CHAPTER 1
INTRODUCTION

1.1 Project Background

The emerging light of electric vehicle industry with its *personal electric vehicle* (PEV) is poised to be the next wave in transportation technology. Today's world congestion and pollution problem that has becomes worst from day to day, the well-being people finally realize and considering changing their perception on combustion engine vehicle into electric motor vehicle. Another problem that might be related to the next wave in transportation technology is due to high population in cities that contributes into increasing of vehicle since many people affordable to have their own vehicle or transportation.

Zainor Faisal (May 2011) in his research write that the trend of designer today, where they tend to consider on inventing an alternative motorized transport which is much friendly toward the environment as well as keeping the users comfortable. This trend seems imminent due to recent awareness and developments in technology, economics, congestion and environmental concerns. In other words, designers today tend to design a PEV as their new background design concept. Figure 1 show how a PEV is constructed based on people physics.

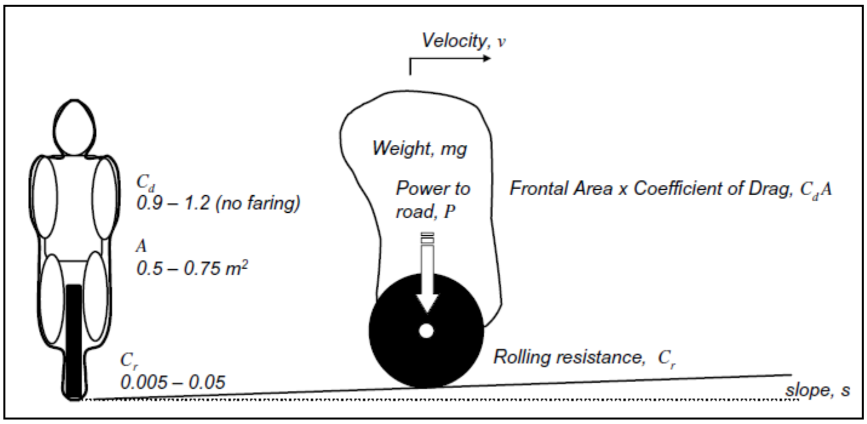


Figure 1 : Schematic representation of physics of personal electric vehicle [2]

Although there are prominent efforts taken to solve the problems by inventing hybrid cars, stricter standards for vehicle emission and improvement of public transportation, people still expecting to have a zero emission vehicle to be used where it is more secure and has very good potential to solve world nowadays congestion and pollution as well as the depletion of crude oil.

The most famous and commercially PEV available in market nowadays is the Seqway Personal Transporter. With features such as battery powered, two-wheels based vehicle and self-balancing, it seems that Segway Personal Transporter has provides excellent solution to congestion and pollution problems in cities if it used as a main way of transportation in cities.

However, the full potential of PEV has not been realized to a large extent since people always questioning the ability of a PEV. According to Ulrich (2006), people keep complaining and claiming on PEV mostly about the PEV feature itself such as not light enough, cannot go far and the cost for a PEV is not reasonable compare with its ability. They also questioning the worthy of trade-offs they need to pay across these dimensions of performance with its efficiency [2].

Since the market value of current PEV is almost same as a price of a car, they comparing it and come out with a conclusion that it is much better to pay for a conventional car rather than buy a PEV since a car gives more benefits and much more convenience when compare to a PEV. While some people view PEV as a vehicle of the future, most of them still consider it as unnecessary. Figure 2 below shows the general overview of the procedure how people make their decision to buy an electric vehicle.

The PEV is typically an open to weather vehicle [2] where the person (rider) can enjoy his/her surround view while driving the PEV since it is designed to create a user friendly and comfortable drive. It does not consume much space as a car although the car also can moves at the same speed as pedestrians which make it suitable to drive on local roadways and pathways[3]. A PEV consist of electric motor, controller, battery and chassis. Using electricity as its main energy source, PEV gives zero contribution to air pollution.

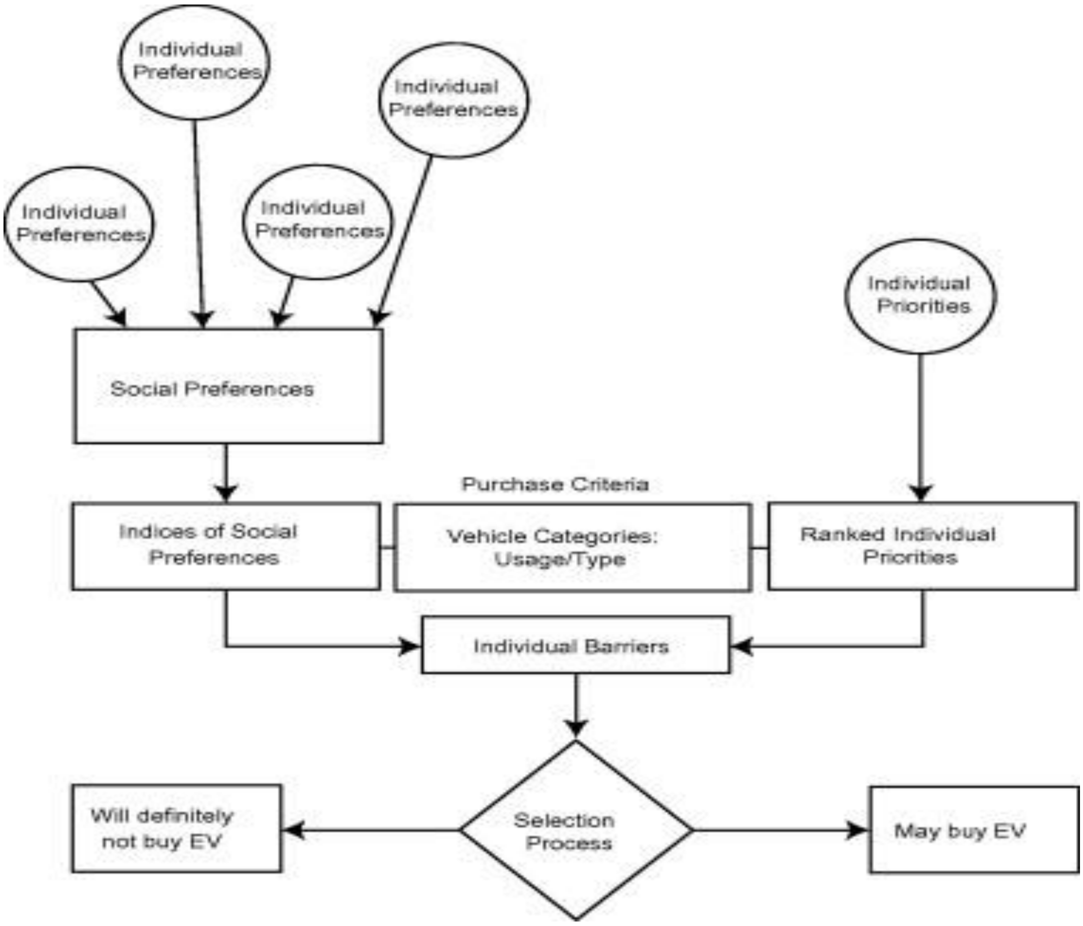


Figure 2 : General overview of the procedure how people make their decision to buy an electric vehicle.[3]

In this project, the author will develop a prototype that contain the most basic mechanism involve in a PEV. The main reason why this prototype being develops is to provide and to facilitate related study especially in PEV performance. For example, conducts a study regarding the relationship between the electric motor selection and its drive mechanisms as well as the cost involves in developing a PEV. With construction of the prototype, the author hopes that the research and testing done on this prototype will help future designers to create much friendlier user and environment PEV at cost where everyone can afford to buy it on their own.

1.2 Problem Statement

Personal electric vehicle has offer several potential benefits and advantages to the society solution. It has been design to inspire to overcome the problems of the typical combustion engine vehicles such as transportation problems of traffic congestion, air pollution and fossil fuel depletion. However, the existing PEVs faces some disadvantages and problems since they are not widely use due to a number of constraints which limit its development and thus its popularity as a personal vehicle of choice. Figure 3 show the Fish-Bone Diagram of problems and factor that contributing in the existing PEV:

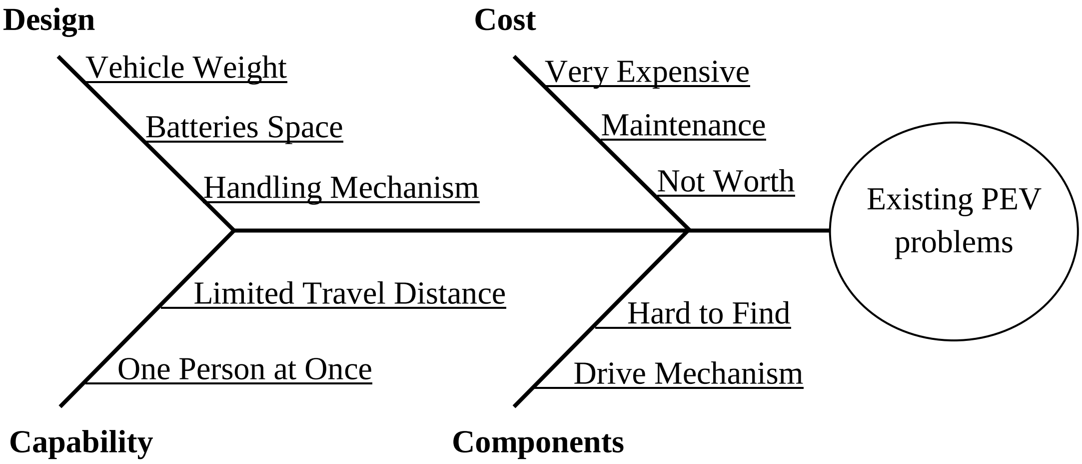


Figure 3 : Fish Bone Diagram – Factors Contributed in existing personal electric vehicle (PEV)

The author chooses to address in problems related to the PEV components and design. The drive mechanism consists of electric motor, battery and tyre is one of the main parts involved in a PEV. The drive mechanism has the most significant contribution in one PEV performance since if the components involve in the drive mechanism is not optimize, it may affect the performance of a PEV. If possible, at the end of this project, the author wishes to test various range of capacities and types of electric motor in detail, after the prototype has produced.

