CONCEPTUAL DESIGN OF DRIVETRAIN SYSTEM FOR BECA MELAKA

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‘I have read this thesis

and from my opinion this thesis

is sufficient in aspects of scope and quality for awarding

Bachelor of Mechanical Engineering (Automotive)’

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This report is presented in

fulfilment of the requirement for the degree of

Bachelor of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering

University Technical Malaysia Melaka

JUNE 2017

DECLARATION

"I declare this report is on my own research except for summary and quotes that I have mentioned its sources"

Signature	: …………………………..
Name of Author	: MUHAMMAD FARIS BIN HASSAN
Date	: …………………………

DEDICATION

Dedicate to my beloved mom, Mrs. Mismah Binti Taslim and my dad,

Mr. Hassan Bin Ayob

ACKNOWLEGEMENT

First of all, thanks to Allah S.T.W for His blessing to me in completing my final project. I have finally managed to complete it successfully. Thus, I would like to take this chance to express my gratitude to all people who have been involved directly and indirectly in the process to complete this project. Without the cooperation and support of all parties, I cannot carry out this project properly and successfully.

I would like to give a special appreciation to my supervisor for this project, Mr. Muhd Ridzuan Bin Mansor who had shown undivided guidance, advices, motivation, encouragement, attention and had given me a lot of lesson and knowledge for me to complete my final year project. Without his continued support and supervision, this report would not be the same as presented here.

I'm also extended my appreciation to all my colleagues who always help me to complete my final year project. I would also not forget to mention all my housemate for their helps and advised in completing this project. I appreciate all their idea and information given.

Last but not less, thanks to my family and any other parties who involved directly or indirectly that always supported me in making this final project to success.

ABSTRACT

Beca Melaka is one of the historical transportation method in the Melaka City. At the present moment, the traditional tricycle is powered by human effort, using conventional single gear-chain system. The current system has been proven able to handle robust operation, but required a lot of the driver's energy to move on inclined road condition. In this project, a new drivetrain system is develop to assist Beca drivers to move their tricycle especially on inclined road condition with less human effort. The new drivetrain proposed utilized a hybrid combination of the existing mechanical single gear-chain system with electric D.C motor system. The 24 N.m electrical D.C motor is powered through a rechargeable lead-acid battery rated at 12 V, 40 Ah. Using a customized gear coupling system (at gear ratio of 11:33) linking the existing gear with the input of motor, the new drivetrain design is able deliver up to 71.6 N.m of torque to move maximum 290kg of load through 12 degree road gradient at maximum 15 km/h. The overall drivetrain system design started with conceptual design of potential solutions, followed by concept design selection using Analytic Hierarchy Process (AHP) method. Later, the final concept design selected was modeled into 3D and 2D CAD drawings using SOLIDWORKS software. Finally, drivetrain system sizing was conducted to determine the required electric motor, battery and the customized gear coupling system specifications. The simple and compact final Beca Melaka hybrid drivetrain design developed in this project is expected able to provide more efficient performance to the tricycle, and help current Beca drivers to carry their passenger with less human energy especially on inclined road conditions.

ABSTRAK

Beca Melaka merupakan salah satu kaedah pengangkutan sejarah di Melaka. Pada masa ini, beca tradisional dikuasai oleh tenaga manusia yang menggunakan sistem rangkaian gear tunggal konvensional. Sistem semasa terbukti dapat mengendalikan operasi yang mantap, tetapi memerlukan banyak tenaga pemacu untuk bergerak pada keadaan jalan yang berbukit. Dalam projek ini, sistem pemacu baru dibangunkan untuk membantu penunggang beca untuk menggerakkan beca mereka terutamanya pada keadaan jalan yang berbukit dengan menggunakan tenaga yang sedikit. sistem pemacu baru yang dicadangkan ini menggunakan gabungan sistem hibrid mekanikal gear tunggal sedia ada dengan sistem motor D.C elektrik. Motor elektrik 24 N.m D.C dikuasakan melalui bateri asid plumbum yang boleh dicas semula pada 12 V, 40 Ah. Menggunakan sistem gandingan gear yang disesuaikan (pada nisbah gear 11:33) menghubungkan gear sedia ada dengan input motor, reka bentuk simstem pemacu baru ini dapat menyampaikan tork sehingga 71.6 Nm untuk memindahkan beban maksimum 290kg melalui kecerunan jalan 12 darjah dengan 15 km / j maksimum. Reka bentuk sistem pemacu ini keseluruhan bermula dengan reka bentuk konsep penyelesaian berpotensi, diikuti dengan pemilihan reka bentuk konsep menggunakan kaedah Proses Hierarki Analitik (AHP). Kemudian, reka bentuk konsep akhir dipilih menjadi 3D dan 2D CAD lukisan menggunakan perisian SOLIDWORKS. Akhirnya, saiz sistem dilakukan untuk menentukan motor elektrik, bateri dan spesifikasi sistem gandingan gear yang disesuaikan. Reka bentuk sistem pemacu hibrid Beca Melaka yang ringkas dan padat yang dibangunkan dalam projek ini dijangka dapat memberikan prestasi yang lebih cekap kepada roda beca, dan membantu pemandu Beca pada masa ini untuk membawa penumpang mereka dengan tenaga manusia yang kurang, terutama pada keadaan jalan yang berbukit.

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LIST OF SYMBOLS

P	=	Power required (in watts)
kr	=	Rolling resistance coefficient
M	=	Mass of bike + rider
s	=	Speed of the bike on the road
ka	=	Wind resistance coefficient
A	=	Frontal area of the bike and rider
v	=	Speed of the bike through the air
d	=	Air density
g	=	Gravitational constant
i	=	Gradient (an approximation²)
Rw	=	Radius of wheel/tire
Vmax	=	Desired top speed
ta	=	Desired acceleration time
α	=	Maximum incline angle
Crr	=	Working surface
ta	=	Time required to achieve maximum speed [s]
Tw	=	Wheel torque
V	=	Nominal voltage
F	=	Force
T_T	=	Total torque for rear tire
F_r	=	Frictional force
F_N	=	Normal force
F_r	=	Force on rear tire
r	=	Radius of tire
W	=	Watts
A	=	Amps
rpm	=	Radius per minute
ω_{rs}	=	Angular speed of the rear sprocket

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This project is intended to meet one of the requirements for Bachelor’s Degree that aimed to enhancing the knowledge and skills of the students in their respective fields, especially identifying the problem and study the methods to solve the problem. This year, the title that are chosen was "Conceptual Design of Drivetrain System for Beca Melaka". This project aims to produce a new design concept on a beca in Malacca drivetrain system without changing the authenticity.

Among the goals of this project is to produce detailed drawings that ultimately will be selected as the best design concept selection. The new design will also be generated when problems are known. To start this project, investigation into the problems that have been faced by the riders riding was required. Following this, a great deal of research was been done into many different systems available to be incorporated into the previous spot drivetrain. At the end of this project, the results will provide a solid foundation for the future generation to implement this research

The new design of the drivetrain system will have features solutions faced by rickshaw drivers when going uphill. Rickshaw drivers will feel comfortable when using it.

1.1 Problem Statement

As we know, there are various modes of transportation in Melaka. But such, which attracts tourists each visit in Malacca is the traditional transport rickshaws. Every rickshaws that is in Malacca has its attractions. With the addition of the decorations on the rickshaws capable of attracting the attention of many tourists. Despite the modifications made have a specific purpose, but by something like this, to some extent affect the physical rickshaws. Problems arise when the rickshaw being cycle in the hilly terrain. Due to the weight of the accessory that is placed in the rickshaws, rickshaw drivers have to use more energy in order to climb the hilly roads. Based on the traditional rickshaw in Melaka, the current rickshaw used single-gear and chain drivetrain system to propel the vehicle. The current drivetrain however is ineffective for hill-climbing purpose, whereby the rickshaw cyclists need to put extra cycling energy to move the vehicle with passengers. The efficient drive unit also needs to be installed in the rickshaw to ensure that the rickshaw can be used for the best performance with less hustle. Therefore, the gap or any opportunity to improve needs to be identified and overcome.

1.2 Objective of Project

There are four main objectives which are:-

i. To develop conceptual designs of drivetrain system for beca Melaka.
ii. To identify best concept design selection.
iii. To develop 3D CAD model and working drawing of the drivetrain system.
iv. To determine the theoretical performance of the drivetrain system.

1.3 Scopes of Study

The scopes of this project are:

i. To develop conceptual designs of drivetrain system for beca Melaka using TRIZ design method.

ii. To perform best concept design selection using Analytic Hierarchy Process (AHP) Method.

iii. To develop 3D CAD model and working drawing of the drivetrain system using SOLIDWORKS.

iv. To analyse the theoretical performance of the drivetrain system using analytical/simulation method.

1.4 Limitation of Study

The study is limited to the design of a new drivetrain which can coupled with the existing beca to provide improve vehicle climbing performance especially at full load. Starting with research of related drivetrain system to gain more understanding of the theory of the drivetrain used on the beca. After done with research of the new design, it need to design an appropriate drivetrain system that the new system can reduce the force when cyclist going up the hill. The scope of this project supports the objectives of the project where it is about how to organize a market survey carried out towards the user and rickshaw pullers. Besides, the project is also to provide a complete design specification of the beca including product design, concepts design, methods used and complete drawings for fabrication purposes later.

1.5 Expected Result

In the end of the project, the expected results are development of new drivetrain system which are able to solve the problem that have been faced by the beca rider that are giving to much energy and effort to climbing the hill.

1.6 PSM Project Flow Chart

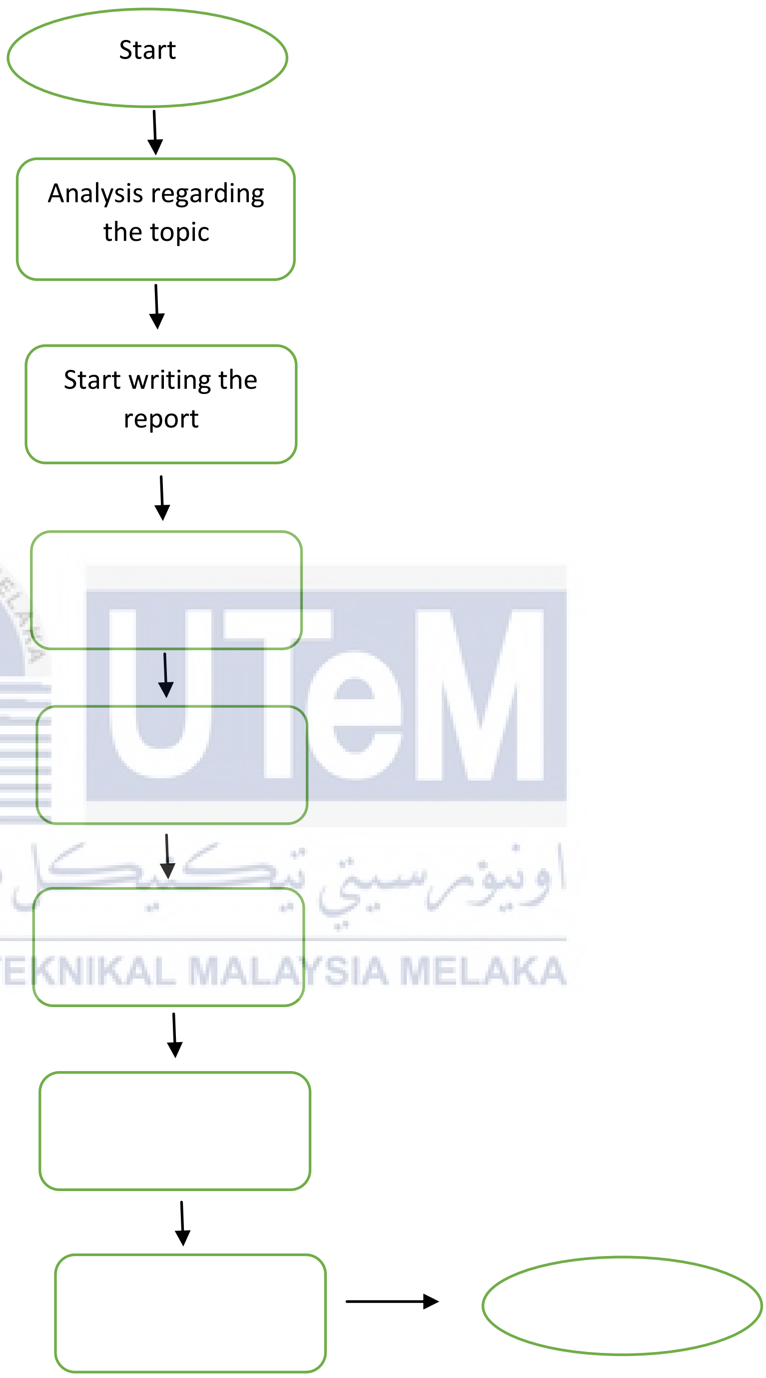


Figure 1.1: PSM Project Flow Chart

No	Activities	Week of Progress 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Literature review study	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
2	Report writing			■	■	■	■	■	■	■	■	■	■	■	■		
	Chapter 1 : Introduction				■	■											
	Chapter 2 : Literature Review				■	■								■	■		
	Chapter 3 : Methodology								■	■	■						
	Chapter 4 : Design Selection												■	■	■		
3	Presentation											■					
4	Report Submission														■		

Figure 1.2: Gantt chart of the Progress for PSM I

No	Activities	Week of Progress 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Literature review study	■		■	■	■											
2	Report writing			■	■	■	■	■	■	■	■	■	■	■	■		
	Chapter 5 : Result and Design Analysis					■	■	■	■	■	■	■					
	Chapter 6 : Conclusion and Recommendation												■	■	■		
3	Presentation																■
4	Report Submission															■	

Figure 1.3: Gantt chart of the Progress for PSM II

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This study involves the search for information by reading the information according with the title of this project. There are a variety of mechanical design process used in industry in different ways. In addition, this study also made to the existing products in the market to get ideas and innovating products so as to achieve the objectives set. Rickshaw is a vehicle that uses human energy to move. Generally, beca have two seats for passenger other than the driver or rickshaw itself. There are various types of rickshaws are available in the country and the sloppy design is in accordance with each country. Beca contained in passenger design is divided MHS has left the rider while pedalling a bicycle rider. Traditionally, this beca were use at the area with many tourists and rickshaw was carrying tourists around the surrounding area than in the past sloppy goals which bring customers into place to reach, such as drivers nowadays. In the state of Malacca, there are many places that can be visited historical relics. So as to maintain the tradition of initiatives rickshaw in Malacca, this service continues even to this day can be one of the attractions for tourists who want to come here. Beca ride service bringing tourists to some extent can be one of the factors contributing to the economy of the country. Besides, it is also helpful in providing job opportunities whether young or old to venture into this job. Problems arise when the rickshaw being cycle in the hilly terrain. Due to the weight of the accessory that is placed in the rickshaws, beca drivers have to use more energy in order to climb the hilly roads

The aim of this project is to find a solution to the problem faced by most rickshaw riding that is difficult to climb the hill. This project is focus on the drivetrain of the bicycle that is use on the rickshaw. To develop a drivetrain system for the bicycle of the beca Melaka, one must also understand what components make up this system. There are various types of transmission and component available on the market. Each of these type of will be briefly described in order to understand the function of it.

2.1 Drivetrain

Bike drivetrain frameworks are utilized to transmit control on bikes, tricycles or other human-power vehicles from the riders to the drive wheels on the back. A large portion of the bike drivetrain additionally incorporate some sort of an instrument to change speed and torque by expanding or diminishing the apparatus proportions. A few early drivetrains utilized straight-cut riggings that consolidate straightforwardly with each other outside of the center point. A few bikes have utilized a double-sided rear wheel, with various estimated sprockets on every side. To change the apparatuses, the rider would stop and dismantle remove the rear wheel and reinstall it in the reverse direction. This situation will take a longer the time to reach the destination. Bike drivetrain frameworks have been produced to transmit control from riders to drive wheels by a variety of strategies. Most bike drivetrain system coordinate freewheel to permit drifting, however coordinate drive and settled apparatus frameworks don't. There are a few sorts of drive arrangement of the bike which are single speed outfitting, derailleur adapting, hub gearing and shaft-driven.

Figure 2.1: Bicycle Drivetrain (https://cyclingtips.com)

2.2 Single Speed Gear

A single speed is more effective than a multispeed bicycle. While the single rigging proportion won't be the "ideal" gear for all conditions, in the conditions which fit the single gearing, it is significantly more productive mechanically than the drivetrain of a derailleur bicycle. Single speed are great if cycling in a place with harsh climate. There are less parts to stop up and wear out with this outfitting (Evans, 2006). These gearing is cheaper than the other geared peers. This gear also simpler than other gear and it is low maintenance as also it easy to be build (Philips, 2016). A single speed bike are lightweight because the mechanism is without the weight of the derailleurs, shifters, cables, extra sprockets and longer chain. In addition, a single speed drivetrain runs the chain in a perfectly in line from sprocket to chain wheel, and avoids the wind through the pulleys of a derailleur. A single speed is quicker and easier to pedal than a multispeed bike in the same ratio. Single speed bikes are also significantly more reliable than multispeed bikes.

