



Wintec

WAIKATO INSTITUTE OF TECHNOLOGY
Te Kuratini o Waikato



Enabling Development; the design of a Single Seat Wintec Electric Vehicle. (SSWEV)

Engineering Development Project
SCCC701-MG7101

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1.0 Abstract

The research project is related to the single seat three-wheel electric vehicle. Due to the high consumption of the oil in New Zealand (NZ) which have a direct impact on the economy, the authorities are now looking for the alternative source to power the vehicles and revolutionize the transport industry. There is another motive behind the development of electric vehicle (EV) which is linked with the environmental conditions of the country. The Internal Combustion Engine (ICE) vehicles increase the air pollution in the country and due to which the global warming has become a serious issue. To reduce the global warming effect and air pollution the electric vehicles have become a strong candidate or choice for the transportation. This project covers the electric vehicle in three parts: the Road Legal Status of EV in New Zealand, the Battery Electric System (BES), and Vehicle Design. There are some limitations which are associated with electric vehicles such as legislation does not encourage the people to purchase an electric vehicle, and the manufacturers are still interested in ICE vehicles. The research project proposes the desired policy for the EV in New Zealand. The possible design of the EV is proposed which is modeled in SolidWorks. Furthermore, the entire battery electric system and its management is included in the report which describes the proposed Battery electric system for single-seat electric vehicle.

The primary goal in developing the battery electric system of the EV was to ensure that it has long driving range. The current EV are struggling to achieve the long driving range. The design selected for the EV is Reverse-trike. The unique features include the shifting of the centre of mass of the more extensive position. This design provides more stability and traction to the vehicle as the weight shift is towards the front wheels of the car.

2.0 Introduction

This report proposes to outline the design of a single seat Wintec electric vehicle (SSWEV), to advance the utilization of electric vehicles (EVs) in NZ. A single seat electric vehicle is picked on the grounds that around 70% of total vehicle trips worldwide are taken with just a single individual in the vehicle (“Driver,” p. 3). New Zealand government is offering incentives to encourage purchasing and selling pure and hybrid EVs, these efforts are examined alongside the country with the most EVs on the road.

This project is covered in three sections, which are: the Road legal status in New Zealand, the Battery electric system, and vehicle design. Each section is discussed through different perspectives. The first chapter is Road Legal status for EV which is also discussed because the proper legislation is required to support electric vehicle on the road and to ensure the safety of the public on the road. The second chapter is related to BES because of the consumption of electricity and charging time required for the batteries to operate effectively. The third chapter is devoted to vehicle design as that requires detailed modeling of the different parts of the vehicle.

The limitations of the project include the collection of the data related to the road legal status of EV in New Zealand. Another limitation is to be related to the design of the electric vehicle and parts. The design selected for the electric vehicle is the reverse trike because it is compact as compared to the other single seat designs which are proposed for this project. The effective transport system developed by the authorities for the NZ roads regarding EVs. Enthusiasm for batteries for EVs can be followed back to the mid-nineteenth century when the EV appeared. Today, since EVs and HEVs can decrease gas utilization up to 75%, EV batteries have increased recharged consideration in the vehicle advertised. A breakdown of the EV components follows, in order to offer a general overview of EV design aspects.

3.0 Project Background

Since the development of the Internal Combustion Engine in 1807 and vehicle production manufacturing in 1908, vehicles have turned into a principal part of present-day living. New Zealand possess the third highest rate of private vehicle ownership and according to the Organization for Economic Cooperation and Development (OECD) they state that more than 2.6 million ICE cars are registered in NZ (Macinko et al, 2003). However, in spite of their intrinsic helpfulness and significance in everyday travel and work, it is becomingly progressively apparent that the over-dependence of the vehicle segment on petroleum products represents various key social and natural issues.

Dependence on petroleum products is imported mainly from other countries, which impact on national economy. As the greater part of NZ's oil-based commodities are transported in from abroad, New Zealand organizations and customers are helpless against oil supply fluctuations and geopolitical issues outside their control. It additionally constitutes a noteworthy extent of nearby income that is being directed abroad (Barton, 2015). By shifting from internal combustion engine car that depends on other countries' energy generations, would involve to reduce the dependency of petroleum products as well as enhance environment condition.

Other inspirations for shifting to EVs incorporate defeating the ecological worries that are installed in the fabricating and driving of vehicles that utilization petroleum derivative for energy. The new concentration for some countries, including New Zealand is of electric vehicles or a hybrid of electric with another framework for energy. Service of Transport has proposed a declaration about the extensive variety of estimations that will improve the augmentation of the use of EVs in New Zealand. EV's are less expensive in term of consumption of energy.

4.0 Design Features

The design of the electric vehicle is established according to specific standards which includes the road legal status and manufacturing standard of the vehicle. There are different aspects of design which were studied thoroughly according to the international standard. The software which is used for the modeling of the different components of the car is SolidWorks. The visibility, driving range, dimensions, and comfortability of the electric vehicle is designed according to the International Standards to ensure the smooth operation of the car, these standards are discussed below.

4.1 Design Methodology

The battery of the electric vehicle is selected on the basis of the performance improvement, and two major Society of Automotive Engineer (SAE) standards are used for this purpose which includes J537 & J1634. J537 is the standard which is related to the battery storage system of the electric vehicle and J1634 is related to the Battery charging and vehicle electricity consumption. In this project, the Inductive method is proposed for the battery electric system which follows the J1773 standard of SAE international. It is related to the Inductive charging of the electric vehicle

The mechanical components of the electric vehicle are designed according to different SAE standards. The braking system of the single seat three-wheel electric vehicle follows the J1402 standard and wheels of the vehicle follows the J1956 standard. These standard contains the brief guideline for the design of the component and the design developed in SolidWorks for EV is selected from these standards and are compatible with the road conditions of the New Zealand. The body dimension of the passenger car was selected after the analysis of the J1270 SAE standard. The goal was to select the most comfortable and stable body shape for single seat EV.

The accompanying determinations address the ability of the driver to play out the essential visual checks when getting ready to drive and amid driving, the solace and capacity of tenant to drive proficiently, and mechanical properties. The determinations depend on SAE measures as they are utilized universally (Bangdar, 2015).

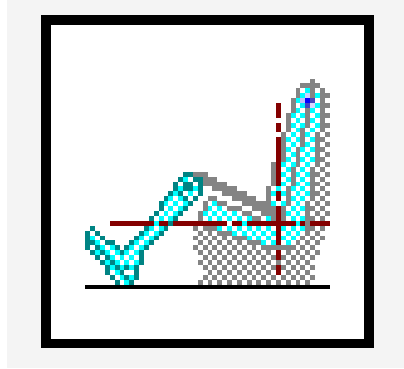


Figure 1: Seating Reference Point (SRP) (KDA, 2014, p. 16)

Occupant packaging standards are related to occupant comfort, safety and ability to drive efficiently (KDA, 2014). Manufacturers use dummy to test these properties for the occupant. In the current research the author, who is the researcher will “replace” the dummy. Driver seating reference curves address the distance the occupant (in this case the driver) can move the seat and takes into account the seatbelt (restraint system) (KDA, 2014). The design for defining the seat measurements is called the H-Point design (See Fig.1). The five measurements that define the location for the SRP are the centerline for the occupant, the seat height, the back angle, the lumbar support and the cushion angle (KDA, 2014).

5.0 Design Outcomes and Drawings

The design of the electric vehicle based on the reverse trike and the different components were designed according to the SAE standards which are described in design feature section. The 2D-drawings are generated in order to understand the proper design of different components. The outcomes of these drawings are the 3D model which is further developed in the SolidWorks. The drawings will help the manufacturers to effectively manufacture the specific parts of the single seat three-wheel electric vehicle. The drawings of the major components which are: steering system, suspension system, electric vehicle body, chassis and braking system are presented in this section. The reason to develop the drawings are to eliminate the constraints which are associated with the development of the components for the electric vehicle.

5.1 Design Outcome

The design proposed in this project for the Electric vehicle and its various components will help in the development and manufacturing of the EV. There are different designs currently in practice in NZ, and some of them are developed by Tesla. However, those designs are not suitable for the single seat electric vehicles due to the weight and expanded body. Therefore, the design is not only compact but also lightweight to ensure the reliability of the electric vehicle and increase its performance.

5.1.1 Steering System Drawing

The steering system is designed according to the following drawing which reflects the side view, top view, and front view. The isometric view of the design is also shown in figure 2 below. To check the drawing of different parts of steering system which includes Pinion Gear, Rack, Universal Joint, and Steering joint see appendix D.

