 3 has complex structure which used the power bank as power supply, the cooling agent has to be put into the device manually and prevent movement or tilt while watery cooling agent is used. Concept 1 and concept 4 has simplest mechanism that is supplied by solar panel which ensure that the device begin operation once expose to sunlight. Concept 2 which has controller for the compress air sprayer make it difficult for user that not know the knowledge so much. Concept 1 and 4 again has highest rate of reliability while concept 3 and 2 is rated 3 and 1 respectively. Concept 4 has highest aesthetic value due to its special outlook shape and curve surface. Concept 1 which is rectangular in shape has the lowest aesthetic value. Concept 2 is rated lower than concept 3 which has been rated 1 and 2 respectively. Concept 3 and 4 which has complex frame required more manufacturing time while concept 1 and 2 required less manufacturing time due to its simple manufacturing assembly.

The total score of concept 4 is the highest which is 2.85, then is concept 3 which is 2.70, concept 1 which is 2.50 and the concept 3 which is 2.20. The rank shows that concept 4 is the first and is selected for further development due to its highest fulfillment of criteria. It has been rated 3 and 4 for all the criteria.

4.7 Final concept design (modified)

The concept design is then modified according to the analysis of weighted decision metrics. The finalized design used thermoelectric Peltier cooling module as the cooling agent. It produce heating and cooling effect at each of side of the module consequently and therefore two ventilation blower which are axial fan is selected to induce the air movement and encourage forced ventilation. Air from surrounding is conducted into the cabin and passed through the cooling surface of module to further lower the temperature of air into the cabin. While hot air in cabin is conducted and passed through the heating surface of the module as well as also conducted the heat from the module to surrounding. The device is hung at the bottom of roof as a built in car cooling device which could be dispatched from its position. Thus, the car manufactured in future would also has a modified design of roof to facilitate the installation of car cooling device.

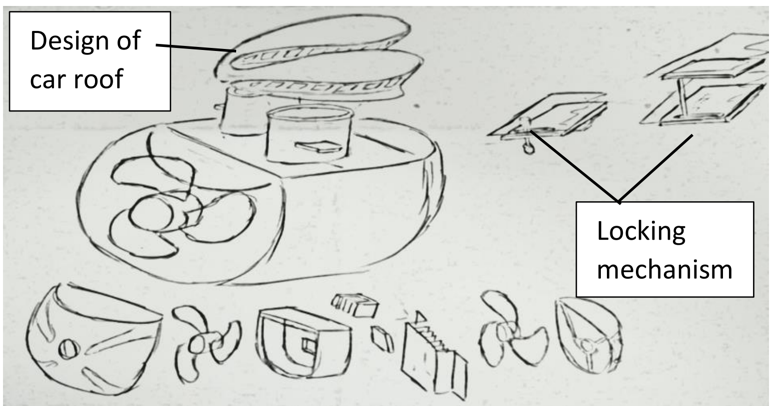


Figure 4.21: Finalized concept design of car cooling device and design of car roof

CHAPTER 5

PRODUCT ARCHITECTURE

5.0 Introduction

This chapter included the arrangement of functional elements when assembly as a product. The flow of material, forces and energy, and also flow of signal and data are represented in the product block arrangement. Then, rough geometric layout is conducted to show clearly the arrangement of the functional block and also the flow of the air into and out of the cabin with all labelled well and clear in the figure shown.

5.1 Arrangement of functional elements

It is the arrangement of functional elements into physical chunks which become the building blocks for the product. Modular product architecture consists of each physical chunk implements one or few functional elements in their entirely chunk. The interaction between chunks are well defined. While integral product architecture consists of several functional element implemented in chunk. The interaction between chunks are poorly defined. However, it increase the performance and reduce cost for product. It helped to drives the design and also has impact on manufacturing cost, product evolution.

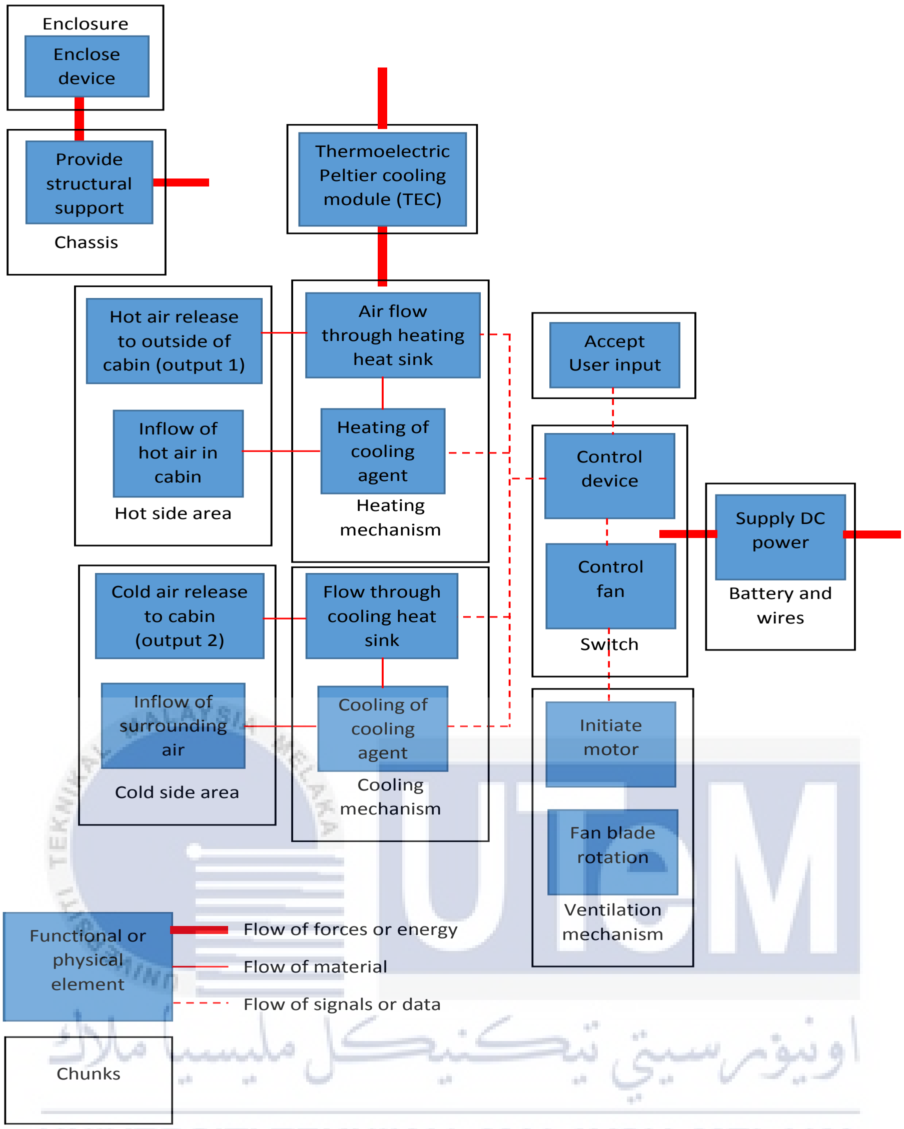


Figure 5.1: Schematic of product

From the schematic drawn, it consists of eleven chunk where five of it contains only one functional or physical elements while another six chunk contains two functional or physical elements. Supply DC power transmits electrical energy to the switch in order to control the initiation of device and fan. Then, the signals is received from user input by turn on the switch. The control fan switch initiate the signal to initiate the motor for fan blade rotation. The initiation of motor and rotation of fan blade has built the ventilation mechanism where the rotation of fan blade causes air movement and therefore there is differences in air pressure. So one side of fan acts as air absorbing and another side of fan acts as air releasing. The switch on of control device is then initiate the cooling and heating mechanism.

Thermoelectric Peltier cooling module received the electric energy. The electric energy passed through the module which consists of P semi-conductor and N semi-conductor. The electron inside the semi-conductor moving around the copper layer in between by releasing and absorbing heat energy.

Therefore, there are two side where one side releasing heat energy and another side absorbing heat energy which heating and cooling respectively. At the hot side area, the hot air in cabin flow through the heating surface and release to surrounding which is also outside of cabin. While air from surrounding flow through the cooling surface and then lower down the temperature of air flow through. The cooler air is then release back to cabin. Enclosure and chassis provide cover and structural support to the device respectively where forces is applied on them. This car cooling device is designed as built in device under roof of car but is allowed to take off when in needed. Therefore, the car roof also has a special design for the installation of car cooling device. Rough geometric layout is shown to show the arrangement of product functional element and also the flow of air into and out of the cabin.

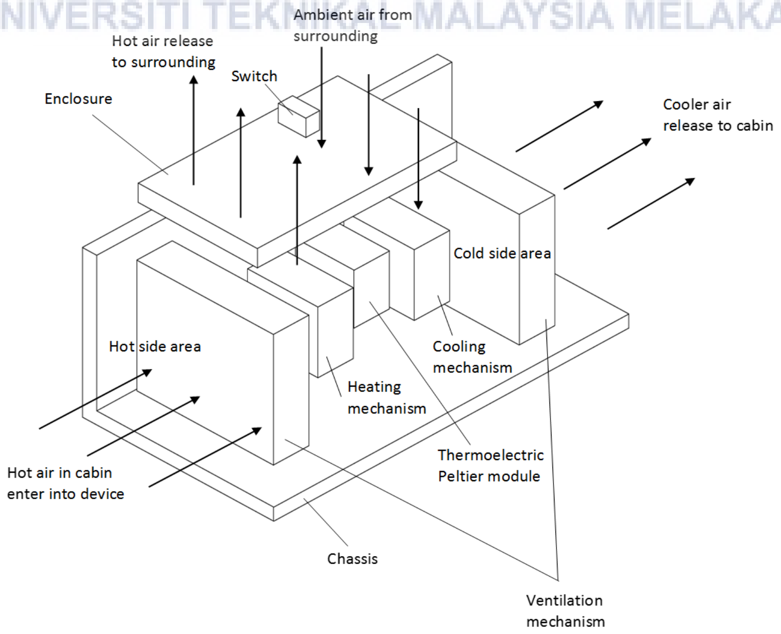


Figure 5.2: Rough geometric layout

CHAPTER 6

CONFIGURATION DESIGN

6.0 Introduction

Configuration design included the selection of materials, manufacturing process based on the constraint and requirement as stated earlier in the product design specification. The availability of materials and manufacturing process of the components is strongly related to further development of a part design. The function of the part has a close interrelationship with the dependency of the material and process to produce it.

6.1 Material selection

According to the product design specification, the material and manufacturing process chose to produce the device will be different based on its component function, requirement, constraint and also suitability. For housing of the device, Acrylonitrile Butadiene Styrene (ABS) is selected as its raw material due to its high resistant to temperature up to 110ºC and melting point up to 200ºC. Besides that, it is waterproof material so that as the housing of the device it could protect the electronic device from spoilage caused by water. It is also a good electric insulator which do not conduct electric. It has light weight so making it convenient and portable. It has also easy way to manufacture and most important is it has lower cost and biodegradable so is environmental friendly material. Its absorbance is great to absorb the vibration caused by the rotation of fan. The material used to manufacture the heat sink must be great heat conductor so that it has good efficiency of absorb and release heat. Copper is too expensive and heavier so aluminium will be selected. Although copper is better heat conductor, but aluminium would be enough to conduct the temperature of a car cooling device with a cheaper cost and lighter weight. Polystyrene is selected as insulator layer due to its ease of shape refining and cheap in cost with long lifetime. The fan selected is 120mm high airflow server grade fan with 2 ball bearings has revolution per minute up to 4400rpm. Therefore, it can induce more air movement to force the ventilation. Manufacturer could manufacture all the component or get some of the component from supplier in quantity to get cheaper price.

6.2 Manufacturing process selection

Process selected to manufacture the housing of cooling device would be injection molding or 3D printing. This is because the mold done could be used repeatedly for a longer life time while 3d printing do not need a mold. Even though 3d printing will be more flexible in design the shape, it has low strength of resist to weight applied. It required longer time to manufacture just one housing. In addition, larger part printed would easily found crack on the part. Thus, injection molding will be faster and cheaper in cost when manufacture in quantity. The product has higher strength also. While heat sink will be produce with either metal casting or cnc milling. Fan blade, fan frame also could be manufacture via injection molding. The assemblies of fan might be done by manpower or machine. The hanger part will be one of the part of housing so that it is more convenient to produce and reduce the quantity of part so that the speed of assembly would also increase.

6.3 Device operation hour

In the cooling device designed, there are two fan of 12V with 1.3A used to promote forced ventilation and also thermoelectric Peltier cooling module plate of 6V with 3A is used to generate cooling effect of the device. The figure below shows the electrical system designed to connect the car battery to the switch, both fan, and thermoelectric Peltier cooling plate module.

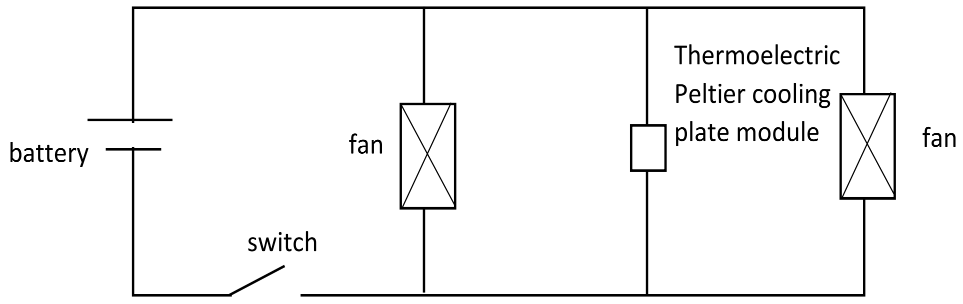


Figure 6.1: Electrical system of cooling device

Total current needed:

1.3A+1.3A+3A=5.6A

To operate the device, the current required is 5.6A.

A fully charged car battery has a capacity of 45amp hour.

Operation hour of the device:

45amp hour/5.6amp=8.03hour

Therefore, with the car battery as the power supply, it can ensure up to 8 hour of device operation.

CHAPTER 7

PARAMETRIC DESIGN

7.0 Introduction

This chapter included the decision of dimension where specific values is determined and tolerance is made if necessary to reduce the variability of the dimension that could lead to convergence of the design to the best design of parts. It increase the part's performance, quality and also manufacturability while minimize the cost. In order to improve the quality and performance of the part designed, failure mode and effect analysis (FMEA) is conducted to detect the possible failure and evaluate its occurrence, detectability, and also severity of the failure mode. Therefore, focus is on the part design and improve the part design before entering next chapter which is detail design.

7.1 Dimension and tolerances

Tolerances is given to ensure the maximum quality and performance while minimum cost is undertaken. The tolerance allowed on the dimension of the components and parts are the same where +/- 1mm only for each of the dimension stated and exact value of dimension is used in detail design.

7.2 Failure mode and effect analysis (FMEA)

Table of FMEA shows that the part and its function, possible failure mode, effect of the failure of the part, root cause of the failure mode and the evaluation of severity, occurrence, detectability according to the table indicator shown. The risk priority number is the product of severity, occurrence, and detectability. The higher the risk priority number, the higher the possible failure mode affect the product and being detected. Critical value is the product of severity and occurrence.