Figure 2.2: Single Speed Gearing (http://www.thebiketoolbox.com)

2.3 Derailleur Gear

The derailleur equip bike is the most well-known sort of multi-speed bike accessible today in the market (Kund, 1993). A bicycle's derailleur, also known as spelled derailed, makes it feasible for a bicycle to change gears. This system pushes a chain starting with one machine gear-piece then onto the next. A derailleur may resemble a favour bit of gear, yet it's truly very straightforward in outline, and the vast majority of the constrain behind its activity is given by the rider (Roberts, 2015). The derailleur chain drive system involves a several of sprockets of different sizes mounted on the back wheel shaft in mix with a moving component which causes the chain to move starting with one sprocket then onto the next, together with a spring actuated device to adjust and keep up the right strain in the chain. The different sizes of the drive sprockets provide the selection of a desired gear ratio depending upon on the specific landscape over which the bike is being driven (Jeffries, 1977). Derailleur for a bike is given that is anything but difficult to work. Cyclist could rapidly change adapting on the fly and hold a lot of this proficiency over shifted landscape, speed, and wind conditions by utilizing this equipping system (Evans, 2006). This system is for transmitting main thrust from the chain transmission component to the front or back wheel. The rider can change the gear position of the derailleur just when driving the bike. A derailleur of this plan is complex. Essentially, derailleur has a mounting part, a chain control and a chain direct positioning component on the system. Derailleur is controlled by a single cable from the shifter, requiring the derailleur to coordinate a huge spring that can pull against the shifter, permitting the shifter to go about as though it is dragging the derailleur forward and backward between a majorities of apparatuses, commonly provided in a set course of action known as a cassette. The actuating cam is organized to pivot just in one heading in light of development of the control component to move the chain manage from a first position to a moment position

Figure 2.3: Derailleur Gears (http://www.cyclinguk.org)

2.4 Hub Gear

A bike hub transmission fundamentally incorporates a hub axle, driver, a hub shell, a planetary apparatus component and a grip in the system. The driver is rotatable upheld with respect to the hub axle internally-mounted multi-speed hub transmissions shape part of the back wheel of a bike and incorporate a center hub that is connected to the bike outline, a driver rotatable was supported by the hub axle for accepting an accelerating power, and the shell of the hub rotatable upheld by the hub axle. The hub transmission additionally includes a clutch for activating the power transmission component to choose unique rigging proportions. The power transmission system regularly consist a planetary apparatus component including a few sun gears, no less than one ring gear and a planet gear carrier each of which is rotatable upheld by the hub axle. A few planet gears are rotatable supported by the planet gear fitting with the sun gears and the ring gears. To change the power transmission ways and the comparing gear ratio, the previously mentioned different gear segments are specifically non-rotatable combined with each other by working the grip (Urabe, 2011). The efficiency undoubtedly relies on upon what number of components of the gear train are in movement as every gear is chosen. This eminent however complex transmission has roller direction and uses light oil as a lubricant. Shifting is very straightforward. Successive gears are come to by pulling on the single cable in one direction or the other (Wilson et al, 2001).

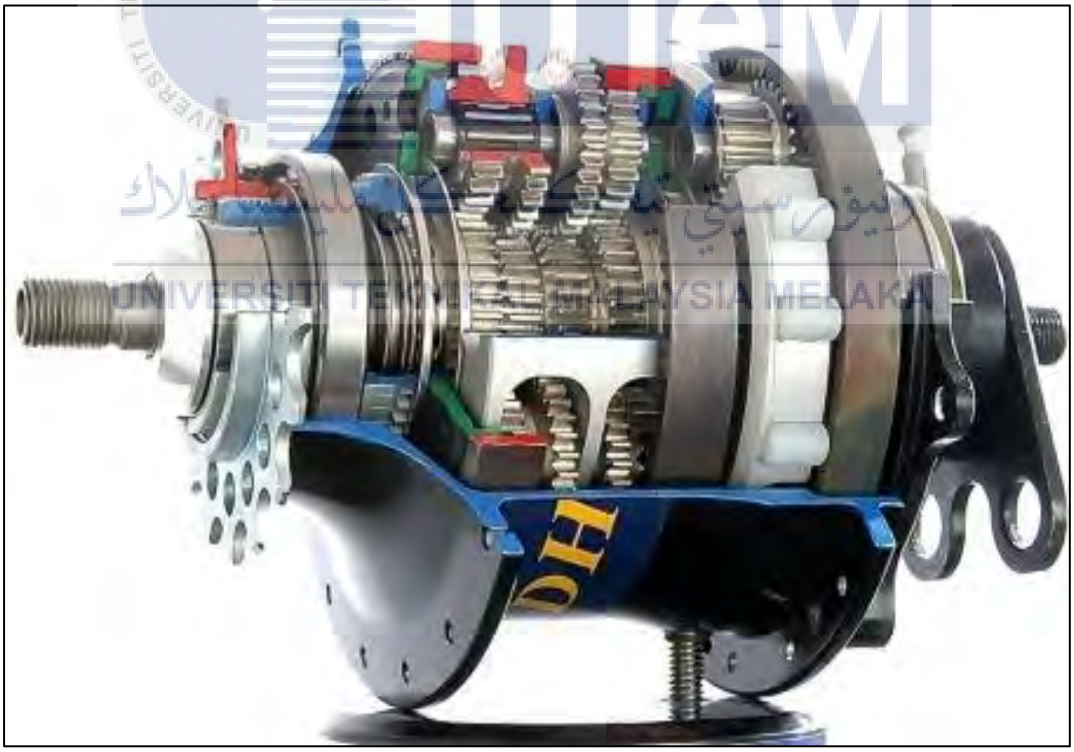


Figure 2.4: Hub Gearing (http://harry.biketravellers.com)

Figure 2.5: Nu Vinci CVP Hub Gear (https://rideonmagazine.com.au)

2.5 Shaft-Driven

A chainless drive system for a bike by utilizing a rotatable drive shaft rather than chain for exchanging the pedal actuated driving force from the pedal crankshaft to the back wheel including shift components to give different drive ratio. This mechanism is less expensive rather than derailleur systems (Jeffries, 1977). A bike drive system contain a front gear face, a back rear gear, a front guide assembly, a back guide assembly, and a drive shaft coupled to a back suspension outline through a back hub and a wrench axle. The bike drive system works autonomously of the frame. Shifting with one gear then onto the next is controlled by a move controller. Every move of the move controller shifts both the front and back guide assemblies in the meantime. The shift controller is ideally coupled to the front and back guide assemblies by means of a link system (Scranton & Le, 2008).

Figure 2.6: Bicycle Shaft Driven (http://www.dynamicbicyclesuk.co.uk/)

Figure 2.7: Shaft Driven Mechanism (http://bicycles.stackexchange.com/)

2.6 Power Assist

Nowadays, there is interest in the using of power assist mechanisms for manually powered vehicles, for example, bikes. By using a power assist, it is conceivable to enlarge the utilization of such vehicles and allow their use by people who may not generally have the capacity to ride or difficult working with it (Izumi Yamashita et al, 2000). For some drivetrain system for the bicycle, there also have adding some power to assist the system. This system would provide some additional power to the trishaw to give some boosting or supplement that provided by the driver. The energy was stored in batteries and been transmitted through an electric motor, or stored through some device of mechanical storage system. This power assist is useful in situations that requiring high torque for example like pedalling the trishaw with passengers uphill or starting the trishaw from rest. This drivetrain system in addition of utilization the power assist helps people having normal or greater than normal abilities also to use the vehicle to a fuller advantage (Saito et al, 1984)

2.6.1 Electric Assist

A pedal-operable bike is given supplemental electric power intends to help the cycler in navigating uneven landscape. The electric power implies contains a capacity battery, a wheel-center mounted direct current engine worked either as an engine or a generator, and handle bar impelled electronic control (Garfinkle et al, 1975). Electric assist in requires with an addition of electric motor that need to modified on the rickshaw frame and energy storage in rechargeable batteries that was stored on the trishaw. This electric assist need other components to generate the motor including a throttle, controller and a method to charging the batteries. This electric assist of bike or rickshaw can be incited by manual accelerating of the operator, or through electrical power activation or a combining of electrical power and manual operation. (Hsu et al, 1989). This power assist which can be arranged by resulting to mounting a power unit on a present bicycle frame without changing the first design of the bike frame (Tsuboi et al, 2014). This system could gave benefit to the drivers but this system have a number of constraints which limit the design and feasibility. The cost to produce the system sometime become prohibitively expensive and sometime cheap depend by the company that make the electric drivetrain. The maintenance of the system also need to be considered as the ability of the local manufacture and repair is need to be considered.

2.6.2 Mechanical Assist

Power assist system also can be done using some form of mechanical energy that is store on some potential energy storage system such as compressed, spring and also flywheel. As for the example of the spring, it could capture energy while the trishaw going down the hills or store the energy while stopping and then release it later to give the driver a boosting when starting to pedalling or going uphill. Whereas for the compressed air, a tank of compressed air can power up air engine or piston to assist the driver to boosting the trishaw. However, there are a challenges with the energy capacity and efficiency of the mechanical storage. Due to the problem, mechanical system can reduce the number of the problem with using full electric assist. While the simple mechanical assist could be a better solution, the amount of power that is needed for useful of electric assist could be difficult to achieve with mechanical energy storage.

2.7 Generating Concept Design

Concept, or idea at early stage, design is thought to be the most troublesome, sensitive and critical design in making an items (Ulrich et al, 2000). It significantly impacts the cost, robustness, manufacturability, and development time of the last items (Nevins et al, 1989). As a general guideline, the cost of designing changes increments by ten circumstances when changes are made in a later stage. A conceptual design could be employed to show and deliver the desired benefits to a potential customer. In a design process, there are many conceptual designs that generated in search for the best design that fit the customer's needs. Conceptual designs are generated by breaking down away the function of the product into smaller parts and sub-function. The sub-function will be recorded in a capacity structure graph. At that point, the thought strategy will be utilized to think of an answer for each sub-function. In conclusion, the sub-capacities chose to satisfy all the function of the item will join together and refined into a concept design. There are a few strategies and method that can be utilized to created new concept design.

2.7.1 Brainstorming

Before begin to create or develops a design in graphic software, it is important to generate creativity to come with concepts and idea for a project. It is sometime often difficult to sit down and design something without a brainstorming. (Al-maghrawy, 2012) defines brainstorming as a gathering innovative discussion for general thoughts. Brainstorming was created by Alex Osborn to deliver thoughts without hindrance. Brainstorming means the use of brain to the active problem solving and the brainstorming session aims to develop creative solutions to problems (Jarwan, 2005). Conceptualizing of brainstorming procedure includes oral and pre-composing practices for helping the learner and for communicating thoughts by the instructor. It is a procedure that is utilized under the discussion method. Brainstorming has an awesome significance in the instructing procedure (Zeitoun, 2001) .The goal of brainstorming is to generate out any and all idea that can be related to a project that we going to do. Even the idea may seem be unrealistic or even downright stupid, it also should be write down. Sometime, any one of the idea can lead to your best work. Those idea can be overall concepts and styles, image, project goal and many other. Just always be remember to write and record everything. There are some tips on how to achieve a good brainstorming. The brainstorming includes:

a) Relate the idea to the goal of the project
b) Sketching and doodling
c) Elaborate on concepts that are promising
d) Looking for connections between the ideas
e) Combining ideas and concepts that are related.

(Al-blwi, 2006) said that there are stages that need to be followed in problem solving when brainstorming session, those are;

1. Expressing the Problem: The instructor who is dependable on the sessions offers an issue and examines its different measurements for students to guarantee understanding.
2. Surrounding the issue: in this stage the instructor or educators decides the issue precisely by reframing the issue in specific inquiries. This may offer worthy arrangements without the requirement for further brainstorming.
3. Working on brainstorming for at least one than one articulation in issue. this step is important when there are many ideas were generated
4. Offering the idea: Brainstorming session prompt to create a major number of thoughts and in this manner, those ideas must be assessed and select the most

appropriate and vital ones as indicated by oddity, innovation, value, term and cost and additionally rationale (Bani Hamad, 2006).

2.7.2 Theory of Inventive Problem Solving (TRIZ)

We already know about brainstorming that already explain on the top, which can help with this situation that need to generate concept idea. For this method however, it depends on the knowledge of the team members, tends to have unpredictable and unexpected results. TRIZ is one of the method of solving methodology based on logic, data and research, not intuition. It shows on the past knowledge of many thousands of engineers to accelerate the projects team's ability to solve problem by creatively. to take care of most troublesome issues, it is not sufficiently only to utilize strategies, it is critical to be fit for perceiving an issue as a piece of framework, to have the capacity to see things at various framework levels, to perceive interfaces between framework parts. To put it plainly, TRIZ depends on three columns: analytical logic, knowledge bases, and a systematic way of thinking (Souchkov, 2007). As for it, TRIZ also provides repeatability, predictability, and reliability to the problem-solving process due to structured and algorithmic approach. This hypothesis build a universal connection to the current problem or similar one which was solved in different places. Based on researching this hypothesis, the main finding been discovered which is:

a) Problem and solution repeated across the industries and sciences.
b) Patterns of technical evolution tend to be repeated across industries and sciences.
c) Creative innovations often use scientific effects outside the field where they were developed.

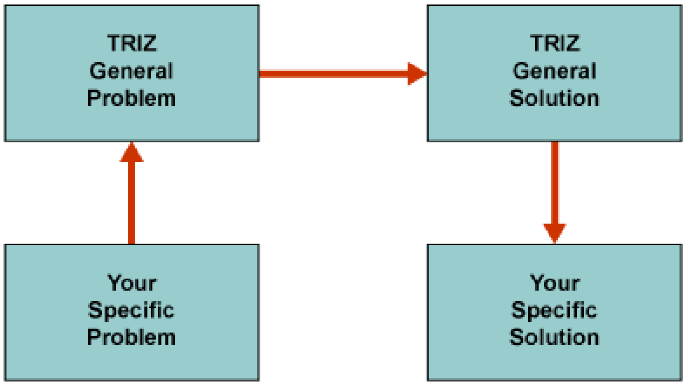


Figure 2.8: TRIZ Problem Solving Method (https://triz-journal.com)

2.7.3 Design for Assembly (DFA)

Design for Assembly (DFA) is process which is the item are been planned considering simplicity of get together. In the item contains less parts, it will take less time to be assemble and thus reducing the assembly costs. On the off chance that the parts are furnished with elements which make it less demanding to move, situate and insert them, it additionally will lessen the assembly time and expenses. The reduction in part number will generally reducing the total cost of parts in the assembly. The aim of this DFA is to simplify the product so that the assembly cost will be reduced. When applying the DFA, it also usually include in improving the quality and reliability, and a reduction in production equipment and inventory. DFA is a sort of design method that can be utilized as a part of two ways - an instrument for get assembly analysis and a guide for assembly design. The previous use is that at the time after the start of the item plan, the engineer makes estimation of assembly plausibility by analysing every one of the variables that can influence the assembly process and give recommendations. The second one is that collecting the information and experience from the get assembly specialists and recording them as configuration guides. By the assistance of these guide, the designer can pick the design plan; decide the item development, for example, under the direction of those specialists (Xie, 2003)

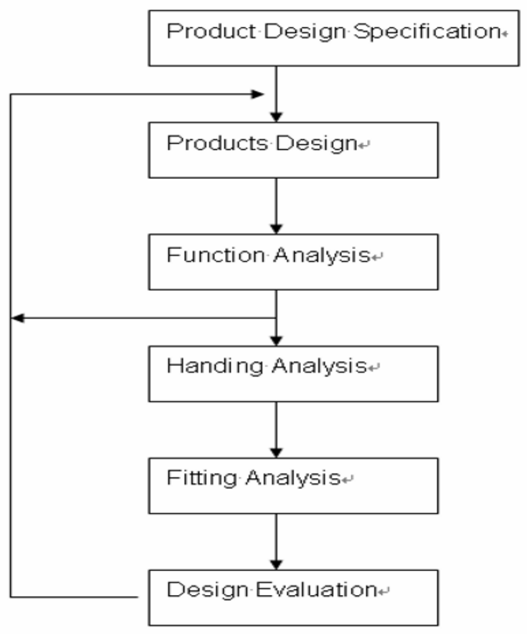


Figure 2.9: DFA method (Xie, 2003)

2.7.4 Morphological Chart

Morphological chart is a visual way to show the product functionality and find the alternative means and combination to achieve that functionality. For short, this method is use to generate ideas in an analytical and systematic manner. For the every element of the product function, there may be some number of possible solutions. This method enables these solution to be shown and provide a structure for considering the other combinations. These solution will form the component in the morphological chart. The morphological method thus yields a matrix of functions and components.

The possible component are been listed on their basic functions. The component are specific and it will places belong to their category. By means of the morphological chart, the products is split into a set or sub-functions. For each of the sub-function, ideas are generated and will combined into an overall solution. Through selection and combination of a set of components, an idea comes out. This idea should be seen as a principal solution, a carefully chosen combination of component and parts together form a conceptual solution.