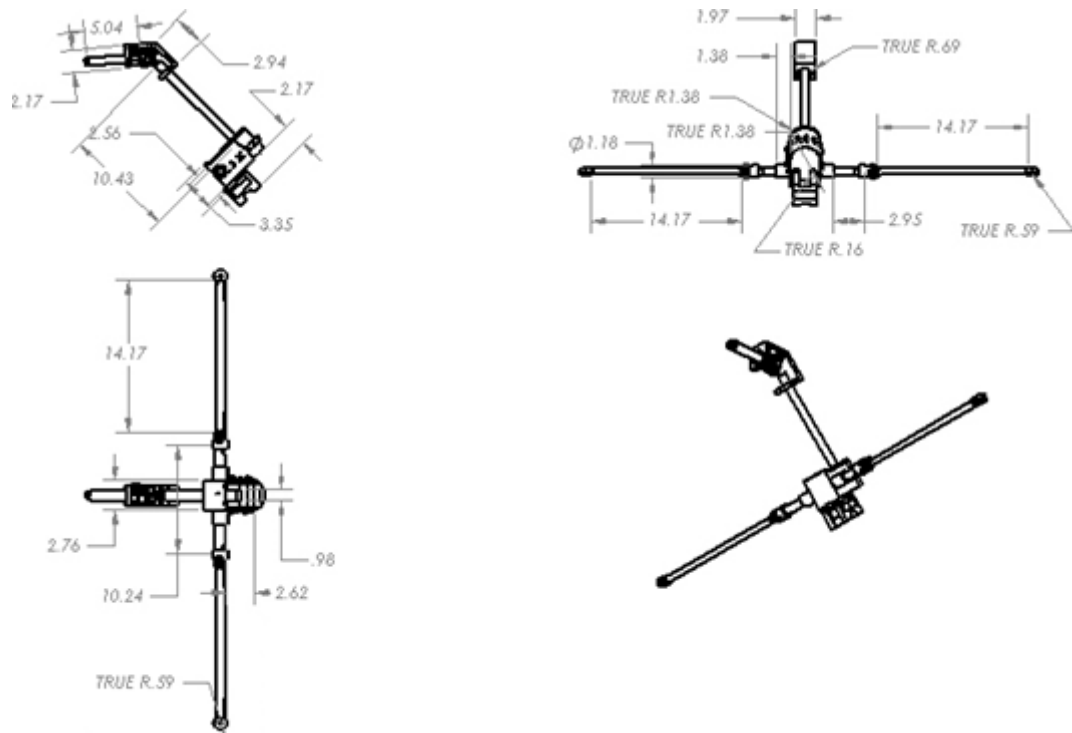


Figure 2: Steering System Drawing (Ytingcom, n. d)

5.1.2 Suspension system drawing

The suspension system is designed according to the following drawing which reflects the side view, top view, and front view. The isometric view of the design is also shown in figure 3 below. To check the drawing of different parts of suspension system which includes Shock Absorber, Wheel hub, Shock Body, Front Axle and Steering joint see appendix E. The dimensions of the major components of the suspension system are given separately for those components

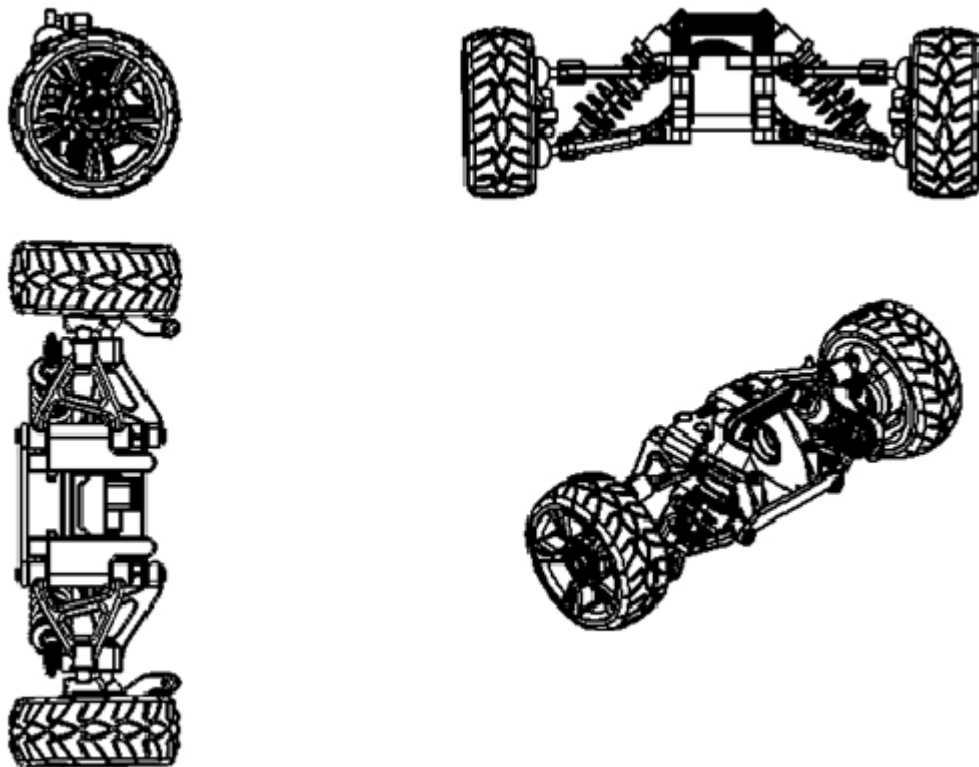


Figure 3: Suspension System Drawing (Ytingcom, n. d)

5.1.3 Braking System Diagram

The braking system is designed according to the following drawing which reflects the side view, top view, and front view. The isometric view of the design is also shown in figure 4 below. The dimensions are given in the drawing according to which the 3D model of the braking system is designed.

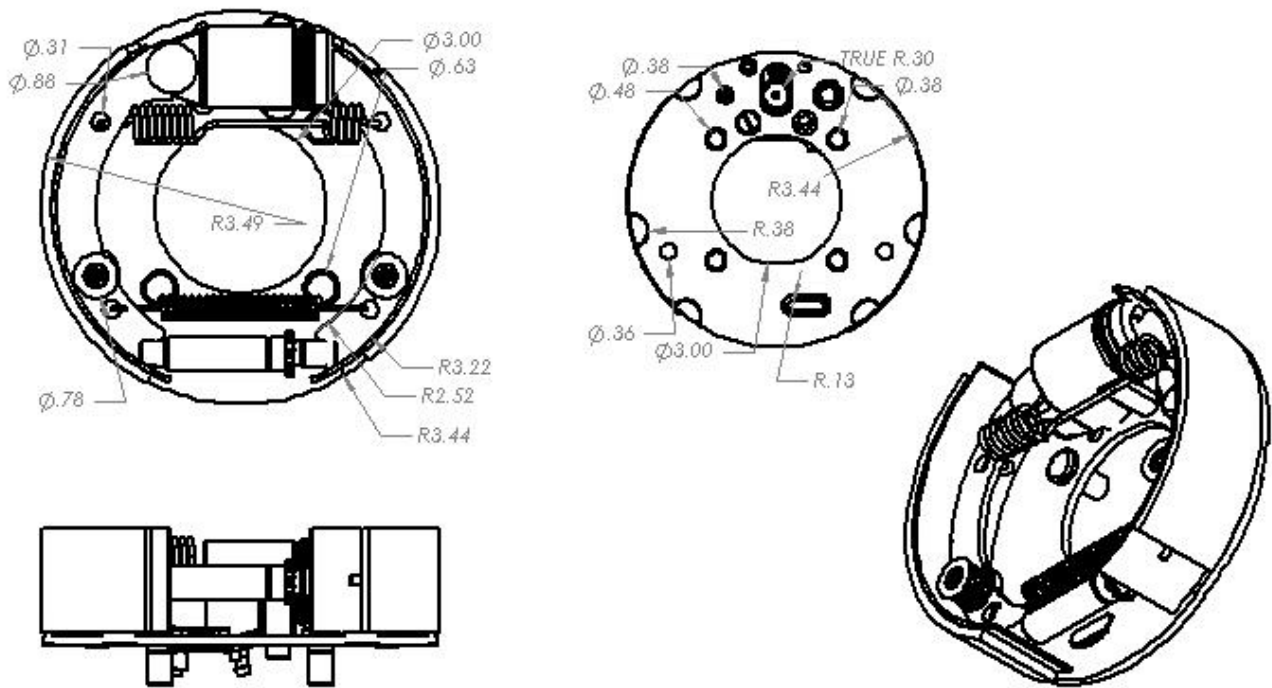


Figure 4: Braking system drawing (Yimgcom, n. d)

5.1.4 Chassis Drawing

The chassis is designed according to the following drawing which reflects the side view, top view, and front view. The isometric view of the design is also shown in figure 5 below. The dimensions are given according to which the 3D model of the chassis is designed.