Table 7.1: Failure mode and effect analysis (FMEA)

Part	**Function**	**Failure Mode**	**Effect**	**Root Cause**	**Severity**	**Occurrence**	**Detectability**	**Risk Priority Number**	**Critical Value**
Switch	Initiates device	Fails to turn on/ off	Device unable to use	Release spring failure	7	3	9	189	21
				Contact fused	8	3	9	216	24
Heat sink (metal block)	Increase surface area for cooling and heat dissipation	Damage of structure	Overheat of Peltier module	Physical damage	7	3	8	168	21
Fan	Induce air movement, introduce ambient air to pass through cooling module then release into cabin, and conduct hot air in cabin out of cabin.	Fails to operate	Fail cooling and low effect of forced ventilation	Battery depleted	7	3	7	147	21
				Overheated motor	10	3	5	150	30
Peltier cooling module	Provide cooling effect	Fails to provide cooling effect	Fail cooling	Random failure	5	4	10	200	20
insulator	Prevent heat from enter into cold side area	Fracture	Less effective of cooling	Structure deformation	6	4	3	72	24
Housing	Act as chassis for the device	Fracture	Danger to user	Plastic deformation	10	3	7	210	30
			Poor insulation						
			Damage to other parts						

Severity (S) Rating	**Type of effects**	**Description**
10	***Catastrophic***	Causes injury to people, property and or the environment
9	Extremely Harmful	Causes damage to product, property or environment
8	Very Harmful	Causes damage to product
7	***Harmful***	Major degradation of function
6	Moderate	Causes partial malfunction of product
5	Significant	Performance loss causes customer complaints
4	***Annoying***	Loss of function is annoying, cannot be overcome
3	Minor	Some loss of performance, but can be overcome
2	Insignificant	Very little function degradation
1	***None***	No noticeable effects in function or harm to others

Occurence (O) Rating	**Likelihood**	**Description**	
10	***Expected***	>30 %	> One per *day*
9	Very likely	30 % (3 per 10)	
8	Probable	5 % (5 per 100)	One per week
7	***Occasional***	1 % (1 per 100)	One per *month*
6	More plausible	0.3 % (3 per 1,000)	One per three months
5	Plausible		
4	***Remote***	0.006 % (6 per 10^5)	One per *year*
3	Unlikely	0.00006 % (6 per 10^7)	One per three years
2	Very unlikely		
1	***Improbable***	< 2 per 10^9 events	> *five years* per failure

Level	**Detection**	**Criteria: Likelihood of Detection by design control**	**Probability (%) of individual defect reaching the customer**
10	Absolute uncertainty	No design control or no chance of detection	86 - 100
9	Very remote	Very remote chance of detection	76 - 85
8	Remote	Remote chance of detection	66 - 75
7	Very low	Very low chance of detection	56 - 65
6	Low	Low chance of detection	46 - 55
5	Moderate	Moderate chance of detection	36 - 45
4	Moderately high	Moderately high chance of detection	26 - 35
3	High	High chance of detection	16 - 25
2	Very high	Very high chance of detection	6 - 15
1	Almost certain	Almost certain detection	0 - 5

From the FMEA table shown, some of the component's failure mode might consists of more effect and root cause. Among all of the possible failure mode of components, the severity of the effect shows that failure mode of housing and fan due to overheated motor are highest rating of 10. While for the likelihood of the failure mode occur, it shows that most of them has 3 to 4 rating where Peltier cooling plate module and insulator rated 4. For the detection of the failure mode by design control, it shows that Peltier cooling plate's failure mode has the easiest detection by design control by rating of 10. However, the risk priority number shows that the failure mode of switch due to contact fused scored highest which is 216 where it should be given focus to improve the quality and performance of the device. Then is the failure mode of housing, Peltier cooling module, switch due to release spring failure, heat sink, fan, and lastly insulator with the risk priority number of 210, 200, 189, 168, 150 and 147, and 72 respectively.

CHAPTER 8

DETAIL DESIGN

8.0 Introduction

The detail design is drawn based on the dimension decided later via CAD software which CATIA is used in this session. According to the best concept design selected via weighted decision matrix which was concept four, there are some modification on the best concept design which generated the finalized concept design and then undergoes further development to its detail, exact dimension and then detail design drawing. The part drawn are housing, fan cover, heat sink, cold side heat sink, aluminium block, thermoelectric module, thermoelectric module insulator, cold side insulator, fan, thermoelectric set holder. The drafting of all part is produced. The assembly with bill of material of the car cooling device is done and also the exploded view with balloon generated.

8.1 View of product

The isometric view, front view, top view and right side view is placed together by using drafting workbench of CATIA. It is then saved as pdf. The bill of materials of the device is shown in the drafting of assembly of product. The exploded view is shown with balloon generated. Material is applied while isometric view and exploded view of product with material applied is shown. Refer **Appendix B** for the drafting.

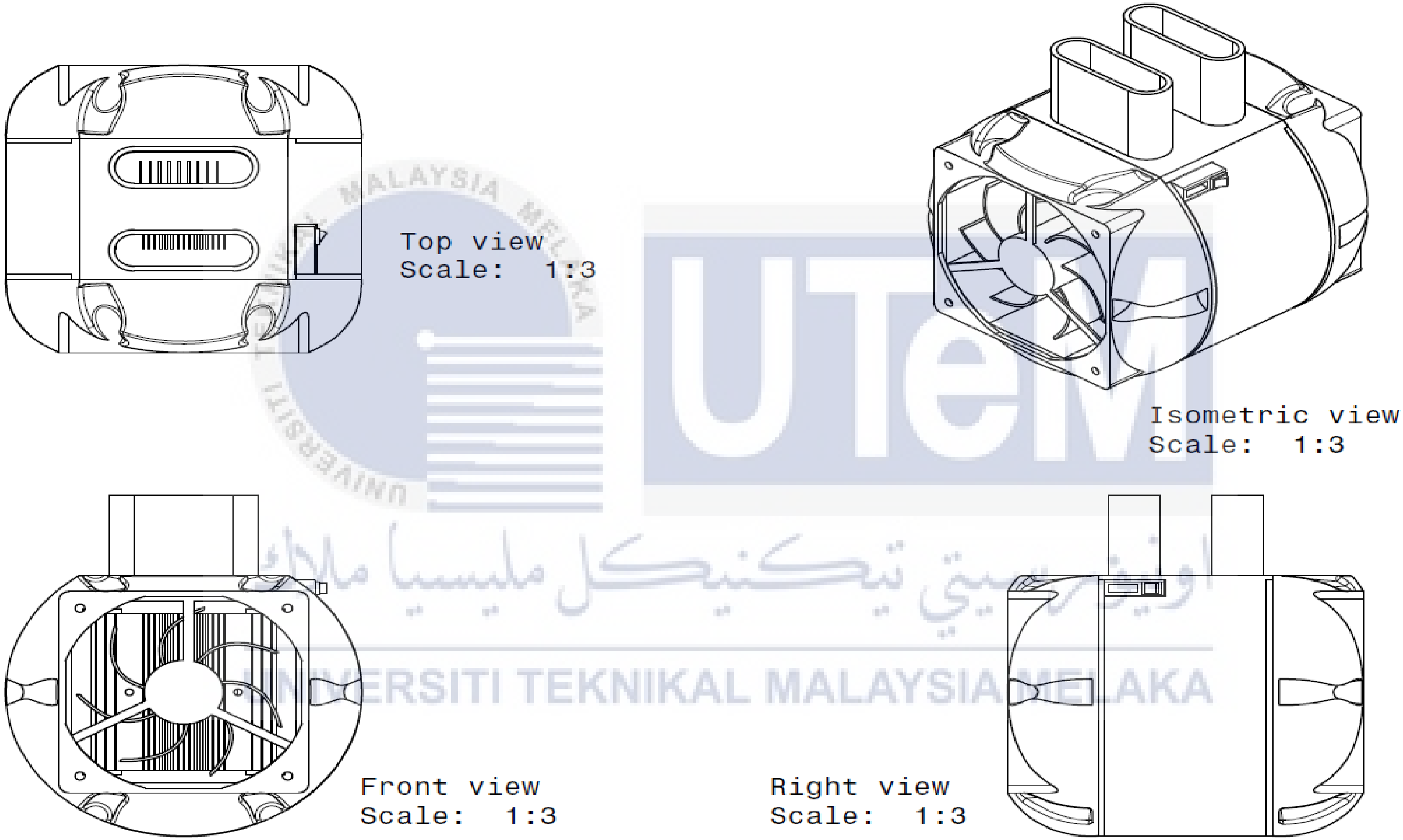
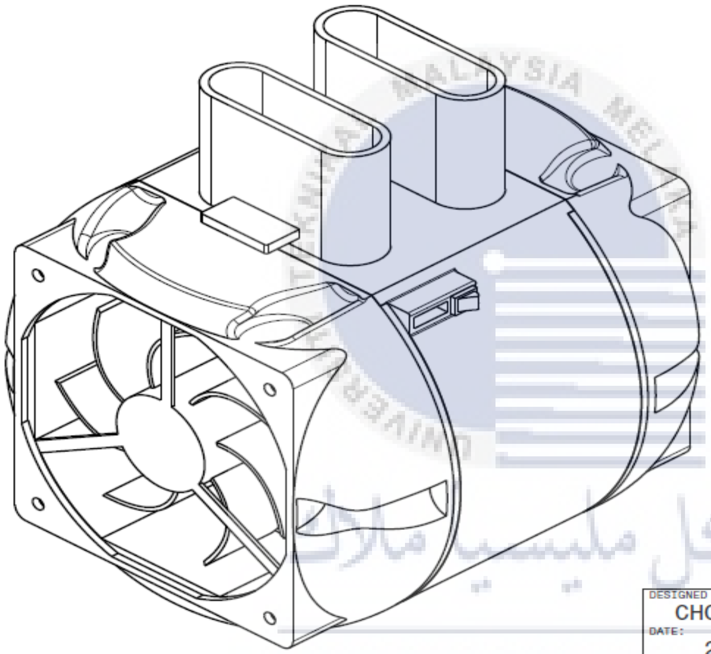


Figure 8.1: Isometric, top, front, side view of device

Bill of Material: CAR COOLING DEVICE

Part Number	Type	Number	Quantity
tec module	Part	1	1
fan	Part	2	2
fan cover	Part	3	2
cold side heat sink	Part	4	1
cold side tec insulator	Part	5	1
hot side heat sink holder	Part	6	1
hot side heat sink	Part	7	1
front polystyrene insulator	Part	8	1
side polystyrene insulator	Part	9	1
switch	Part	10	1
housing	Part	11	1



Isometric view
Scale: 1:2

DESIGNED BY: CHOO HAE LING
DATE: 24/3/2018
CHECKED BY: XXX
DATE: XXX

ASSEMBLY

SIZE: A4

DASSAULT SYSTEMES

SCALE: 1:2
WEIGHT (kg): XXX
DRAWING NUMBER: CAR COOLING DEVICE
SHEET: 1/1

This drawing is our property; it can't be reproduced or communicated without our written agreement.

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_

Figure 8.2: Assembly view with bill of material

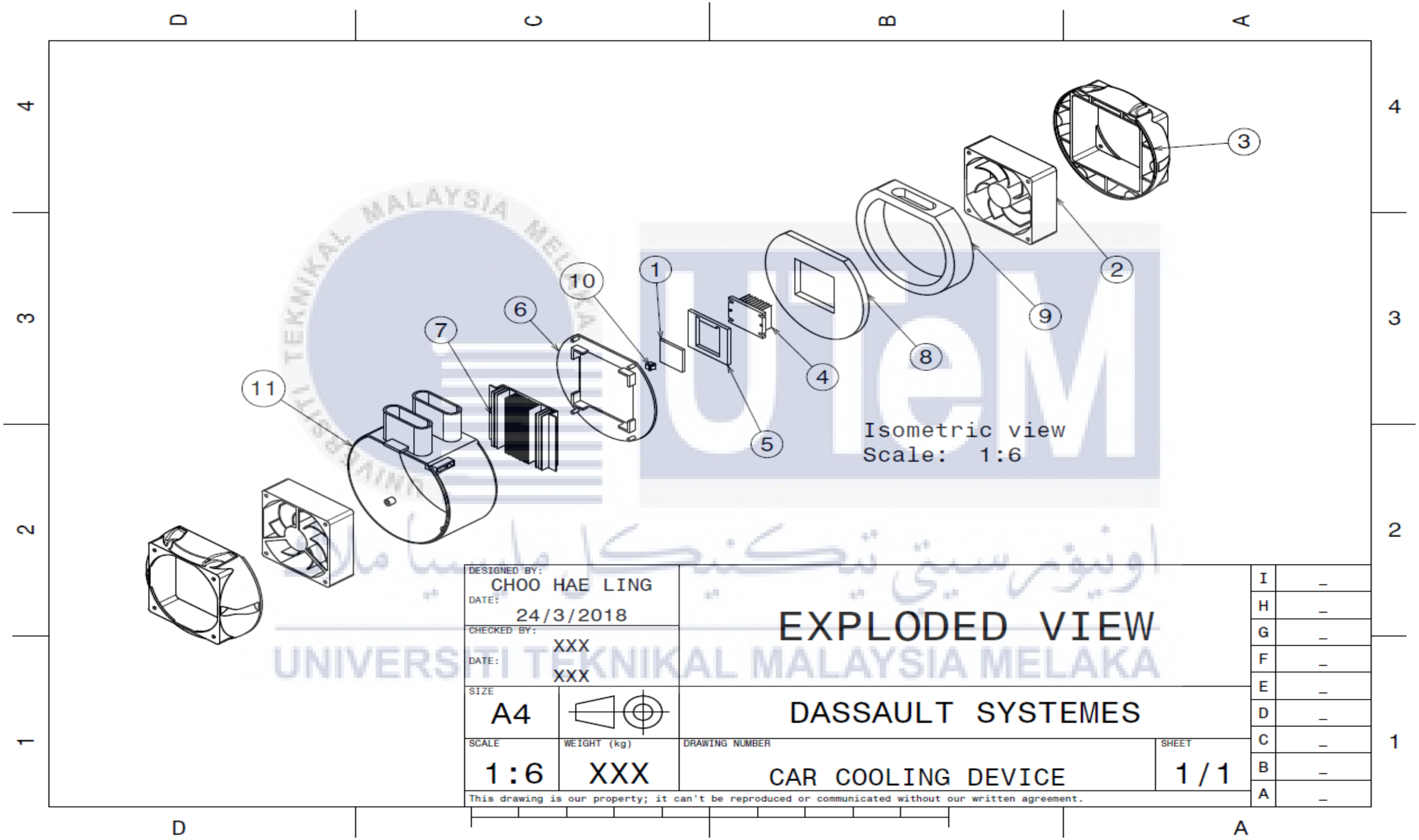


Figure 8.3: Exploded view with balloon generated

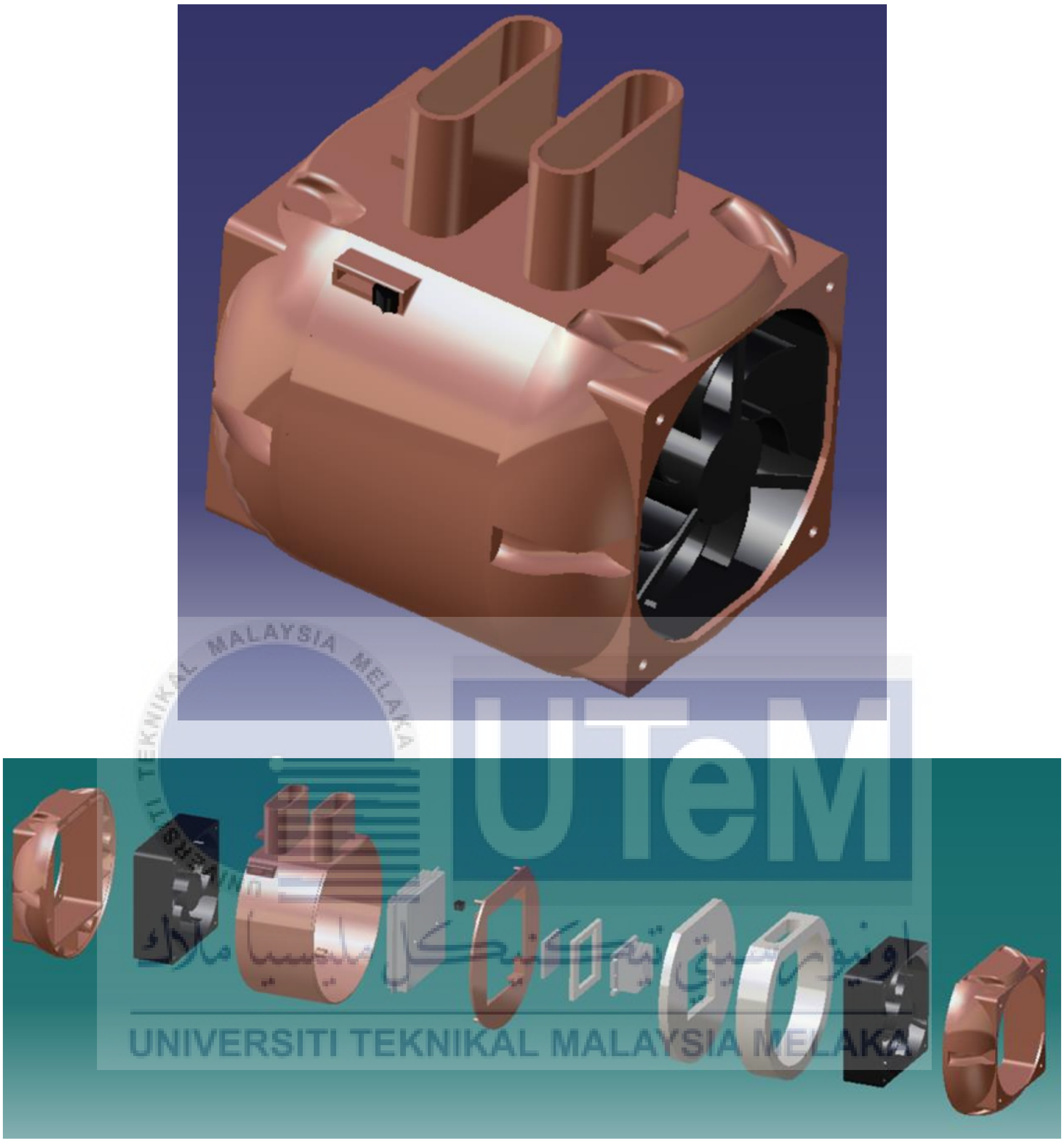


Figure 8.4: Isometric view and exploded view with material

CHAPTER 9

COSTING

9.0 Introduction

The costing is conducted to identified the manufacturing cost of the product and also the profit from expected price of the product. The simple product costing model is conducted for both product and prototype.