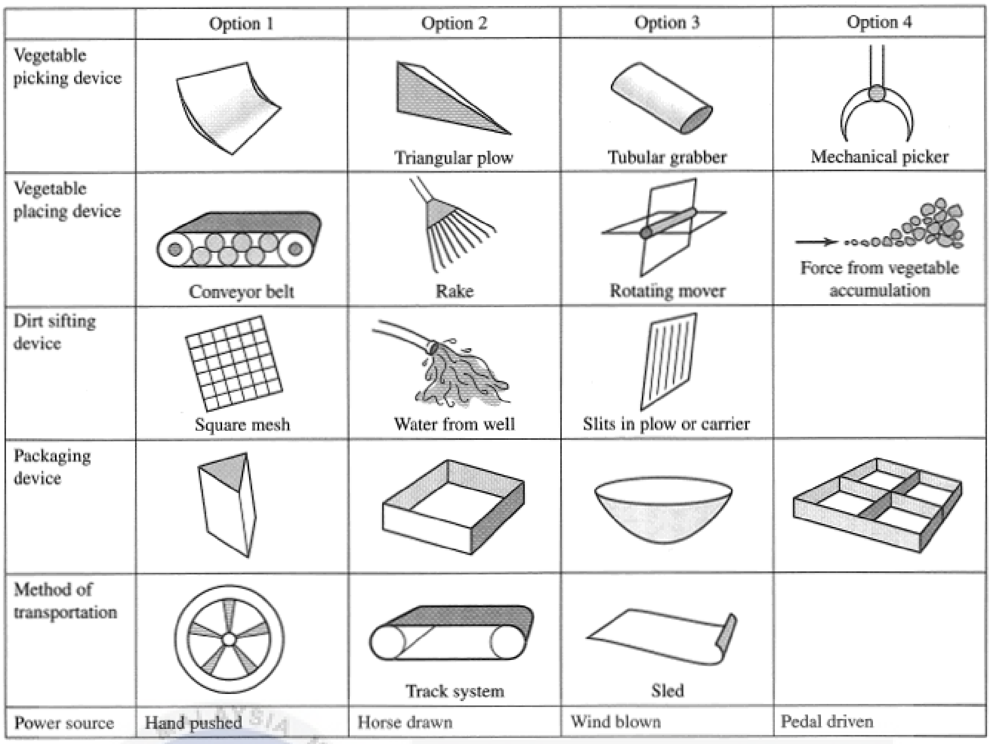


Figure 2.10: Example of morphological chart (http://cuba.coventry.ac.uk)

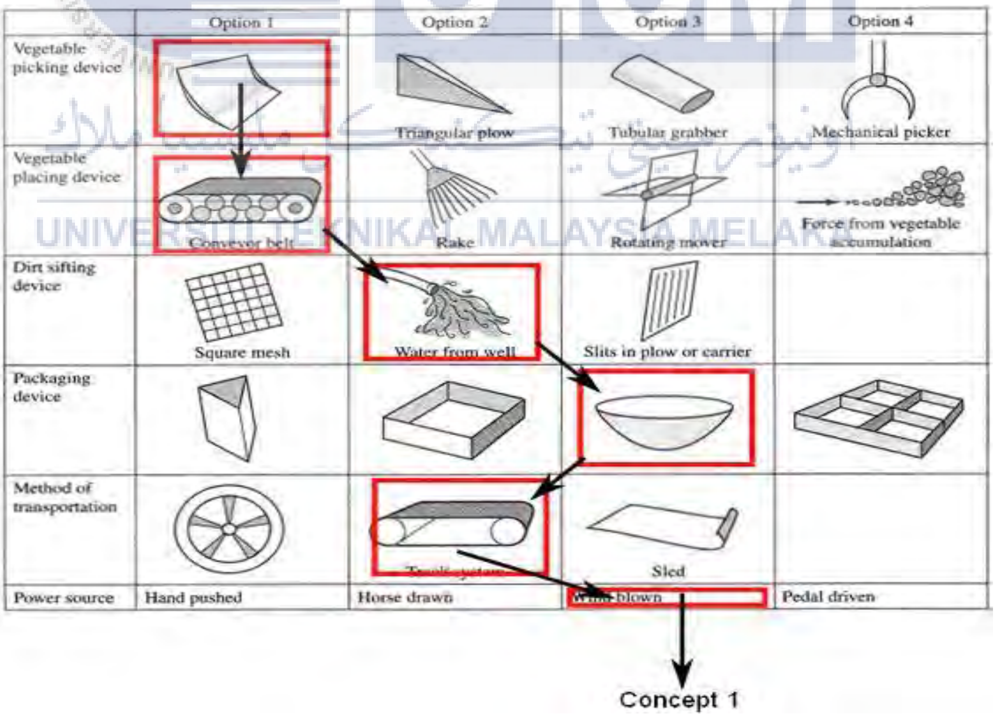


Figure 2.11: Morphological chart after selecting the best combination (http://cuba.coventry.ac.uk)

2.7.5 Gallery Technique

Gallery technique is a strategy that gets students emerge and out of their seats into a method of dynamic engagement with the other. The advantage of the method is its adaptability and the variety of advantages. A Gallery technique can be conducted with a PC, paper on tables, or with posted graph paper. It can be directed around 15 minutes or for a few class periods. It is an opportunity to share considerations in a more intimate, steady setting as opposed to a bigger, unknown class for the student and it's a possibility for the educator or teacher to gauge the depth of student's comprehension of specific ideas and to challenge misconceptions. For a short, this technique can be outlines as below:

- Problem introduction (more effective notification for preparation and more reading)
- Idea generation stage.
- Associate of idea stage. At the end of the stage, new concepts can be generated of just focusing the developing the current product proposed.
- Idea generation stage 2. Stage3, 4 can be repeated if necessary.
- Selecting the idea and further development.

2.8 Selecting the Best Concept Design

Concept design selection is a process of evaluating concept with the respect to the customers want and other criteria, comparing the relative strengths and the weaknesses of the concepts and select more than one or just one concept for further development, testing and investigation. The method presented will useful later in the development process when you itself or the team must select subsystem concepts, component and production processes.to select the best concept design, and there are many design method (Wassenaar et al, 2001) that can be used to select the best design concept to help designers in making the correct decisions during the concept selection phase including Pugh's concept scoring

(Pugh, 1990), the analytic hierarchy process (AHP), fuzzy set (Thurston et al, 1992), the fuzzy AHP method (Yeo et al, 2004), flexible design concept selection (Sivaloganathan et al, 2004), the hypothetical equivalents and in-equivalents method (Lewis et al, 2002), quality function deployment (QFD) (Hauser et al, 1988), and axiomatic design (Suh, 1990). Between all of this concept, the AHP methods are most commonly used in industry (Salonen et al, 2005).

2.8.1 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) was originally created by (Saaty, 1990) as an excellent MCDM (multi criteria decision making) tool which was approved by many researchers (Zahedi, 1986). Analytic Hierarchy Process is one of the effective tool for facing with complex decision maker to set priorities and make the best decision. It gives an extensive and objective framework for organizing a decision problem, for representing and quantifying its components, for relating those components to general objectives, and for assessing alternative solutions (Juntian, 2008). By reducing intricate decisions to a series of pairwise comparisons, and then synthesizing the results, the AHP avails to capture both objective and subjective aspects of a decision. In integration, the AHP incorporates an utilizable technique for checking the consistency of the decision maker's evaluations, thus reducing the partialness in the decision making process. For short, AHP is a method to derive scale from paired comparisons. All the input can be obtain from the actual measurement such as weight, price and other or from an opinion such as feeling and preference. This method allow some inconsistency of judgement because all the human not always right and consistent.

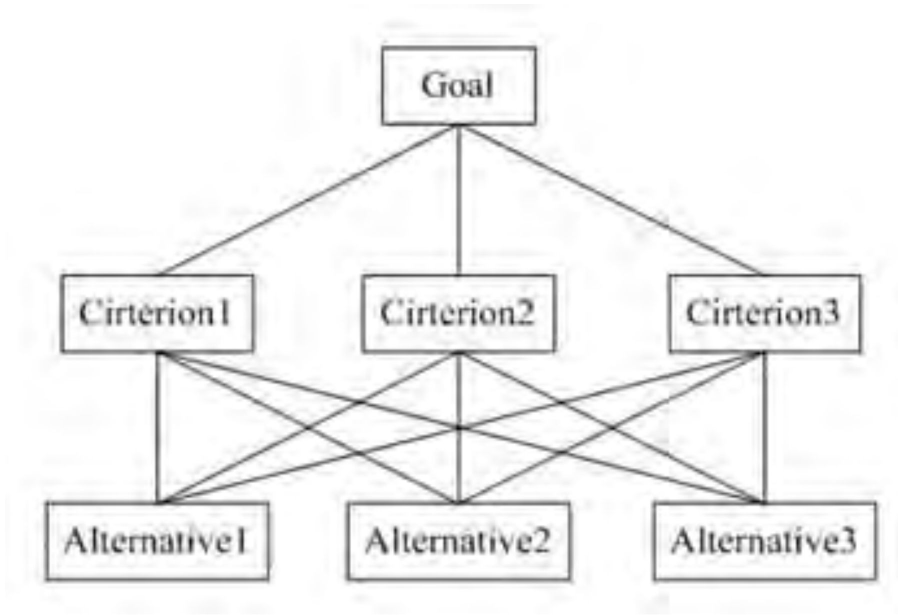


Figure 2.12: AHP Hierarchy Structure (http://www.jiem.org)

2.8.2 Pugh Matrix

This Pugh Matrix is one of the other type of comparison of a number design method that design candidates leading to which the best meets a set of criteria. This method also easy to use and relies upon a series of pairwise comparisons between design candidates against number criteria of requirements. This method provides a simple approach to taking those multiple factors when reaching a decision. The Pugh Matrix also lets simple analysis to be performed, thus providing some information as the robustness of some decision. This method can be used whenever to decide something between a number of alternatives. It can be used by an individual or team and the outcome depends upon the experience of the team or individual. (Burge, 2009)

This method also very effective for comparing concepts that are not refined for direct comparison with the engineering requirement. It most effective if all of each member performs it independently and will usually lead to repetition of the method.

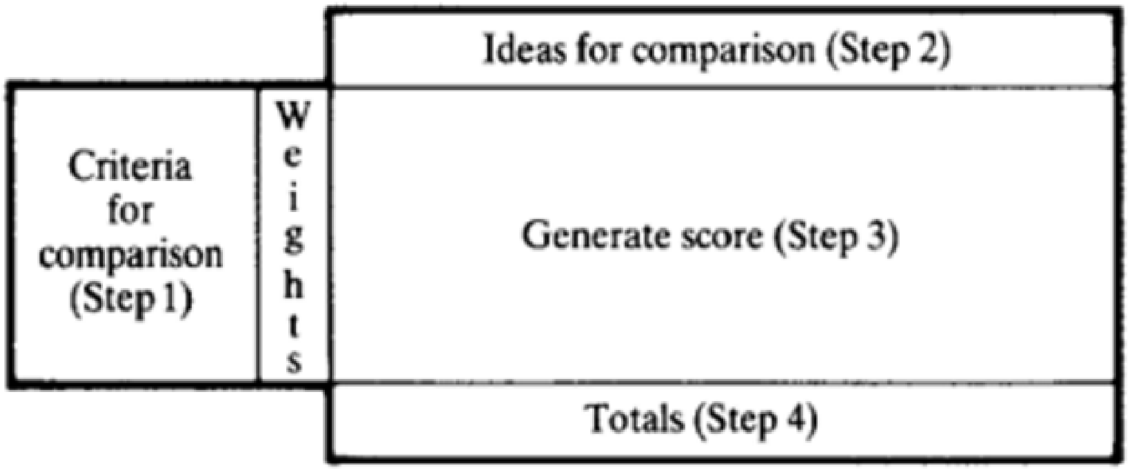


Figure 2.13: General format of the Pugh Matrix (http://smartsol2u.blogspot.my)

2.8.3 Technique for Order Performance by Similarity to Ideal Solution (TOPSIS)

TOPSIS is one of a useful technique when facing with multi-criteria decision making problems. It also helps the decision maker to solved the problems that been organize and carry out the analysis, comparisons and rankings of the alternatives. The basic idea of the TOPSIS is straight to the point (Shih et al, 2007). A systematic and proficient approach towards conceptual design and material choice is important with a specific end goal to choose the best option for a given engineering application. This TOPSIS will help planners and engineer to achieve a consensus on design and materials selection for a particular application. The procedure is based on an intuitive and simple idea, which is that the optimal ideal solution, having the maximum benefit, is obtained by selecting the best alternative which is far from the most unsuitable alternative, having minimal benefits. The best solution will rank with ‘1’ or one and the worst will be rank as ‘0’ or zero (Srikrishna et al, 2014). The application of the TOPSIS method will be involves in the below step.

1. Establish the decision matrix.
2. Calculate a normalised decision matrix.

3. Determine the weighted decision matrix.
4. Identify the Positive and Negative Solution.
5. Calculate the separation distance of each competitive alternative from ideal and non-ideal solution.
6. Measure the relative closeness of each location to the ideal solution.
7. Rank the preference order.

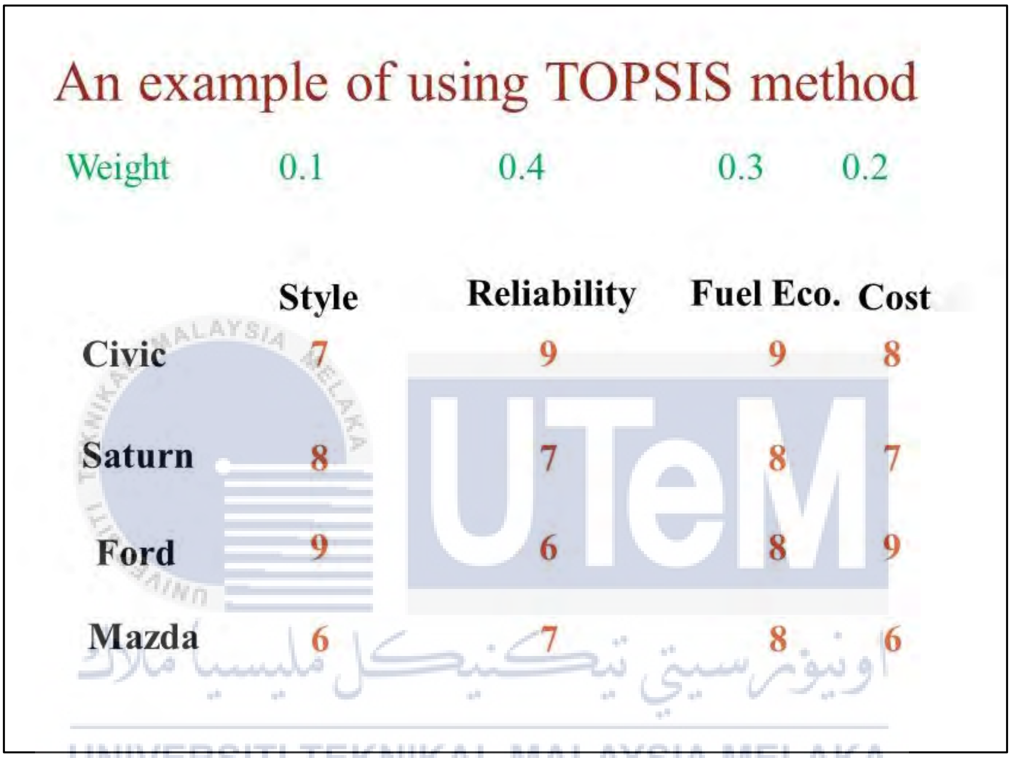


Figure 2.14: Example of TOPSIS Method (http://slideplayer.com/)

2.8.4 VIKOR

This method were been developed for optimization of the complex systems multi-criteria. VIKOR focuses on the ranking and selecting from a set of alternatives in the presence of conflicting criteria. Multi-criteria optimization is the process of determining the best solution according to the criteria that been given (Sayadi et al, 2009). The VIKOR was been introduced as one of the technique that can be used to be implemented within

MCDM problem and it was created as a multi decision making method to solve decision making with non-commensurable and conflicting criteria.

CHAPTER 3

RESEARCH METHODOLOGY

3.0 Introduction

This chapter will explain briefly about all the methodology that was used in this PSM project started from the beginning of conceptual design of the drivetrain system of the trishaw. Because of the rule to let the original design of the trishaw, the drivetrain system need to be develop to meet the criteria that need to be achieved based on the problem that is faced by the trishaw cycler. Based on the original design of the trishaw, the size and the weight of the drivetrain will be measured and be redesign to meet the criteria to solve the current problem.