The development of the prototype also necessary in order to estimate the cost involves in manufacture a PEV. In addition, Universiti Teknologi PETRONAS (UTP) lack of research materials and facilities to test and experimental current PEV technology. Besides, there are no PEV prototype exists in UTP before this. Thus, to develop and produce one PEV prototype is relevant in this project. In electric motor selection and improvement in drive mechanism, there are many criteria need to be consider to fulfill the PEV specifications since it related to the PEV weight, cost development and selling price.

1.3 Objective

The objective of this project is to develop a prototype with facility to test PEV drive mechanism and analyze their performance. However, the design and the prototype requirement may be changed due to changes in measurement or material selection in order to complete the prototype. The simplified drive system will be consisting of only main parts which are the motor, controller, and battery as well as the gearing system.

In this project, the author also includes some calculation that might involve in developing a PEV. The power requirement of a PEV and its specific motion capability and performance specifications parameter to access the performance of the PEV motion is to be established. Thus, at the end of this project, a prototype of PEV will be developed with facilities to test PEV drive mechanism as well as its performance.

1.4 Project Scope of Study

This project will be focus on the development of PEV prototype. The prototype development will be based on the specification set by Mr Faisal Zainor (2011):

- Total mass (PEV + rider) = 30Kg + 80Kg = 110 Kg
- Maximum speed, V = 30 Km/hr
- Distance travel per full batteries charge = 10 Km
- Maximum full charging time = 4 hours
- Maximum slope angle of ascent = 25^o
- Motor selection = 24V 500 W (model MY 1020)

At the end of this project, the author will develop one PEV prototype with facility to test various electric motors in order to increase PEV's drive mechanism and evaluate their performance.

1.5 Significance of Project

The existing of the prototype in one research is a great opportunity to its researcher since it will give more accurate data and result of the study. If this project is success, it will benefit both designer and the manufacturer of PEV by providing those data and guidance of electric motor, battery and tyre as well as the drive mechanism selection with a low cost, much reliable and consume less energy. It also will improve the future PEV to be more users friendly and comfortable to ride.

By developing the prototype at lower cost, it is hope that many data can be obtained from the analysis of the drive system. It is also hopefully will provide very useful information to the designer and manufacturer in future.

CHAPTER 2
LITERATURE REVIEW

Many research and development have been done on Personal Electric Vehicle (PEV) during these recent years. As a result, many models have been produced and developed by various companies and research bodies. The following are the review of the existing PEV in current market and also the review of research done by previous researcher.

2.1 Segway Personal Trasnporter

There are various type of PEV currently available in market nowadays since there have been a few different designs being designed by inventor around the world. The similarities between those design are that they are all powered by rechargeable batteries and they can only carry one or the most two person at one time [3]. Most of the PEV designs available nowadays are four wheel bases or two wheel (front and rear) bases except the most famous and commercially available PEV in current market; the Segway Personal Transporter.

Figure 4 : Segway Personal Transporter

It has ability to stand on its own with only two wheels side by side. With high-technology system such as a series of sensor system, a control system and a motor system, it is said that Segway PEV has provide an excellent solution to the congestion and pollution problems [3]. A Segway personal transporter costs approximately $5350 - $7200 (RM 18000 – RM 24000) each depending on the model [4]. Each wheel in the Segway personal transporter are equipped with a 2HP motor independently which make it easier to move right and left based on one motor operate faster than other motor concept. The series of sensor system will check and adjusting its own balancing, stability and the vehicle speed.

2.2 Personal Electric Vehicle Designed by Syahril Izzat

The PEV designed by Syahril Izzat [1] is mainly to reduce the cost of manufacture and selling price of the transporter. He also targeted that the PEV designed by him are affordable to the most developing country consumer.

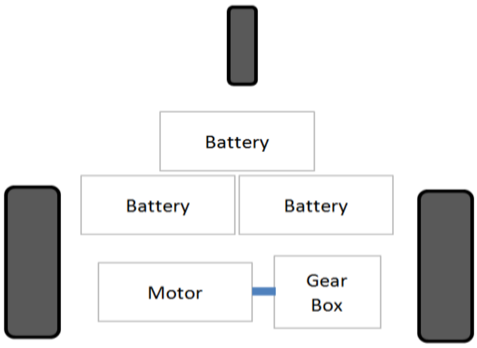


Figure 5 : PEV proposed by Syahril Izzat

Based on research done by Zainor Faisal (May 2011), he stated that the PEV designed by Syahril Izzat is not design for an easy mobility since the PEV has total weight up until 95Kg. He claimed that the usage of three batteries consume the most space which contribute to the total weight of the vehicle. Using a single 100W motor and only one gearbox to runs two wheels at back and considering its weight, this PEV can run at maximum speed 20Km/h.

2.3 Personal Electric Vehicle Designed by Zainor Faisal

Zainor Faisal also targeted to produce low cost PEV with improvement in drive system. By taking very analytical calculation and consideration, he manages to come out with a very fine design.

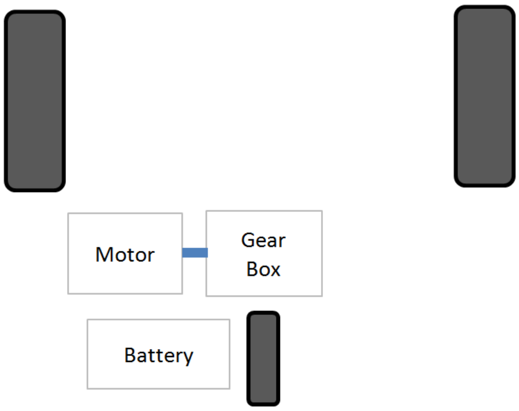


Figure 6 : PEV proposed by Zainor Faisal

Using only one battery and place the motor as near as possible to rear, this PEV manage to reduce it weight with tremendous drop. He manages to reduce the PEV weight until the PEV has weight at most 30Kg. The design also can be categorized as very safe. With two wheels at front, it create under-steer gradient which is same as a typical car. So, the safety of the raider can be ensuring especially if the rider lost his/her PEV's control and handling.

2.4 Personal Electric Vehicle Type

According to Ulrich (2005), there are three discrete market segments as points of comparison. The three segments are (1) stand on scooter, (2) sit-on cycles and (3) mobility scooter as shown below:

Figure 7 : Example of commercial product from each segment [2].

Stand-on-Scooter is a very simple, unique and it is tuneable patent if it is equipped with suspension system. It also travels much faster than standard mobility scooters. A stand-on-scooter is very economical and involves significantly less cost compared to sit-on-cycle and standard mobility scooter. However, the vehicle reliability and rider standing room problems have prevented these types of vehicles from reaching true success.

Sit-on-Cycles basically is same as a stand-on-scooter vehicle. The different is it has space for the rider to sit while driving the vehicles. It has motorcycle-like feature such as front and rear light, hydraulic brake system and a little luggage space. In other word, a sit-on-cycle vehicle is a combination of a bicycle and a motorcycle. It is suitable for people who are like to take their time to enjoy and appreciate their surround view. However, the design complexity and functional limitation plus with the individual needs may affect the suitability of a particular model. In addition, scooter limitations may vary depending on model and manufacturer.

Mobility Scooter is a great alternative for individuals who do not want to be limited by the slowness of a mobility scooter. It can move up until 4-6 times faster than walking or pedestrians and about 3-4 times faster than a sit-on-cycle. However, the drawbacks include mobility scooter length, has limits their turning radius and ability to use some lifts or wheelchair-designed access technologies. Some mobility scooters have low ground clearance which can make it difficult to navigate certain obstacles, such as travelling in cities without proper curb cuts. Navigating in restricted spaces, whether in the home or in public spaces and buildings can also be a problem.

In this project, the author will developed a PEV prototype from stand-on-scooter type or segment since it is simple and easy to manufacture. Besides, it involves the least cost if compare with other PEV type or segment as shown by Ulrich in Figure 7.

CHAPTER 3
METHODOLOGY

The methodology implemented in this project is to combine the technical model of vehicle performance in order to estimate the cost and mass of a vehicle for a given set of function requirement.