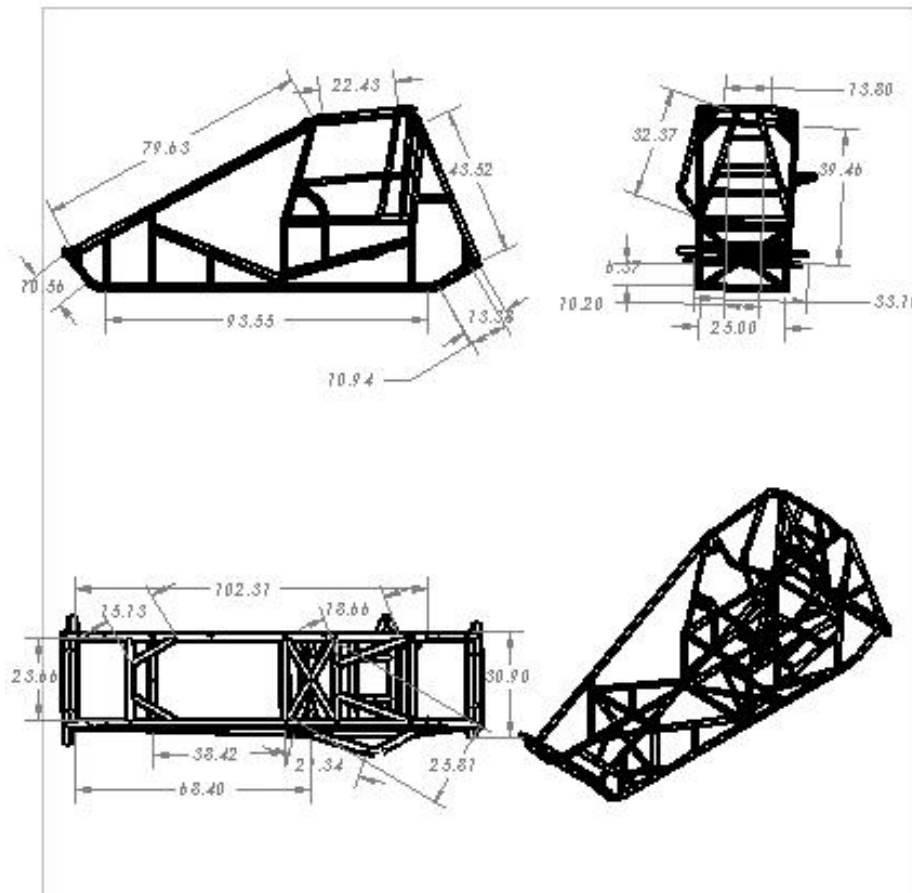


Figure 5: Car Chassis Drawing (Ytimgcom, n. d)

5.1.5 EV Body Drawing

The electric vehicle body is designed according to the following drawing which reflects the side view, top view, and front view. The isometric view of the design is also shown in figure 6 below:

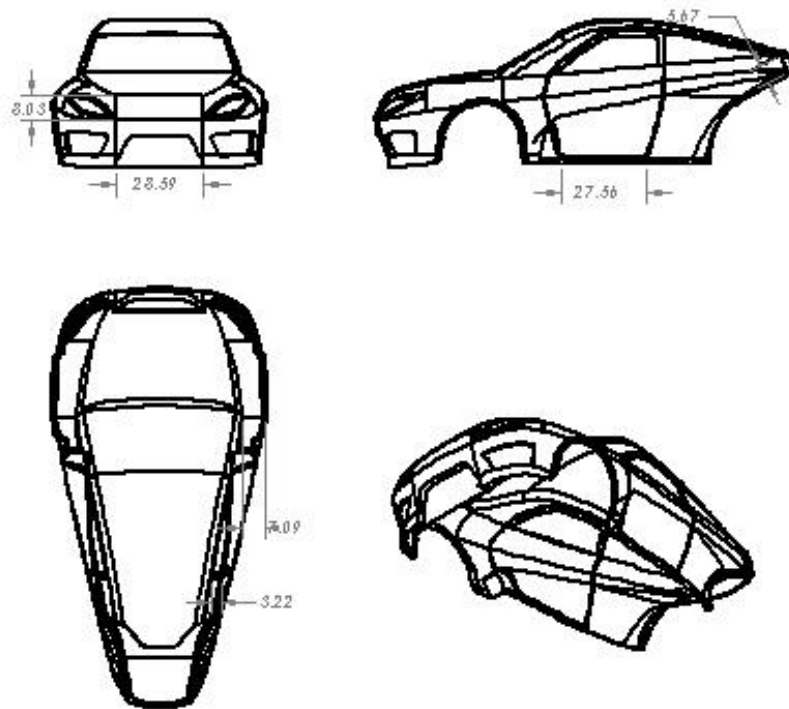


Figure 6: Car Body Drawing (Ytingcom, n. d)

5.2 Methodology

In this section, three phases are comprised to constitute and construct the life-cycle of this project. Additionally, it highlights and identifies some environmental issues and means of transportation problems that require to be addressed. These phases are presented respectively below.

5.2.1 Road Legal Status in New Zealand

This section of the report deals with the legal status of the electric vehicles on the roads of NZ. New Zealand is one of the countries who has an emphasis on the use of the electric vehicles due to reasons which include the pollution, greenhouse effect, and efficiency. The section briefly discusses the effective transport system developed by the authorities for the NZ roads regarding vehicles. There is a valid reason why authority or government need the separate policy and regulations regarding the electric vehicle, and that is the performance of the electric vehicle and its requirement.

In the recent year's electric vehicles have been the main attraction of the automobile companies and government due to their environmentally friendly performance. The current transport system is expensive due to the negative impact on the environment. The greenhouse gases, noise pollution, and petrol consumption are some of the factors which have the main negative contribution (Mark, 2016). New Zealand government has found the alternative to this system which is the utilization of electric vehicles and for that proper legislation is required.

The policy addresses the subsidies, fuel efficiency, and electrical charging stations across the country, carbon dioxide legislation, public awareness, and safety measures. It is very clear that EV policy requires the basic foundation of internal combustion engine vehicles. The main purpose is to develop the policy for EV which eliminates the constraints present in the current conventional vehicles policy (Barton, 2015).

The Goods and Service Tax (GST) is required in NZ because it is suitable for the transport and road conditions of the country. Recommendations are also made for the EV policy, and proper actions are required to be taken to develop the effective mobility strategy which addresses the core issues EV facing in the New Zealand roads. It would force charges and give discounts on an income impartial premise. It would be bolstered by mindfulness measures to enhance general society's understanding and acknowledgment of EVs, and measures to energize the development of charging and upgrades in the value flag sent by the Emissions Trading Scheme (Magnusson, 2012).

In New Zealand most of electric vehicles are short-extend Nissan Leaf hatchbacks with 1276 cars around the country, however, other cars' company such as BMW, Toyota, and Hyundai are less in sale numbers (Magnusson, 2017). Some full measured, long-extend, superior cars by Tesla Motors are found here and are extremely mainstream abroad. The up and coming Tesla Model S will give the primary medium range and cost electric vehicle in New Zealand, however, its prevalence will make long conveyance times. In 2017, the entry of electric cars by Tesla and Volkswagen into New Zealand will expand the determination of electric cars customer can purchase. The three-wheel electric vehicle is still not common on the roads of New Zealand due to the present in the EV policy. The automobile companies can manufacture the three-wheel car once the proper legislation is done regarding EV in the New Zealand.

The electric battery can be charged at home, or wherever customer can locate an electrical attachment, and the fuel tank can be topped off at oil stations. The reason for this is to enable the consumer to drive short separations electrically, effortlessly and without contamination, and long separations are utilizing petroleum, staying away from the need to energize often for long excursions (Dyson, 2017).