9.1 Costing of prototype

The batch for the product costing is set to be 100 unit per batch. The cost to fabricate the prototype shown is the total cost for 100 unit. From the costing, it shows that the fan and battery cost higher which is RM60 and RM58 per unit respectively. The price for manufacturing process is estimated also for 100 unit which is one batch of production. Total making cost for the prototype is RM18350 and therefore the making cost for one unit of prototype is RM183.50. the time required to produce one unit of prototype is 6 hour, with the labor cost of RM5 per hour, it shows that the total manufacturing cost for one unit of prototype is RM213.50. The prototype is recommended to sell with a price of RM299. By retailing to retailer with a 10% of retail margin, the trade price for retailer is RM269.10 per unit. Profit from the prototype is RM55.60 per unit which is 20.66%.

PRODUCT COSTING MODEL							
Product	CAR COOLING DEVICE PROTOTYPE						
	Batch Size (units)				100		
Materials:							
Qty	**Materials**	**Cost**	**Shipping**	**Other**	**Total**		**Per Item**
		£	**£**	**£**	**£**		**£**
100 SET	THERMOELETRIC PELTIER MODULE	4320.00			4320.00		
100 PCS	BATTERY 7.2A	5800.00			5800.00		
13 PCS	POLYSTYRENE FOAM 300MM*300MM	260.00			260.00		
50 PCS	PLYWOOD 1200MM*300MM*4MM	600.00			600.00		
400 PCS	L BAR	100.00			100.00		
1200 PAIR	BOLT AND NUT M4	120.00			120.00		
3600 PCS	CONCRETE NAIL 1INCH	50.00			50.00		
100 PCS	FAN 1.3A	6000.00			6000.00		
100 METE	WIRES	300.00			300.00		
200 PCS	SWITCH	500.00			500.00		
	Batch Total				18050.00		
Production Costs:		**Cost**	**Shipping**	**Other**			
	Process	**£**	**£**	**£**			
	CUTTING	100.00			100.00		
	GRINDING	50.00			50.00		
	JOINING	100.00			100.00		
	DRILLING	50.00			50.00		
					0.00		
					0.00		
	Batch Total				300.00		
Total Making Cost					18350.00		183.50
Time:							
	Hours to make batch				600.00		
	Hourly rate				5.00		
	Time cost per batch				3000.00		30.00
Profitability:							
	Recommended Retail Price (RRP)				299.00		299.00
	Retail Margin				10%		
	Trade Price						269.10
	Total material/time cost						213.50
	Profit Contribution (before overheads)						55.60
	Profit Contribution %						20.66%

Figure 9.1: Prototype costing model

9.2 Costing of product

The batch for the product costing is set to be 100 unit per batch. The cost to manufacture the product shown is the total cost for 100 unit. From the costing, it shows that the fan cost higher which is RM60 per unit. This product do not consist of battery cost due to the product will be receiving the electrical energy from car battery directly. The fan should be cheaper if the batch size is further increase. Manufacturing process involved in the product manufacturing included injection molding, assembly and finishig. The price for manufacturing process is estimated also for 100 unit which is one batch of production. Total making cost for the product is RM17360 and therefore the making cost for one unit of prototype is RM173.60 which is RM9 cheaper than the prototype cost. The time required to produce one unit of product is reduced to 3 hour compared with the time required by same batch size of prototype production due to the used of machine and equipment would increased the rate of production. With the labor cost of RM5 per hour, it shows that the total manufacturing cost for one unit of product is RM192.60. The product is recommended to sell with a price of RM299. By retailing to retailer with a 10% of retail margin, the trade price for retailer is RM269.10 per unit. Profit from the product is RM76.50 per unit which is 28.43%. Further increase the batch size could reduce further the cost for materials and therefore can has higher profit.

PRODUCT COSTING MODEL						
Product	CAR COOLING DEVICE					
	Batch Size (units)				100	
Materials:						
Qty	**Materials**	**Cost £**	**Shipping £**	**Other £**	**Total £**	**Per Item £**
100 PCS	THERMOELETRIC PELTIER MODULE PL	600.00			600.00	
200 PCS	WIRES 1METER	500.00			500.00	
13 PCS	POLYSTYRENE FORM	260.00			260.00	
34 KG	ACRYLONITRILE BUTADIENE STYRENE	250.00			250.00	
200 PCS	FAN 1.3A	12000.00			12000.00	
100 SET	ALUMINIUM HEAT SINK	3500.00			3500.00	
100 PCS	SWITCH	250.00			250.00	
					0.00	
					0.00	
					0.00	
	Batch Total				17360.00	
Production Costs:		**Cost**	**Shipping**	**Other**		
	Process	**£**	**£**	**£**		
	INJECTION MOLDING	300.00			300.00	
	ASSEMBLY	50.00			50.00	
	FINISHING	50.00			50.00	
					0.00	
					0.00	
					0.00	
	Batch Total				400.00	
Total Making Cost					17760.00	177.60
Time:						
	Hours to make batch				300.00	
	Hourly rate				5.00	
	Time cost per batch				1500.00	15.00
Profitability:						
	Recommended Retail Price (RRP)				299.00	299.00
	Retail Margin				10%	
	Trade Price					269.10
	Total material/time cost					192.60
	Profit Contribution (before overheads)					76.50
	Profit Contribution %					28.43%

Figure 9.2: Product consting model

CHAPTER 10

TESTING AND RESULT

10.0 Introduction

This chapter included the experiment testing and result of the testing. Testing is done by using the prototype fabricated similar to the concept design selected in order to test the method selected in the concept design. Experiment is carried out at the residence area which is Taman Kerjasama, Bukit Beruang, Ayer keroh, Malacca. Three similar car which is hatchback type car, Perodua Myvi, all without tinted is placed at the parking area under direct exposure of sunlight from 11pm until 3pm. Each of the car represented different condition of cabin which is fully enclosed cabin, cabin installed with prototype, and cabin with only one window gap of 4cm opened.

10.1 Prototype

The prototype is made similarly to the concept design selected. Due to the shortage of time, equipment and material availability, cost, technique, and so on, the prototype is fabricated to hang on the window where a gap of 4cm is opened instead of modify the roof of the car as the entrance for ventilation. There are fan, heat sink for both cold and hot side, insulator, thermoelectric Peltier cooling plate in the prototype. The materials, dimensions and physical outlook is slightly different from the concept design. Material for housing has been replaced with plywood which also is not a thermal conductor. The power supply is replaced with a rechargeable battery. The electrical system and connection is same as the concept design.

(a) (b) (c)

(d) (e) (f)

Figure 10.1: Prototype (a)Back view, (b)Front view, (c)Side view, (d)Top view, (e) (f)Isometric view

10.2 Experiment

The venue selected is at the parking lot of residence area at Taman Kerjasama, Bukit Beruang, Ayer Keroh, Malacca. The car used is Perodua Myvi without tinted. Three car is placed together from 11pm at the same day 8th May 2018 with each of the condition of fully enclosed cabin, cabin with prototype, and cabin with single 4cm window gap opened.

Figure 10.2: Similar car with condition (1)Fully enclosed cabin, (2)Cabin installed with prototype, (3)Cabin with single window gap of 4cm opened

The prototype is installed by hanging at one of the window with 4cm gap opened and battery is placed at the bottom area under covered.

(a) (b)

Figure 10.3: Prototype hanging on window gap viewed from (a) external, (b)internal

Each of the car installed with one thermocouple thermometer. The reading of the thermometer is took manually by three driver from 12pm to 3pm, each data recorded every 5minutes each. At the same time, the temperature of surrounding also measured and recorded every 5minute start from 12pm to 3pm. The data is tabulated into a table.

Figure 10.4: Position of thermocouple thermometer when taking reading of (a)Surrounding temperature, (b)Air temperature in cabin

10.3 Result

Result is recorded into a table and graph is plotted to show the trend of changes of the air temperature from time to time for different condition of cabin. Average temperature of every condition is calculated and recorded into table. The differences between average temperatures to other condition is also calculated and recorded. The negative sign shows that reduction of air temperature in cabin when compared to the condition. While positive sign or no sign shows that increasing of air temperature in cabin when compared to the condition. The percentage of temperature reduction is also calculated.

Table 10.1: Air temperature from time to time for three kind of condition and surrounding temperature

Time (minutes)	Air temperature in cabin of different condition of car (˚C)			Surrounding temperature (˚C)
	Fully sealed cabin	Cabin with prototype	Cabin with single window gap of 4cm opened	
0	53.20	41.20	49.10	31.40
5	53.50	41.30	49.50	32.90
10	53.40	41.20	49.20	32.50

15	53.20	40.80	48.00	30.70
20	53.50	40.50	48.10	31.30
25	53.50	40.60	48.50	31.50
30	53.60	41.20	47.90	30.00
35	53.40	40.90	47.50	29.80
40	53.90	41.40	48.00	31.20
45	54.10	41.80	50.50	31.50
50	54.60	42.30	51.00	33.00
55	54.80	41.90	49.90	32.90
60	54.70	41.60	51.10	33.10
65	54.90	41.40	51.70	33.10
70	54.60	41.60	50.90	32.60
75	54.60	40.90	50.80	33.10
80	54.70	40.90	50.80	33.20
85	54.60	41.00	51.00	32.30
90	55.10	41.10	51.30	34.50
95	55.80	41.20	51.50	34.90
100	54.90	40.50	50.10	32.20
105	54.90	40.60	50.30	32.70
110	54.70	40.50	49.90	32.80
115	54.60	40.50	49.80	33.10
120	54.60	40.70	49.80	33.20
125	54.80	40.90	51.00	33.70
130	54.30	40.80	49.70	33.30
135	53.90	40.30	49.10	32.90
140	54.30	40.40	50.00	33.90
145	55.30	40.90	52.30	34.50
150	54.90	41.20	51.10	34.90
155	55.10	41.10	52.30	33.60
160	56.40	41.70	53.00	35.60
165	57.10	42.20	53.80	36.10
170	56.90	42.10	52.40	35.40
175	57.50	43.30	52.80	35.90
180	57.90	43.60	52.90	35.80
Average temperature	54.75	41.25	50.45	33.11
Differences in average temperature compare with first condition	0.00	-13.51	-4.30	-21.64
Differences in average temperature compare with second condition	13.51	0.00	9.20	-8.14
Differences in average temperature compare with third condition	4.30	-9.20	0.00	-17.34

Differences in average temperature compare with surrounding	21.64	8.14	17.34	0.00

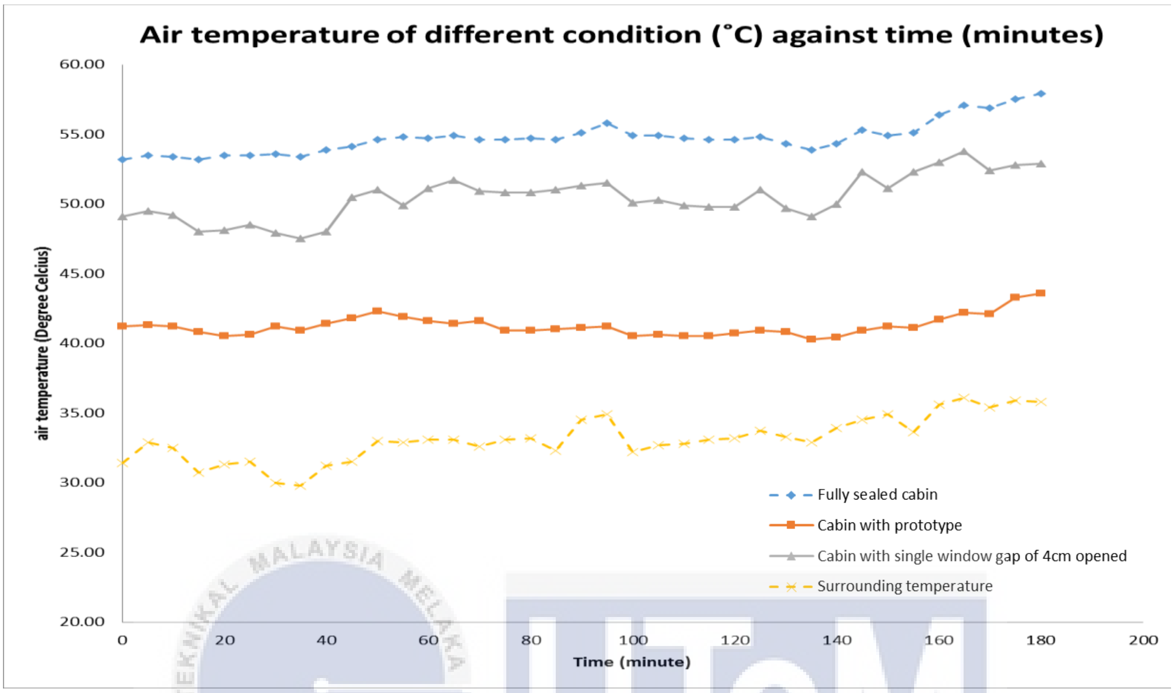


Figure 10.5: Air temperature of different condition (˚C) against time (minutes)

Based on the result above, the air temperature in fully enclosed cabin increase slowly throughout the experiment period where the highest air temperature recorded is 57.90 ˚C at 180 minutes (3pm) while lowest temperature recorded is 53.20 ˚C at 0 minute (12pm) and 15minutes (12.15pm). The temperature differences is 4.70 ˚C (8.12%) and has an average temperature of 54.75 ˚C. For the air temperature in cabin with single window gap of 4cm opened, the trend shows strong fluctuation where the highest temperature recorded is 53.80 ˚C at 165minutes (2.45pm) while lowest temperature recorded is 47.50 ˚C at 35minutes (12.35pm). The temperature differences is 6.30 ˚C (11.71%) and average temperature of 50.45 ˚C. Another trend of strong fluctuation occurred at the air temperature changes of surrounding. The highest temperature recorded is 36.10 ˚C at 165minutes (2.45pm) while lowest temperature recorded is 29.80 ˚C at 35minute (12.35pm). It has an average temperature of 33.11 ˚C and percentage of temperature differences 17.45% (6.30 ˚C). Both condition of cabin with single window gap opened and surrounding air has same temperature differences of 6.30 ˚C but difference percentage. The trend of air temperature in cabin installed with prototype has most stabilised trend which shows least fluctuation, increment and decrement. The highest temperature recorded is 43.60 ˚C at 180minutes (3pm) and lowest temperature recorded is 40.30 ˚C at 135minutes (2.15pm) with a temperature differences of 3.30 ˚C (7.57%) and average temperature of 41.25 ˚C.