3.1 Brief Description on Methodology

In this project, the author has divided his works into several phases. In phase one, the objective of the project has been selected based on result from defining problems available in existing PEV. In phase two, the author take his time to do some research and literature review on existing PEV available in market as well as study back the previous design produce by Zainor Faisal. Phase three is where the result of the finding is out by defining it through design modification. The author believes that there will be some modification in the previous design in order to synchronize it with the project objective. Electric motor selection as well as other main components will be in phase four before the author proceeding to the phase five, prototype development.

3.2 Flow Chart

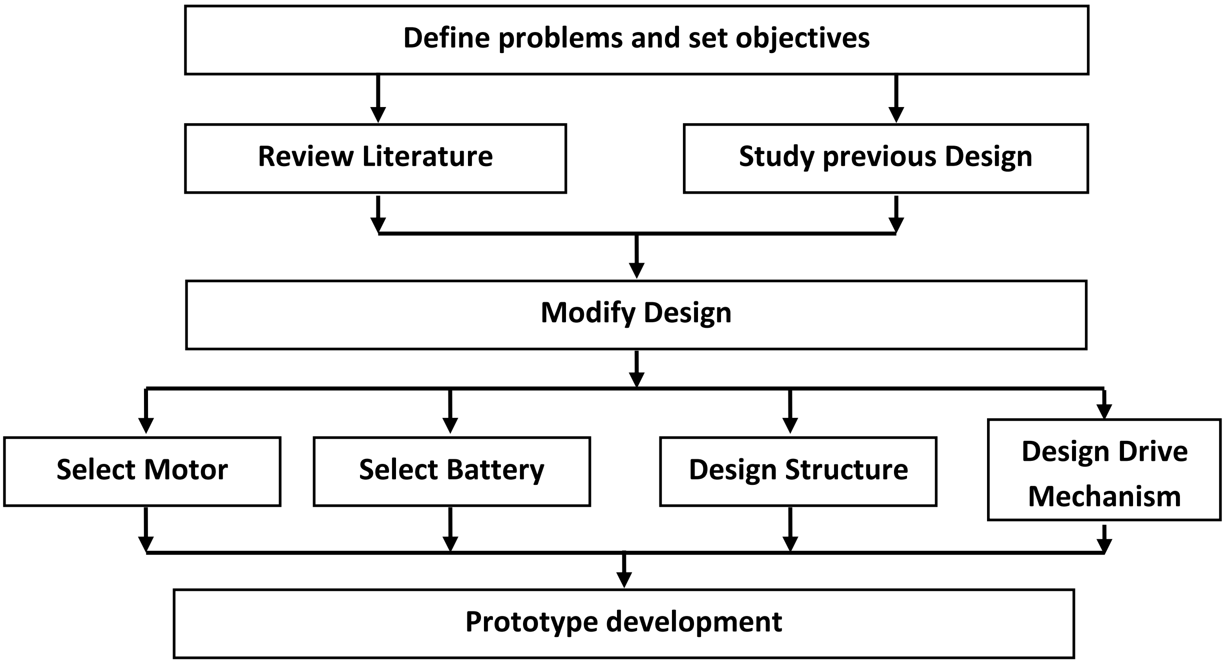


Figure 8 : Methodology flow process

3.3 Gantt Chart

Along with the flowchart preparation, Gantt Charts are also developed to ensure that all tasks given are performed and finished within the timeline given. However, the milestone of each task might be altered from time to time due to accommodation of additional work scope. Figure 8 and figure 9 show the Gantt Chart developed by the author.

Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of Project Topic														
Research and Analysis Problems														
Determine the scope of Drive System														
Design modification														
Detail drawing for each part														
Selecting material / components														
Prototype Development														

Figure 9 : The flow of the project progress for January 2012 (FYP 1)

Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Prototype development														
PEV testing														
Result / conclusion														

Figure 10 : The flow of the project progress for May 2012 (FYP 2)

CHAPTER 4
DESIGN REQUIREMENT

4.1 Design Theory

The specifications of the PEV prototype are based on the study done by Zainor Faisal as well as other resources such as articles and journals. The articles and the journals are used by the author as references to modify the Zainor Faisal design requirement.

Maximum Speed – 30 Km/h

According to Mureika and Jonas (2001), standard running speed of a human being is within 15 – 25 km/hr [6]. It is safe to raise the maximum speed of the PEV prototype from 20 Km/hr into 30 Km/hr, since the highest speed that considered safe on pedestrian walk is less than 30 Km/hr. Beside, the maximum speed raise is still within allowable zone of easy manoeuvrability and breaking.

Travel Distance – 10 Km

The PEV is created and designed to be a short distance vehicle. The specification that had been set is considered sufficient enough for consumers to travel safely throughout the city. Since the space between buildings in a city is compact, 10 Km of travelling distance is considered as exceeding a PEV limitation.

Maximum Weight – 30 Kg

Consumers will be expecting a light weight PEV which will provide them mobility to catty the vehicle wherever they want.

Slope to Overcome – 20^0

The target of the designed PEV is on the economical aspect of PEV rather that a performance. However, the performance of the PEV will be design to compete the performance propose by Zainur Faisal.

4.2 Drive System and Steering System

The proposed design is a three wheeled PEV. The PEV will be driven by an electric motor which will be connected to the rear wheel. The method chosen is due to the simplicity of the design proposed by former researcher. The front wheels are the steering wheels for the transporter and is design using the Ackermann theory. It is design to solve the problem of wheels on the inside and outside of turn needing to trace out circle of different radii.

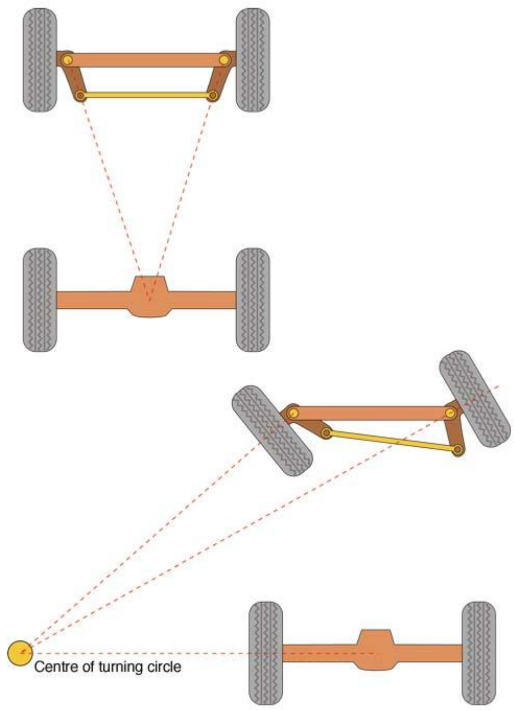


Figure 11 : Ackerman Theory of Turning Radius

The very first aspect of a design for Personal Electric Vehicle (PEV) is the drive system of means power transmission. Motor will transmit power to the rear wheel. The motor control will be decided for motor speed and braking. They will be incorporated using a simple joystick to facilitate operation by the user.

The difficulty faced for this type of drive system is to get the required speed reduction when the high speed motor is providing power. The problem can be solved by using a gear motor but since the objective of the project is to reduce cost, simple single gear transmission will be conducted in the project.

4.3 Design Process

Detail Design

All dimensions used are based on dimension given by previous research, Zainor Faisal. However, the author has made some modification especially in dimensioning the material used through analysis and try-and-error approach. Beside, the previous researcher just comes out with a design concept without any detail drawing. All dimensions are in millimeter, mm. The detail design of the prototype can be view at attachment.

Power Determination

Some calculation are needed to determine how much power required by the motor in order to drive the PEV at the desired specification. Electric motor usually has mostly ideal speed-torque characteristic. From figure below, as the motor speed increase to the base speed, voltage increase to the rate value while flux remains constant. Beyond that, the voltage remains constant while flux is weakening. This result in constant power while torque decline hyperbolically. Figure below shown the performance graph of electric motor

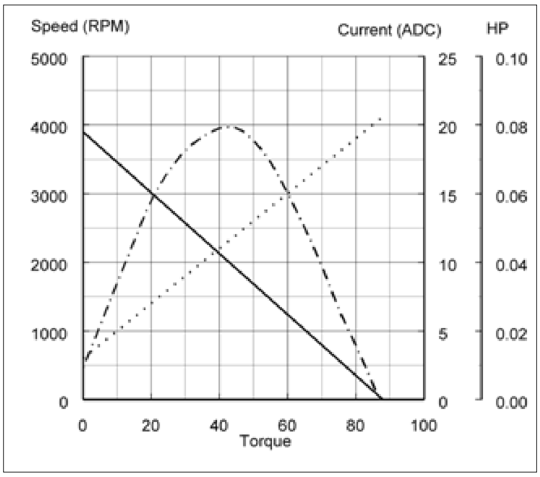


Figure 12: Electric motor performance graph

The movement behavior of a vehicle along its moving direction is completely determined by all the forces acting on it in this direction. There are three major forces at work which resist a vehicle from moving:

- Rolling resistance
- Air resistance
- The force of gravity as a vehicle moves up a hill