5.2.1.1 Safety Rules for Electric Vehicles

The first phase which government and authorities encounter during the legislation of Electric vehicle is the safety of the driver and other people on the road. Safety is most important for the automobile companies and government emphasis on the safety of the consumer. The electric vehicle technology is the emerging technology in the New Zealand and due to the lack of public awareness and knowledge can cause the potential risk on the road to the consumer (Barton, 2015). Some of the safety issues which are associated with the Electric vehicles are explained below:

5.2.1.2 Electric System Risks

Electric vehicle technology carries the inherent risks because this technology is based on the electric propulsion technology. Batteries have become the center of attraction for the manufacturers because the electric vehicle uses more batteries as compared to conventional cars. The safety concerns which are associated with the battery includes the leakage of electrolyte, and its cause is cell casing damage. The chemical reaction within the battery at extreme temperature is also a risk that might cause an explosion, and most importantly short circuit can cause severe damage to consumer and vehicle. Therefore, the Ministry of Transport has set the guideline for the manufacturing of battery and electric system of electric vehicles. The guideline includes the series of test to perform before approval of the product and utilization of alternative method to reduce the risks associated with the electric system of the car (Ethan, 2017). The lithium ion in the batteries is profoundly receptive, and the electrolytes are exceptionally combustible.

5.2.1.3 Low Noise Risks

The low noise in the operation of the vehicle is considered as the advantage in the electric vehicle can also become the cause of the accident. The reason is that due to the lack of engine noise in electric vehicles the consumer cannot judge the engine condition or problem unless there is proper signal system is provided in the car. That is why Ministry of transport has issued a guideline for the safety of electric vehicles on the road and the sensor which must be installed on the car to reduce the risk of an accident. The warning signal system can alert the consumer in the absence of noise from the engine (Miller, 2013).

In conventional cars, the engine noise can indicate the risks or damages to the engine, but in the Electric vehicle, it is hard to detect the engine noise. The pedestrians were able to detect the engine noise from conventional cars at the distance of 36m, but this was not in the case of electric vehicles.

According to study, the electric vehicles like Toyota Prius have very low engine noise due to which pedestrian was only able to hear the engine noise from distance of 14m. This raised the safety concern for the pedestrian on the roads and especially for the blind pedestrian and those have poor hearing sense. That is why proper warning signal systems are required within the electric vehicle which indicates any minor problem in the engine. In an examination of 15 outwardly hindered members, the expansion of moving toward Vehicle Sound for Pedestrians (VSP) ready framework to an HEV brought about essentially faster and more solid discovery than an indistinguishable vehicle with no VSP framework, and a traditional ICE vehicle.

There are no distinctions to separate between the expected pathways of the vehicle proposing that a VSP framework may just empower quicker recognition of the nearness of a vehicle (Barton, 2015). The study also proves that most pedestrians respond the engine noise quickly as compared to siren or horn of the car.

5.2.1.4 Electric Vehicle Charging Guidelines

The New Zealand Ministry of Transport has issued safety guideline for the charging system of the electric vehicle. The charging system if not use according to the guideline can cause potential damage or risk to the consumer and electric vehicle. According to the guideline, the EV charging stations must be designed and installed according to the Electric Safety Regulation 2010. This includes the testing of the charging station and its inspection. The most important risk, in this case, is a short circuit which can damage the entire charging station. The guideline emphasis on the transportation companies to develop the charging stations which are supplied from the sub-circuit and protected by the Residential Current Device (RCD), which is compatible with the charging supply for an EV and it, is for the personal protection of the consumer. The charging stations must have the earth continuity monitoring system because it can disconnect the supply in case of any potential risk or accident (Simon, 2007).

The disconnection can cause the electric supply to stop and hence saving the severe damage. In this case, the monitoring system protects against overload of either charging supply or incoming supply.

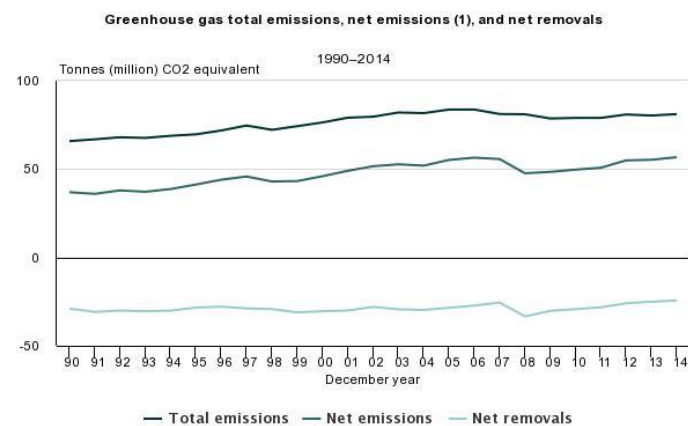
The guidelines indicate that all the operations of the EV charging station must stop working to the safety or in other words, must fail. The charging stations play an important role in the safety of the EV and Road. The person or company wants to install the EV charging station must verify the design and construction of the station to ensure that it is compatible with the guideline provided by the New Zealand Ministry of Transport. The charging station must have a supply at a nominal frequency of 50Hz. The charging stations must keep the record of test certificates which are required for the operation of the EV charging station to comply with the ICE standards. The EV charging stations are bound to follow the NZS 3000 rules and regulations which are related to the manufacturer's instructions (Widdman, 2012).

5.2.1.5 (GHG) Emissions Regulation

The motor vehicle sales are usually based on the efficiency standards. The efficiency standard includes fuel efficiency and performance of the vehicle. The greenhouse gasses (GHG) emission is the standard for the cars which is regulated across the globe. The reason to use the GHG emission standard is to tackle the increasing threat of climate change and global warming.

Productivity models are typically coordinated at the normal execution of the fleet of vehicles that a maker or merchant offers in a year. It gives an organization and the obtaining open some significant adaptability; the organization can offer less proficient models as long as they are adjusted with offers of the more effective models in its range (Monteiro, 2005). It is practicable to complete this averaging exercise where an organization makes or imports thousands or a huge number of vehicles, yet it might be more troublesome if the market is comprised of various little organizations.

In New Zealand, an efficiency standard was considered in 2008. However, it was dropped after a change in government. The reasons given by the Ministry were that the measures would be unpredictable and that its expenses would exceed its advantages (Magnusson, 2012). The Minister's Cabinet paper noticed that vehicle GHG emanations had been rising, and that basically all developed nations had a system to control and enhance the normal mileage of vehicles entering their fleet, either by a motivating force customized or by a normal efficiency or CO₂ standard. It contended that New Zealand had included vehicle powers in its Emissions Trading Scheme; that there was an intentional pattern towards more productive vehicles, and that the expenses of control would be considerable, particularly due to the huge number of little shippers of utilized ICE vehicles.



Source: Ministry for the Environment

Figure 7: GHG Emissions in New Zealand (Wordpresscom ,2014)

5.2.1.6 Legislation of Electric Vehicles

This section illustrates the legislation system which is desirable to the electric vehicles and this arrangement is distinguished that have believability and a demonstrated record of accomplishment globally, and that is reasonable for New Zealand conditions. The main points of the legislation are mentioned below:

- The user charge plot, applying to the entire of the light engine or electric vehicle system, in the event of the underlying enrollment of a vehicle in New Zealand, giving a value advantage or charge on the premise of the CO₂ discharges of the vehicle. The measure of advantage or charge per unit of emanations would be set to give a genuine effect on the choice of vehicles in the New Zealand advertising, and the rotate point would be re-set consistently to create income lack of bias. A successful expense bate framework would evade the need to present value sponsorships for EVs. It would work as a type of fuel productivity standard for the advantage of the electric vehicles (Barton, 2015).
- Public Awareness measures to enhance open mindfulness, observations, and information of EVs as a choice. The measures should be precisely coordinated at various gatherings of people, and outlined in the light of research on recognitions and conduct.
- Measures to support the development of an open charging framework; standard-setting for charger fittings and correspondence conventions, and forces for street controlling experts to oversee road movement.
- Enactment to give lucidity and perpetual quality of approach expectation, enhancing the venture atmosphere, evacuating obstructions, and clearing up purposes of vulnerability.
- Value weight on the utilization of hydrocarbon fills through the Emission Trading System (ETS), at a level sufficiently high to realize changes in vehicle utilize.