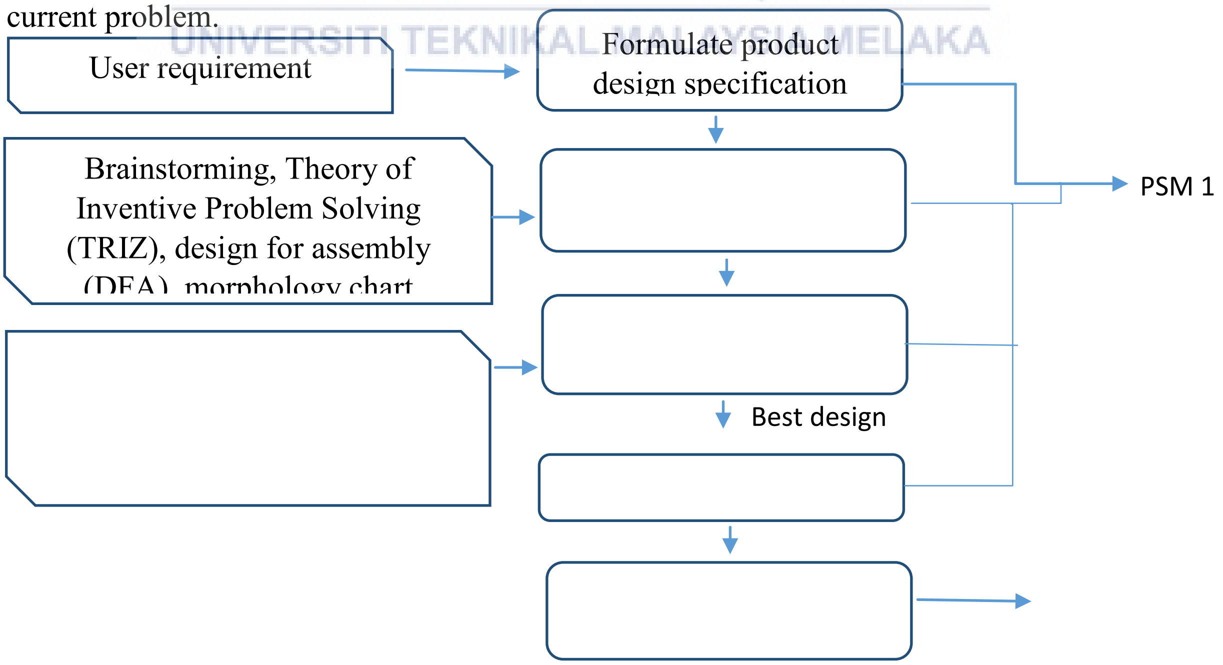


Figure 3.1: Overall PSM flowchart

3.1 Conceptual of the Drivetrain System

Before beginning the design of the beca of specifically bicycle drivetrain system, the concept of designing drivetrain system must be stated first. Several design of bicycle drivetrain were selected to see what kind of subject matter which is suitable to design the new concept of drivetrain system of beca Melaka in this project and what can be improved to solves the current problem that was faced by the beca rider. Figures 3.2 below show the current drivetrain that is use in the bicycle.

Figure 3.2: Current Beca Drivetrain (https://abgrara.wordpress.com)

By comparing the five conceptual design that is being discuss in the next chapter, there is one main design that can be used as the final selection design to develop the new drivetrain for the beca.

3.2 Modelling of Drivetrain System

For this project, all the 3D modelling of the drivetrain system were created by using CAD software. The CAD software that was used are SOLIDWORKS 2015. The SOLIDWORKS was one of the best choice to use to create 3D modelling for commercial industries and other wide variety of industries such as government, education and also research which provides simple command in creating shape and irregular contour.. This software is a geometric modelling software that were developed by the Dassault Systems. This software also provide computer-aided engineering (CAE) for analysis environment. This SOLIDWORKS analysis environment made designers are able to use the familiar SOLIDWORKS user interface and perform analysis directly on their master reference model in SOLIDWORKS. It certainly is a powerful system and it includes remarkable functionality for developing just about any type of physical component. To make this project run smoothly, the analysis of drivetrain system will be done in SOLIDWORKS analysis and simulation workbench.

3.3 Project Activities

To make sure the project were run smoothly, there are some main tasks that have been planned to develop the drivetrain of the Beca. Regarding to this plan, the project was been arrange and flow smoothly.

3.3.1 Literature Review and Finding Information

For the purpose doing the research before starting the project is to know the theory and how to improve the current design to solve the problem and type of material that would be used in developing the new system. From the theory, it will be the guideline to do the project and understand all the principle that are related to the system. Moreover, from this research also will come out the advantages and the disadvantages for the current design of the drivetrain that has been done by the other person. All the advantages will give a lot of helpful advice to do the project whereas the disadvantages will give some idea that can be improve through this project. All of this section has already been discussed in the chapter 2 of this report.

3.3.2 Analyse the Problem

The problem with the current drivetrain system are they will need higher force to climb the hill. Because of this problem, the rider will tired faster when they cycling. So the new drivetrain system will be redesign. By redesign the current drivetrain, the problem that has been faced will be solve and this design could be the design of the future drivetrain of the Beca Melaka.

3.3.3 Conceptual Design

On this section, this is the step to get some idea about the design of the drivetrain by sketching some conceptual design. There are five design of the drivetrain that will be sketch. From the several conceptual design, only one the best idea will be chosen for further design selection which is more realistic and more functioning thus can solve the problem.

3.3.4 Detailing

There are few design constraint that must be follow in order to make the original design of trishaw was not change. This design requirement is got from the measurement of the current drivetrain system and shape of the frame. The dimension must be accurate to prevent misunderstanding when designing the conceptual design using CAD software.

3.3.5 Working Drawing

This is the last step after the detailing process. The actual design for the drivetrain system which will be draw by using computer aided design software, SOLIDWORKS. SOLIDWORKS is used widely in automotive industries since it is easy to use and easy to create any hard shape based on the author experience. The drawing has the entire dimension for the component in order to show the actual size of the drivetrain.

CHAPTER 4

DESIGN SELECTION

4.0 Introduction

The purpose of this final year project are the drivetrain that will be used for the future Beca drivetrain for Melaka. As for the problem that have been faced by the Beca rider that difficult for them to climb the hill or slope when they cycling and it became more difficult when they carried passenger together with them. The function of drivetrain system are to transmit the power from the front gear to the back and thus to the wheel to move the Beca through the chain or belt. To begin the process of selecting the best concept of the drivetrain system for the Beca Melaka. To begin the selecting process of the best drivetrain system for the Beca, it will be focused on design criteria and then produced some conceptual designs to choose from the development. The dimensions of the drivetrain system must be compatible with the dimensional constraints set by the frame and the design will not affect the original design of the current Beca frame.

4.1 Total Design Method

Total design is the systematic activity necessary, from the identification of the market/use need, to the selling of the successful product to satisfy the need. It is also an activity that encompasses product, process, people and organization. Under this approach, social exchange theory is used to identify ways to improve the quantity and quality of survey response by organizing the data collection process in a way that increases trust that the rewards of responding will be seen by the respondents as outweighing the costs of doing so. This is sometimes referred to as the product delivery process or the product development process, abbreviated in either case as PDP.

The achievement of the integration of technological or non-technological subject material in an effective and efficient manner is greatly enhanced by having visible operational structure. Visibility are crucial factor in bringing about integration in the design (Sapuan et al., 2009). Total design may be the core of activities, all of which are imperative for any design, irrespective of domain. Briefly, this core, the design core, consists of market needed, product design specification, conceptual design and detail design until the design was choose. All the design should or not with a need that, when it is satisfied, will fit into an existing market or create market of its own. From the statement, a product design specification (PDS) must be formulated and the specification must be design. The PDS will acts as the control for the total design activity because it places the boundaries on the subsequent designs.

4.1.1 Market Investigation

In Malaysia, the original pedestrian-pulled rickshaws were significantly replaced by cycle rickshaws. Cycle rickshaws were always been here up to the 1970s in cities. Since then, rapid urbanization has increased demand for more efficient public transport, resulting in decreasing in cycle rickshaw numbers. Today, cycle rickshaws are operated mostly as a tourist attraction, operating in Malacca, Penang, Kelantan and Terengganu.

Nowadays, the design of the trishaw still the same like the original trishaw that was introduced long time ago. The drivetrain also not change and still using the single speed gearing. The trishaw have been give an impact to the economic or Melaka as the trishaw also one of the attraction why they come here. The market of the trishaw gradually increase because the tourists come visit to Melaka was increase by year thus the rickshaw was increases. In this field, drivetrain system design is one of the main concerns in this survey because, the cycler often get tired and difficult when they cycle the trishaw on the hilly and slope road.

Before starting the design of the vehicle, it is very crucial for a designer to deeply understand the rule and regulation. But for this trishaw, designer must understand the constraint that majority of the trishaw owner still hold on like the original shape of trishaw frame. They want to look as original as ever. In this project design, the trishaw is entirely following the original frame but the drivetrain will change. The ratio on the current rickshaw model is 44-tooth sprocket at the pedal driving and 16-tooth sprocket on the rear wheel. Again, this makes pedalling difficult, especially with the added weight of passenger when climbing hill or slope. Changing the number of teeth on one of the sprockets in the drive system could reduce the ratio of the vehicle, making it easier to pedal and less physically taxing on the driver. While this solution is simple and can be used, it still not a complete solution to the current gearing problem.

4.1.2 Product Design Specification (PDS)

Product Design Specification (PDS) is an essential in all fields of design activity from engineering, shipbuilding, architecture and other. This PDS is a document created during the problem definition activity on the early stage of design process. It shows and detail out the requirement that must be follow in order for the product or process is successful and follow the rule and constraint. The document lays the groundwork for all the design activities and ensures that all relevant factors are follow. At the end of the design activity, the design of the product is in balance with the PDS even at all the way through it been changed. In order to establish a balance PDS, we need to encompass every major element and aspect as they are primary triggers from which the PDS evolves. The PDS for this project can be refer at (Table 4.1)

4.1.3 Conceptual Design

Conceptual design is a process that been made after the product design specification (PDS) was come out. The concept design is unlimited that the designer can design how many design that they want. The generation of the design must meet the stated need. The evaluation of these solution to select the one that is most suited to match the PDS. In this part, 5 concept design is being generated.

There are several method that can be used by designer to generate ideas to find a lot of conceptual design solutions, these methods are:

- Brainstorming
- Theory of Inventive Problem Solving (TRIZ)
- Design for Assembly (DFA)
- Morphological Chart
- Problem Decomposition
- Gallery Technique

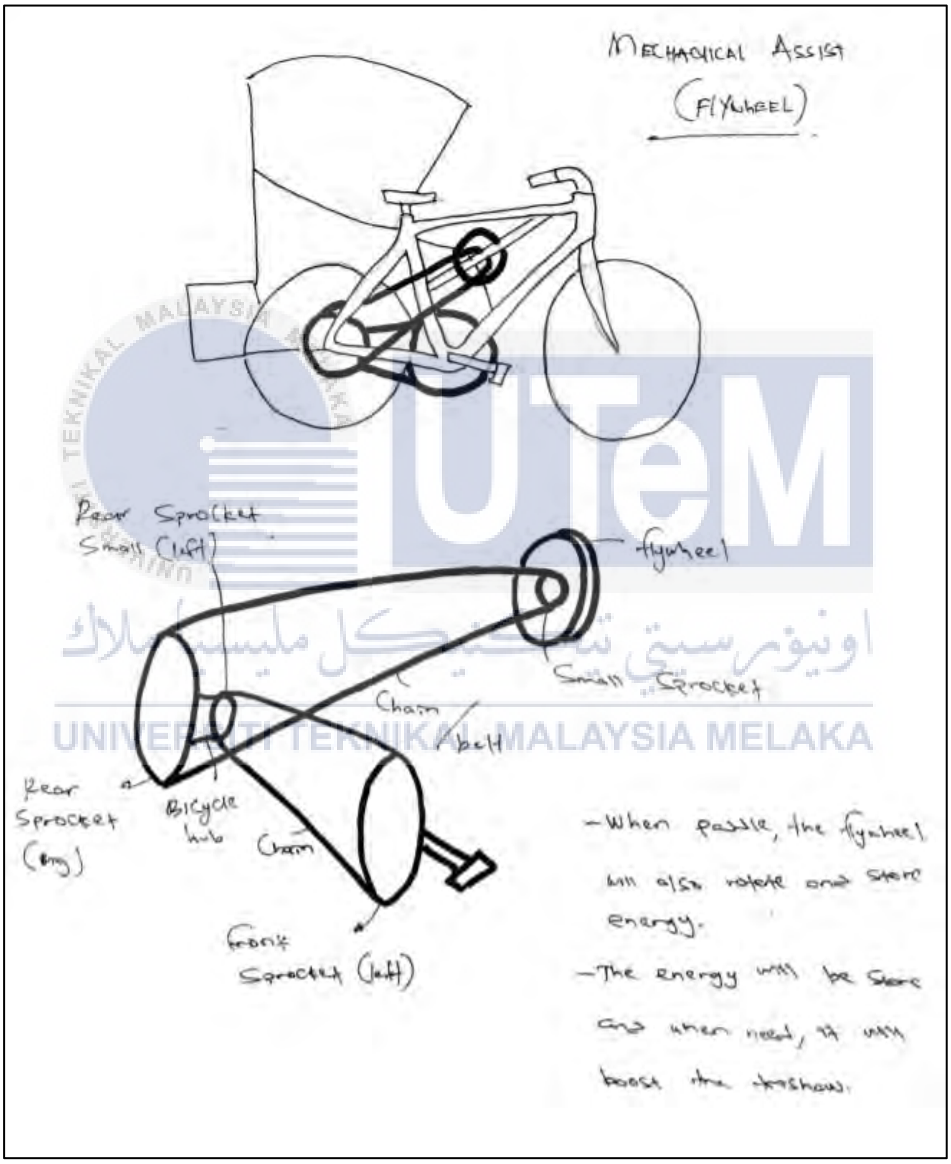
For this design, the brainstorming and gallery technique were been used to come out all the conceptual designs. All the explanation was been explained at the chapter 2 of this report.

Table 4.1: Product Design Specification for Drivetrain Beca Melaka

Ref. No.	Requirement
1	Performance • Use human power mechanism, mechanical or electrical assist • Boosting
2	Size • Able to fit current trishaw frame • Max height, width and length = no constraint
3	Weight • Max weight = 8kg
4	Maintenance • Easy to maintain • Easy to find spare part
5	Material • Use steel material (non-corrosive material) • Frame using steel (stainless steel)
6	Ergonomic • Easy to adjust the chain • Large part on the hidden section
7	Target product cost • Low cost for sparepart (maintenance) • Low fabrication cost
8	Installation • Quick and easy to assemble

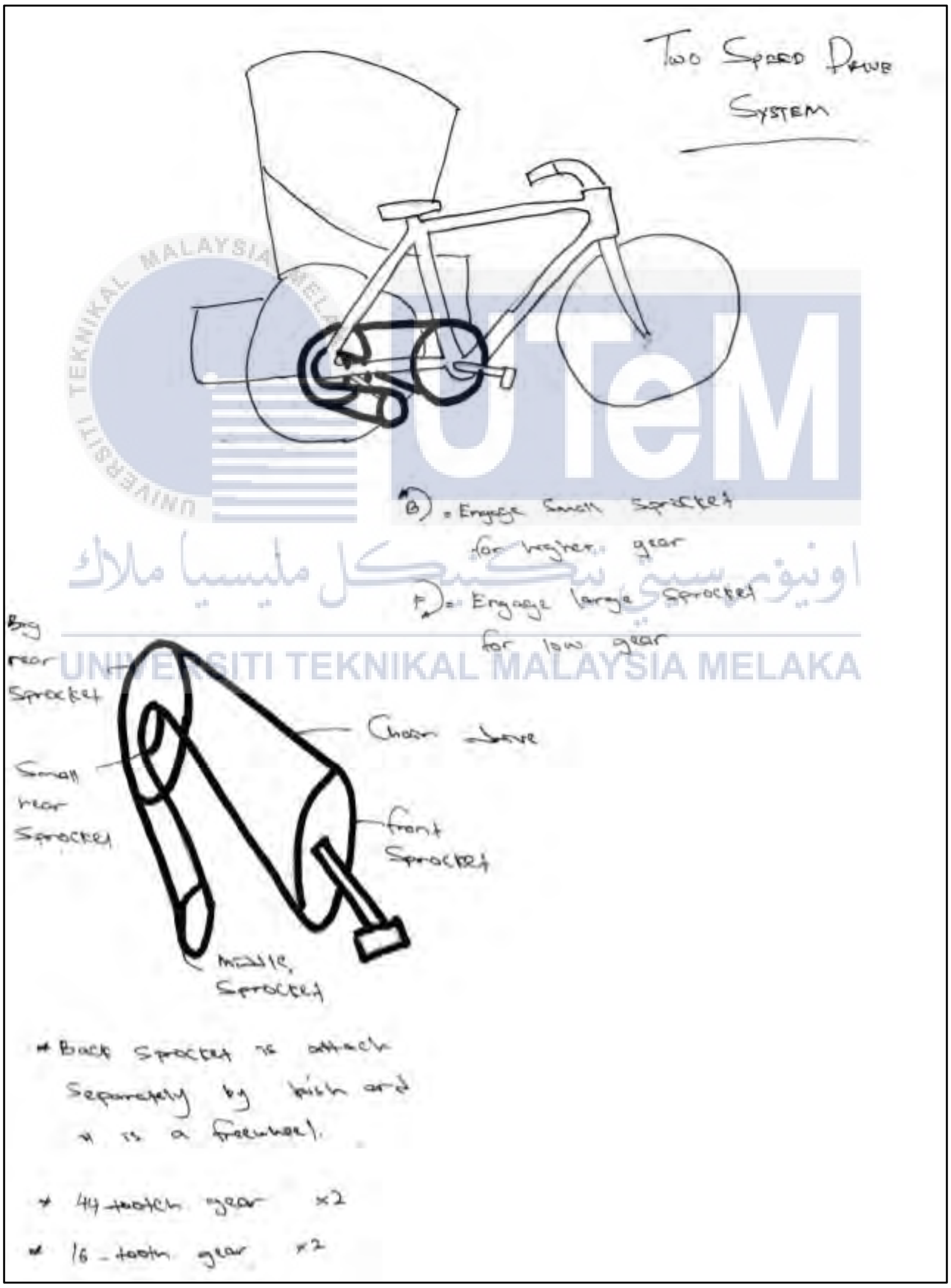
4.1.4 Concept Design 1

The following design are the first conceptual design. It consist of one flywheel that is attach at the middle of the beca frame. The energy will be store when the beca is paddle and when the driver want to climb uphill, it will boost the beca for a short time.