From the average temperature of each of the condition, fully enclosed cabin has highest average temperature 54.75 ˚C then cabin with window gap, cabin with prototype and surrounding temperature where 50.45 ˚C (4.30 ˚C temperature differences, 7.85%), 41.25 ˚C (13.5 ˚C temperature differences, 24.66%), 33.11 ˚C (21.64 ˚C temperature differences, 39.53%) respectively. Surrounding temperature has least average air temperature and thus has highest percentage of air temperature differences.

Table 10.2: Temperature differences from time to time between condition of fully enclosed cabin and cabin with prototype

Time (minutes)	**Air temperature (˚C)**		**Temperature differences (˚C)**
	Fully enclosed cabin	**Cabin with prototype**	
0	53.20	41.20	12.00
5	53.50	41.30	12.20
10	53.40	41.20	12.20
15	53.20	40.80	12.40
20	53.50	40.50	13.00
25	53.50	40.60	12.90
30	53.60	41.20	12.40
35	53.40	40.90	12.50
40	53.90	41.40	12.50
45	54.10	41.80	12.30
50	54.60	42.30	12.30
55	54.80	41.90	12.90
60	54.70	41.60	13.10
65	54.90	41.40	13.50

70	54.60	41.60	13.00
75	54.60	40.90	13.70
80	54.70	40.90	13.80
85	54.60	41.00	13.60
90	55.10	41.10	14.00
95	55.80	41.20	14.60
100	54.90	40.50	14.40
105	54.90	40.60	14.30
110	54.70	40.50	14.20
115	54.60	40.50	14.10
120	54.60	40.70	13.90
125	54.80	40.90	13.90
130	54.30	40.80	13.50
135	53.90	40.30	13.60
140	54.30	40.40	13.90
145	55.30	40.90	14.40
150	54.90	41.20	13.70
155	55.10	41.10	14.00
160	56.40	41.70	14.70
165	57.10	42.20	14.90
170	56.90	42.10	14.80
175	57.50	43.30	14.20
180	57.90	43.60	14.30

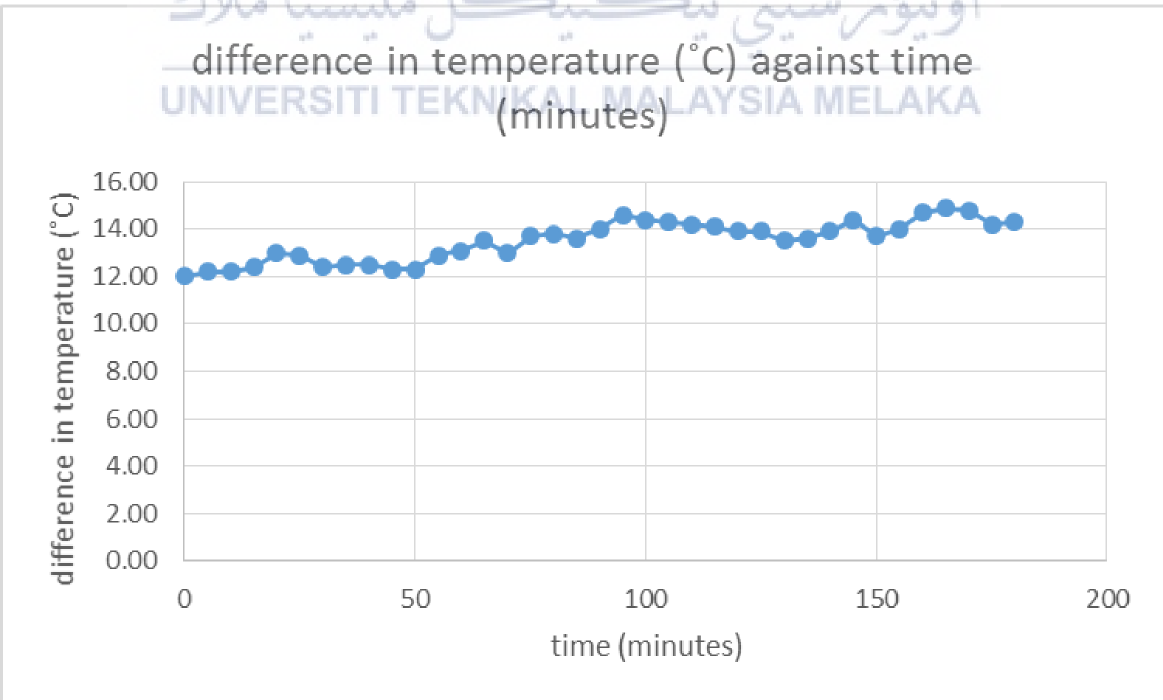


Figure 10.6: Temperature differences (˚C) against time (minutes)

Based on Table 10.2, it has shown that the temperature differences is in range of 12 ˚C to 15 ˚C. The highest temperature differences is found at 165minutes (14.90 ˚C) and the lowest temperature differences is found at 0minutes (12.00 ˚C). The graph shown slightly fluctuation but gradually increasing which means that the temperature difference is increasing and therefore the prototype is maintaining lower temperature.

Table 10.3: Temperature differences from time to time between conditions of cabin with window gap opened and cabin with prototype

Time (minutes)	**Air temperature (˚C)**		**Temperature differences (˚C)**
	Cabin with prototype	**Cabin with window gap opened**	
0	41.20	49.10	7.90
5	41.30	49.50	8.20
10	41.20	49.20	8.00
15	40.80	48.00	7.20
20	40.50	48.10	7.60
25	40.60	48.50	7.90
30	41.20	47.90	6.70
35	40.90	47.50	6.60
40	41.40	48.00	6.60
45	41.80	50.50	8.70
50	42.30	51.00	8.70
55	41.90	49.90	8.00
60	41.60	51.10	9.50
65	41.40	51.70	10.30
70	41.60	50.90	9.30
75	40.90	50.80	9.90
80	40.90	50.80	9.90
85	41.00	51.00	10.00
90	41.10	51.30	10.20
95	41.20	51.50	10.30
100	40.50	50.10	9.60
105	40.60	50.30	9.70
110	40.50	49.90	9.40
115	40.50	49.80	9.30
120	40.70	49.80	9.10
125	40.90	51.00	10.10

130	40.80	49.70	8.90
135	40.30	49.10	8.80
140	40.40	50.00	9.60
145	40.90	52.30	11.40
150	41.20	51.10	9.90
155	41.10	52.30	11.20
160	41.70	53.00	11.30
165	42.20	53.80	11.60
170	42.10	52.40	10.30
175	43.30	52.80	9.50
180	43.60	52.90	9.30

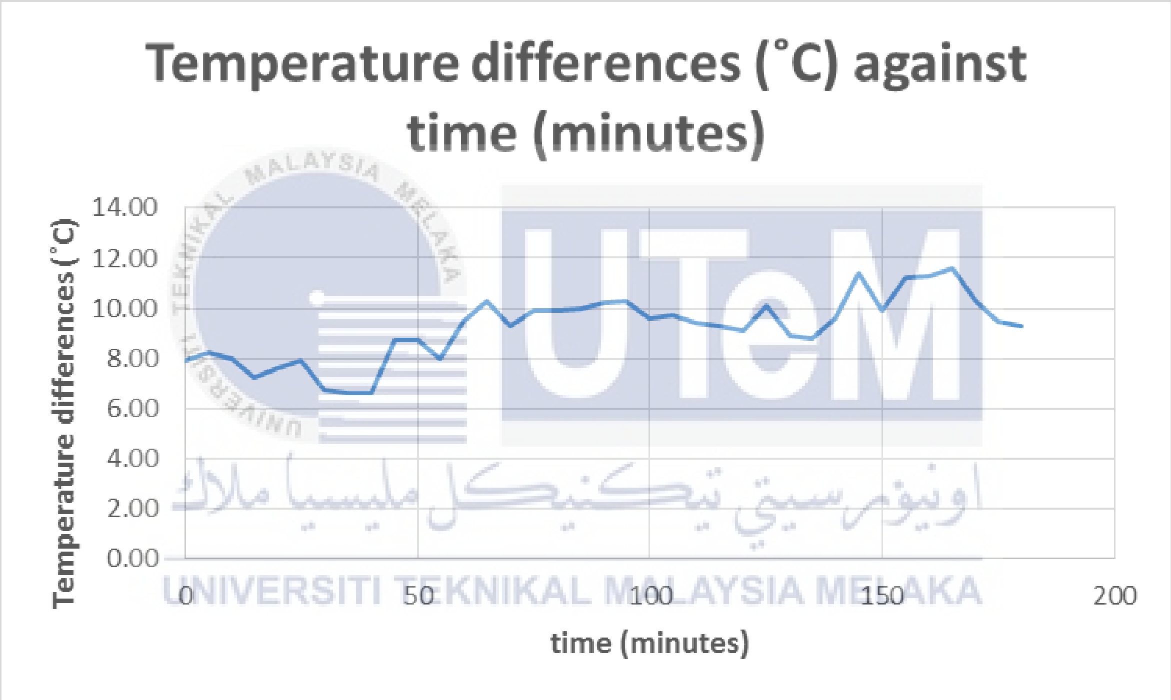


Figure 10.7: Temperature differences (˚C) against time (minutes)

Based on table 10.3, it has shown that the temperature differences is in range of 6 ˚C to 12 ˚C. The highest temperature differences is found at 165minutes (11.60 ˚C) and the lowest temperature differences is found at 35minutes and 40minutes (6.60 ˚C). Obvious fluctuation is observed. The trend increasing gradually. The difference in temperature changed from small to large.

Table 10.4: Temperature differences from time to time between conditions of cabin with prototype and surrounding temperature

Time (minutes)	Air temperature (˚C)		Temperature differences (˚C)
	Cabin with prototype	Surrounding temperature	
0	41.20	31.40	9.80
5	41.30	32.90	8.40
10	41.20	32.50	8.70
15	40.80	30.70	10.10
20	40.50	31.30	9.20
25	40.60	31.50	9.10
30	41.20	30.00	11.20
35	40.90	29.80	11.10
40	41.40	31.20	10.20
45	41.80	31.50	10.30
50	42.30	33.00	9.30
55	41.90	32.90	9.00
60	41.60	33.10	8.50
65	41.40	33.10	8.30
70	41.60	32.60	9.00
75	40.90	33.10	7.80
80	40.90	33.20	7.70
85	41.00	32.30	8.70
90	41.10	34.50	6.60
95	41.20	34.90	6.30
100	40.50	32.20	8.30
105	40.60	32.70	7.90
110	40.50	32.80	7.70
115	40.50	33.10	7.40
120	40.70	33.20	7.50
125	40.90	33.70	7.20
130	40.80	33.30	7.50
135	40.30	32.90	7.40
140	40.40	33.90	6.50
145	40.90	34.50	6.40
150	41.20	34.90	6.30
155	41.10	33.60	7.50
160	41.70	35.60	6.10
165	42.20	36.10	6.10
170	42.10	35.40	6.70
175	43.30	35.90	7.40
180	43.60	35.80	7.80

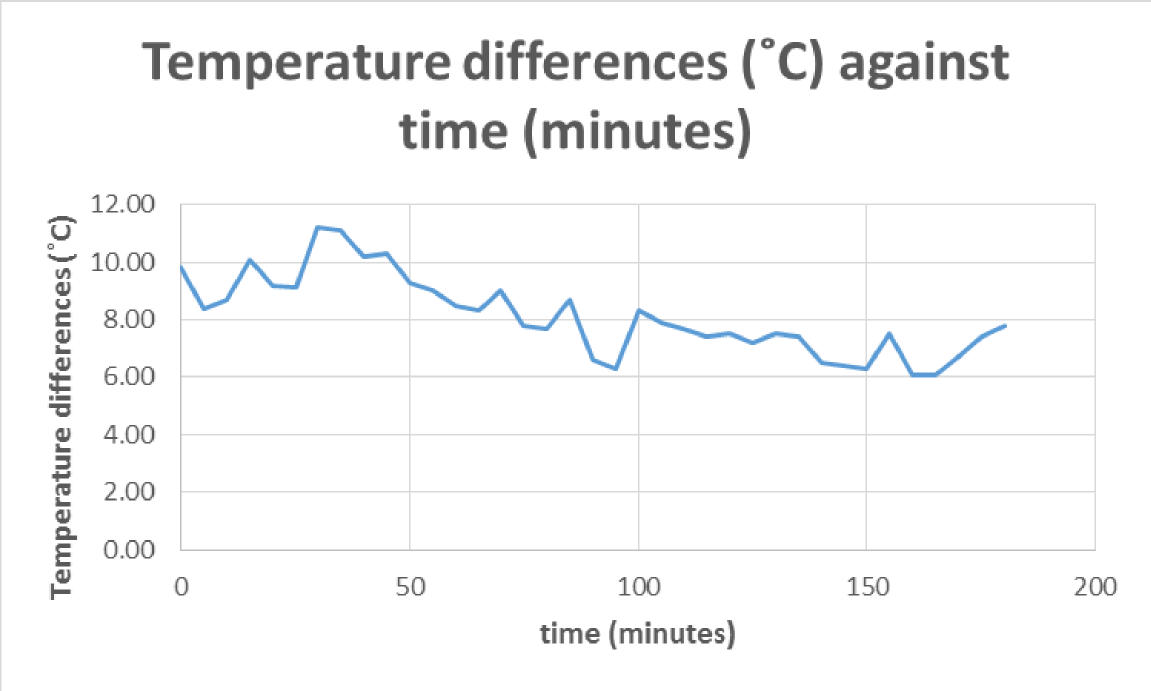


Figure 10.8: Temperature differences (˚C) against time (minutes)

Based on Table 10.4, it has shown that the temperature differences is in range of 6 ˚C to 12 ˚C. The highest temperature differences is found at 30minutes (11.20 ˚C) and the lowest temperature differences is found at 160minutes and 165minutes (6.10 ˚C). Obvious fluctuation is observed while the trend decreasing gradually. The prototype maintained lower temperature and therefore the temperature difference between surrounding air and cabin air become smaller.

CHAPTER 11

DISCUSSION AND ANALYSIS

11.0 Introduction

By referring to the result from the chapter before this, the analysis and discussion is done in this chapter. This chapter explained the reasons to the important finding with deep analysis and rigorous discussion related to background theory of the project. Discussion is carried out based on the engineering judgement and comparison to similar established work in orderly manner.

11.1 Prototype Discussion

Due to the limitation of equipment, technique, budget and duration, the prototype is designed and fabricated slightly different from the concept design. The entrance for ventilation and air in and out from cabin is on top of the device and installed at the bottom of modified cabin roof while prototype's entrance for ventilation is designed at side of the device and installed at the window. A gap of 4cm is opened to hang and fix the prototype. Therefore, the condition for experiment is added from two condition which are fully enclosed cabin and cabin with prototype to three condition which the extra condition is the cabin with single window gap of 4cm opened. This is because the modified roof of concept design is fully enclosed when the device is not installed on it. The modified roof consists a cover that can be manually open to install the device on it. Thus, the extra condition is tested to determine how opening of window gap would affect the result of prototype. The fan used to conduct hot air in cabin out to the surrounding is a 0.20A 92mm diameter axial fan. It has only 2000rpm and airflow of 42.3cfm. The exhaust fan used in concept design is 1.3A 120mm two bearing axial fan with 3200rpm and airflow of 189.3cfm. The airflow shows higher cubic feet per minutes indicates more air could be moved in a minutes for certain volume. Thus, the effect of the prototype is analysed to know the functionality of the method selected. The result of the prototype is used as the reference to the concept design because the product which has sufficient materials, equipment, and technique could produce a better effect product according to the concept design.