5.3.1.7 Charging Facilities Rules

The legislation should cover the charging facilities rules within the New Zealand. Openly available chargers can be introduced in work environment and mall stopping, and as the quantities of EVs increment, it is likely that administration stations and different organizations will discover business specialties to offer rapid charging. If charging offices are to be given in the city, the city or locale chamber should oversee stopping and signage. A few urban areas, cooperatives, and organizations may advance EV auto-sharing plans (Barton, 2015). Although providing the public charging facility can have a positive impact on the public awareness regarding electric vehicle but most of the owners rely on the ordinary charging facility in their garage. The research indicates that almost 85% of the houses in New Zealand have garages which means that people or public is more comfortable with having the charging facility in their garage for overnight charging of the electric vehicle. Therefore, proper legislation is required.

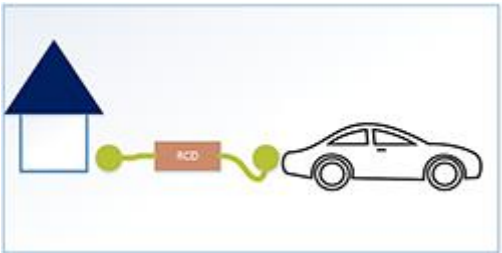
The general picture that is probably going to unfold is one where there is positively a requirement for some administration activity to empower the development of a successful charging system (Ethan, 2017). However, where the private organization is by and largely ready to lead the presentation of the innovation, and address the issues of vehicle proprietors if genuine quantities of EVs begin to show up. There is a plan for the law change, not being investigated in detail here, to approve standard-setting for chargers, and to guarantee that nearby government and road controlling authorities have the fundamental bearing and powers to oversee and advance EV charging offices (Dyson, 2017).



Component energy affirms this conclusion, which demonstrates that it is not vital for the administration to give extensive scale access to a national open charging framework for early EV reception. The examination and research conclude that an open system may give some level of mental consolation and that it should develop later on, however, that the very suitable locations for charging will be in off-road stopping, to which 70 for each penny of new auto purchasers approach. Government activity in giving charging framework does not appear to be the way to EV take-up.

The fundamental part of government activity in New Zealand is by all accounts direction for standard-setting and the advancement and control of on-road movement, for example, stopping at charging points.

The New Zealand Ministry of Transport has issued safety guideline for the charging system of the electric vehicle. A ‘mode’ describes the safety communication protocol between electric vehicles and charging stations. These are internationally recognized definitions. In this project, only Mode 3 and Mode 4 are suitable for public charging infrastructure in New Zealand. The modes are outlined below:

Table 1: away from home infrastructure (Ministry of Transportation, 2016)

Charging mode	Description	Recommended use
<p style="text-align: center;">Mode 2 - commercial</p> 	<ul style="list-style-type: none"> ✓ The electric vehicle is connected to the AC supply network (mains) using a standardized single-phase or three-phase socket outlet. ✓ Single-phase and three-phase socket outlets must not exceed 32A or 250 V AC. ✓ An in-cable control and protection device (IC-CPD) must be used to protect the user. ✓ Charging capability up to 22kW. 	<ul style="list-style-type: none"> ✓ Suitable for controlled environments with restricted access. For example hotels, fleet car parks and repair facilities.

Charging mode	Description	Recommended use
<p>Mode 3</p> 	<ul style="list-style-type: none"> ✓ The electric vehicle is connected to the AC supply network (mains) using an electric vehicle charging station. ✓ The control device is contained within the electric vehicle charging station, permanently connected to the AC supply network (mains). <p>Charging capability up to 43kW.</p>	<ul style="list-style-type: none"> ✓ Suitable for public charging infrastructure.
<p>Mode 4</p> 	<ul style="list-style-type: none"> ✓ The electric vehicle is connected to the AC supply network (mains) using an electric vehicle charging station with an off-board charger. This mode supplies the electric vehicle with a DC supply. ✓ The control device is contained within the EV charging station, permanently connected to the AC supply network (mains). ✓ Charging capability up to 50kW. 	<ul style="list-style-type: none"> ✓ Suitable for public charging infrastructure.

5.2.1.8 Public Awareness

Instructive and data measures are in this way fundamental. In fact, in New Zealand, most people use the cars as the primary means to travel due to which the charging facilities can charge the EV on the road fully. However, hybrid module cars do not have huge range restrictions by any stretch of the imagination, yet 'range' is a worrying issue by numerous potential purchasers.

The uncommon number plates in Norway are a decent case of a push to enhance open mindfulness, recognizing EVs and giving them special rights as to transport paths, stopping, street charges and ships. Advantages of this kind, principally non-money related advantages, are probably going to support EVs, and do not force evident financial expenses. They are likewise measures that a district can execute (Simon, 2007).

In New Zealand, the energy efficiency and conservation authority created an online instrument for vehicle buyers to analyze the aggregate cost of responsibility for EV and different cars. Corporate or government vehicle acquisition on a huge scale can likewise goad EV deals, by driving popular supposition and quickening economies of scale (Erik, 2012).

Nonetheless, there might be a component of sponsorship in such buys on the off chance that they are costlier than ICEs unless there is a business defense. The authorities can set the specific goal to include the number of EV cars in the current fleet of cars to support the production and consumption of EV cars.

A current public awareness measure applying to all vehicles in New Zealand is the Energy Efficiency Regulations 2007. Its references to liters per 100 km are inadmissible for EVs, yet a variety has been presented, giving buyers a gauge of efficiency in light of power costs. More broad public awareness measures for EVs are plainly fundamental and are boundless globally. It is impossible that they are sufficient all alone to change the perspectives of planned buyers to such an extent as to exceed the hindrances of high EV buy costs, constrained driving reach, and the restricted assortment of models; more so where ICEs do not confront critical control of GHG emissions. Public awareness approaches in this way have a part in supporting strategies went for cost and fuel effectiveness.

5.2.1.9 Legislation Statute

The legislation statute can have the significant impact on the usage and public awareness of EV. A statute is a formal and moderately perpetual articulation of the collective goal, which underscores that an issue is not simply one of individual activity, and that makes a setting for the crystallization of general sentiment. It sends more grounded motions about the term and steadiness of strategy than does an approach explanation or an official clerical statement, and essentially enhances speculation assurance (Li, 2013). A statute can likewise present a command on an office that is then plainly assigned as the champion for the strategy, and that has a claim on monetary assets to do that statutory obligation. That is why in New Zealand the Ministry of Transport must form the Statute of EV to ensure the security of EV in the future. In New Zealand, an Act or Amendment of this kind could deal with focuses that have been noted where changes to the law appear to be important to expel a hindrance. Examples are the authorities and forces of the electricity authority, the authorities and forces of street controlling experts, and the setting of benchmarks for charging hardware. Fuel productivity guidelines, as they have seen, are as of now conceivable under the Energy Efficiency and Conservation Act 2000. A charge bates conspire presumably requires a change of the Land Transport Act 1998.

5.2.1.10 Desirable policy for New Zealand

The New Zealand Minister of Energy and Transport is excited about EVs and says a policy is an underdevelopment, with an accentuation on organizing charging focuses and enhancing public awareness, and with a notice not to expect appropriations or government financing of charging focuses. The investigation of the present road rules and legislation in regards to EV have given the diagram of the present circumstance of EV in New Zealand. However, a few decisions about the character of EV arrangement for New Zealand are separated from the examination which is portrayed beneath:

- There are clear open approach methods of reasoning for activity to energize EVs in New Zealand, in the specifically associated issues of GHG emanations, energy proficiency, and energy security, and in connection with air contamination.

- Arrangement for EVs should be a piece of a general versatility system that takes a 'stay away from, move, enhance' approach that incorporates urban and provincial settlement shape, open transport, the upgraded person on foot and cycle get to, and rising types of 'portability administrations.' EVs have parts to play in a supportable society, despite the fact that they are not the 'one major arrangement' to all vehicle issues. It is not important to anticipate the specialties that EVs will fill first (Barton, 2015). EVs may well give individual portability to driving. Be that as it may, there might be less promptly predictable potential outcomes for heavier EVs on long courses, for example, mail conveyance and waste accumulation.
- Public awareness and policy is distinguished as the fundamental driver for the take-up of EVs. Without open strategy activity, on capital cost as well as foundation and open mindfulness, the market settings of the present and the medium-term future are probably not going to deliver the important force. Non-financial strategy measures, for example, EV stopping and path benefits, and consolation of charging foundation are imperative, despite the fact that their genuine impact even with the value issue and without fuel productivity measures is suspicious. Different arrangement activities are required, as opposed to one single whole arrangement.
- A take-up of EVs is uncommon in authorities that do not have noteworthy financial motivators for value bolster. The value hindrance, particularly the forthright capital cost, is a noteworthy obstruction to EV buys without some value bolster. There are different issues influencing buy choices.
- New Zealand is particular globally in not directing vehicle fuel effectiveness at all past a marking necessity. Not very many nations, assuming any, are attempting to advance EVs without fuel proficiency measures. It may not be conceivable to advance EVs without fuel proficiency prerequisites; it would make EV approach with one hand tied behind our backs. New Zealand may not prevail with EVs on the off chance that it tries.
- There is plentiful proof that a compelling ETS gives a general value motion for the consuming of hydrocarbon fuel that is vital, however not adequate alone, to actuate critical change. The New Zealand ETS, obviously, should be fortified considerably to wind up plainly compelling.