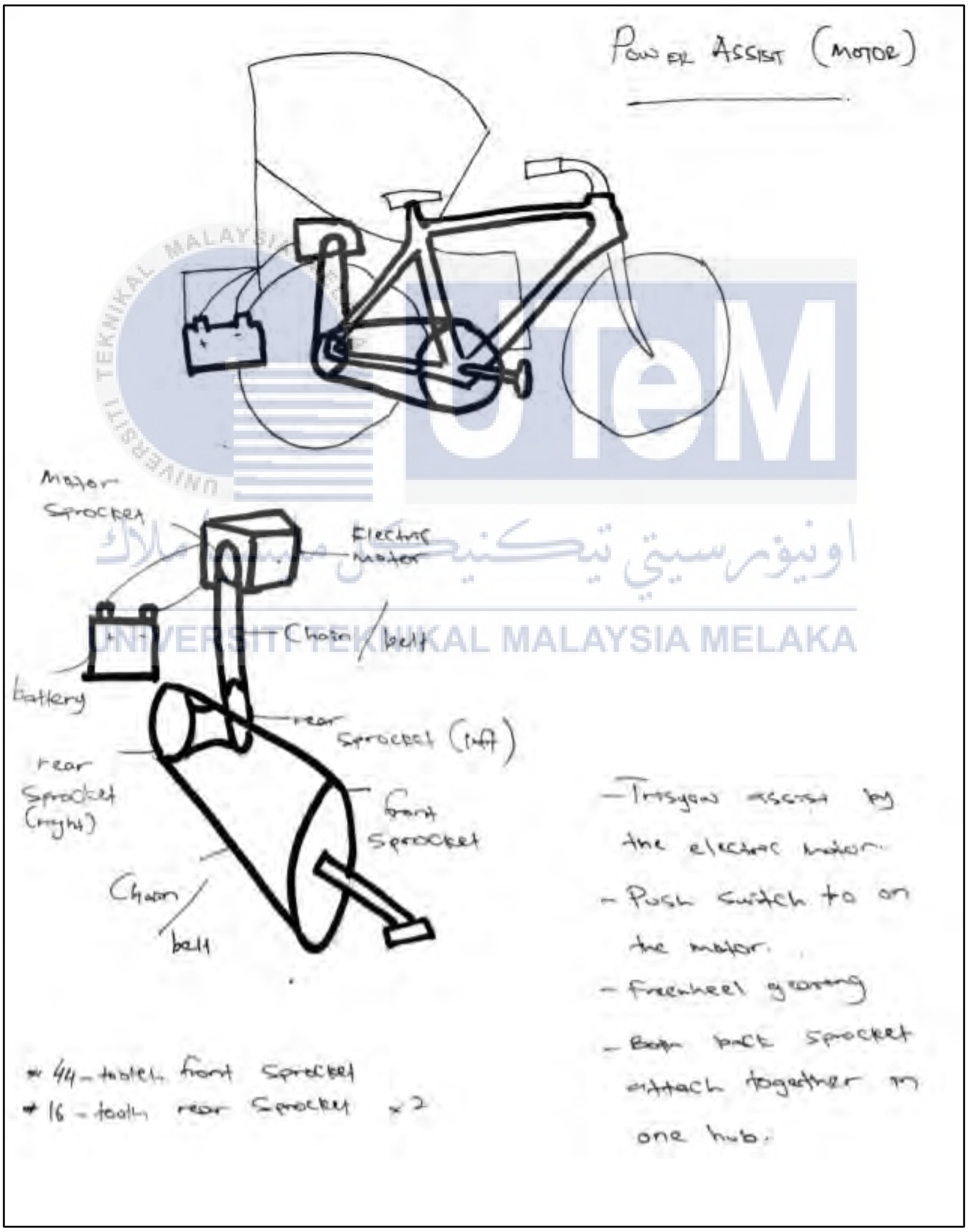
4.1.5 Concept Design 2

This design consist of two large gear and two small gear. The back side consist of 1 large gear and one small gear attach together by a freewheel. The middle part consist the small gear. When the beca cycle backward, it will engage the small sprocket for high gear whereas when cycle forward, it will engage large sprocket for low gear.



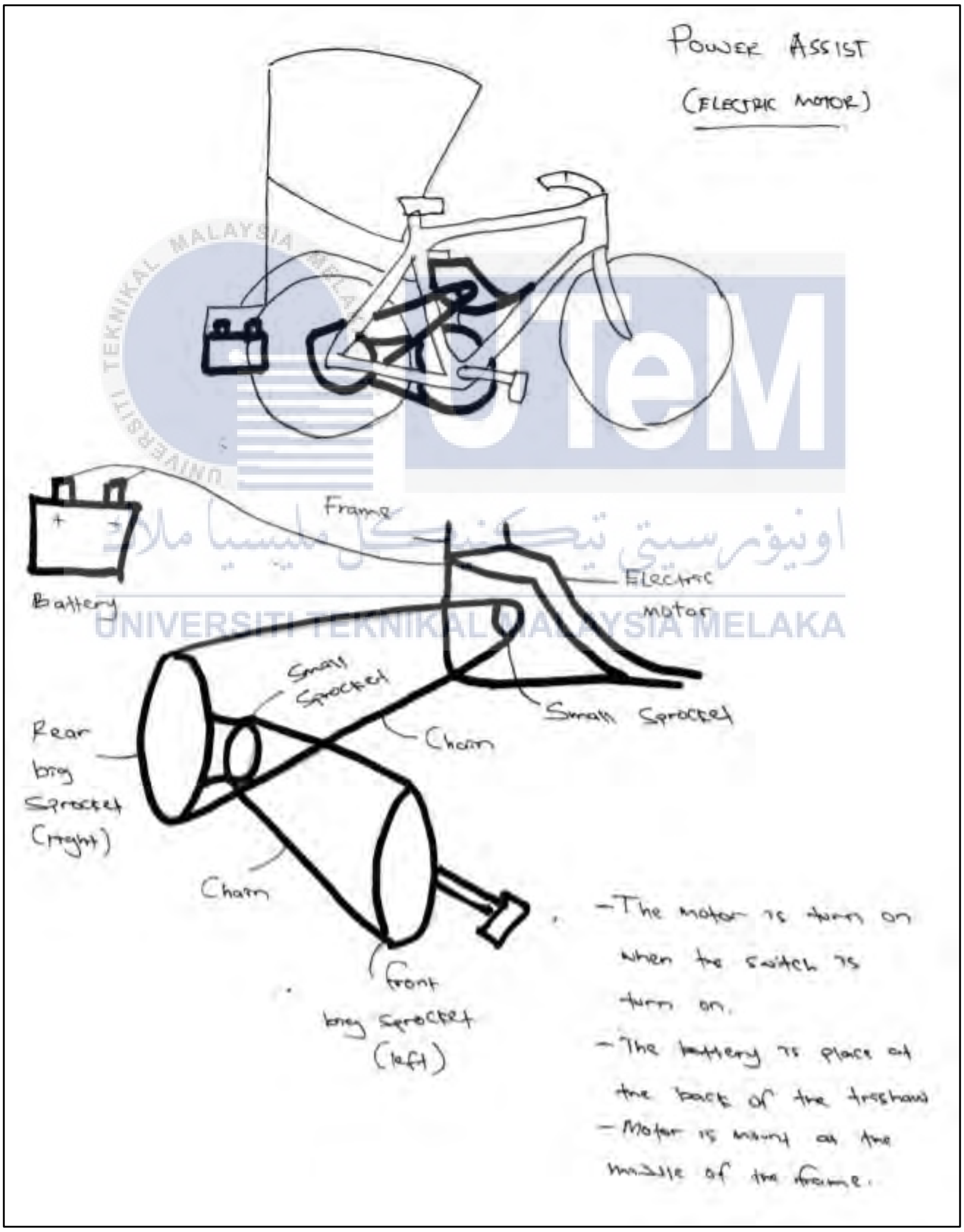
4.1.6 Concept Design 3

In this concept design. There are consist of one electric motor that is attach at side the passenger beca body. The rear hub will consist of two freewheel gear. The left side of gear will connect with the motor by using chain or belt and the right gear will be connect with the front gear. The motor will operate by using on/off switch.



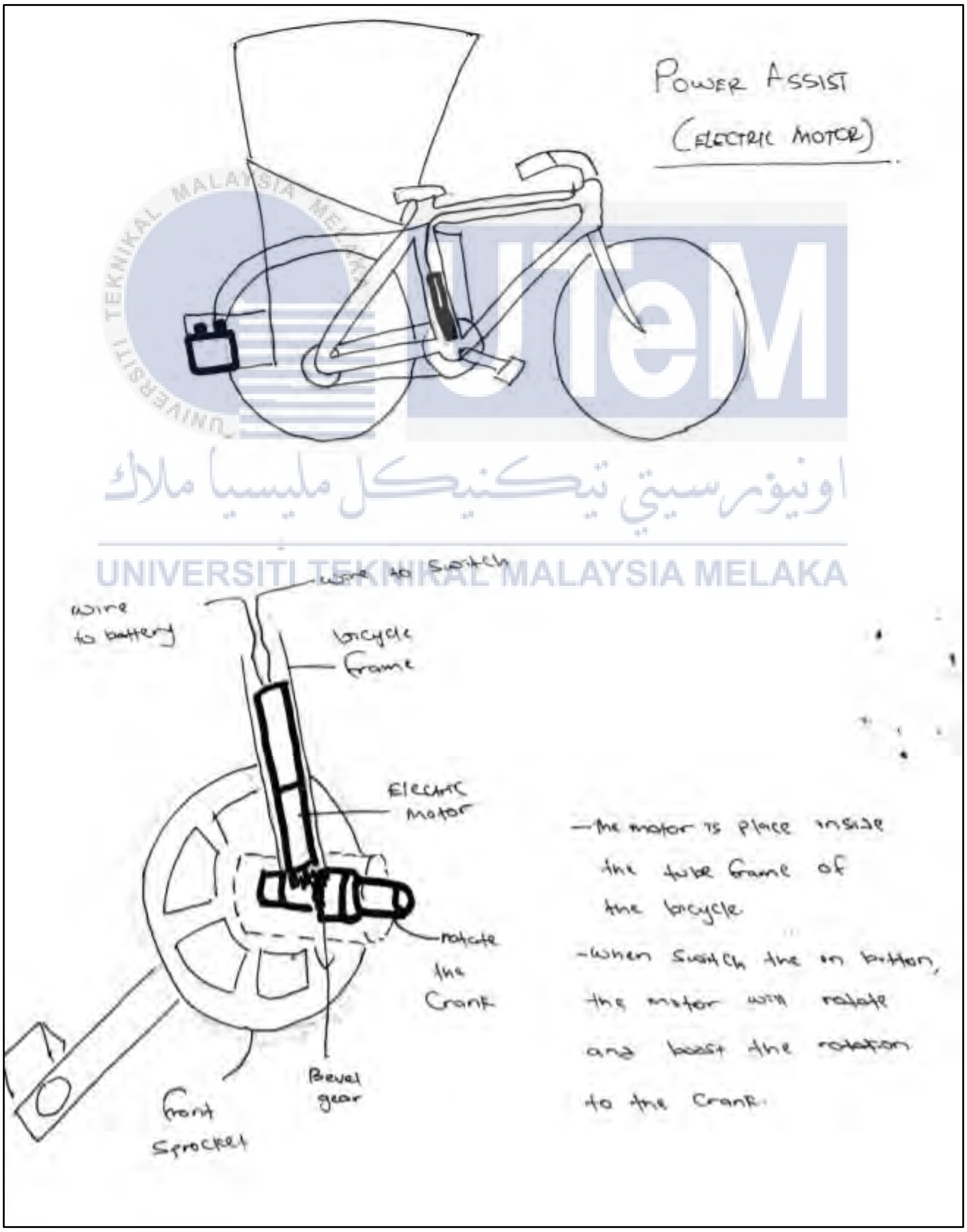
4.1.7 Concept Design 4

In this concept design. There are also consist of one electric motor that is attach at middle of bicycle frame. The rear hub will consist of two freewheel gear. The left side of gear will connect with the front gear by using chain and the right gear will be connect with the motor by using chain or belt. The motor will operate by using on/off switch.



4.1.8 Concept Design 5

On the last concept design, it consist one motor that is hide on the bicycle frame align with the cycler seat. The motor consist bevel gear on the end of the motor and the bevel gear will connect with another bevel gear that is attach with the crank. When the switch is on, the bevel gear on the motor will rotate thus the bevel gear on the crank will also rotate.



4.1.9 Concept Design Selection using Analytic Hierarchy Process (AHP) Method

For the further step, Expert Choice software will be used to select the best conceptual design. This software were used to make the user easier to do the Analytical Hierarchy Process (AHP) calculation to choose the best design. This software is used because it easy to understand and used by the student and design team. Before this software were used, Product Development Selection (PDS) and the conceptual design must be done and complete first. The AHP and this software were using the same principle that is hierarchy system. To be easier doing the AHP calculation on this software, the hierarchy were been sketch.

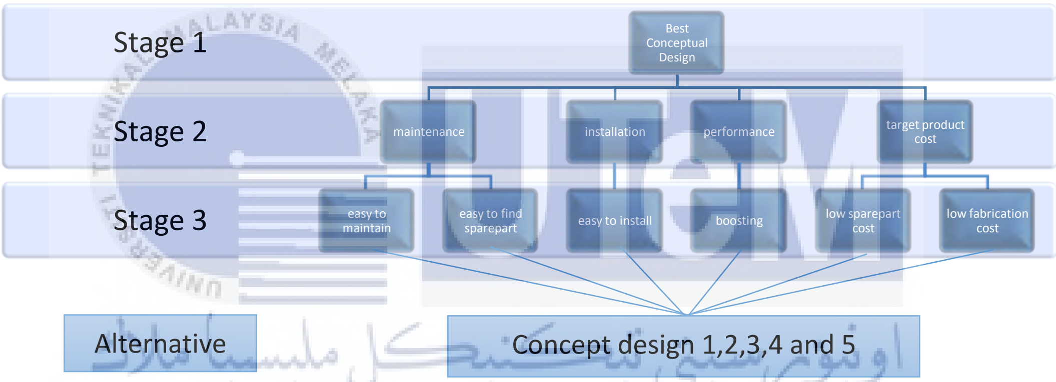


Figure 4.1: Hierarchy of Best Concept Design

After the hierarchy were been sketch, it time to shortlist all of the 5 concept design to find the best design to be used for the final design. After the best concept design been chosen, the detail design will be draw on the CAD software. The criteria for the analytical hierarchy process will based on the previous PDS. For this hierarchy, only 4 element will be used that is installation, maintenance, performance and also target product cost. All of the 4 element will be compare using the AHP software based on their criteria and the sub-criteria that were been chosen. The criteria will be compare using pair wise technique. Every element need to put value that based on AHP standard to get the final decision. The calculation also can be done using the manual calculation based on the Eigen Method and matrix method but by using this software, the calculation work getting much easier.