The tractive force, F_t in the contact area between the tires of the driven wheels and the road surface propels the vehicle forward. The total forces that need to overcome is:

$$F_{Tractive} = F_{Air} + F_{Roll} + F_{Slope}$$

Rolling Resistance

The force of the rolling resistance is a function of the weight of the vehicle multiplied by a coefficient of the rolling resistance. This force is mostly independent of car speed.

$$F_{Roll} = C_r\ M\ a_{gravity}$$

Where:

C_r - the rolling resistance coefficient. Typical values for the rolling coefficient (u_{roll}) = (0.0136)*(0.04 x 10^{-6})*$(3.6v)^2$, where v is the function of speed

M – Mass of the vehicle (Kg)

$a_{gravity}$ – force of gravity (taken as 9.81 m/s^2)

Air Resistance

The force of the air resistance is proportional to the square of the speed, the density of the air, the silhouette are of the car, and the drag coefficient for the vehicle. A vehicle travelling at a particular speed in air encounters a force resisting its motion, referred to as aerodynamic drag resulting from two component; shape drag and skin friction

$$F_{air} = \frac{1}{2} C_d\ A_f\ \rho\ v^2$$

Where:

C_d = Drag coefficient

A = Frontal surface area of vehicle/rider (m^2)

ρ = Density of air (1.2 Kg/m^3 at sea level at normal temperatures)

v = speed of the vehicle (m/s)

PEV frontal area = 0.2 m^2

Human Surface Area = $\sqrt{\frac{h * m}{3600}}$

Take; h = 180 cm

m = 80 Kg

$$= \sqrt{\frac{h * m}{3600}} = \sqrt{\frac{(180\ cm) * (80\ Kg)}{3600}} = 2$$

Frontal Surface Area = (2/5)*Body Surface Area

= (2/5)*2 m^2

= 0.8 m^2

Thus, Total Frontal Area, A_f =0.2 m^2 + 0.8 m^2 = 1 m^2

Drag Coefficient, C_d = 1.5

Air density, ρ = 1.225 Km/m^3

Power Required for Forward Motion

Power is a measurement of work per unit time. Work is a measurement of a force moved at some distance. Therefore, to determine the power required to move a vehicle at a certain speed, it is simply the total of all forces to overcome multiplied by the speed.

$$\text{Power, } P = (F_{roll} + F_{air} + F_{slope})\ v$$

Power Required for Acceleration

The Personal Electric Vehicle is set to accelerate at the rate of 1 m/s^2. To calculate the power required to accelerate a vehicle, first determine the amount of energy required to accelerate a vehicle from 0 to a speed of v:

$$\text{Kinetic Energy, } E_k = \tfrac{1}{2} m v^2$$

Then, to calculate the power, divide the energy required by time it takes to acceerate the vehicle:

$$\text{Power, } P = E_k/t$$

The Speed Control

Motor controller is required to turn the control signal rom the micro-controller into a varying power level to drive the motor. The PEV prototype will have a Pulse Width Modulation (PWM) controller as te speed controlling device. PMW is a one method to communicate between micro controllers to a motor controller.

Another type of speed controlling device that can be implemented is Resistive Motor Control (RMC). It consisted of two switches. One switch operated the motor at a low speed, running current through a power resistor, and the second resistor shorted out the resistor, giving full speed. Using Ohm Law, the voltage and current needed is calculated.

The only advantage that Resistive controller has against PWM is that it may potentially more reliable. The PWM offers better performance in speed control and have improve efficiency of vehicle.

Gearing System Determination

Since the speed-torque motor is close to ideal, single gear or double gear transmission is usually employed. For this project, a single gear transmission will be employed.

The basic equations used are:

$P = (1/60) * \pi * N * T$

$N_1/N_2 = M_2/M_1$

Where:

P= Power (KW)

N = RPM speed

T = Torque (Nm)

M = Number of teeth of the respective gear

Total Forces Encounter

$F_{roll} = C_r\ m\ g$

$= (0.01862)\ (110\ Kg)\ (9.81\ m/s^2)$

$= 20.1\ N$

$F_{air} = ½\ \rho\ C_d\ A_f\ v^2$

$= ½\ (1.225\ Kg/m^3)\ (1.5)\ (1\ m^2)\ (20\ m/s * 1000/3600)^2$

$= 28.4\ N$

$F_{slope} = mg \sin \Theta$

$= (110\ Kg)\ (9.81\ m/s^s) \sin 25^0$

$= 456\ N$

Total tractive force acting on the PEV prototype, F_T:

$F_T = F_{roll} + F_{air} + F_{slope}$

$= 28.4\ N + 20.1\ N + 456\ N$

$= 504.5\ n$

From calculation, it can be conclude that the highest possible forces will be taken into calculation in order to get the maximum traction forces that the PEV prototype will face is 504.5 N.

Torque Required at Wheel

From definition of torque itself, the torque applied at the wheel, T_w is:

$T_w = F_T\, r$

Where;

F_T = Total Traction Forces acting on wheel

r = Radius of the driven wheel

Therefore, the torque at the wheel is

$T_w \quad = F_T\, r$

$= (504.5\ N)\ (0.2)$

$= 100\ Nm$

Rotational Speed and Torque at Wheel

Since the torque has been calculated, the rotational speed of the wheel needed in order to move the PEV prototype to the required speed is:

Velocity, $v = \omega r$

Where:

ω = Rotational speed of the PEV prototype

r = radius of the driven wheel

Since the value of v = 20 Km/h and r = 0.2 m;

Thus the rotational speed, ω is

$\omega \quad = v/r$

$= (20\ km/h * 1000/3600) / 0.2\ m$

$= 27.8\ rad/s$

From calculation, the required rotational speed required is 27.8 rad/s to achieve translational speed at 20 Km/hr.

Electric Motor Selection

For this project, 24 V 500 W DC electric motor has been chosen to run the PEV prototype. The required torque for the PEV prototype. Table 1 below show the specification of the chosen electric motor.

Model	MY1020
Type	Brush
Voltage	24V DC
Rated Speed	2500 RPM
Rated Current	27.4 mp
Sprocket	8mm, 13 tooth pinion gear
Output Power	500 W
Dimension(Length x Weight x Height)	174 mm x 72 mm x 184 mm

Table 1: Specification of MY1020[1]

Figure 13: Electric motor model MY1020

Battery Performance

Before selection of battery being made, the time needed for the PEV prototype to travel at least 10 Km with the it maximum speed 30 Km/hr is calculated:

Time to travel = (10 Km) / (30 Km/h)

= 0.3333 hours (20 minutes)

The motor is drawing a steady 27.4 A (please refer to Table 1) of current and the PEV prototype needs the motor to run for at least 20 minutes. Thus:

Capacity battery needed = 27.4 A * 0.333 hours

= 9.13 Ahr

However, in order to get a long life span of battery, the battery should have at least 20% left of the total capacity. Therefore:

Capacity of battery = (9.13 Ahr) (0.8)

= 7.31 Ahr

To power the motor, a 24 V 13 Ah NimH battery pack is selected. This type of battery is widely used for hi-power E-bike and robots. it consist of 20 pieces of F-sized 13 AH NimH cell ina plastic container. The battery need to be charged using the Smart Charger (1.8A) with 3-pin connector which is installed to the home plug.

Figure 14: Battery and charger of 24V 13 Ah NimH

Nominal Voltage	24 V
Nominal Capacity	13 Ah
Maximum Charging Time	160 minutes
Weight	5.4 Kg
Dimension (length x Weight x Height)	76 mm x 168 mm x 181 mm

Table 2: Specification of the battery selected

The performance of the battery will be based on the assumption that the vehicle is operated at an elevated surface where the inclination is 0^0. Therefore, the battery will last for time, t where

$$\text{Time, } t = (13\text{ Ah}) / (27.4\text{ A})$$
$$= 0.474\text{ h}$$
$$= 28.5\text{ minutes}$$

The vehicle will operate at a speed of 30 Km/hr. So, the total distance that the vehicle may cover is D, where:

$$\text{Distance, } D = (30\text{ Km/hr})*(0.474\text{h})$$
$$= 14.2\text{ km}$$

Since the objective of the project is to get a total distance of at least 10 Km, therefore the objective is achieved.

Steering / Handle Mechanism

Steering mechanism plays an important part in providing comfortable way to control the direction and accelerating the PEV prototype. Many considerations had been made during the designing progress. Two of the rejected ideas were wheel mounted in the upright post in front of the PEV prototype and a simple knob on the post itself. It was decided that the twist grip would be most appropriate for the project. It seems simple for user to use as well as the deigning process.

The basic idea of accelerating the PEV prototype is using potentiometer in the twist grip handlebar to control the current going through the electric motor. Therefore, the speed of the motor can be controlled by manipulating the resistance on the potentiometer.

Figure 15: Example of motor controller and twist-grip potentiometer.

CHAPTER 5
RESULT AND DISCUSSION

After reviewing several designs of existing PEV as well as the design specification stated in Chapter 4, the author finally comes out with two conceptual designs. However, the design specifications are subjected to change from time to time depending on requirement and new design specification will be added should the needs arise.