- The approach ought to be specifically connected to vehicle CO₂ discharges. The strategy should apply to the whole vehicle armada, not a subset thereof. The strategy should set expenses that differ persistently over the range of CO₂ discharges, instead of charges that apply to a constrained CO₂ territory or expenses that are invariant over a secured scope of CO₂ outflows, just like the case with stepwise arrangement structures.
- Strategies that apply both to the season of procurement and all through a vehicle's lifetime impact a customer's vehicle substitution choice and, in this manner, can yield more noteworthy CO₂ diminishments than a solitary time-of-procurement arrangement alone.

5.2.1.11 Crashing test of electric vehicle

The electric vehicles can be tested by applying various scenarios which can determine the crashworthiness of electric vehicles.

First scenarios named moderate overlap front crash test. A dummy is placed inside the car acting as driver and the car moves 64 km/h letting a 40 percent overlap on driver side to hit a deformable barrier. The second test is small overlap front crash. This test is similar to previous crashing test but 25 percent overlap on driver side hits a rigid barrier with radius on the right edge. Other test is Side crash test. The car moves 50 km/h and hits a deformable mobile barrier into driver side. The last test is roof strength. This test involves that a quasi-static loading is placed on driver side of vehicle (O'Malley, 2016).

After the tests are accomplished the features of rating are given the car in each test mode. According to the measurements obtained by sensors during the test as well as noticeable movement and measurements of safety cage deformation the ratings of crash test are determined. However, the roof strength test is based on the crashing test force and displacement of the platen (O'Malley, 2016).

It is concluded that thinking about a more extensive variety of strategy measures coming into utilization to energize the take-up of EVs, one is actuated to come back to the explanations for them; air contamination, commotion, environmental change, energy security, and vitality productivity for the most part. The justification for urging EVs is to be found in the externalities and other market defects that lead us to utilize petroleum derivatives in unsafe ways and found in economies where little power is produced from non-renewable energy sources. All the more particularly, approach enthusiasm for EVs emerges in the examination with Internal Combustion Vehicle (ICV). It emerges by approaching how EVs are better for people and society in correlation with the option, ICV.

The EV approach practice is essentially one of examination with ICVs. It along these lines requires precise examinations that incorporate a full scope of social expenses, and specifically the non-disguised expenses of contamination, atmosphere, and wastefulness. At exactly that point can the genuine cost of EVs be assessed. At the center of our contention is that the examination of EVs should contrast like and like. Another result is that an EV arrangement fundamentally incorporates ICV approach. This is especially applicable to New Zealand which doesn't have fuel effectiveness principles.

5.2.2 Battery Electric System (BES)

The battery is one of the most important components of the electric vehicle. It is also the essential part of the internal combustion vehicle and is used as the main source of energy in different applications. Enthusiasm for batteries for EVs can be followed back to the mid-nineteenth century when the EV appeared. Today, since EVs and HEVs can decrease gas utilization up to 75%, EV batteries have increased recharged consideration in the vehicle advertised. Boston Consulting Group has revealed that, by 2020, the worldwide market for cutting-edge batteries for electric vehicles is to reach NZ \$25 billion, which is three times the measure of the present whole lithium-ion particle battery showcase for purchaser hardware (Chon, 2007).

The hybrid electric vehicles and pure electric vehicles mainly run on the effective battery electric system within the car. This section of the research focuses on the battery electric system and explore the different dimensions of the system. The goal is to identify the maximum capacity of the battery for EV and the effective battery management system requires in the Electric vehicles.

To develop the market, the offer of EVs and HEVs, safety and dependability are the best worries of clients. Notwithstanding, the two are liable to the battery innovation as well as the administrative framework for the battery. Hence, a Battery electric framework goes about as the connector between the battery and the vehicle, assumes an essential part in enhancing battery execution and streamlining vehicle operation in a sheltered and dependable way (Corey, 2008). In perspective of the quick development of the EV and HEV showcase, it is critical to building up a thorough and develop BES. Like the motor administration framework in a fuel auto, a gauge meter ought to be given by the BES in EVs. BES pointers should demonstrate the condition of the security, utilization, execution, and lifespan of the battery.

At any irregular conditions, for example, finished voltage or overheating, are recognized, the BES ought to advise the client and execute the preset adjustment method. Notwithstanding these capacities, the BES likewise screens the framework temperature to give a superior power utilization conspire and speaks with singular segments and administrators (Bangdar, 2015).

5.2.2.1 Current BESs

Far-reaching and develop BESs are at present found in versatile gadgets, for example, smartphones PDAs. However, they have not been completely sent in EVs. This is on account of the quantity of cells in a vehicle's battery is several times more prominent than that in compact gadgets. In addition, a vehicle's battery is planned not exclusively to be an enduring energy framework, yet in addition to being a powerful framework. Batteries for EVs and HEVs need to give high voltage and high present. These make BESs for EVs significantly more than those for versatile hardware. From an equipment structure point of view, three sorts of topologies have been executed in BESs, including incorporated, conveyed structures (Ethan, 2017).

The elements of the BESs for each situation are comparable. These ideas can be consolidated into a bland BES structure with the fundamental capacities as appeared in Figure 8. Different sensors are introduced in the battery pack, the information is utilized to keep up the framework's wellbeing and decide the battery state. The battery state decides the charge time, release system, cell evening out, and warm administration among the cells.

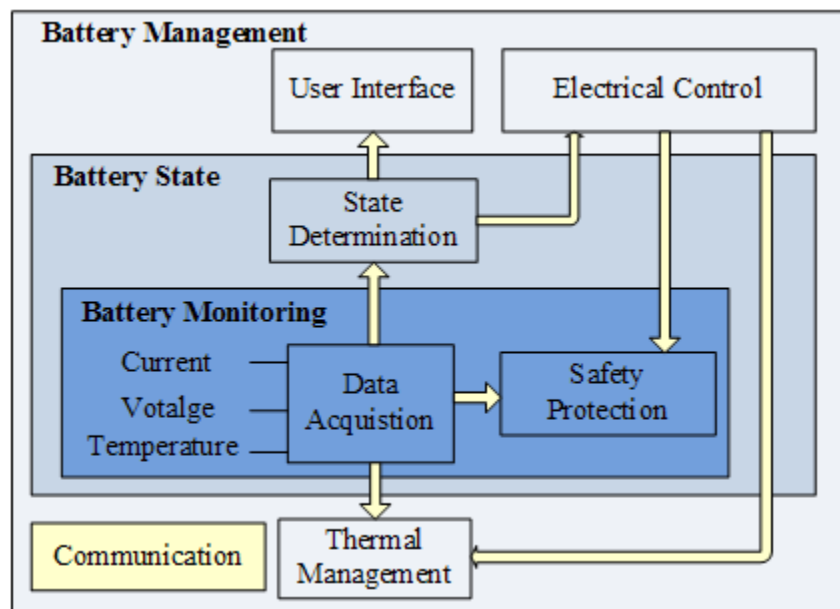


Figure 8: Battery Electric System (mdpi, 2017)

The current commercialized BESs each perform the basic functions differently. Drawbacks of the mentioned BESs include the following:

- Restricted information logging capacity. The information logging capacity assumes a vital part in database foundation, which stores the driving example. This profile can develop and refresh the condition of charge display (Corey, 2008).
- Non-exchangeable among current BESs. As each battery electric unit (BEU) has its own particular cell adjusting plan also, correspondence instrument, it is difficult to use the current segments to frame a new BES.

5.2.2.2 Current Limitations of BES in EV

In light of its promising properties, for example, high energy thickness, long life cycle, and low self-release, lithium-particle battery innovation has been created and connected in the previous decade when the advancement of BESs for EVs has been moderate and inadequate (Isac, 2011).