For the first, comparison matrix need to do based on the criteria that already been chosen above. Because there have 3 comparison, thus the matrix is 3 by 3 matrix. If the judgment value is on the left side of 1, need to put the actual judgment value. If the judgment value is on the right side of 1, put the reciprocal value. After that, calculate the matrix and sum all the value. Next, the value of the summation is divide with the value of sum that were gain respectively to show that the last value is equal to one. The value can be shown below,

$$A = \begin{matrix} Performance \\ Maintenance \\ Target\ product\ cost \\ Installation \end{matrix} \begin{bmatrix} Performance & Maintenance & T.Cost & Installation \\ 1 & 5 & 7 & 4 \\ & 1 & 4 & 3 \\ & & 1 & 1/3 \\ & & & 1 \end{bmatrix}$$

To fill the lower triangular matrix, use the reciprocal values of the upper diagonal and thus now we have complete comparison matrix.

$$A = \begin{matrix} Performance \\ Maintenance \\ Target\ product\ cost \\ Installation \end{matrix} \begin{bmatrix} Performance & Maintenance & T.Cost & Installation \\ 1 & 5 & 7 & 4 \\ 1/5 & 1 & 4 & 3 \\ 1/7 & 1/4 & 1 & 1/3 \\ 1/4 & 1/5 & 3 & 1 \end{bmatrix}$$

Sum each column of the reciprocal matrix to get

$$A = \begin{matrix} Performance \\ Maintenance \\ Target\ product\ cost \\ Installation \\ Sum \end{matrix} \begin{bmatrix} Performance & Maintenance & T.Cost & Installation \\ 1 & 5 & 7 & 4 \\ 1/5 & 1 & 4 & 3 \\ 1/7 & 1/4 & 1 & 1/3 \\ 1/4 & 1/5 & 3 & 1 \\ \frac{223}{140} & \frac{129}{20} & 15 & \frac{25}{3} \end{bmatrix}$$

Then divide each element of the matrix with the sum of its column, normalized relative weight were gain. The sum of each column is 1.

$$A = \begin{matrix} \\ Performance \\ Maintenance \\ Target\ product\ cost \\ Installation \\ Sum \end{matrix} \begin{bmatrix} Performance & Maintenance & T.Cost & Installation \\ 140/223 & 100/129 & 7/15 & 12/25 \\ 128/223 & 20/129 & 4/15 & 9/25 \\ 20/223 & 5/129 & 1/15 & 1/25 \\ 35/223 & 4/129 & 31/5 & 3/25 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

The normalized principal Eigen vector can be obtained by averaging across the rows

$$W = \frac{1}{4} \begin{bmatrix} 140/223 + 100/129 + 7/15 + 12/25 \\ 128/223 + 20/129 + 4/15 + 9/25 \\ 20/223 + 5/129 + 1/15 + 1/25 \\ 35/223 + 4/129 + 31/5 + 3/25 \end{bmatrix} = \begin{bmatrix} 0.5874 \\ 0.2268 \\ 0.05878 \\ 0.1270 \end{bmatrix}$$

The normalized principal Eigen vector is called priority vector. Since it normalized, the sum of all elements in priority is 1. The priority vector shows relative weights among the things that being compare. In the criteria above, performance is 58.74%, maintenance is 22.68%, target product cost is 5.88% and installation is 12.7%. The most preferable is performance followed by maintenance, installation and target product cost. In this case, we know more than their ranking. The relative weight by divide among them can be show. It can say that, performance is higher than maintenance 2.59(=58.74/22.68) more. Performance 9.99(=58.74/5.88) times more than target product cost and 4.63(=58.74/12.7) higher than installation. It also shows that maintenance 3.86(=22.68/5.88) higher than target product cost and 1.79(=22.88/12.7) higher than installation. Whereas for the target product cost, it is 2.16(=12.7/5.88) lower than installation

All of this calculation that been done manually will be compare to calculation that been calculate on the software.

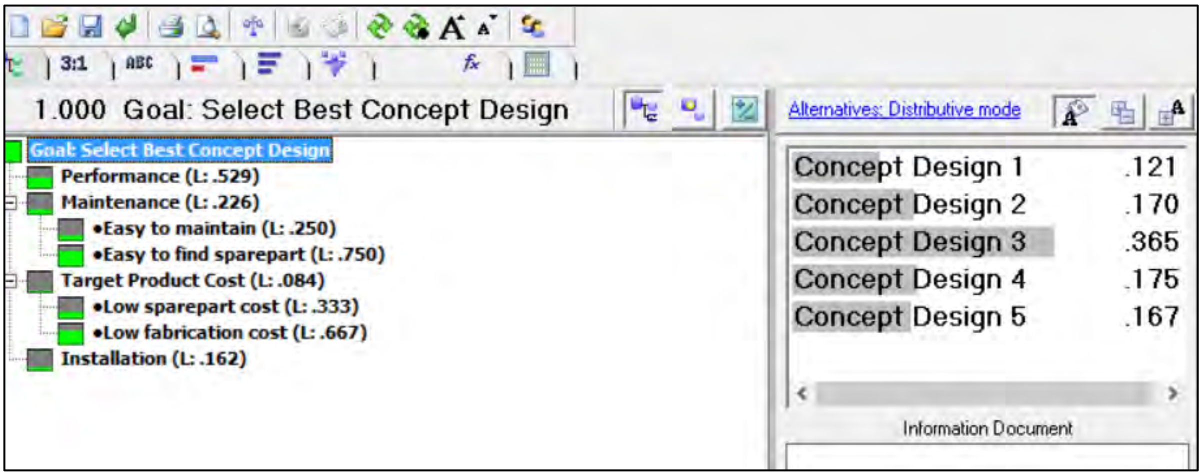


Figure 4.2: Hierarchy of system

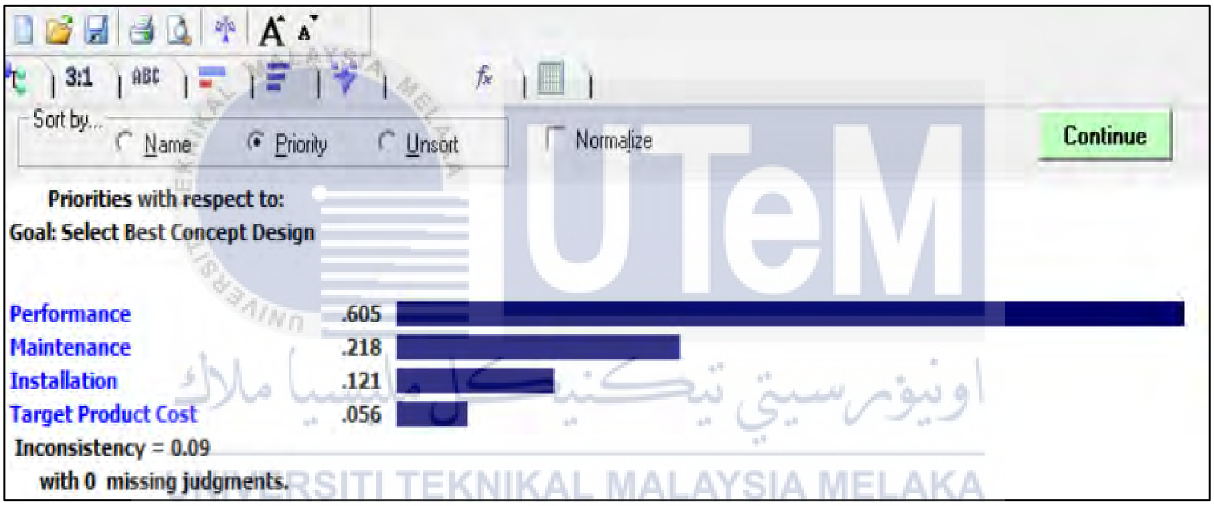


Figure 4.3: Pair wise selection for the criteria

The above figure 4.3 shows the pair wise numerical selection for the criteria. It shows that the performance criteria is the most higher than the other criteria.it shows that the calculation using the software is similar with the manual calculation. All the judgement method can be used in manual or by the software. By using this software, it also can generated the best selection design for the final concept design by using the pair wise comparison. It will combine all the value to get the best result. The comparison between the concept design alternative are shown on the figure 4.4 below.

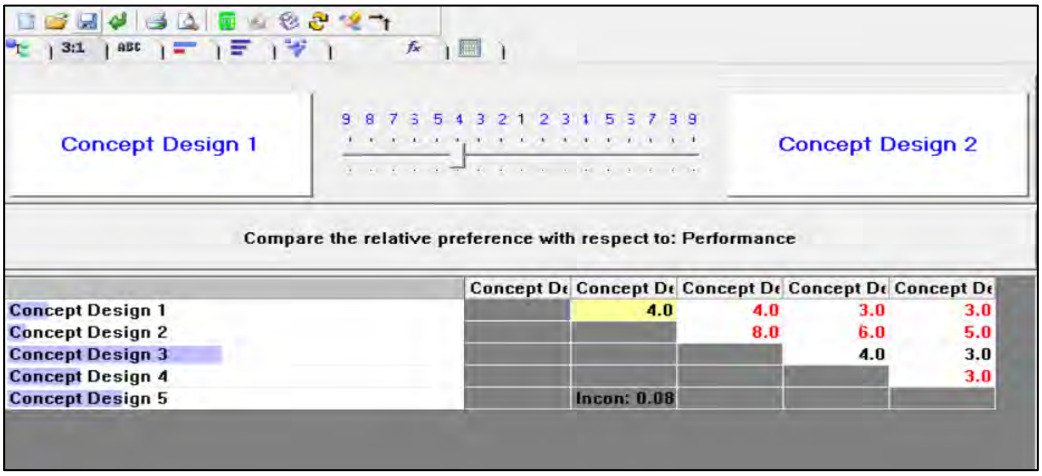


Figure 4.4: Pair wise comparison between the concept design alternative respects to performance

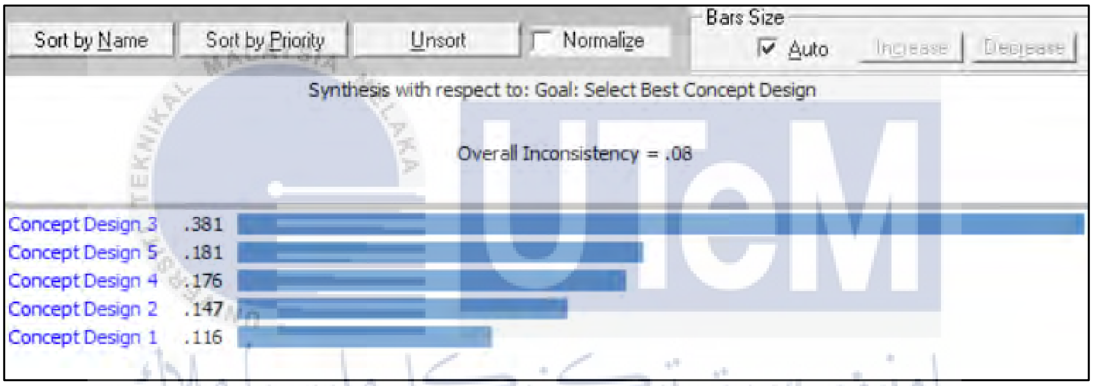


Figure 4.5: The final concept design selection

For the last, the final concept design will be selected among the other conceptual design after the software compute all the data that have been put. The conceptual design of number 3 was been choose for the best selection among the other design that have been compare. The next step is proceed as the detail design is draw using the CAD software