11.2 Experiment Discussion

The air temperature of surrounding is measured to identify the changes of the climate whether affect the temperature in the car cabin. The trend shows strong fluctuation and the temperature increase from time to time. This is because the air at surrounding might affected by the wind movement, wind velocity, humidity, intensity of sunlight and so on. Therefore, due to the changes of the temperature is different from time to time, the experiment is conducted by preparing three similar car with all without tinted in order to make the data record under same experience of surrounding temperature changes. All of the car is parked near to each other from 11pm. The data logger thermometer at Universiti Teknikal Malaysia Melaka is not enough in quantity where high demand is found and also due to the shortage of time to collect data and conduct experiment, thermocouple thermometer is used as alternative way to collect data manually. The position of the thermocouple thermometer is same for all three car cabin to ensure same resource of the temperature data. To make sure the data is taken at the same time, each people in charge of each thermocouple thermometer. Data is taken every 5 minutes to have better observation of the temperature changes.

11.3 Result discussion

According to the graph plotted and data recorded, air temperature within the fully enclosed cabin is highest with an average temperature of 54.75 ˚C while the other two condition of cabin where window gap is found has lower average temperature of 50.45 ˚C and 41.25 ˚C for cabin with window gap opened and cabin with prototype respectively. Air temperature of surrounding has least average temperature of 33.11 ˚C. The lowest average temperature is due to the wind movement and its velocity to induce more air movement around the surrounding. Hot air is replaced with cooler ambient air at opened area. Therefore, surrounding air temperature has lowest temperature recorded compared to the three condition of temperature in cabin.

Other than that, highest average temperature recorded in fully enclosed cabin where largest temperature increment of 21.64 ˚C (39.53%) found when compare to average temperature of surrounding air. This is because the heat transferred into the cabin is trapped within the cabin. With only the natural ventilation of air conditioner duct, the air movement within the cabin is slow and less and thus the replacement of hot air with ambient air and removing of hot air to surrounding is slower. The rate of the heat receiving is faster than heat releasing and therefore heating the air in cabin continuously make the air temperature in cabin recorded increasing slowly. It was found that started from 135minutes, the temperature gradually increased until 180minutes which is the highest temperature of 57.90 ˚C recorded. The increasing of the temperature might because of the increasing of surrounding temperature and also due to the materials within cabin trapped the heat which then further increased the temperature from time to time as more heat is trapped after long period of heat receiving.

The temperature human feels would be 5 ˚C higher than the temperature recorded. Therefore, when passenger entered into the cabin with 57.90 ˚C, passenger would feel like

62.90 ˚C. Compared with the human body temperature of 37 ˚C, there are 20.90 ˚C (36.1%) temperature increment which is high enough to induce strong thermal shock and thermal uncomfortable under this kind of high temperature. When children or pets leave unattended in the fully sealed cabin, the increasing heat within the cabin and slow natural ventilation and air movement would cause heat stroke that causing fatality. Malaysia is a country receiving sunlight exposure throughout the years, the high temperature trapped within the cabin might increasing further until sunset hour. High temperature also capable to destroy and increase the rate of deform of material such as plastic as one of the main materials found to build the interior of cabin.

The average temperature for car cabin with window gap of 4cm opened is 50.45 ˚C where it has the most of 17.34 ˚C (34.37%) temperature increment from the average temperature of surrounding air. At the same time, it also has a 4.3 ˚C (7.85%) temperature reduction when compared with highest average temperature of fully enclosed cabin. This has proved that with extra opening of duct acts as ventilation duct would further decreased the temperature in cabin. According to the literature review study, the area of opening window is directly proportional to the rate of ventilation. When the area of opening is larger, the faster the rate of ventilation, the faster the air movement, the faster the hot air replaced with cooler ambient air, and the faster the hot air and heat released to the surrounding, therefore the faster the temperature dropped. However, the opening of the window gap of car would lead to the risk of car to the criminal cases. Thief might broke the window and stole the car or valuable things in the car. Therefore, the concept design of cooling device is a built in device that has a latest design on roof of cabin to facilitate the installation of the device based on the consideration of safety problem. The latest design on roof has better refinement and cover to close the entrance of air exchange when not in used.

The average temperature for car cabin with prototype is 41.25 ˚C which is the least average temperature among three of the car cabin condition. It has the most temperature reduction of 13.5 ˚C (24.66%) when compared with average temperature of fully enclosed cabin meanwhile has least temperature increment of 8.14 ˚C (19.73%) when compared with average temperature of surrounding air. When compared with average air temperature of car cabin with single window gap of 4cm opened, there is a reduction temperature of 9.2 ˚C (18.24%). The further reduction of temperature is due to the effect of thermoelectric Peltier cooling module. When a voltage passed through the module, electric current is induced. The electrons of n-semiconductor and p-semiconductor move across the copper in between by absorbing and releasing heat energy. The side that electron absorbing heat energy become colder while the side releasing heat energy become hotter. The cool side of the thermoelectric module is then used as the cooling agent of the device. Ventilation is important to reduce the temperature, but with the cooling agent, the cooler ambient air introduced from surrounding passed through the cool side could further reduce the temperature before entering cabin.

11.4 Peltier module efficiency

For the same cabin that both condition also had window gap of 4cm opened, the cabin with prototype further reduced the temperature to 41.25 ˚C showed that the functionality of the thermoelectric module's cooling effect. The efficiency of Peltier module is calculated as below:

Input power = 12V*3A = 36W = 36joules/second

Input energy = 36joules/second*3600seconds = 129600joules

Average temperature of cabin with prototype = 41.25 ˚C

Temperature change, F = [(Average temperature of cabin condition – Average temperature of cabin with prototype)*1.8] + 32

BTUs = 0.55lbs*(temperature change)*1BTU/lbf

Energy used for cooling, joules = BTUs*1055joules/1BTU

Efficiency = (energy used/input energy)*100%

Table11.1: Summarize table for Peltier cooling efficiency when different average temperature of cabin condition used as initial temperature

Cabin condition	**Average temperature**	**Temperature change (F)**	**BTUs**	**Energy used (joules)**	**Peltier cooling Efficiency**
Cabin with window gap	50.45˚C	48.56F	26.708	28176.94	21.74%
Fully sealed cabin	54.75 ˚C	56.30F	30.965	32668.08	25.21%

The efficiency of Peltier module is higher than 20% when compared to both condition. The Peltier efficiency contribute to further reduction of temperature as a cooling agent of cooling device. It has no moving parts, virtually maintenance free, no vibration and no chlorofluorocarbon emission, therefore it is safe to use and suitable to be used as the cooling agent of a cooling device.

11.5 Ventilation blower

Ventilation is one of the necessary part that contributed to the reduction of temperature. A better ventilation improved the air movement in and out of the cabin and surrounding. Hot air is conducted out to the surrounding and the static pressure gradient induced would cause the inflow of ambient air from the surrounding into cabin. The more air conducted out from the cabin, the more air introduced into the cabin. It increased the efficiency of air replacement and consequently reduce the temperature.

Figure 11.1: Dimension of Perodua Myvi in mm

From the dimension of Myvi, the mm dimension is converted into ft:

Interior length: 1850*0.00328 = 6.0696ft

Interior width: 1380*0.00328 = 4.5276ft

Interior height: 1265*0.00328 = 4.1503ft

Cabin size = 6.0696*4.5276*4.1503 = 114.0532 ft^3

Frequency of ventilation = 20

Cubic feet per minutes (CFM) = 114.0532*20/60 = 38.0177cfm

Airflow of fan selected and used is 189.3cfm which is sufficient as its cfm is larger than the cfm required for Myvi's ventilation. Therefore, the forced ventilation induced from the installation of selected fan gave better effect to the reduction of temperature. Air movement around the cabin is induced and hot air is replaced with cooler ambient air vigorously.

11.6 Concept design

The position of the device is decided to be installed at the middle of the roof because the hot air would be more likely to flow upward due to lower density. Thermal distribution shows the area near roof has more thermal accumulation (see Figure 2.3). By modifying current roof design to a latest design, a cover is used as the locking mechanism to close the entrance for air exchange. Thus, the car installed with car cooling would be safer due to no gap from the window is needed for installation.

11.7 Maximum temperature differences

It was claimed that the average temperature differences of fully enclosed cabin and surrounding air is between 20 ˚C to 23 ˚C (21.64 ˚C). Under this temperature difference, the air conditioner is not favourable due to large amount of thermal load to the air conditioner. Similarly to the result of their studies, the maximum air temperature reduction of their ventilator is around 15 ˚C while the car cooling device achieved maximum reduction of air temperature at 165minutes of 14.90 ˚C when the air temperature is compared from time to time between condition of fully enclosed cabin and cabin with prototype (Sudhir and Jalal, 2015). The maximum reduction of temperature from time to time among cabin with prototype and cabin with window gap opened is 11.60 ˚C also at 165minutes. It might due to the prototype installed would be more likely to maintain the temperature inside cabin. When the surrounding temperature increase to 165minutes, the prototype still managed to maintain lower temperature of air cabin. At 30minutes, the maximum temperature difference between cabin with prototype and surrounding temperature is 11.20 ˚C.

CHAPTER 12

CONCLUSION AND RECOMMENDATION

12.0 Introduction

This chapter is the last chapter of the research where it included the conclusion and recommendation. Conclusion is made based on the result and whether it achieved the objective of the research while research conducted with appropriate methodology and within the constraint and scope stated. Recommendation is given for next related research as a new guideline for the topic in order to further study the research regarding to the topic.

12.1 Conclusion

The car cooling device which implemented the thermoelectric Peltier cooling module as cooling agent and combined with the ventilation system has been designed via the engineering design process within the time management planned. The concept design is tested by prototype fabricated to ensure the functionality of method selected. The experiment is conducted at same day and same duration with three similar car without tinted for different condition which is fully enclosed cabin, cabin with prototype, and cabin with window gap 4cm opened. Surrounding air is measured also to observe the changes of the temperature. The average temperature of the air in cabin with prototype is 41.25 ˚C which is also the least average temperature among three condition. While the average temperature of fully enclosed cabin is highest (54.75 ˚C), next is cabin with window gap opened (50.45 ˚C). Reduction of average temperature achieved is 13.5 ˚C (24.66%) and 9.2 ˚C (18.24%) when compared with average temperature of fully enclosed cabin and average temperature of cabin with window gap opened respectively. Ventilation blower increased the rate of ventilation where hot air is conducted to the surrounding and replaced with the cooler ambient air due to the static pressure gradient induced. Meanwhile, electrons of p-semiconductor and n-semiconductor in Peltier module move across by absorbing heat energy and releasing heat energy where one of the surface be cold and another surface be hot respectively. The cold surface is used as the cooling agent to further reduce the temperature of ambient air introduced into cabin. Efficiency of Peltier module is 21.74% for fully enclosed cabin case and 25.21% for cabin with window gap case. With the idea of built in device, the concept design along with the modification of roof for installation mechanism prevent the safety issue. Product design specification is followed. Device designed is 213mm x 180mm with 12V voltage input and 3200rpm of fan with 189,3cfm which is 4.98times sufficient for a hatchback car ventilation air movement. It cost RM197.60 and consists of 11 sub-functional part that can operate up to 8.03 hour with fully charged of 45amp hour car battery. The least temperature reduction of cabin with prototype from time to time is 6.60˚C compared to cabin with window gap opened. As conclusion, the objective of the research is achieved where the car cooling device designed has reduced the air temperature at least 5 ˚C from time to time no matter compared with which condition. A safer, effective car cooling device could reduce the thermal shock, deformation of materials in cabin, consumption of fuel for fast cooling using air conditioner, and also air temperature in cabin. The method selected is functional.

Table 12.1: Summarize table of result specification compared to earlier specification

Engineering characteristic	**Result specification**	**Earlier specification**
Manufacturing cost	RM197.60	<RM200
Number of Sub-functional part	11 (total 13)	<12
Operation hour	8.03 hour	>8 hour
Rotation speed	3200rpm	1500rpm-5000rpm
Size (height x width x length)	180mm x 130mm x 213mm	250mm x 250mm x 300mm
Voltage	12V	>5V
material	ABS, aluminium	Plastic, metal

12.2 Recommendation

It is recommended to conduct the research by compromising another cooling agent such as compressed liquid air, phase change material, and so on. Innovation for other kind of method except ventilation such as innovation on the materials of tinted or window also recommended. Besides the method, the design of the device also can be innovate further by using creativity in order to design a car cooling device with aesthetic value and more convenient to user. Electronic control is also recommended such as remote control, phone application control, automatic sensor control and so on. The aspect of controlling such as fan speed and temperature could be further developed for smarter device design.

REFERENCES

Adeel Waqa, Jie Jia, 2017. Thermal Management of Conventional PV Panel using PCM with Movable Shutters – A numerical study. *Solar Energy 158* , pp. 797–807

A Sunawar and I Garniwa, 2017. Maximum Potential of the Car Cabin Temperature in the Outdoor Parking Conditions as a Source of Energy in Thermoelectric Generator. *IOP Conf. Ser.: Mater. Sci. Eng. 180 012104*

Allen Khin Kiet Lau, Elias Salleh, Chin Haw Lim, Mohamad Yusof Sulaiman, 2016. Potential of Shading Devices and Glazing Configurations on Cooling Energy Savings for High-Rise Office Buildings in Hot-Humid Climates: The case of Malaysia. *International Journal of Sustainable Built Environment (2016) 5,* pp.387–399

Changyu Liu, Yangyang Wu, Yongjian Zhu, Dong Li, Lingyong Ma., 2017. Experimental Investigation of Optical and Thermal Performance of a PCM-Glazed Unit for Building Applications. *Energy and Buildings-Volume 158,* 1 January 2018, Pages 794-800,2017

Chunling Qi, Yaxin Helian, Jiying Liu, Linhua Zhang, 2017. Experiment Study on the Thermal Comfort inside a Car Passenger Compartment. *10th International Symposium on Heating, Ventilation and Air Conditioning, ISHVAC2017, 19-22 October 2017, Jinan, China*

C.-Y. Tseng, Y.-A. Yan, J.C. Leong, 2014. Thermal Accumulation in a General Car Cabin Model. *Journal of Fluid Flow, Heat and Mass Transfer (JFFHMT). Volume 1,* Pages 48-56

Du Yingmeng,LiZhi, &Fan Zhikang, 2014. Research on Heat Transfer Characteristics and Pre-cooling of Car Cabin in Parking and Staring Process Based on Simulation Analysis. *2014 7th International Conference on Intelligent Computation Technology and Automation.*

Eduard Oró, Erik de Jong, Luisa F.Cabeza, 2016. Experimental Analysis of a Car Incorporating Phase Change Material. *Journal of Energy Storage. Volume 7,* August 2016, Pages 131-135

Emad Elnajjar, 2017. Using PCM Embedded in Building Material for Thermal Management: Performance Assessment Study. *Energy and Buildings. Volume 151*, 15 September 2017, Pages 28-34.