5.1 Conceptual Design

i. Conceptual design 1

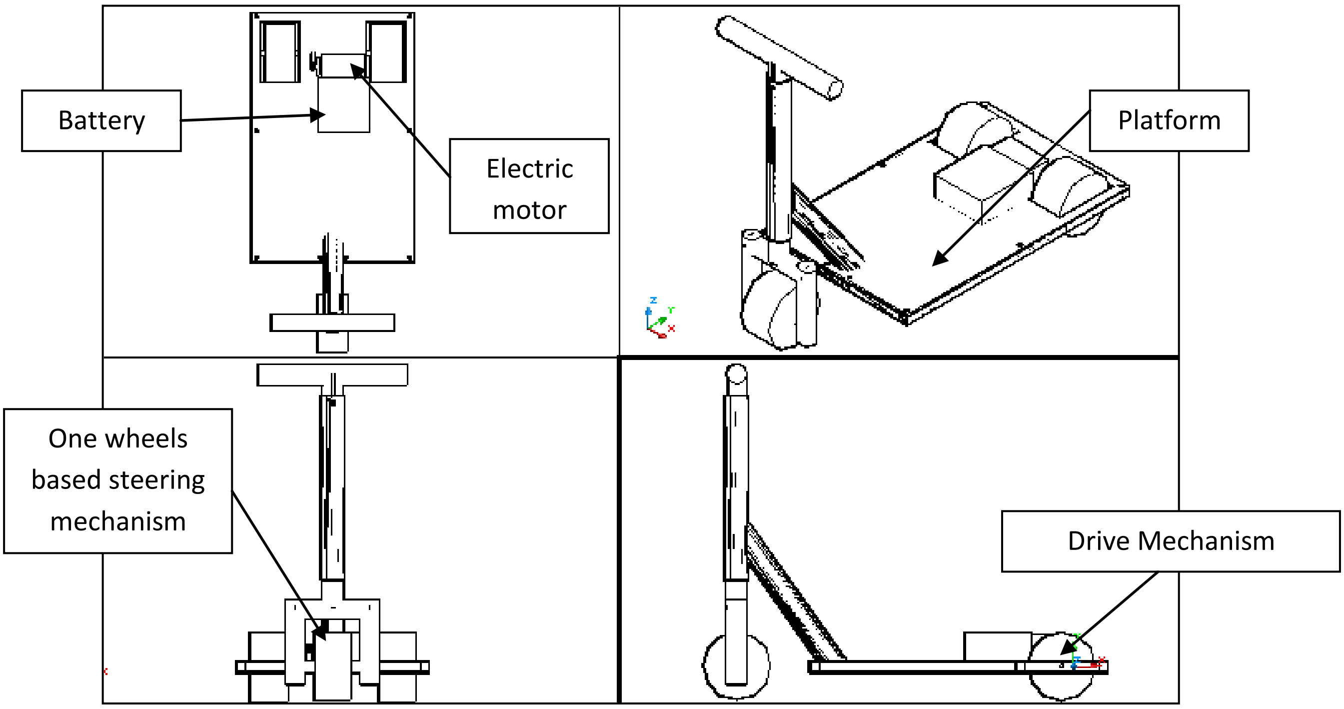


Figure 16 : Conceptual design 1

ii. Conceptual design 2

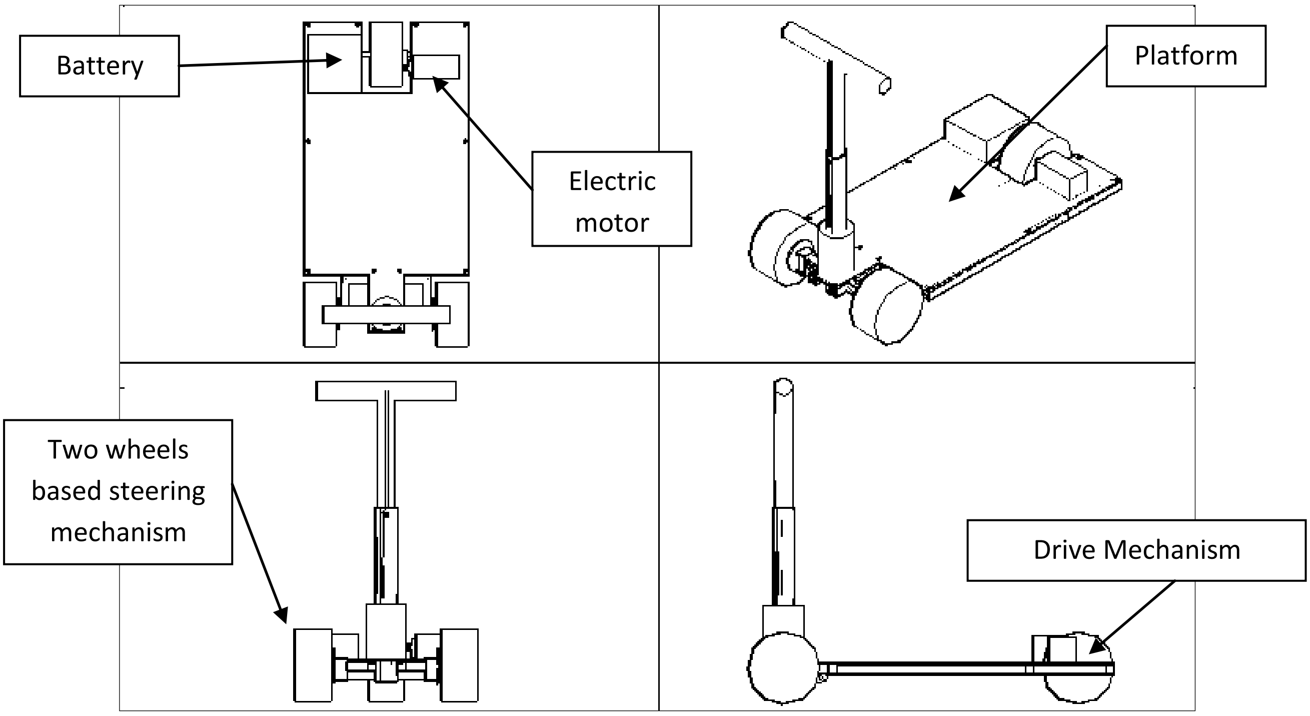


Figure 17 : Conceptual design 2

Both of the prototype will used same system of drive mechanism. The author used chain as the mechanism to transfer the work done by electric motor to the rear axle to move the prototype. Using combination of gear and the chain, the mechanism is shows as below.

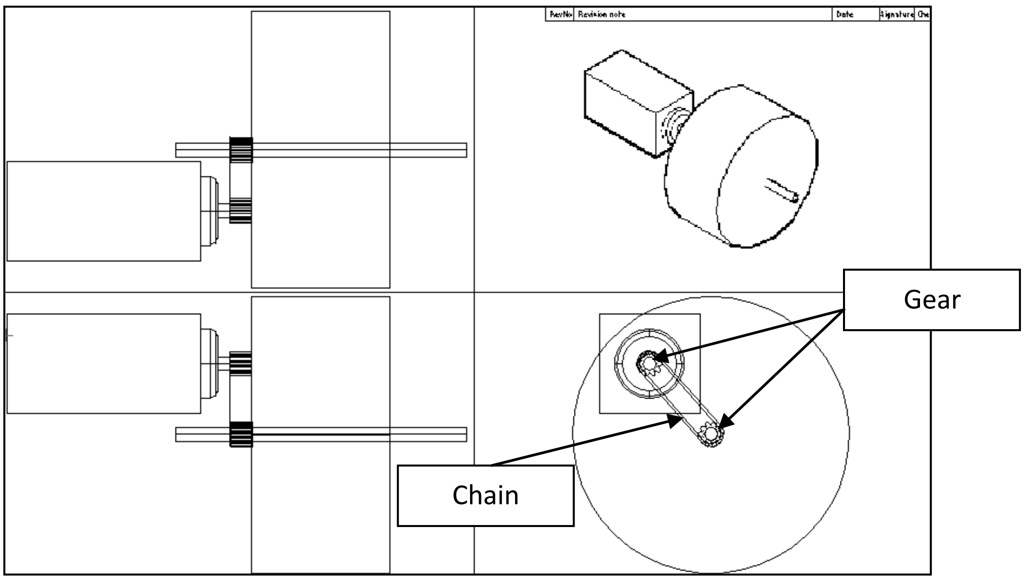


Figure 18 : Drive mechanism used to move the prototype

5.2 Conceptual Design Analysis

Conceptual Design 1

This conceptual design used three wheels where one wheel been installed at the front and the other 2 wheels are installed at the platform. The prototype maneuvering is done by the front wheel like typical motorbike and bicycle based steering. By installing two wheels at the rear side of the prototype, it will give more stability to the prototype especially during the user drive the prototype. The disadvantage of this design will be the loss in efficiency during transferring the work done by the electric motor to the tyre. The work from the electric motor will be transfer to the chain and the rear axle before reach the tyre.