4.2 Final Design Selection

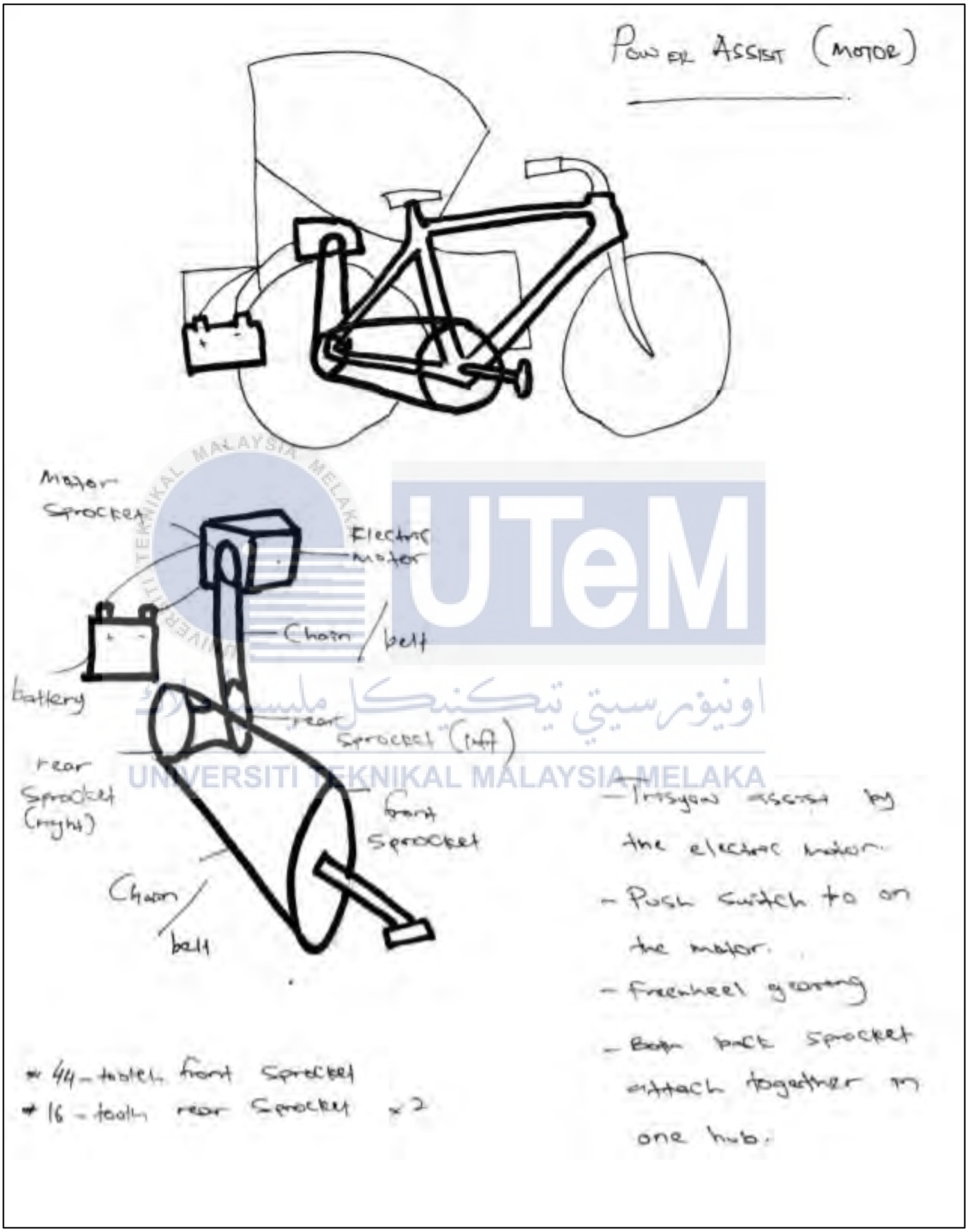


Figure 4.6: The Concept Design that have been Choose

4.2.1 Detail Design

Figure 4.7: Overall Final Design

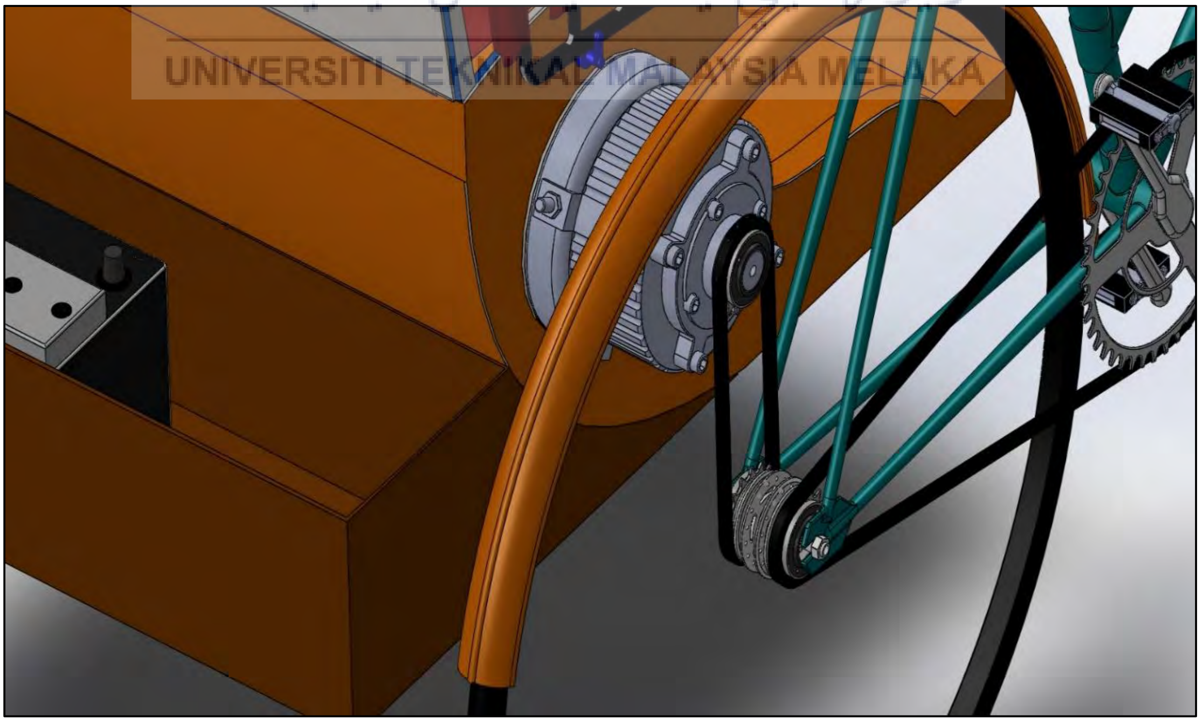


Figure 4.8: Assembly View of Drivetrain Design

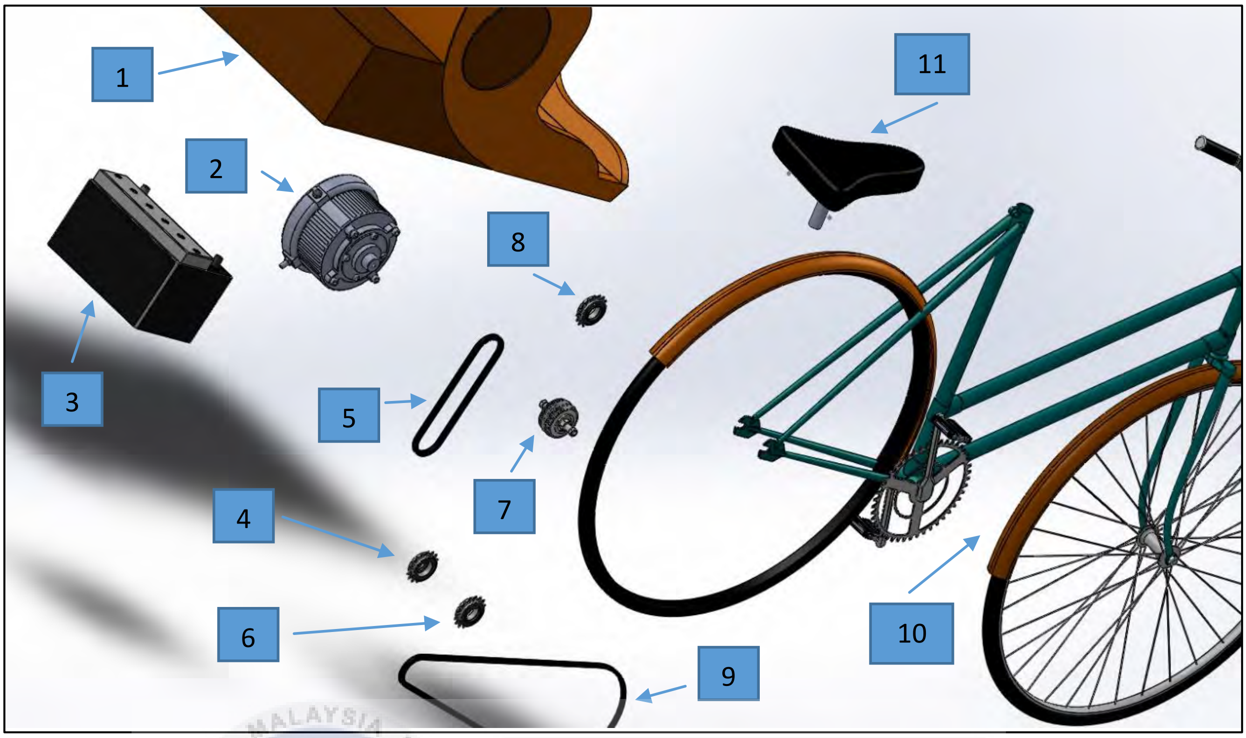


Figure 4.9: Explode View of Drivetrain Design

Table 4.2: Part number and Name in Exploded View

Part No.	Part Name
1	Passenger seat
2	Electric motor
3	Battery
4	Rear left gear (small)
5	Chain
6	Rear right gear (small)
7	Rear hub
8	Motor gear
9	Chain
10	Bicycle frame
11	Driver seat

CHAPTER 5

RESULT AND DESIGN ANALYSIS

5.0 Introduction

The drivetrain design can be any system capable of transmitting the power from the paddle or motor through the tyres contacting the road. The drivetrain design same as the original beca that is rear-wheel drive and will add new feature that is motor at the back of the beca. The design required calculation in order to determine the power that is need to propel the new beca design.

5.1 Power Determination

Before proceed to the next step, the power of the beca need to be calculate to make sure the motor that be use can handle the power that is required from the beca to move it uphill. For a start we need to realise that there are three main forces acting against a cyclist while riding: wind resistance, road friction and gravity. These three forces can be represented in the following formula:

$$\mathbf{P = k_r Ms + k_a Asv^2 d + giMs}$$

Where,

P = power required (in watts)

k_r= rolling resistance coefficient

M = mass of bike + rider

s = speed of the bike on the road

k_a= wind resistance coefficient

A = the frontal area of the bike and rider

v = speed of the bike through the air (i.e. bike speed + headwind or – tailwind)

d = air density

g = gravitational constant

i = gradient (an approximation[2])

The power required is calculate based on the assumption to move upwards a hill of 12% gradient at a speed of 10 km/h, with below requirements:-

- k_r= rolling resistance coefficient = *0.005 (for a typical bitumen road on clinchers[3])*
- M = mass of bike + rider = *80kg + (70x3 person) kg = 290kg*
- s = speed of the bike on the road = *2.78m/s (10km/h)* or *4.17m/s (15km/h)*
- k_a = wind resistance coefficient = *0.5 (no headwind or tailwind)*
- A = the frontal area of the bike and rider = *1.65mx1.8m = 2.97m²*
- v = speed of the bike through the air = *2.78m/s (no wind)*
- d = air density = *1.226kg/m³ (at roughly sea level)*
- g = gravitational constant = *9.8m/sec²*
- i = gradient = *0.12*

At 10km/h (2.78m/s)

$$P = (0.005)(290)(2.78) + (0.5)(2.97)(2.78)(2.78^2)(1.226) + (9.81)(0.12)(290)(2.78)$$

$$= 4.031 + 39.12 + 949.06$$

$$= 992.21 \text{ W}$$

At 15km/h (4.17m/s)

$$P = (0.005)(290)(4.17) + (0.5)(2.97)(4.17)(4.17^2)(1.226) + (9.81)(0.12)(290)(4.17)$$

$$= 6.047 + 132.01 + 1423.59$$

$$= 1561.65 \text{ W}$$

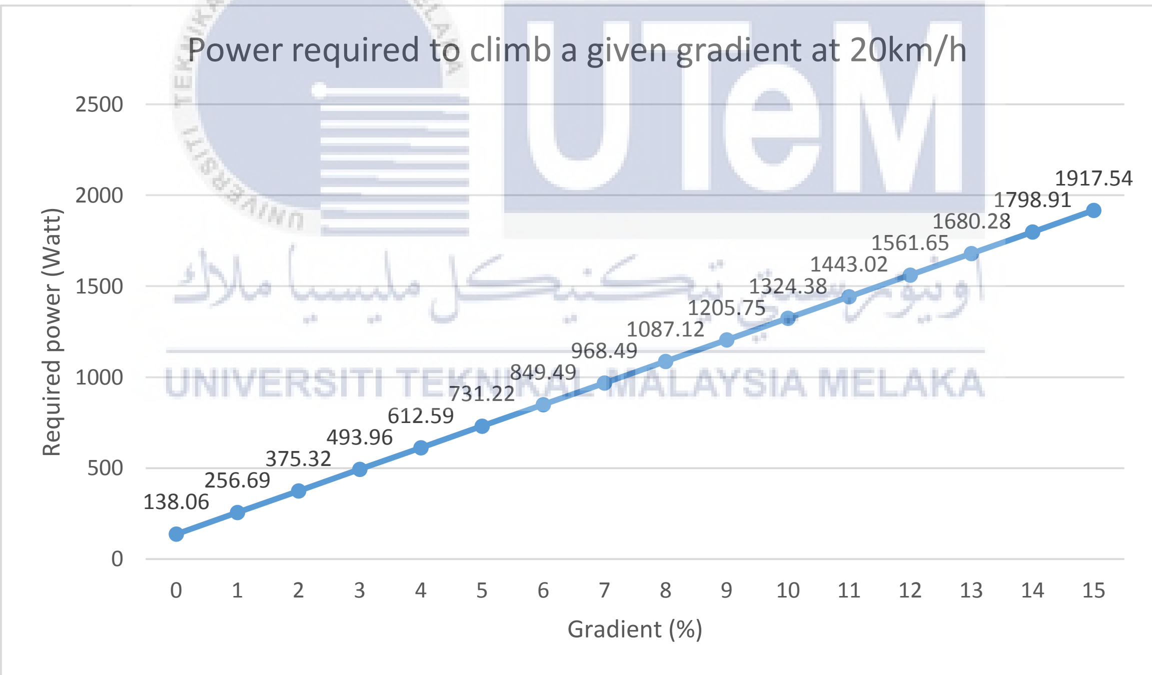


Figure 5.1: Power required graph

As shown in Figure 5.1, the line of best fit is straight, meaning the required power increases proportionally with the gradient of the hill. So, at 290kg (rider + bike), and with the assumptions made above, we need to produce roughly an extra 118.63W of power for every percentage point the gradient increases by, in order to maintain 15km/h. This number will be different for every rider, and depends on many factors. One of the biggest factors, of course, is weight. If the load is lighter, need a less mass to haul uphill and therefore less power required to rid. Used the higher one that is P=1561.65W that is the max gradient at Bandar Hilir hill as the benchmark to determine the motor power that will use on the design.

Drivetrain efficiency also can estimate the at roughly 80% for average maintenance of the total power through:

$$\text{For } 10\text{km/h} = 992.21 \div \frac{80}{100}$$

$$= 1247.76 \text{ W}$$

$$\text{For } 15\text{km/h} = 1561.65 \div \frac{80}{100}$$

$$= 1952.06 \text{ W}$$

5.2 Torque Required

When selecting a motor for a vehicle, the torque must be find to determine the best motor that can counter the total torque that the vehicle is need to move. Below is one of the method that can be used to find the torque.

Vehicle design criteria:

Gross vehicle weight (GVW): 290kg

Radius of wheel/tire (Rw): 0.1524m

Diameter of wheel/tire: 0.3048m

Desired top speed (Vmax): 4.17m/s

Desired acceleration time (ta): 2 sec

Maximum incline angle (α): 12 degree

Working surface (Crr): 0.017 asphalt (fair)

To choose motors capable of producing enough torque to move the beca, it is necessary to determine the total tractive effort (TTE) requirement for the beca:

TTE [kg] = RR [kg] + GR [kg] + FA [kg]

Where:

TTE = total tractive effort [kg]

RR = force necessary to overcome rolling resistance [kg]

GR = force required to climb a grade [kg]

FA = force required to accelerate to final velocity [kg]

5.2.1 Rolling Resistance (RR)

Rolling Resistance (RR) is the force that is use to move the beca over a certain surface.

RR [kg] = GVW [kg] x Crr [-]

Where:

RR = rolling resistance [kg]

GVW = gross vehicle weight [kg]

Crr = surface friction

RR = 290kg x 0.017

= 4.93kg

Table 5.1: Rolling Resistance for Rubber Wheels

Contact Surface	Crr
Concrete (good / fair / poor)	.010 / .015 /.020
Asphalt (good / fair / poor)	.012 / .017 / .022
Wood (dry/dusty/wet)	.010 / .005 / .001
Dirt (smooth / sandy)	.025 / .037
Mud (firm / medium / soft)	.037 / .090 / .150
Grass (firm / soft)	.055 / .075
Sand (firm / soft / dune)	.060 / .150 / .300

5.2.2 Grade Resistance (GR)

Grade Resistance (GR) is a force that is use to move a vehicle up a slope or gradient.

GR [kg] = GVW [kg] x sin (α)

Where:

GR = grade resistance [kg]

GVW = gross vehicle weight [kg]

α = maximum incline angle [degrees]

GR = 290kg x sin (12^o)

= 60.29kg

5.2.3 Acceleration Force (FA)

Acceleration Force (FA) is the force to accelerate from rest to maximum speed in specific time.

FA [kg] = GVW [kg] x Vmax [m/s] / (7.81 m/s^2] x ta [s])

Where:

FA = acceleration force [kg]

GVW = gross vehicle weight [kg]

Vmax = maximum speed [m/s]

t_a = time required to achieve maximum speed [s]

$$FA = \frac{290 \ x \ 4.17}{7.81 \ x \ 2}$$

= 77.42kg

5.2.4 Total Tractive Effort (TTE)

Total Tractive Effort (TTE) is the sum of all the force from the step 1 until 3.

TTE [kg] = RR [kg] + GR [kg] + FA [kg]

TTE = 4.93kg + 60.29kg + 77.42kg

= 142.64kg

5.2.5 Wheel Motor Torque (TW)

The Total Tractive Torque is necessary to calculate the torque based on the tractive effort.

Tw [Nm] = TTE [kg] x Rw [m] x RF

Where:

Tw = wheel torque [Nm]

TTE = total tractive effort [kg]

Rw = radius of the wheel/tire [m]

RF = “resistance” factor [-]

The resistance factor accounts for the frictional losses between the wheel and the axles and the drag on the motor bearing value that range between 1.1 and 1.15

Tw = 142.64kg x 1.1 x 0.3048

= 47.82Nm

5.3 System Sizing

Before proceed to find the required power and also torque that is produce from the beca to select the best motor, the system sizing need to be determine to make it easy to understand the initial power input and the power output diagram. The below diagram is the overall sketching from the battery to the wheel.

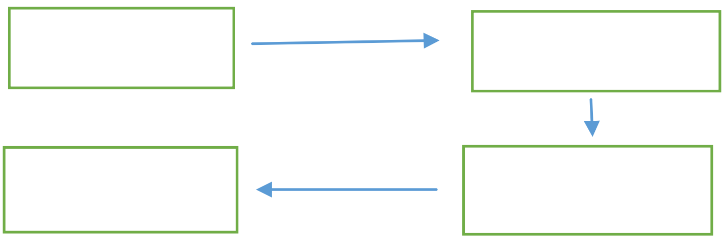


Figure 5.2: Overall system sizing

5.3.1 Battery

As we know, most of the beca in Melaka has a battery that was attach at the back of the compartment area. The battery that is use is to give electricity to the sound system at the beca to attract the tourist. For this project, the motor that is use will using just the battery that was already at the beca. The battery that was use is a standard car battery that is a typical 12 V, 40 Ah lead-acid car battery. The battery is a rechargeable battery that can be fully charge around 12–16 hours. The battery has a capacity of around 40 amp hours which means that, fully charged, it delivers 1 amp for 40 hours, 2 amps for 20 hours and so on.

Figure 5.3: Type of battery that recommend
(http://www.centurybatteries.com.au/products/car-passenger-vehicles)

Table 5.2: Battery specification (http://www.centurybatteries.com.au)

Parameter	Rating
Type of battery	century (ns40z mf)
Physical dimension (LxWxH) (mm)	196 x 128 x 201
Number of battery	2 battery connect in series
Voltage	12 v each, total 24v
Amp-hour rating	40
Nominal voltage (V)	12
Weight (kg)	10.3
Recharging time – 0-90% (hrs.)	8-10

5.3.2 Motor Chosen

For the motor, it must be the most suitable for the new design of the beca drivetrain. The power, speed and the torque are all the major performance parameters that will affected the overall performance of the beca because this motor will generate the enough power to move the beca uphill.

Figure 5.4: Manta 2 D.C Motor (http://www.hydrogenappliances.com/manta.html)

Table 5.3: Manta 2 / D.C. Motor Specifications (http://www.hydrogenappliances.com)

7.91o" diameter / 7.75" length
3/4" shaft with 1/8" or 3/16 or 1/4" keyway by 1" long
Power maximum: 5000watts
Torque constant: 1.14 in-lb/Amp (0.13 Nm/Amp)
12V to 48V (4550 RPM MAX)
For cooler running and longer life run only 36 Volts for all continuous duty applications.
Great for VERY low voltages at high amp loads
Graphite brushes last up to 275,000 hours of motor working
6 horsepower continuous duty at 36 volts without cooling
10 horsepower max at 48 volts / 60% duty max motor temp not to ever exceed 125F

5.3.3 Tire Friction

In the most of vehicles the maximum amount of torque to be transferred through the drivetrain is limited to the traction of the tires. The normal force on the tire and the coefficient of friction at which a tire will break traction and slip. The coefficient of friction is vary depending on the tire compound from different brand manufacturer, tire wear and temperature, the smoothness and roughness of the surface and many of condition. The value of coefficient of friction on the pavement is range from 0.7 to 1.3. The total weight of the beca was estimated to be 290kg including the beca and the driver. An average value for the friction coefficient was taken as 1. Weight distribution of the beca is estimated around 30:70 from the front to rear.

$$\mathbf{F = mg}$$

Where:

F = force

m = mass

g = acceleration due to gravity (m/s^2)

The normal force on the rear tyres is:

$$\mathbf{F_N = mg}$$

F_N = [360 (70/100)] x 9.81

= <u>2472.12N</u>

The frictional force with a coefficient of friction of 1:

$$\mathbf{F_r = Fn\ (\mu)}$$

F_r = 2472.12 (1)

= <u>2472.12N</u>

Total torque at the rear tire (Nm)

$$\mathbf{T_T = F_R\ (r)}$$

Where,

T_T = total torque for rear tire

F_r = frictional force

F_N = normal force

F_r = force on rear tire

r = radius of tire

$T_T = 2472.12(0.1524)$

$= \underline{376.75Nm}$

5.3.4 Gear System Ratio

Gears are not just used to transfer power, they additionally give a chance to modify the mechanical favourable position of a component. In this cases where a motor itself is powerful enough for an application but the motor's output characteristics are not well suited to the beca. The motor that is quick however has just a tiny bit of torque would not be reasonable to move an high load and in these cases it is important to utilize equip proportions to change the yields to a more proper adjust of torque and speed.

Table 5.4: Electric motor specification

Parameter	Rating
Efficiency	100 %
Watts	5000W
Volts	50V
Amps	2000A
Rpm	2000rpm

<u>Power to Torque Calculation of Electric Motor</u>

Torque (N.m) = 9.5488 x Power (kW) / Speed (RPM)

Torque (N.m) = 9.5488 x 5000 / 2000

= 23.872 N.m

So, for the electric motor, it just produce only 23.872 N.m thus it's not enough torque to move the beca because lack of torque that was produce from the motor. For this problem, gear ratio for the system is need to increase the torque.