E. Rusinski,J. Czmochowski, P. Moczko, D. Pietrusiak. *Monitoring and Testing of High Power Industrial Fans Vibration.*

Francesco Babich, Malcolm Cook, Dennis Loveday, Rajan Rawal, Yash Shukla, 2017. Transient Three-Dimensional CFD Modelling of Ceiling Fans. *Building and Environment. Volume 123*, Pages 37-49

G. Angelini, T. Bonanni, A. Corsini, G. Delibra, L.Tieghi, D. Volponi, 2017. Optimization of an Axial Fan for Air Cooled Condensers. *Energy Procedia 126 (201709)* pp.754–761

Haksung Lee, Akihito Ozaki, Myonghyang Lee, 2017. Energy Saving Effect of Air Circulation Heat Storage System using Natural Energy. *Building and Environment pp. 124*

Hongye Pan, Lingfei Qi, Xingtian Zhang, Zutao Zhang, Waleed Salman, Yanping Yuan ,Chunbai Wang, 2017. A Portable Renewable Solar Energy-Powered Cooling System Based on Wireless Power Transfer for a Vehicle Cabin. *Applied Energy 195* pp.334–343

Hamdi E.Ahmed,B.H.Salman,A.Sh.Kherbeet,M.I.Ahmed, 2018. Optimization of Thermal Design of Heat Sinks. *International Journal of Heat and Mass Transfer. Volume 118, March 2018*, Pages 129-153

JunghoKim, 2007. Spray Cooling Heat Transfer*: The state of the art International Journal of Heat and Fluid Flow.Volume 28, Issue 4, August 2007,* Pages 753-767

Kaj Lampio, Reijo Karvinen, 2017. Optimization of Convectively Cooled Heat Sinks. *Microelectronics Reliability 79* pp. 473–479

Lavinia Socaciu, Oana Giurgiu, Daniel Banyai, Mihaela Simion, 2016

PCM Selection Using AHP Method to Maintain Thermal Comfort of the Vehicle Occupants. *Sustainable Solutions for Energy and Environment, EENVIRO* - YRC 2015, 18-20 November 2015, Bucharest, Romania

Maan Al-Zareer, Ibrahim Dincer, Marc A. Rosen, 2017. Development and Analysis of a Portable Compressed Liquid Air Cooling System for Fast Vehicle Cabin Cooling. *International journal of refrigeration 84 pp. 117–127*

N S Hamdan, 2017. Dual Direction Blower System Powered by Solar Energy to Reduce Car Cabin Temperature in Open Parking Condition. *J. Phys.: Conf. Ser. 908 012072*

Nicholas R. Jankowski, F. Patrick McCluskey, 2014
A Review of Phase Change Materials for Vehicle Component *Thermal Buffering. Applied Energy 113,* pp.1525–1561

Pushpendra Singh, 2015. Alternate System for Car Cabin Comfort Cooling Solar Powered. *International Journal of Mechanics and Thermodynamics.. ISSN 2278-361X Volume 6, Number 1*, pp. 11-16

Preeda Chantawong, 2017. Field-measured Performance of Lightweight Roof Chimney Integrated with DC fans. *International Conference on Alternative Energy in Developing Countries and Emerging Economies*
Road Transport Department Malaysia. Installation of Tinted Windows, 2017 *http://www.jpj.gov.my/web/eng/installation-of-tinted-windows*

Shuo Feng, Wenju Hu and Deying Li, 2017. The Experimental Study On The Spray Cooling Device Of Domestic Air Conditioning In Beijing Area. *Procedia Engineering 205* pp.1034–1041

Sudhir Chitrapady Vishweshwara and Jalal Marhoon AL. Dhali. 2015. Experimental Investigations on the Performance of Solar Powered Cabin Air Ventilator. *World Journal of Engineering 12(6) (2015)* pp.607-618

Wei-Hwa Chiang, Chia-Ying Wang, Jian-Sheng Huang, 2012
Evaluation of Cooling Ceiling and Mechanical Ventilation Systems on Thermal Comfort using CFD Study in an Office for Subtropical Region. *Building and Environment 48*

Y.-A. Yan, C.-Y. Tseng, J.C. Leong, 2012
Feasibility of Solar Powered Cooling Device for Electric Car. *Energy Procedia 14* pp. 887 – 892

Young Min Seo, Man Yeong Ha, Seong Hyun Park, Geun Hyung Lee, Young Soo Kim, Yong Gap Park, 2018
A Numerical Study on the Performance of the Thermoelectric Module with Different Heat Sink Shapes. *Applied Thermal Engineering 128* pp.1082–1094

APPENDICES

Survey on Car Cooling Device

I am fourth year Mechanical Engineering students from Universiti Teknikal Malaysia Melaka who is undergoing a survey to find out the design of car cooling device requirement by public . Please kindly use 2 minutes to fill up our survey form. I would appreciate for your help in participating the survey.

* Required

Instruction: Please tick as appropriate.

A. Gender *

- [ ] Male
- [ ] Female

B. Age Category *

- [ ] 17- 20 years old
- [ ] 21 to 30 years old
- [ ] 31 to 40 years old
- [ ] 41 to 50 years old
- [ ] Above 50 years old

C. Living Place *

- [ ] City
- [ ] Outskirts

D. Income *

- [ ] Below RM 1000
- [ ] RM 1001 to RM 3000
- [ ] RM 3001 to RM 5000
- [ ] RM 5001 to RM 8000
- [ ] Above RM 8000

E. Reasonable price of car cooling device in your opinion *

- [ ] Below RM 100
- [ ] RM 101 to RM 300
- [ ] Above RM 300

Respondent Requirement

I would like to determine the respondents' requirements based on their responses to the question below.

Instruction: Please tick on the boxes which range from 1 to 5 for each statement to show your level of agreeableness towards the statement: [1- Disagree ; 2- Slightly Agree ; 3 - Agree]

1. You prefer a durability car cooling device. *

	1	2	3	
Disagree	○	○	○	Agree

2. You prefer a simple and user friendly car cooling device. *

	1	2	3	
Disagree	○	○	○	Agree

3. You prefer an affordable car cooling device. *

	1	2	3	
Disagree	○	○	○	Agree

4. You prefer an easy maintenance car cooling device. *

	1	2	3	
Disagree	○	○	○	Agree

5. You prefer a portability car cooling device. *

	1	2	3	
Disagree	○	○	○	Agree

6. You prefer a reliability car cooling device. *

	1	2	3	
Disagree	○	○	○	Agree

7. You prefer a functionality car cooling device. *

	1	2	3	
Disagree	○	○	○	Agree

8. You prefer a small size and space saving car cooling device. *

	1	2	3	
Disagree	○	○	○	Agree

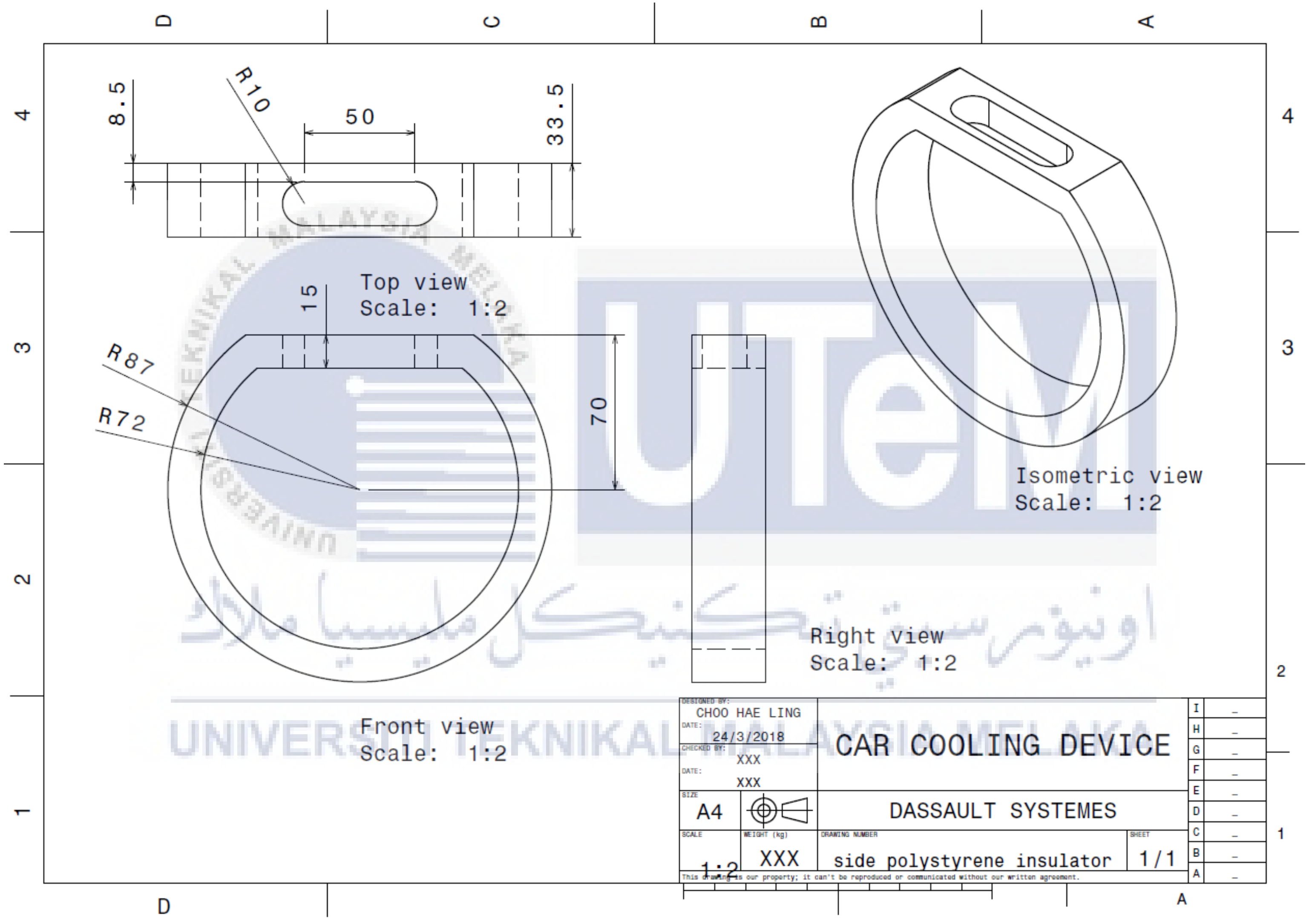
9. You prefer a robustness car cooling device. *

	1	2	3	
Disagree	○	○	○	Agree

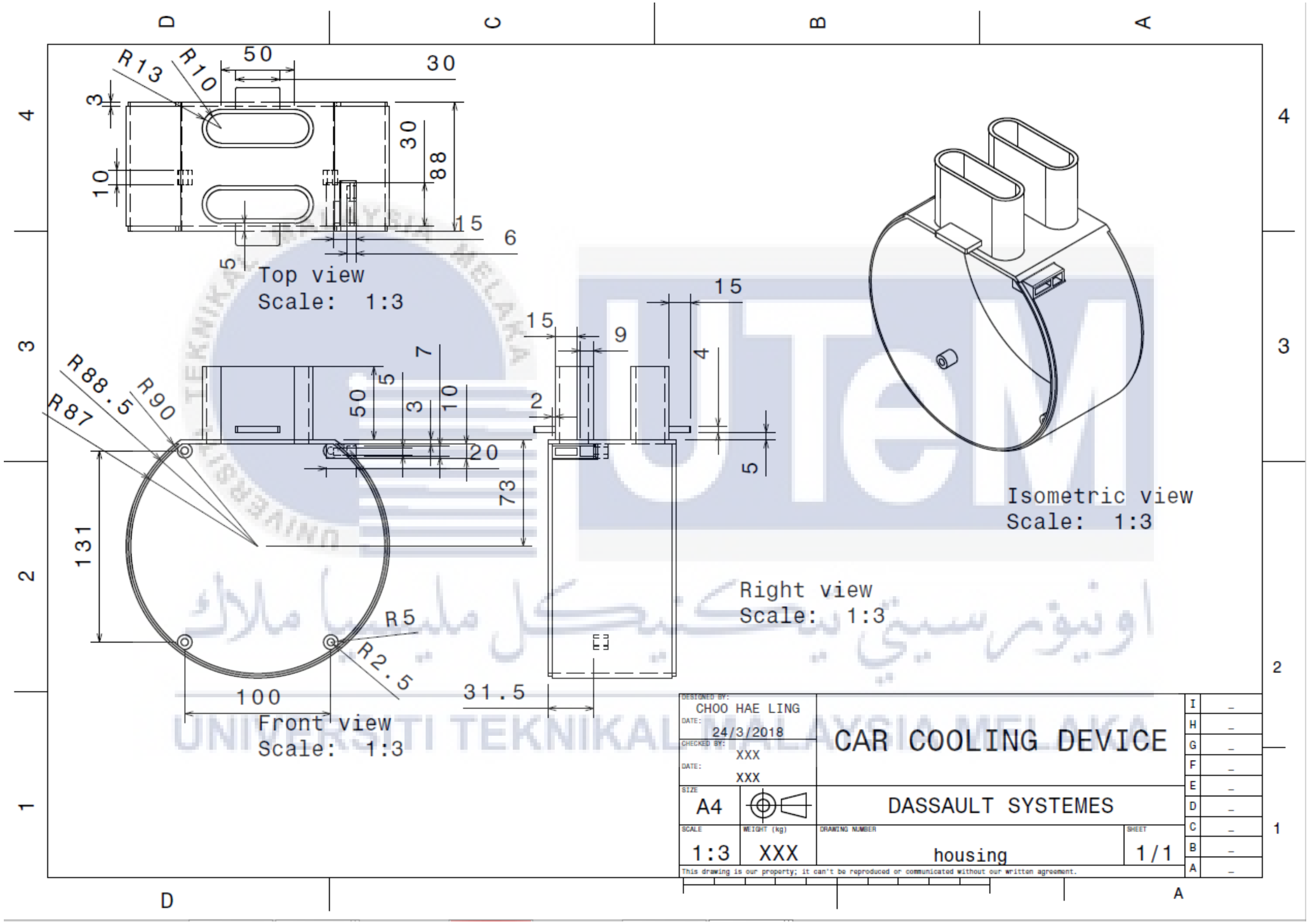
10. You prefer an aesthetic car cooling device. *