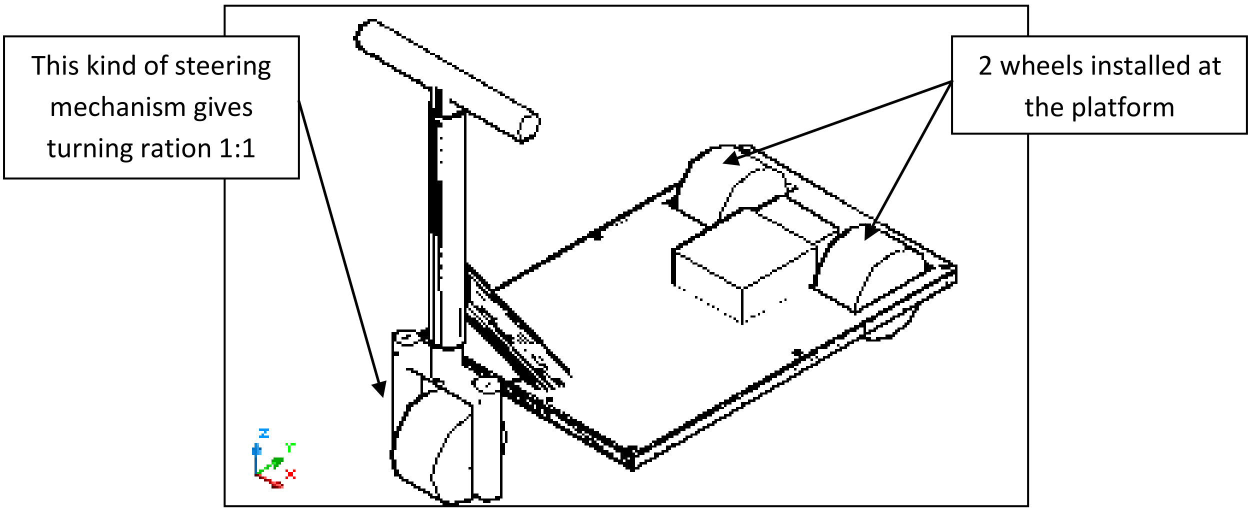


Figure 19: Conceptual Design 1 Analysis

Conceptual Design 2

Like conceptual design 1, this conceptual design also used three wheels. The different is just there will be only one wheel being install to the platform and another two wheels will be installed to the steering. The two wheels being installed at the steering mean that the maneuvering and the power drive will be carried out by the same two wheels

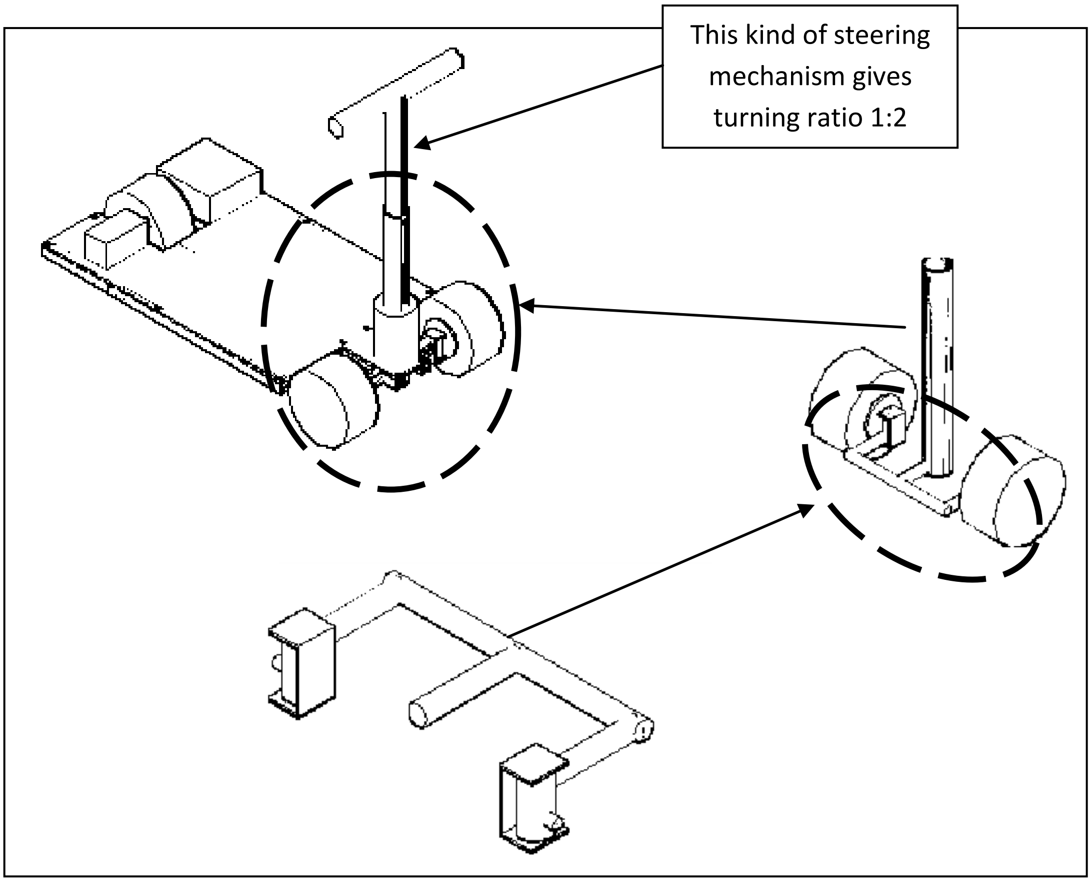


Figure 20: Steering mechanism of conceptual design 2

Having discussed the conceptual design of the prototype, the advantages and disadvantages of each design are analyzed and presented as shown in table 3.

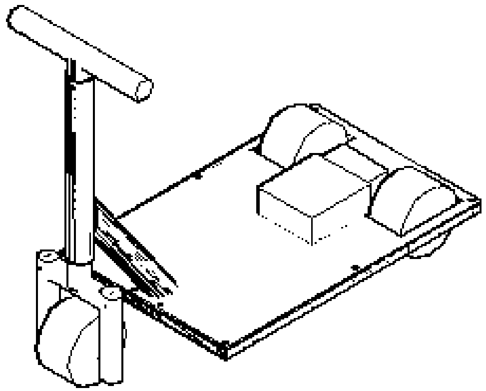
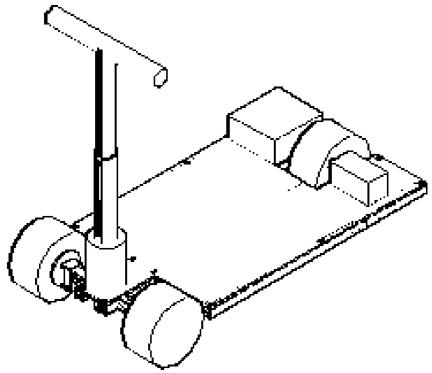
Design / Items	Conceptual Design 1	Conceptual Design 2
CAD Drawing		
Advantages	- Simple steering mechanism - Easy to maintain since it involve simple mechanism - Involve low cost development	- Easy to maintain -involve low cost development
Disadvantages	- Not very stable during turning due incapability of the steering mechanism	- Involve complex steering mechanism

Table 3: Conceptual design analysis

From the advantages and disadvantages analysis of the conceptual design, it can be concluding that both of the designs involve low cost of manufacturing. Both of the design also easy to main since does not involve complex mechanism except the steering mechanism of conceptual design 1.

If we compare the stability of both of the conceptual design, it is obviously shows that the conceptual design 1 has much more stability compare with the conceptual design 2. This is because of the wheels installation into the platform. With 2 wheels being installed to the platform, it offers uniform weight distribution along the platform. However, the design concept 1 is not very stable especially during turning as the incapability of the steering mechanism to provide tilting.

For conceptual design 2, although it is not very good in term of weight distribution on the platform, it is very stable especially during turning. This is because of the two wheels being installed at the steering which mean that the maneuvering and the power drive will be carried out by the same two wheels. However, to make this kind of steering mechanism is not easy to manufacture since it involve complex mechanism

5.3 Decision Matrix

To ensure that the final design chosen meet it requirement and all design criteria set earlier, the author decided to employ decision matrix to compare between both of the conceptual design. This step is important since there are many consideration and studies need to be done before finalizing the design. Besides, the author also employed decision matrix to study and compare the relationship of the steering mechanism with the number of wheel being install to it as well as to study the relationship between the prototype stability with the installation of tyre to the platform.

This criterion is important to be considering since it will affect the performance and the drive mechanism of the prototype.

		Decision Making Criteria				
Option	**Option**	**Cost**	**Design Complexity**	**Maintainability**	**Overall Stability**	**Total**
	Conceptual Design 1	**9**	**9**	**7**	**8**	**33**
	Conceptual Design 2	**9**	**7**	**8**	**6**	**30**

Table 4: Decision matrix to choose the best conceptual design

Note: The rating is in the range 1 – 10 where 10 represent the best and 1 represents the worst

From the decision matrix analysis above, the conceptual design 1 is the best in term of serving and may fulfill the objectives of this project. Although both of the design has same cost for development, but in term of design complexity and overall stability, conceptual design 1 is much more better when compare with conceptual design 2. Despite this design has the disadvantage of being maintainability, it still serves the other design criteria perfectly.