<u>Determination of Gear Ratio</u>

As discussed above, the Gear Ratio is denoted as (Driving Gear Teeth): (Driven Gear Teeth). Driving gear with 11-tooth and the driven gear with 33-tooth so the above pair of gears could be described as 11:33 (or 11 to 33).

The Gear Reduction is calculated as Driven Gear Teeth / Driving Gear Teeth

So, **Gear Reduction** = Driven Gear Teeth / Driving Gear Teeth

= 33 / 11

= 3

The stall-torque of the second shaft can be calculated using the following formula:

Output Torque = Input Torque x Gear Reduction

Output Torque = 23.872 N.m x 3

= <u>71.616 N.m</u>

The free-speed of the second shaft can be calculated using the following formula:

Output Speed = Input Speed / Gear Reduction

$= 2000\ rpm / 3$

$= \underline{666.67\ rpm}$

The speed decreased, but the torque increased. The beca will move due to the increasing in torque that is 71.616 N.m

Since the rear sprocket is attached directly to the rear wheel, it rotates exactly as the rear wheel does. Every revolution of the rear wheel is a revolution of the sprocket. Hence, the angular speed of the rear sprocket is:

$$\omega_{rs} = 666.67rpm = \frac{666.67rpm}{1min}\ x\ \frac{1min}{60sec}\ x\ \frac{2\pi}{1}$$

$$= \underline{69.81\ rad/s}$$

Since the rear wheel has a radius of r = 0.1524 meters, the linear speed of the wheels is:

$$\omega = \frac{v}{r}$$

$$69.81 = \frac{v}{0.1524}$$

$$v = 69.81\ x\ 0.1524$$

$$= 10.64\ m/sec$$

$$= \underline{38.30\ km/h}$$

Thus, the bicycle rear tyre will move at the speed 38.30 km/h without the load on it.

5.3.5 Chain Selection

When creating human powered vehicles, a chain drive will likely be the chosen power transfer system, as it is an inexpensive, easy-to-install and highly efficient drive mechanism. Bicycle chains are fairly simple, requiring only one inexpensive tool to remove and attach links. Since a recumbent cycle will often require a chain that is one and a half to three times the length of a regular upright bicycle chain, some basics should be known.

There are two basic types of bicycle chain: single speed chain and multi-speed chain. Single speed chain is mainly used on kids' bikes, BMX bikes, coaster brake cruisers, and heavy cargo bikes. This types of bicycle chain have a pitch of 1/2 inch (ANSI standard #40). This measurement indicates the length of the links. Although every type of bicycle chain and freewheel have a 1/2 in pitch, the width of chain varies quite a bit, from 3/32" to 1/8".

Single speed bicycle chain is wider, having a width of 1/8 inch. This type of chain will not fit a multi-speed freewheel nor will it fit properly through a derailleur cage. Both chain types look very similar when see the pitch, vice versa when look at width. So for this project, 1/8 chain will be use.

5.4 Discussion

During the design proses, there are several design that need to be considered because all of the design contribute to the improvement of the existing beca performance. This electric motor beca has been choose and it diminishes the physical labour of the beca cycler. Problem also arise when to choose the perfect motor for the beca. Most of the motor don’t have enough power to carry the beca uphill because the weight was too high. At the end, the Manta motor have been choose because of the capability to move the heavy beca going uphill. This improvement of performance give extra comfort and less energy required for the beca cycler.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In conclusion, the objective of this project were successfully achieved where a new conceptual design of the drivetrain for the traditional beca was developed. The selection criteria for the beca drivetrain were determined but the traditional design of the beca itself were remain unchanged. All of the component design and selection were focused on increased the performance of the beca while maintaining reliability and the traditional design of the beca. This project has achieved all of the objective that already mention earlier in the report, and it believe that this system will be effective in providing extra power to the beca cycler when they cycle at the hill. From the outcomes at the final phase of design selections, there are a several conditions that can be considered as meeting the objective and the gaining values. The initial idea was to find out the new design of drivetrain system of beca Melaka. As total design method was been carried out through the design planning process, and it is believed that this concept design that have been choose can lead to better product in future of beca Melaka as they want to keep the original design of the beca and can solve the problem of beca driver that difficult to cycle uphill.it has been proven that the final design were been choose based on criteria that been calculate using AHP Expert Choice software. One of the major lessons learned that designing an appropriate technology is a huge challenge. Appropriate is more than just availability for replication, it considers longevity, reliability, and efficiency. After through the consideration of drivetrain systems, the renovation of this traditional beca still using the chain drive but assist by the electric motor. The new drivetrain will different in design because the rear wheel will be adding extra freewheel sprocket on the left side of the wheel. This design has given extra torque and acceleration compared to the traditional beca that has only basic drivetrain system that need to be propel by the pedal cycle. Whether on the slope or straight road, this electric motor can reduce the energy require by the cycler to move the beca. Finally, it can be say that this project has been a success considering the changes and the improvement to the traditional beca. It is expected that the new drivetrain design can operate safely as per design requirement and able to boost the performance of the current traditional beca for the future use.

6.2 Recommendation

To further improve the outcome of this project in the future, the author would like to suggest several future recommendation that can be used. The first recommendation is to reduce the weight of the beca. The weight of the beca is too heavy because of the beca itself plus the passenger and also the cycler. When all of the weight is sum, the total sometime will exceed 250kg. This problem can cause the rider difficult to cycle the beca on the straight road and especially the hill. The material for the beca body can be change and using the lighter material that can be used to reduce the weight of the bicycle and thus can improve the drivetrain efficiency.

The second recommendation is for a study to create an actual sized improved beca design. In doing this, the further studies would be very real in a way that the verification stage of the study is well experimented. If an actual sized working electric motor beca prototype is made, the passenger samples could again ride the prototype and the measuring of all data. In that way, the comparison between the data from the existing design and the proposed design is indeed concrete. The second recommendation was not executed by the researcher of this study for another constraint. This constraint is the resources. Creating an actual sized- working prototype would cost a lot. As an undergraduate, this is not possible for the researcher does not have big amount of money.

The third recommendation will be performed once the actual working prototype was made. This is by considering the weight of the passengers when riding a beca. By doing this, the future researchers would then be able to determine the more appropriate materials to utilize in order to make the beca design stable and balanced when the beca cycle uphill. The future researchers could examine the future deign by using Free Body Diagram (FBD) in determining what part of the beca must be heavy or light

REFFERENCES

Burge, S. (2009). The Systems Engineering Tool Box, 1–15.

Evans, M. (2006). Single Speeds, (42).

Hsu, C., Yu, C., Chao, S., & C.J.Huang, M. (1989). ELECTRIC BICYCLE.

Izumi Yamashita, Yoshiharu Yokoyama, T. N. (2000). POWER ASSISTED BICYCLE.

Jeffries, W. E. (1977). CHAINLESS BICYCLE DRIVE MECHANISM.

Kund, A. (1993). Bicycle gear display.

P. Garfingkle, I., & Mcnai, R. J. (1975). BICYCLE WITH ELECTRIC MOTOR ASSIST.

Saito, M., & Ito, M. (1984). POWER ASSISTED MANUALLY POWERED VEHICLE, (I).

Sapuan, S. M., Ham, K. W., Ng, K. M., Woo, C. K., Ariffin, M. K. A., Baharudin, B., … Jalil, N. A. A. (2009). Design of composite racing car body for student based competition. *Scientific Research and Essays*, *4*(11), 1151–1162. Retrieved from <Go to ISI>://WOS:000274021500001

Sayadi, M. K., Heydari, M., & Shahanaghi, K. (2009). Extension of VIKOR method for decision making problem with interval numbers. *Applied Mathematical Modelling*, *33*(5), 2257–2262. https://doi.org/10.1016/j.apm.2008.06.002

Scranton, P., & Le, P. E. D. (2008). BICYCLE DRIVE SYSTEM, *1*(12).

Shih, H., Shyur, H., & Lee, E. S. (2007). An extension of TOPSIS for group decision making, *45*, 801–813. https://doi.org/10.1016/j.mcm.2006.03.023

Souchkov, V. (2007). Accelerate Innovation with TRIZ. *Technology*.

Srikrishna, S., A, S. R., & Vani, S. (2014). A New Car Selection in the Market using TOPSIS Technique, *2*(4), 177–181.

Tsuboi, M., & Miura, S. (2014). Motor-assisted bicycle and power unit, *2*(12).

Urabe, H. (2011). BICYCLE HUB TRANSMISSION.

Wilson, D. G., & Berto, F. (2001). Human power, (52).

Xie, X. (2003). Design for Manufacture and Assembly Xiaofan Xie Dept. of Mechanical Engineering, University of Utah, 1–12.

Al-maghawry, A. (2012). Effectiveness of Using the Brainstorming Technique to Learn Some Basic Skills and Collection of Knowledge for Beginners in Volleyball. World Journal of Sport Sciences 6 (4): 361-366

Zeitoun, A. (2001). Methods of Teaching Science, Amman: sunrise house for Obada, A. (1992). Creative Solutions of Problems: Theory and Practice. Bahrain: Dar Al-hikma Press

Al-bwli, Q. (2006). The effectiveness of using brainstorming strategy in developing creative thinking in Islamic Education among Third secondary students in Tabouk City. Master Thesis. Mut'a University, Krak. Jordan.

Bani Hamad, F. (2006). The effect of brainstorming strategy in Graduate studies students. Master Thesis, Amman Arabic University. Jordan

Jarwan, F. (2005). Teaching Thinking: Definition and applications. Amman: Dar Al-fkir. Jordan.

K.T. Ulrich, and S.D. Eppinger, Product Design and Development 2nd ed., McGraw-Hill, New York, 2000.

J. Nevins and D. Whitney, Concurrent Design of Products and Processes, McGraw-Hill, New York, 1989.

H.J. Wassenaar and W. Chen, "An Approach to Decision-Based Design", Proceedings of ASME DETC'01, September 9-12, 2001, Pittsburgh, Pennsylvania, USA.

S. Pugh, Total Design - Integrated Methods for Successful Product Engineering, Addison-Wesley, MA, 1990.

D.L. Thurston and J.V. Carnahan, "Fuzzy Ratings and Utility Analysis in Preliminary Design Evaluation of Multiple Attributes", Journal of Mechanical Design, Vol. 114, 1992, pp. 648-658.

S.H. Yeo, M.W. Mak and A.P. Balon, "Analysis of Decision-making Methodologies for Desirability Score of Conceptual Design", Journal of Engineering Design, Vol. 15, 2004, pp. 195-208.

A.M. King and S. Sivaloganathan, "Development of a Methodology for Concept Selection in Flexible Design Strategies", Journal of Engineering Design, Vol. 10, 1999, pp. 329-349.

T.K. See and K. Lewis, "Multi attribute Decision Making Using Hypothetical Equivalents", Proceedings of ASME DETC'02, September 29 - October 2, 2002, Montreal, Canada.

J. Hauser and D. Clausing, "The House of Quality", Harvard Business Review, May 1988, pp. 67-73.

N.P. Suh, "The Principles of Design", Oxford University Press, New York, 1990.

M. Salonen and M. Perttula, "Utilization of Concept Selection Methods – A Survey of Finnish Industry", Proceeding of IDETC/CIE 2005, September 24-28, 2005, Long Beach, California USA.

T.L. Saaty, "The Analytic Hierarchy Process", RWS Publications, Pittsburgh, PA.1990

F. Zahedi, “The analytic hierarchy process—a survey of the method and its applications”, Interfaces; vol.16, no. 4, 1986, pp. 96–108.

Juntian, W. (2008). *Study on the acquirement-mode improvement on AHP judgment information and its related decision-making approach*. Jilin University.

Retrieved online at 5 December 2016 from

https://cyclingtips.com/2014/08/beyond-the-big-ring-understanding-gear-ratios-and-why-they-matter/

Retrieved online at 5 December 2016 from

http://www.thebiketoolbox.com/choosing-between-single-speed-folding-bikes-or-multi-gear-bikes/

Retrieved online at 5 December 2016 from

http://www.cyclinguk.org/cyclists-library/components/transmission-gears/derailleur-gears

Retrieved online at 5 December 2016 from

http://harry.biketravellers.com/our-gear/our-bikes-santos-travelmaster-with-rohloff-gearhub/

Retrieved online at 5 December 2016 from

http://www.dynamicbicyclesuk.co.uk/shafttechnology/

Retrieved online at 5 December 2016 from

http://bicycles.stackexchange.com/questions/20591/any-experience-with-shaft-driven-bikes

Retrieved online at 5 December 2016 from

https://triz-journal.com/innovation-methods/innovation-triz-theory-inventive-problem-solving/using-triz-enhance-quality-functional-deployment/

Retrieved online at 5 December 2016 from

http://cuba.coventry.ac.uk/maedesign/concept-design/l1-sketching-brainstorming-ideas-and-morphological-analysis/l1-morphological-analysis/

Retrieved online at 5 December 2016 from

http://www.jiem.org/index.php/jiem/article/view/685/400

Retrieved online at 5 December 2016 from

http://smartsol2u.blogspot.my/2011/11/pugh-concept-selection-method.html

Retrieved online at 5 December 2016 from

http://slideplayer.com/slide/7685703/

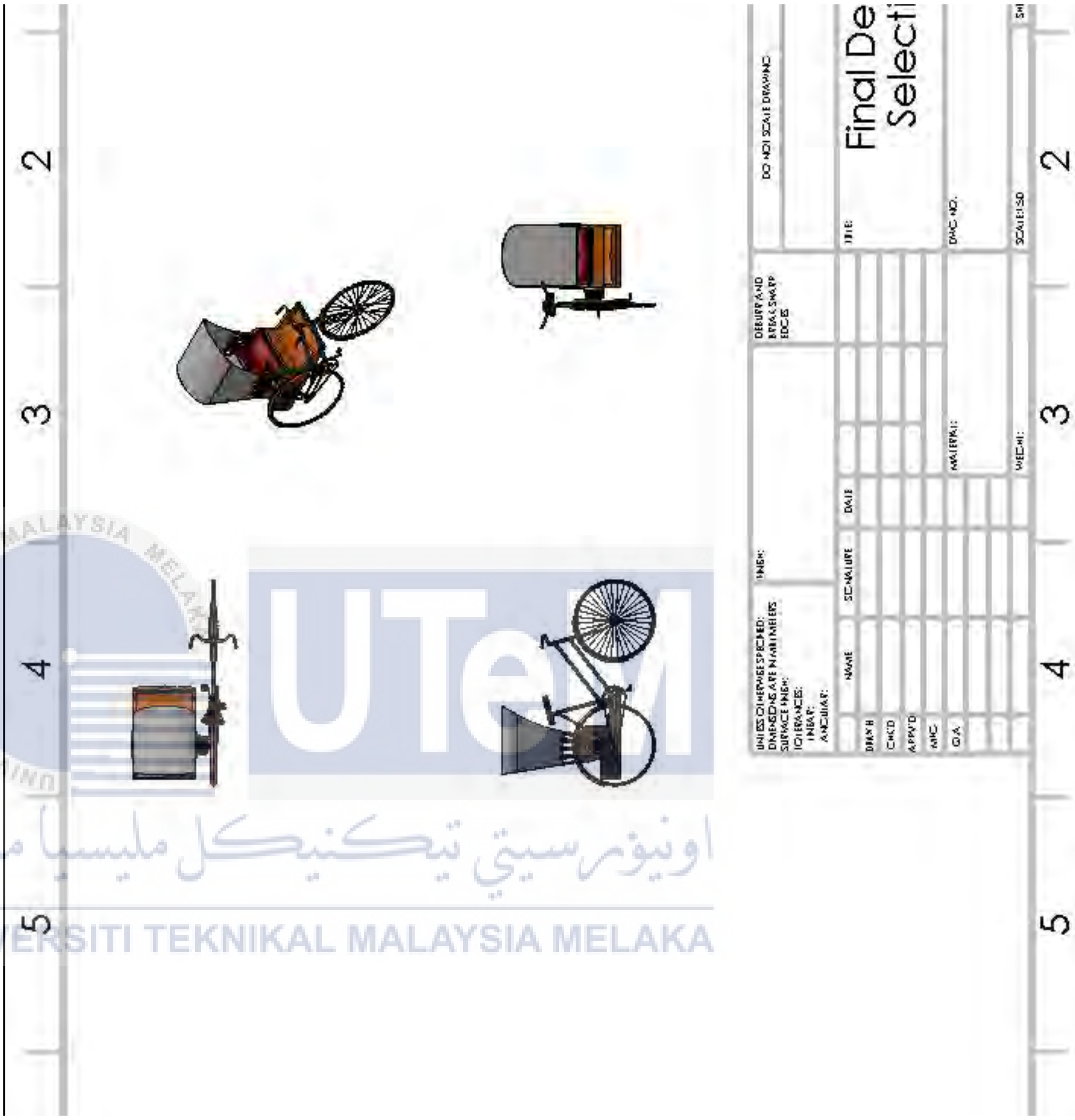
Retrieved online at 5 December 2016 from

https://abgrara.wordpress.com/2013/08/19/melaka-tidak-sangka-allah-bayar-cepat/

Retrieved online at 5 December 2016 from

https://rideonmagazine.com.au/hub-of-the-matter/

Appendix A



Appendix B