	1	2	3	
Disagree	○	○	○	Agree

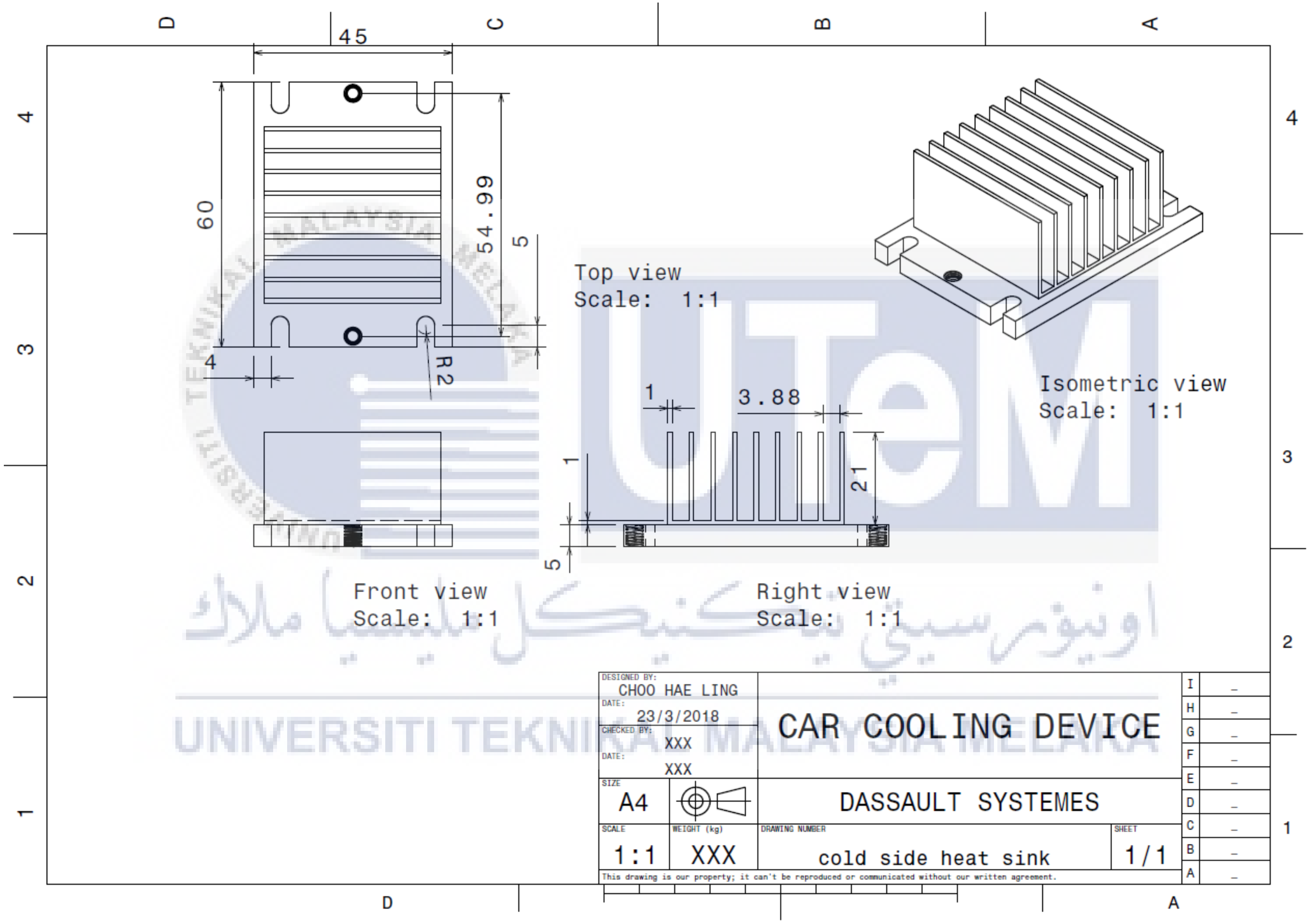
Appendix A: Survey form



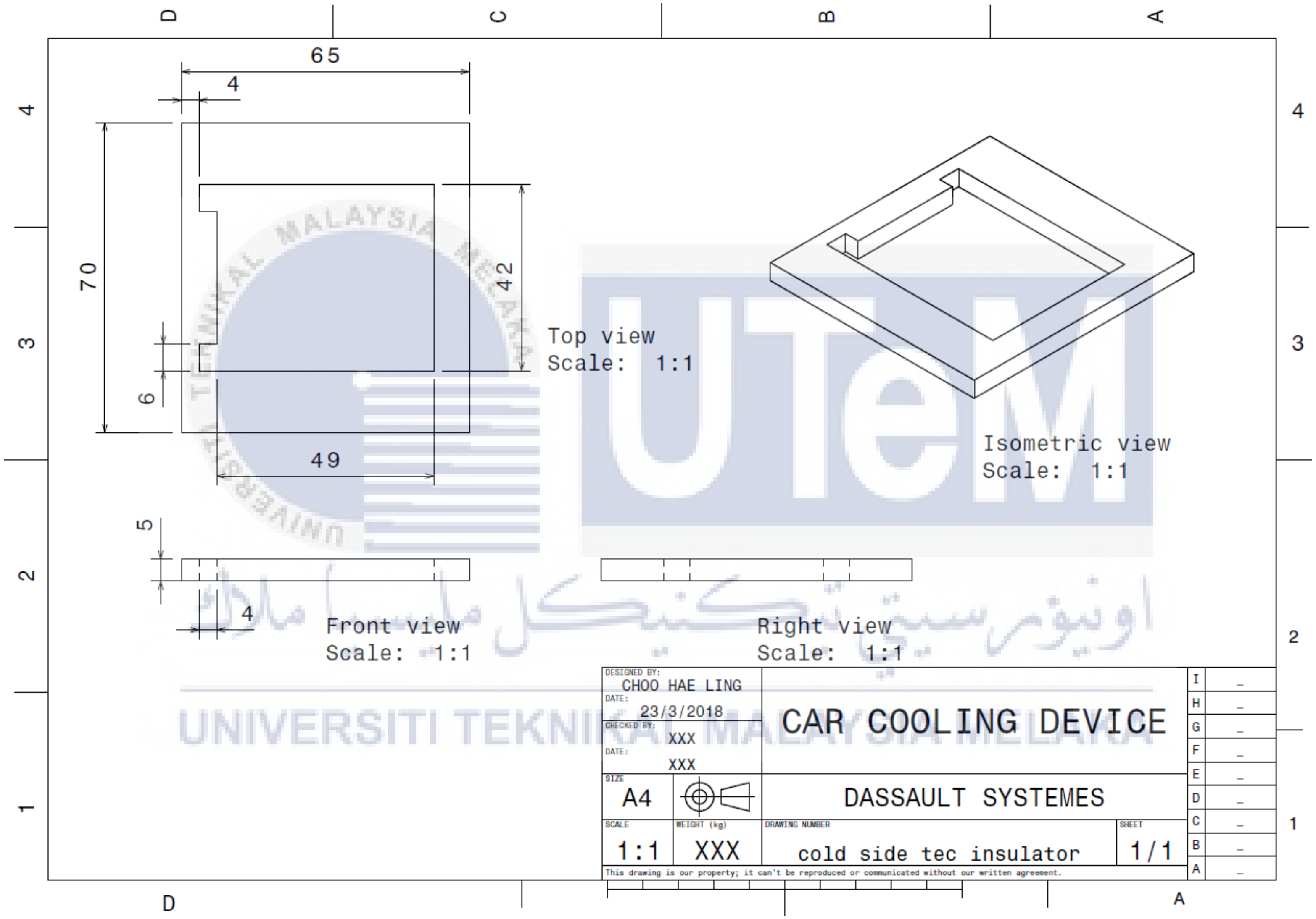
Appendix B1: Side polystyrene insulator



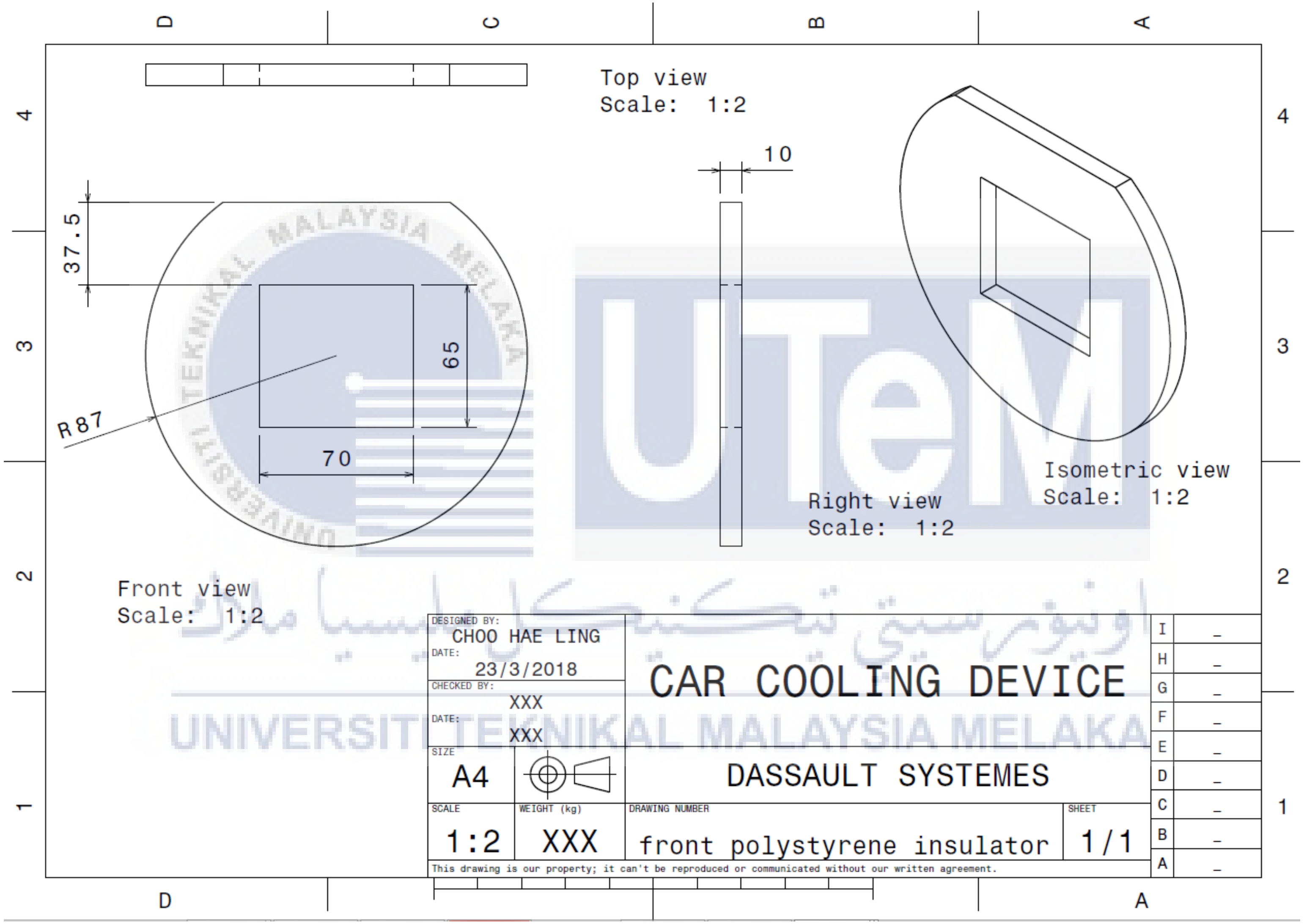
Appendix B2: Housing



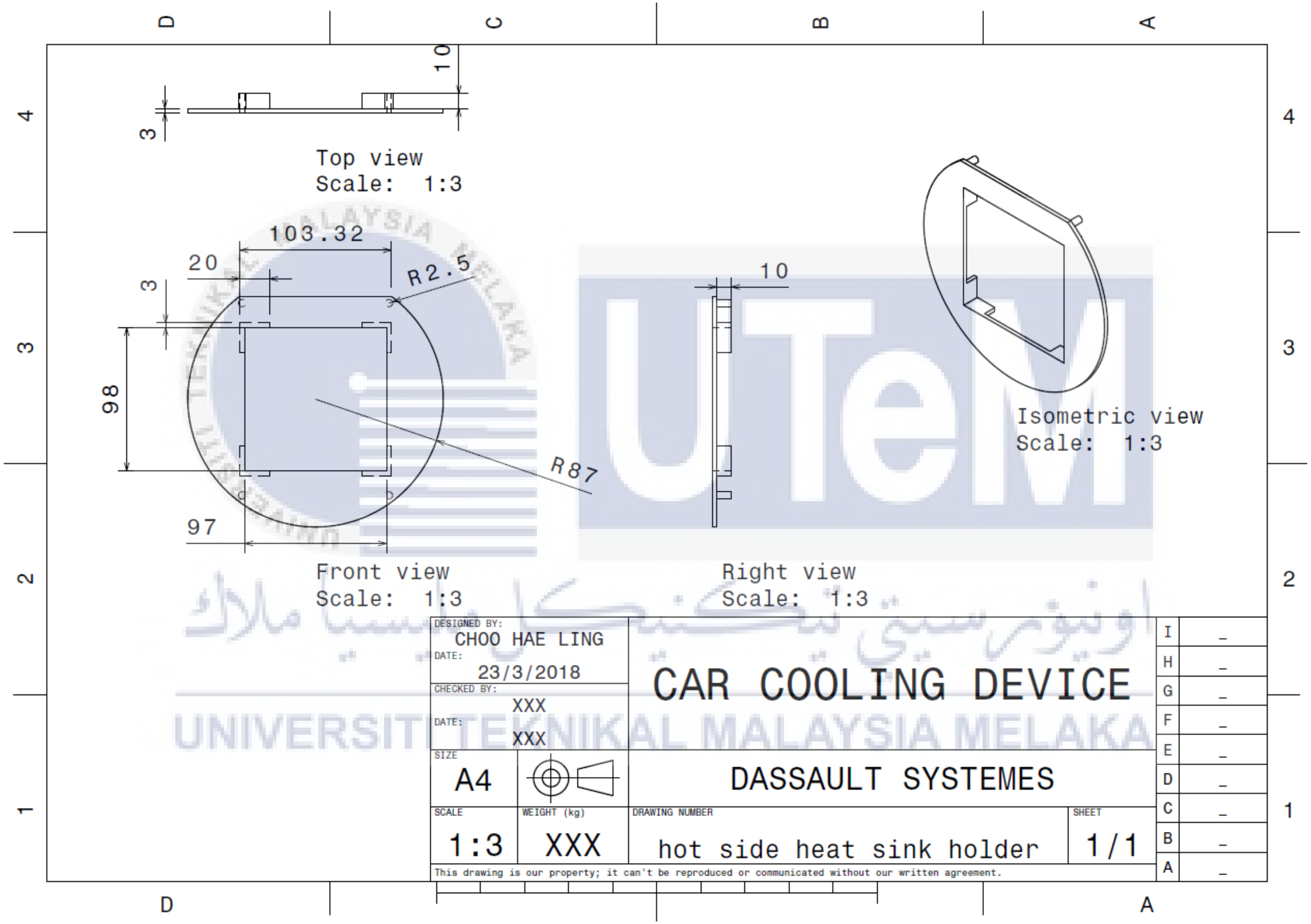
Appendix B3: Cold side heat sink



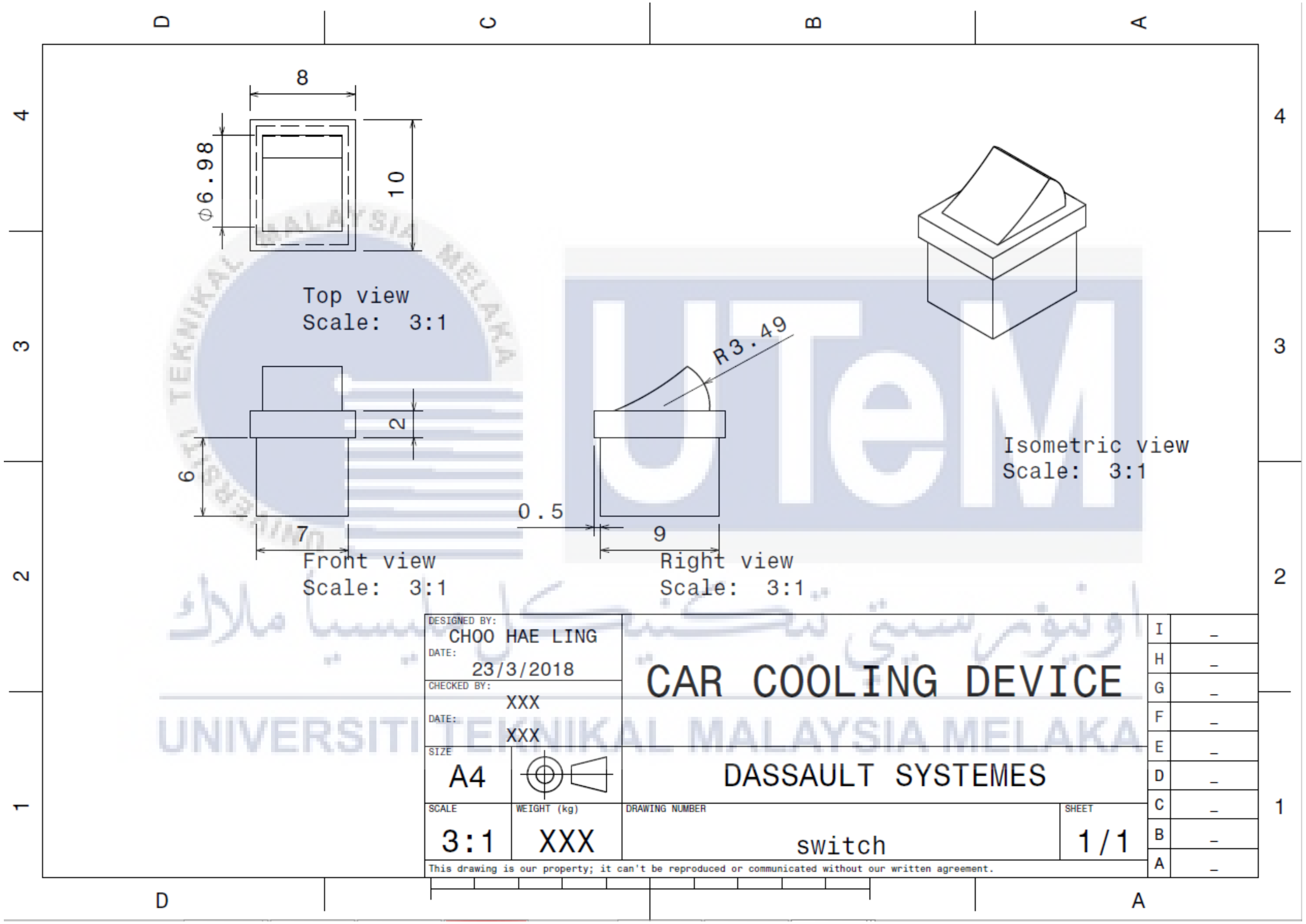
Appendix B4: cold side TEC insulator