5.2.2.3 Battery State Evaluation

Learning of the battery state not just decides if the operational condition is protected and solid yet, also, gives data about the charge-release operation, which is particularly imperative for cell adjusting. Usually, the battery state incorporates with State of Charge (SOC) and State of Health (SOH) assurance. SOC is the fuel use sign in petrol vehicle, yet the battery is out of reach for measuring, differing natural conditions, and charge-release cycles, which will make it troublesome for a BES to give a precise SOC estimation.

The State of Health represents the level of battery life remaining. In any case, there is no agreement on the meaning of SOH since it does not compare to the estimation of a particular physical quality. Despite the fact that the proportion of the present ability to the most extreme limit that the battery can hold, it is typically seen as a wellbeing marker, more parameters alluding to the field execution must be considered amid SOH assessment (Lowe, 2010). The genuine recipe of the SOH for a particular application is frequently a competitive innovation.

The System Operating Limit (SOL) is alluded to in writing as the time when the battery must be replaced. It is like SOH, yet evaluates the rest of the time until the point when the battery will be not able to perform. Forecast of battery execution encourages the architect to design upkeep techniques, and handle transfer and substitution issues.

5.2.2.4 Battery Modeling

Setting up a battery is troublesome because of the confused electrochemical components of batteries. From the viewpoint of synthetic qualities. There are distinctive voltage-to-limit profiles of a few Li/Li⁺ materials. As of now, battery displaying for SOC assurance is created from different proportionate circuit (RC organize) models, which are particular for various material attributes and exactness prerequisites. In any case, the non-exclusive model depends on the supposition that the inside protection is steady amid charge and release cycles. Along these lines, the precision of this model is liable to challenge (Ethan, 2017).

5.2.2.5 Cell Balancing

In EVs, cells are joined in the parallel to shape a square while a few pieces (or cells) are associated with an arrangement to give a high voltage. Every phone in particular because of assembling and concoction counterbalance. Hence, the cells in an arrangement have a similar current yet unique voltage.

As it was, it will experience the negative effects of overcharging while all whatever is left of the cells achieve their full charge. So also, finished release may occur on the weakest cell, which will flop before others amid the releasing procedure (Roger, 2012). At the point when the battery comprises of multi-cells in the arrangement, it will be liable to a higher disappointment rate than any single cell because of an arrangement organize.

5.2.2.6 Different Batteries Performance

In this section, the different batteries are compared to determine the most suitable battery for the electric vehicles. There are different factors which have an impact on the performance of the vehicle battery system. Cost is dependably a main consideration, and the nickel–metal hydride (NiMH) battery finishes the rundown in cost with overwhelmed lead batteries being the most modest. What is lost in the cost interpretation is the way that NiMH batteries yield almost double the execution than do traditional lead corrosive batteries (Ethan, 2017). The charging and discharging time of the battery is also considered as the crucial element in the performance of the battery because mostly lead battery requires significant time for charging which can exceed up to 8 hours.

Lead batteries, on account of their synthetic composition, cannot manage high voltage consistently during the process of charging. The lead plates inside the batteries warm quickly and cool gradually. An excessive amount of heat brings about a condition known as "gassing" where hydrogen gas is discharged from the battery's vent top. After some time, gassing diminishes the viability of the battery and furthermore builds the requirement for battery upkeep. Batteries, for example, NiCad and NiMH are not as vulnerable to warm and can be revived rapidly, taking into consideration high voltage charges which can bring the battery from a 20% condition of charge to 80% condition of charge in as brisk as 20 minutes (C. Gerdes, 2011).

5.2.2.7 Lithium-ion Battery

There are two important factors which have an impact on the performance of the battery, energy and power. Energy is taken as the main driving source for the battery. The ability to-energy (P/E) proportion indicates how much control per unit of energy is required for the application. EVs just utilize an electric engine fueled by batteries to control the vehicle. Batteries for EVs require more energy limit given longer driving extents, so EVs have the most minimal P/E factor (Lowe, 2010). The battery gets completely charged and released (profound cycles) and requires 1,000-cycle sturdiness. The battery size of EVs is bigger than that for PHEVs or HEVs. Lithium-particle battery packs for conservative EVs will utilize 1,800 to 2,000 cells (Gerdes, 2011).

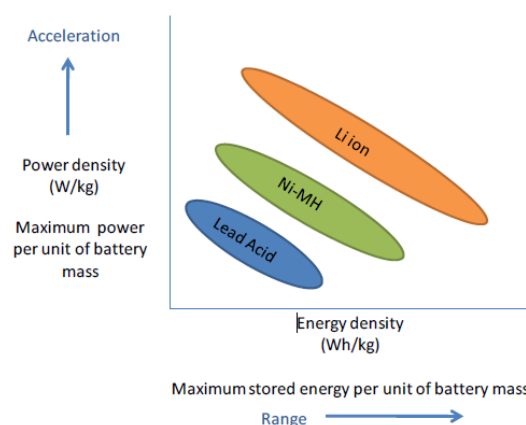


Figure 9: Different Batteries Power Graph

Lithium-particle batteries have a vast potential to additionally expand energy thickness by utilizing propelled anode and cathode materials. Lithium-particle batteries' energy thickness is expanding quickly.

5.2.2.8 Battery output power

Pure electric vehicle type uses chemical energy that is stored in the rechargeable lithium battery pack. Thus, EVs must have electric motor as well as controller instead of internal combustion engine for propulsion. Based on (goldenmotor, 2017) they state that Brushless Direct Current (BLDC) motors are widely utilised for many applications such as scooters, forklift and EVs. In fact, the power range of BLDC is between 200W – 20KW which ideal in our design, hence, the two motors will be used in the design are between the range 10-15 KW. In addition, a controller is a necessity for linking the battery and motors and producing enough amperes.

Meanwhile, Battery system for the project of SSWEV is dependent upon the peak motor current draw, motor operating voltage and its controller and the capacity (Holmes, 2016). Consequently, the amount of input power that is required to drive the EV is thirty cell lithium-ion pack with 128V, 80AH, and 13kWh. This amount should be fine for a lightweight single seat used for commuting or short trips, but not applicable for long-range distances. The battery pack weight needs to be light so the overall weight will remain light, so, 15 cell lithium-ion pack is estimated to weight is less than 100 Kg which in our case is lighter considering one cell is 6.2 Kg weight.

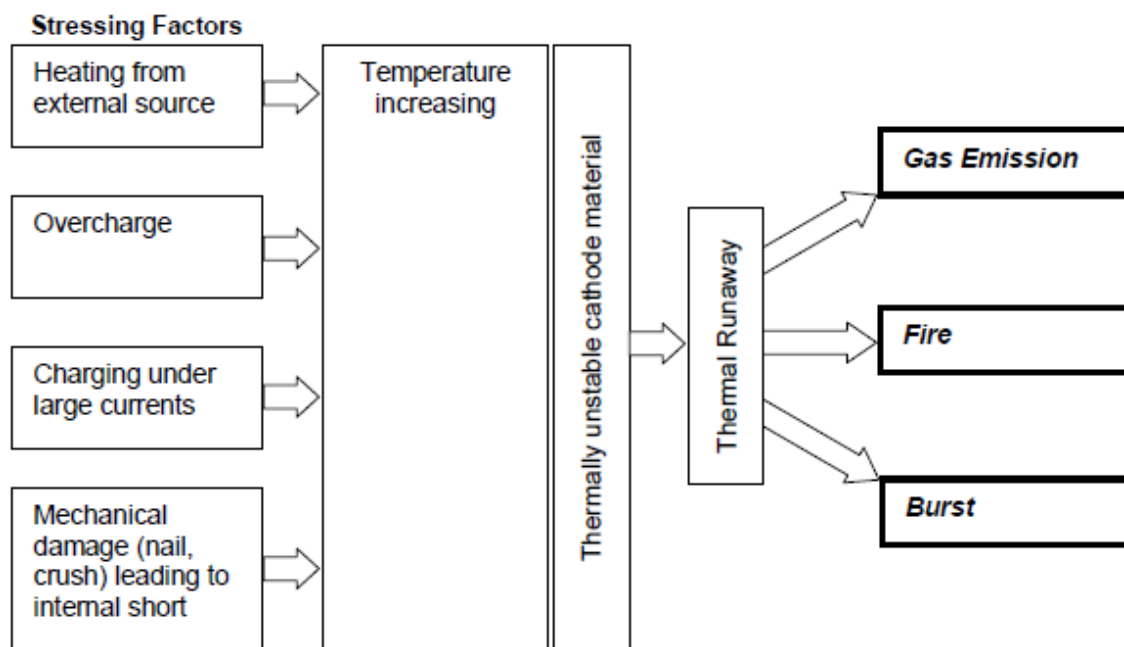


Figure 10: stressing factors list (Schafer, 2011, p. 83).