In this project, the author will develop the PEV prototype based on the conceptual design 1.

5.4 Calculation for Stability Analysis

After decided upon the design as well as the dimension of the overall prototype, it is time to analyze the stability of the overall design. The design's primary stability concern will be during the prototype turning. With the prototype specification given in Chapter 4, the turning stability of the prototype is analyzed. However, some assumption need to be made and perform to make sure the stability calculation is accurate.

To simplify the analysis, the following assumption has been made by the author:

- The steering wheel is the driving wheel
- The rear wheels are mounted independently on the rear axle
- Right cornering at a turning radius of 2 m from the rider's point of view
- The cornering is done by 50% of the maximum speed, 15 Km/h

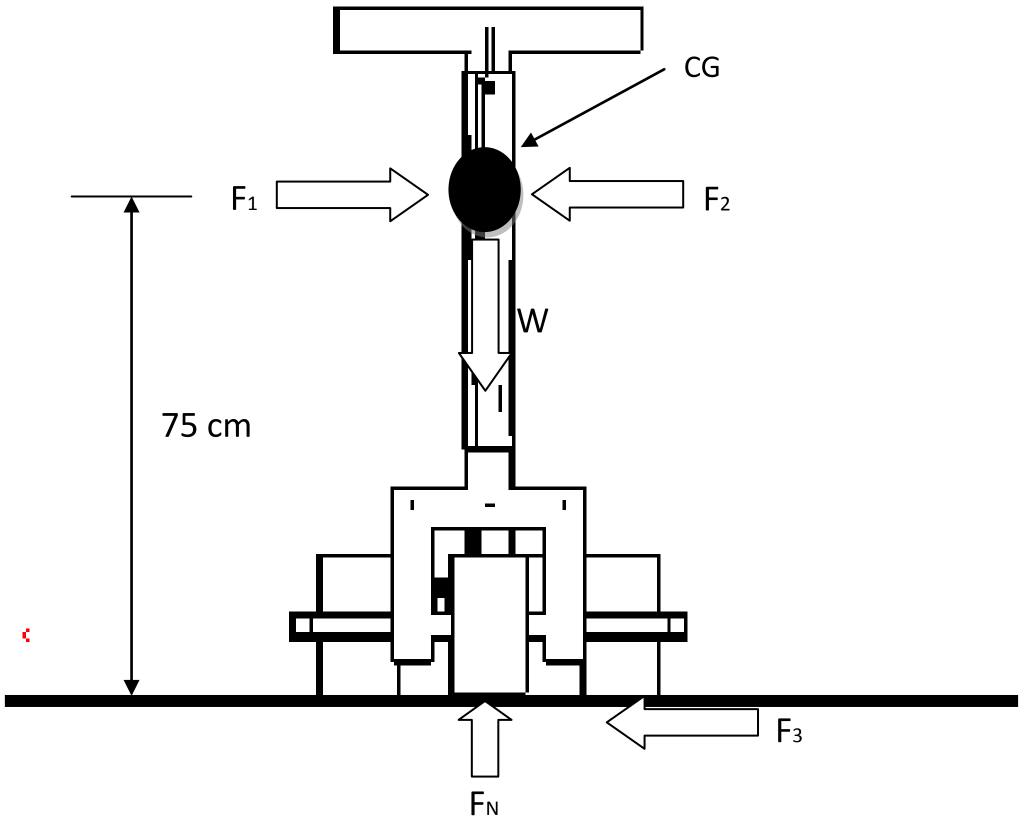


Figure 21: Free body diagram of the prototype

Where:

CG – Center of Gravity

F_1 – Centrifugal Force

F_2 – Centripetal Force

W – Overall weight

F_3 – Overall friction force

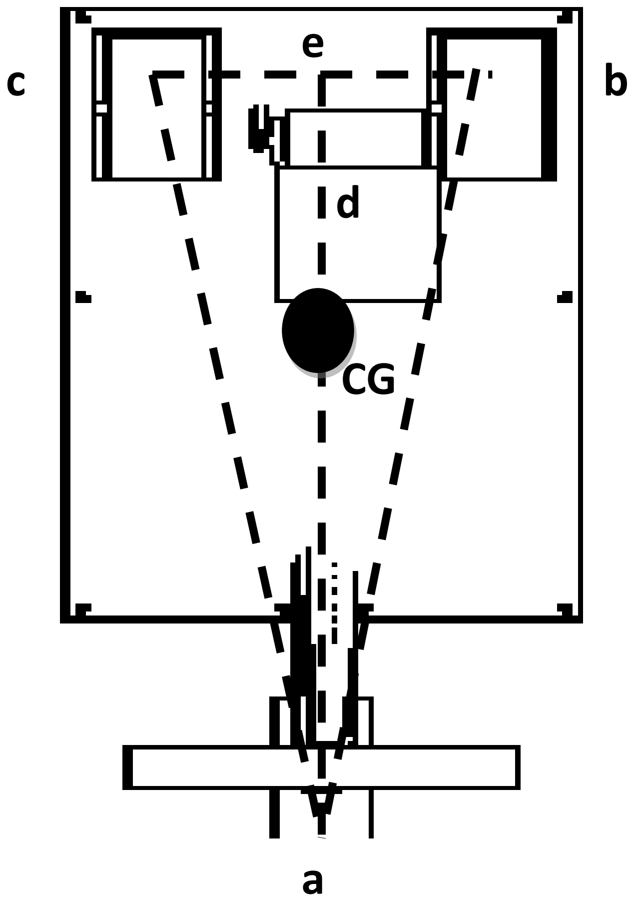


Figure 22: Free body diagram of the prototype from top view

First, all the important unknown forces are calculated as follow, since F_1 and F_2 are centrifugal and centripetal forces respectively, both of the forces has same magnitude but in different direction. The magnitude may be calculated by using following formula:

$$F_{1,2} = \frac{mV^2}{r}$$

$$F_{1,2} = \frac{(80\ Kg + 30\ Kg)x\ (15\ {}^{Km}/_{h}\ x\ \frac{1000\ m}{1\ Km}\ x\ \frac{1\ h}{3600\ s})^2}{2}$$

$$F_{1,2} = 954.86\ N$$

W is the overall weight of the prototype and the rider, where it can be calculated by:

W = (Prototype mass + rider mass) x gravitational acceleration

= (80 Kg + 30 Kg) x 9.81 m/s^2

W = 1079.1 N

Since F_3 is the overall frictional force due to the contact points of the three wheels at a, b and c, the weight at each of the wheel need to be determine first. Using principle of moments, the weight at each wheels are calculated. To find the weight on wheel a, the author uses the equilibrium equation of moment around axes b and c as the following:

$$W \text{ x de} = w_a \text{ x ae}$$

$$1079.1 \text{ N x } 0.36 \text{ m} = w_a \text{ x } 0.88 \text{ m}$$

$$w_a = 441.45 \text{ N}$$

While to find the weight on wheels b and c, the author again uses the equation of equilibrium of moment around axes a as following:

$$W \text{ x da} = w_{b,c} \text{ x ae}$$

$$1079.1 \text{ N x } 0.53 \text{ m} = w_{b,c} \text{ x } 0.88 \text{ m}$$

$$w_{b,c} = 645 \text{ N}$$

thus, $w_b = w_c = 645 \text{ N} / 2 = 325 \text{ N}$

F_3 is simply the summation of the frictional forces at each of the wheels

$$F_3 = \mu w_a + \mu w_b + \mu w_c$$

Where μ is the coefficient of friction and is assumed to be 1.7 for tyre and concrete contact under good condition.

$$F_3 = (1.7 \text{ x } 441.45 \text{ N}) + (1.7 \text{ x } 325 \text{ N}) + (1.7 \text{ x } 325 \text{ N})$$

$$F_3 = 1855.47 \text{ N}$$

To check the turning stability of the design, force analysis is carried out based on the principle presented by Archibald Sharp (2003) which states that if the resultant, R of

W and F_1 cut the ground at point p, outside the wheelbase a, b, and c, and then the design will overturn.

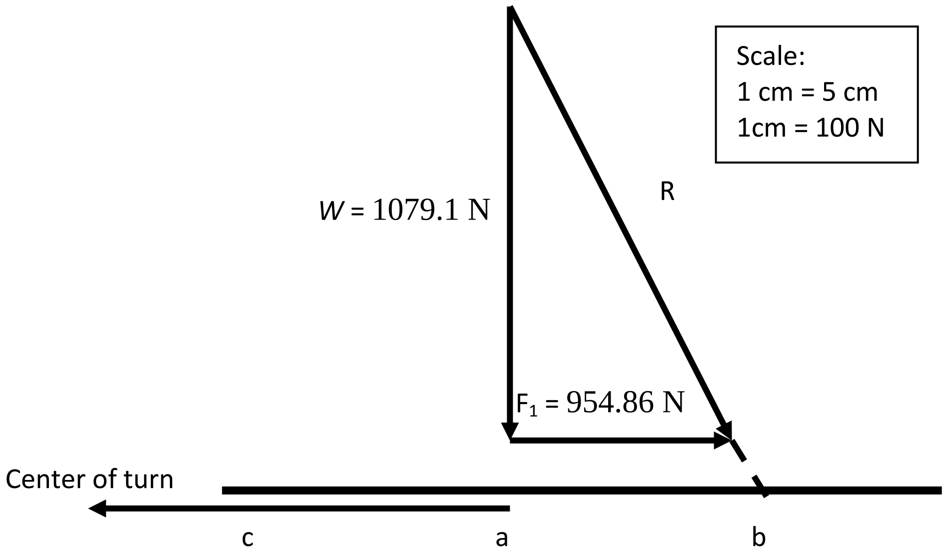


Figure 23: Force analysis

and c of the prototype. It is good enough to show that the design is still stable in terms of turning stability if a rider is to turn through a turning radius of 2 m at speed 15 Km/h. Thus, the author concludes that the design is safe to turn through a turning radius of 2 m at speed of 15 Km/h.