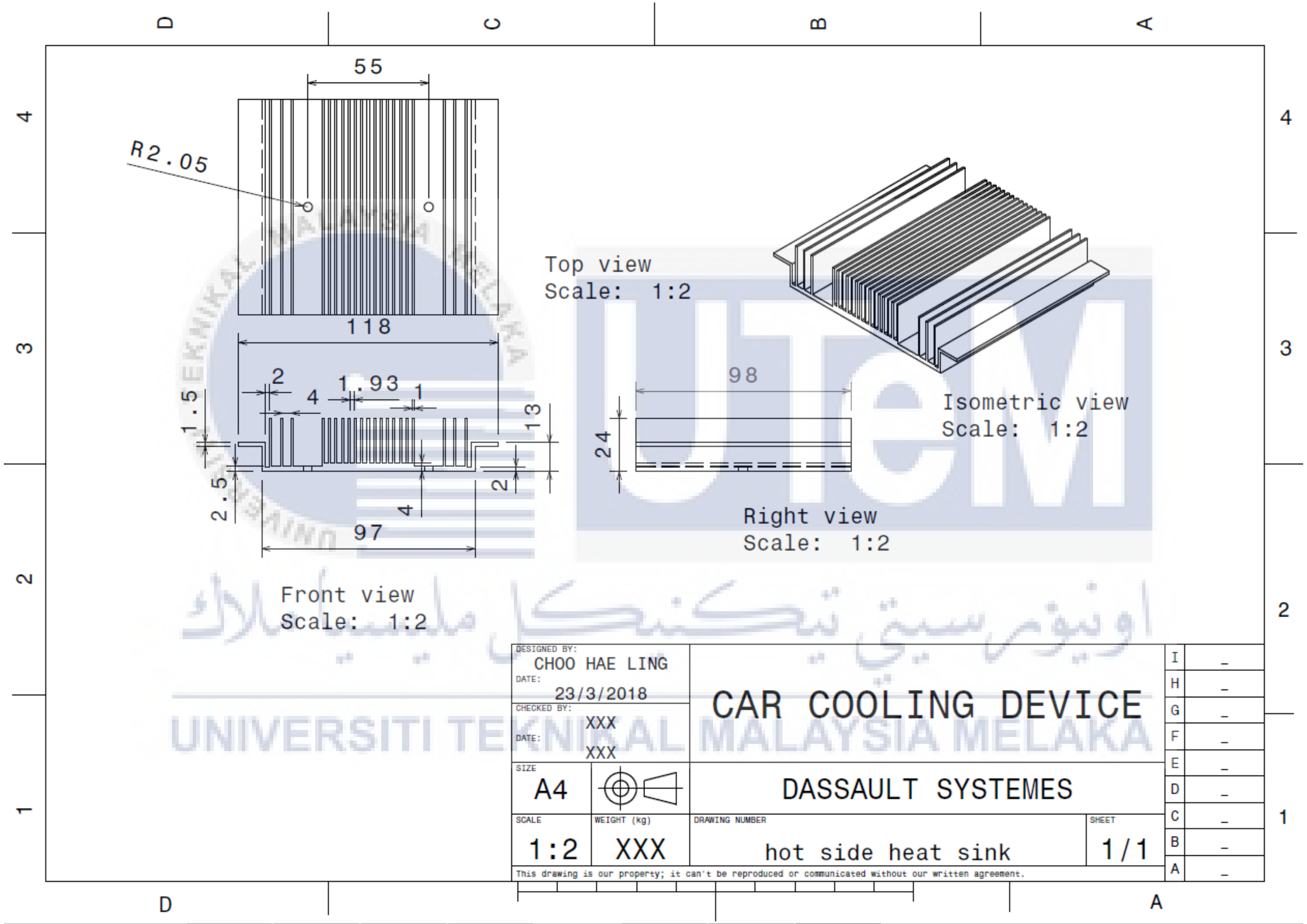
Appendix B5: Front polystyrene insulator



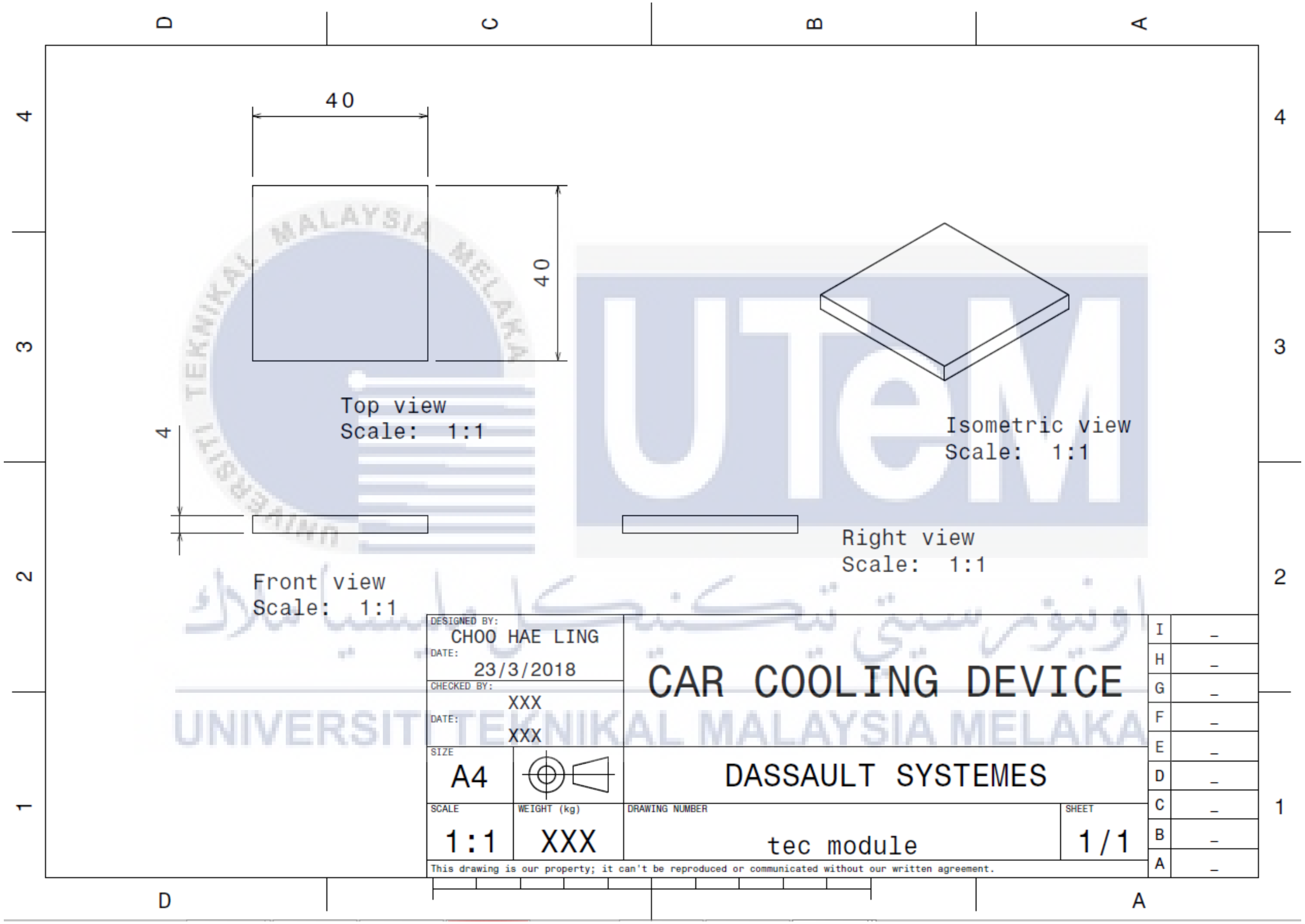
Appendix B6: Hot side heat sink holder



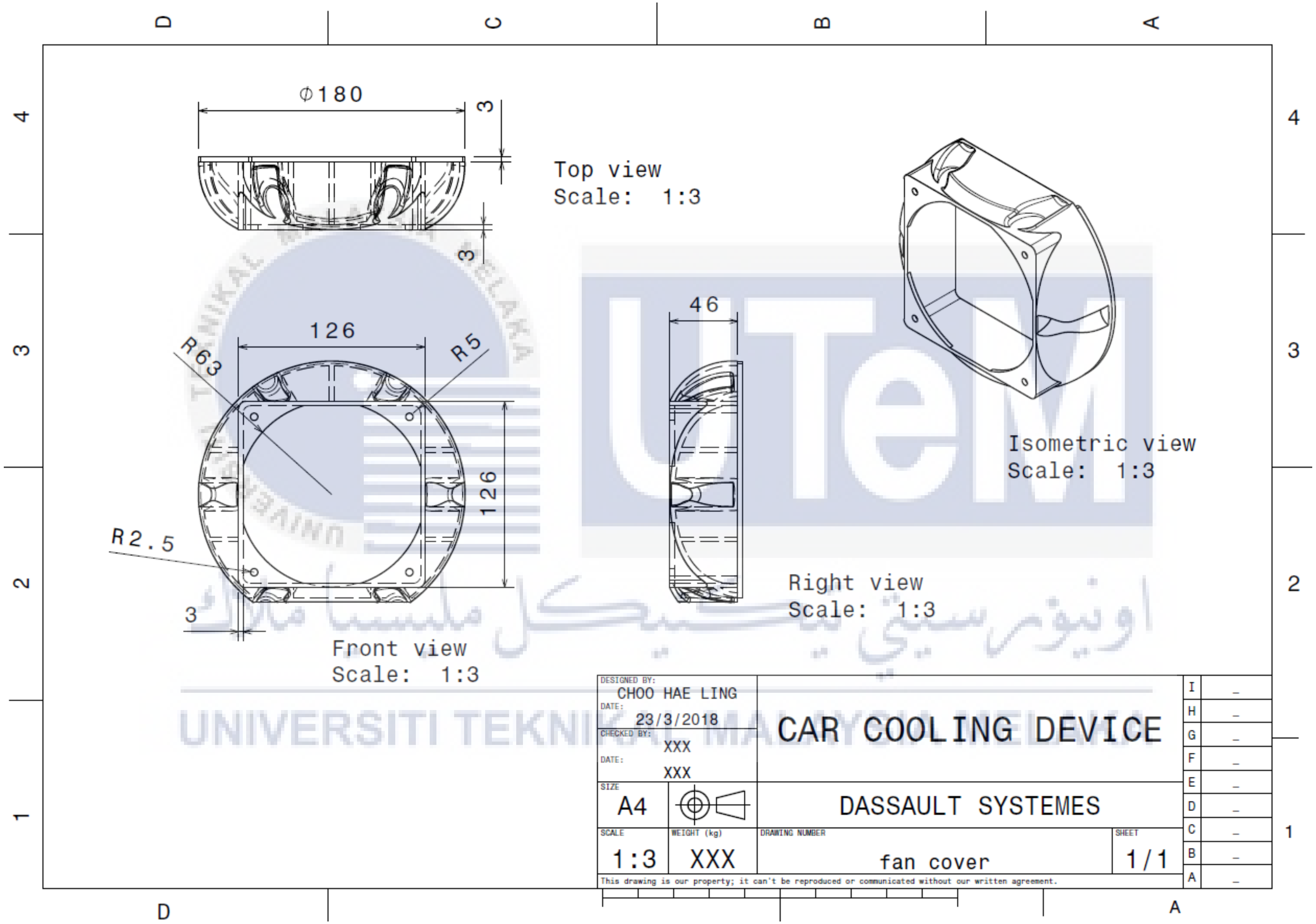
Appendix B7: Switch



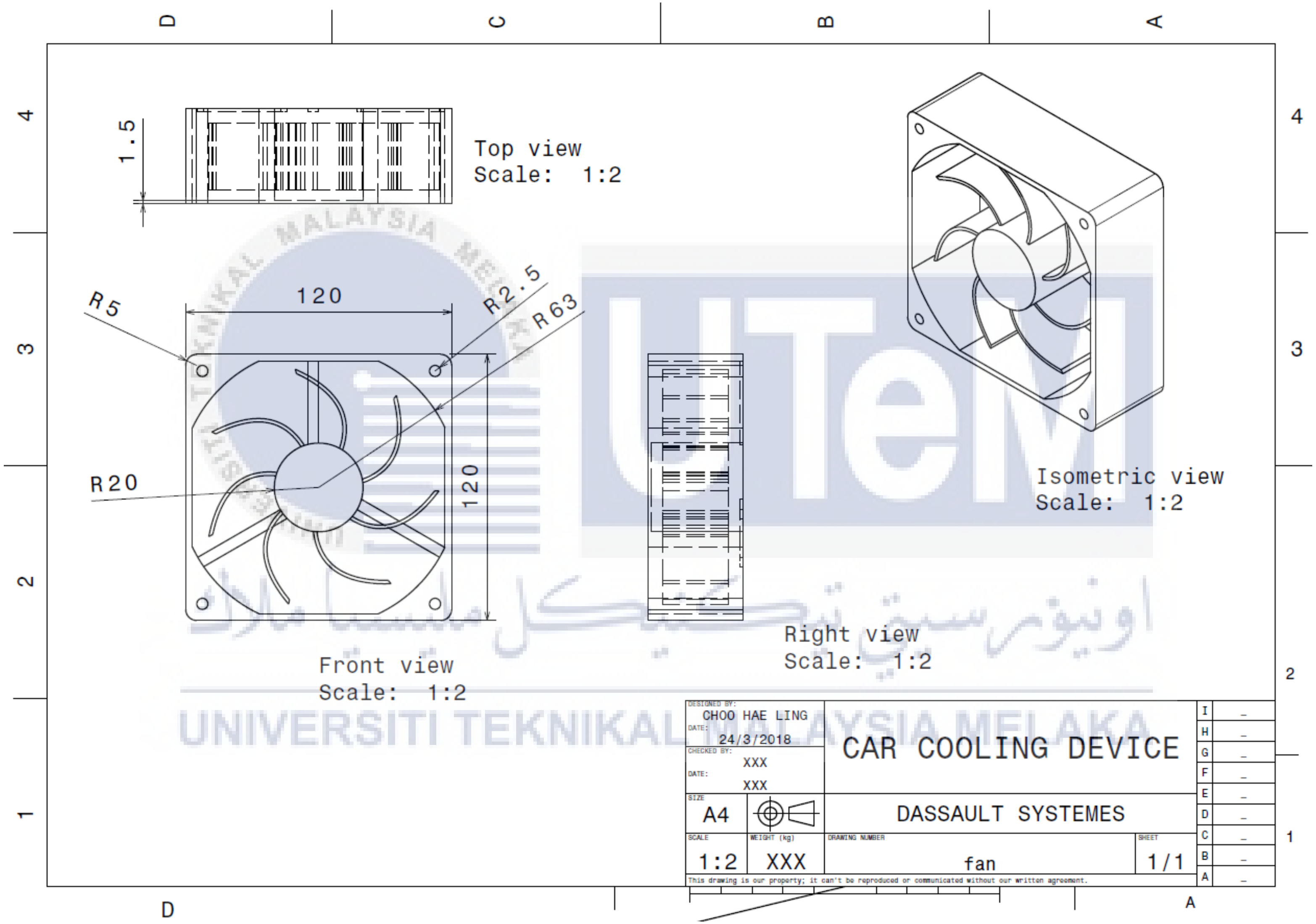
Appendix B8: Hot side heat sink



Appendix B9: TEC Peltier module



Appendix B10: Fan cover



Appendix B11: Fan