5.5 Prototype Development

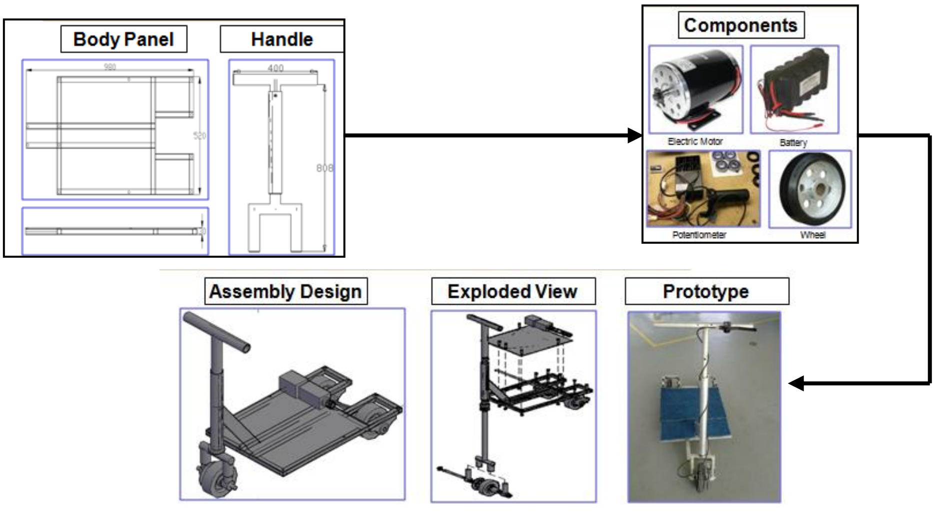


Figure 24: Steps and activities performed during prototype development

Understanding the material selection process is the key to engineering any application and/or part design. Material selection is the foundation of all engineering applications and design. This selection process can be defined by application requirements, possible materials, physical principles, and selection. The author has take into consideration of the major overall of the PEV prototype requirements which are speed, safety, comfort, and endurance towards several testing. The prototype weight also is the key of one of the requirement set by the Author. The specific material must be selected in order to fulfil the entire requirement needed. In this project, the author has divided the development of the PEV prototype into three elements, which are Frame, Handle and Components. Figure 15 show the possible of material selection can be used by the author.

	Modulus of Elasticity, E (GPa)	Ultimate Tensile Strength (MPa)	0.2% proof stress at Yield (MPa)	Elongation at Failure (%)	Fatigue Limit/ UTS (5x10 cycles)	Density (Mg/m - specific energy
Steels						
Medium Carbon	200	520	310	26	0.5	7.85
CrMo (AISI 4130)	200	1425	1240	12	0.5	7.85
Aluminum Alloys						
2024-T4	73.1	470	325	20	0.29	2.8
6061-T6	68.9	310	276	12	0.31	2.8
7075-T6	71.7	570	503	11	0.265	2.8
Magnesium	44	248	200	5 to 8	0.37	1.79
Titanium Alloys						
IMI 125	105 to 120	390 to 540	340	20 to 29	0.5	4.51
IMI 318	105 to 120	1000	900	8	0.55	4.42
Composites						
"S" glass-epoxy	90	3750	3450	3.5	0.16	2.63
HT graphite-epoxy	221	3600	2000	1.25	0.25	1.75
Boron-epoxy	250	1200	?	?	0.8	1.9
Boron-Aluminum	165	1025	?	0.65	0.7	2.4
Kevlar-49-resin	75	1380	?	2.75	0.7	1.45
Glass-nylon	2.3	59.9	59.9	14	?	1.18
Woods	12	100	60	?	?	0.67

Figure 25: Possible materials that can be used for the PEV prototype development

There are many type of materials can be chosen and used in developing the PEV prototype. The author has divided the material available into two categories; metal and non-metal material. In this project, the Author prefers to use material with metal basis, based on the objective of this project. However, since each of the material has its own physical and mechanical properties, the author need to decide on which one of the material is the best to be selected. Based on research and analysis done by the Author, the best material selection that can be used to develop the PEV prototype is Aluminum.

Frame and Handle

The frame is the core to the PEV prototype as a complete functional unit. Material selection importance should lay with strength and weight. A major consideration is the hollow square frame design. Taking all the consideration, the Author decided to use hollow square Aluminium as the material for the PEV prototype frame and handle. This is because aluminium is now the second most widely used metal in the world after iron. Unlike iron, aluminium has a unique combination of attractive properties such as low weight, high strength, superior malleability and easy machining. With one third density of steel, Aluminium is light as 2.7 Kg/m^3. Aluminium also is easily worked using most machining methods – milling, drilling, cutting, punching, and bending which can be found within the university's lab facilities. Furthermore, the energy input during machining is low.

Aluminium also is much cheaper compared to other steel materials. It is also can easily be found in any hardware shop. Plus, since the prototype will be used just for several testing and experiment, Aluminium is the best material can be used. Beside, since the main objective of the testing and experiment are just to gather some data and info regarding the PEV drives mechanism and performance, it does not really matter to have a perfect material such as carbon fibre or carbon plastic like been used by existing PEV.

Aluminium also is the perfect 'eco-metal'. If the prototype is broke down or destroy during the test or experiment, with appropriate sorting, scrap aluminium can advantageously be recycled to produce the same sorts of products over and over again. Furthermore, recycling requires only 5% of the original energy input. Scrap aluminium is a valuable resource that is set to become even more important. In principle, all scrapped aluminium can be recycled into a new generation of products.

Components

In this project, the components used by the Author are mostly from bicycle parts component. Since the component involve are a moving mechanical parts, the components from bicycle is the best parts can be chosen since it has similar in term of movement and function as the PEV prototype. Figure 26 show some of the bicycle's parts except crank that will be used by the Author to be implemented to the PEV prototype.

The author also choose to used most of the bicycle components such as chain, chainwheel and brake to be implemented in the PEV prototype since that parts can be used and easily implemented to the prototype. Plus, the size is fit and compatible with the PEV prototype size.

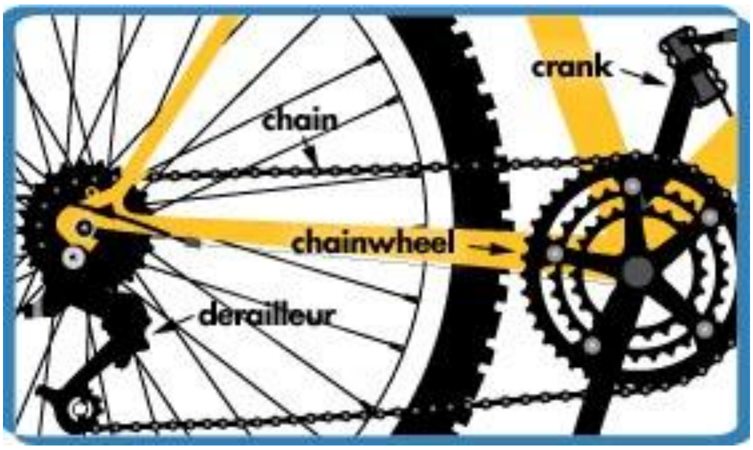


Figure 26: Some of bicycle parts used in the PEV prototype.

CHAPTER 6
CONCLUSION AND RECOMMENDATION

The author finally manages to develop a prototype with facility to test its performance and drive mechanism. Below is the finished prototype managed to be developed by the author.

Figure 27: Completed PEV prototype

The author also manages to produce and developed the prototype with low cost, easy to maintain, simple mechanism and provides effective turning which may lead into one of the new design of PEV in future. If the overall project is a success, it will not be long before citizens in developing country such as Malaysia are affordable to buy one PEV as their most needed personal vehicle. The author also hope that by the improvement made into existing PEV using data gather by this prototype, it will lead into solution of the world congestion and pollution problems that become worsen especially is metropolitan cities.

Besides, in order to improve the design as well as its performance, the author would like to recommend that the successor of this project will do the following items:

- Conduct simulation using ADAMS or ANSY to get more accurate data on material selection
- Do experiments that involve various type of electric motor using this prototype to evaluate its performance so that the optimum electric motor can be find resulting from the experiment.
- The test is recommended to be done on the road surface rather than at the lab
- All data gathered and obtained from each testing or experiment should be fully utilized so that it will become benefits for future researcher and designer.

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