Most battery failures, associated by thermal runaway, and thus that result an internal fault caused by stress factors as shown in figure 10 (Schafer, 2011, p. 83). Despite, the chemical material and processes involved too in this failure. An example is taken to show the heat and the thermal runaway if the battery pack is in a short circuit condition. It can be assumed that battery pack is heated in an adiabatic condition which means it will get heated very quickly without transferring heat to surroundings. Battery internal resistance controls the electrical stored energy that is converted to thermal energy. An assumption is made that temperature is 20°C and the thermal runaway starts when the temperature is above 100°C (Schafer, 2011).

Lithium-ion pack specifications are exemplified to be:

- Pack configuration; 88S1P (88 Series 1 Parallel)
- Pack weight 160 kg
- Voltage 360V
- Heat capacity C_p Range = 1000 – 4000 J/kg/K
- The cell internal resistance is assumed as 1.0 mΩ.

According to Schafer he stats that when the battery cells are placed in series would give pack internal resistance with $88(1.0) = 88 \text{ m}\Omega$ (p. 83). The short circuit pack is going to draw $360/0.88 = 409 \text{ A}$ at a power of 147 kW. So, the energy that would take to heat the battery up to 100°C can be estimated by using the following expression;

$$Q = m C_p \Delta T$$

Where:

m = mass (g)

C_p = specific heat capacity

ΔT = change in temperature (Final Temperature – Initial Temperature = ΔT)

$$Q = m C_p \Delta T = (160)1000(80) = 12800 \text{ kJ}$$

At this heating power 147 KW that would give $12800 \text{ kJ} / 147 \text{ KW} = 87$ seconds time to get the battery heated. In fact, that rough calculation illustrates that during a short circuit in the battery pack of EV would result uncontrollable thermal runaway in about 1 – 6 minutes. It must be noted that with such a high temperature the amount of cell internal resistance will decrease in association with short circuit.

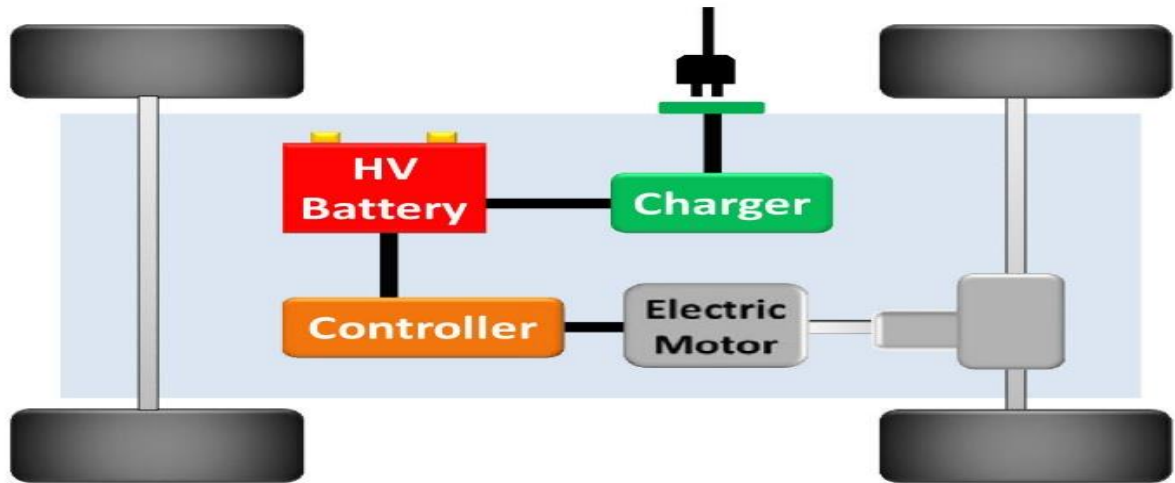


Figure 11: battery electric main components (springernature, 2017)

The figure above illustrates the basic version of EV main components which consists battery pack, controller and motor. The battery is providing a direct current which is goes to the inverter. In our case, a BLDC motor is used, so inverter is not used to convert direct current to alternating current in order to feed motor as it requires because the battery and the motor are in Direct Current. Then the motor will convert the electrical energy into mechanical energy. Preceding, the controller is used to supply a controlled energy as the acceleration pedal is pressed. As the BLDC motor is highly recommended for EV, induction motor or (AC) is not applicable in our design, table below shows BLDC verses AC motor:

Table 2: BLDC vs induction AC (springernature, 2017)

BLDC Motor	AC Induction Motor
<p>The speed/torque characteristics is flat in nature. It enables operations at all speeds with rated load.</p>	<p>The speed/torque characteristics is non-linear in nature. It enables lower torque at lower speeds.</p>
<p>Output power/ Frame size is high. Because it has permanent magnets on the rotor, the smaller size can be achieved for a given output power.</p>	<p>Output power/frame size is moderate. Because both stator and rotor have winding, output power to size is lower than BLDC.</p>
<p>The rotor inertia is low. This enables better dynamic characteristics.</p>	<p>The rotor inertia is high. This enables poorer dynamic characteristics.</p>
<p>The starting current is rated. No special starter circuit is required.</p>	<p>The starting current is approximately up to 7 times of rated. Stator circuit rating should be carefully selected. It normally uses a star delta starter.</p>
<p>A controller always required to keep the motor running. The controller can be used for variable speed control.</p>	<p>No controller is required for fixed speed. A controller is required only if variable speed is desired.</p>
<p>No slip is experienced between stator and rotor frequencies.</p>	<p>The rotor runs at a lower frequency than the stator by slip frequency and slip increases with load on the motor.</p>

5.2.2.9 Battery Management System

According to (Young, et al) they state that Battery Management System (BMS) plays an important role in making decision on charging and discharging rate in accordance with load demand, current, cell voltage, temperature, and the estimated state of charge (SoC) (2013, p. 42). Within pervious variables, the state of charge is one of most critical indicator. Thus, that is specifically for lithium batteries, hence, overcharge can accelerate the battery degradation, resulting catching fire incident or a worst scenario such cause an explosion. Technically, overcharged battery can also result capacity loss and shorten the life cycle of a battery. In most electric vehicle applications, frequent charge and discharge are common. At present, BMS relies on cell voltage regulation which the means of controlling the state of charge of the battery. The main function of the BMS is to;

- Certify that battery is operated safely as well as to achieve the optimum performance over its life.
- Extend battery life cycle.
- Provide data of battery current performance and state.
- Balancing the electrochemical cells.

5.2.2.10 High Voltage isolation fault detection

High Voltage (HV) isolation fault detection system is essential in order to ensure that driver will not be exposure to any hazardous electric shock. As cited in (Dhameja 2002) some accidental loss of isolation between negative and positive electric busses with respect to metallic parts such as chassis or frame of the vehicle would result a serious injury or even death to user (Schafer, 2011, p. 63). Additionally, in order to overcome such a hazardous exposure, several methods can be used they are as follows:

- Using Residual Current device (RCD) the principle behind this method is comparing the current flow between battery traction by the usage of differential transformer. Thus, if there is a leakage current that indicates that the main contactor need to be operated.
- Monitoring and measuring the isolation or insulation resistance. The monitoring system of isolation resistance should be monitored periodically between the electric chassis and live parts.
- Monitoring and measuring chassis voltage in accordance with voltage bus.

5.2.2.11 Working of Li-ion Battery

A lithium-particle battery is a rechargeable battery in which lithium particles move between the anode and cathode, making power stream valuable for electronic applications. In the release cycle, lithium in the anode is ionized and produced to the electrolyte.

Lithium particles travel through a permeable plastic separator and embed into nuclear-estimated openings in the cathode. In the meantime, electrons are discharged from the anode (Lowe, 2010). This ends up plainly electric current flying out to an outside electric circuit. While charging, lithium particles go from the cathode to the anode through the separator. Since this is a reversible concoction response, the battery can be energized. Figure 12 below reflects the working of Li-ion battery.

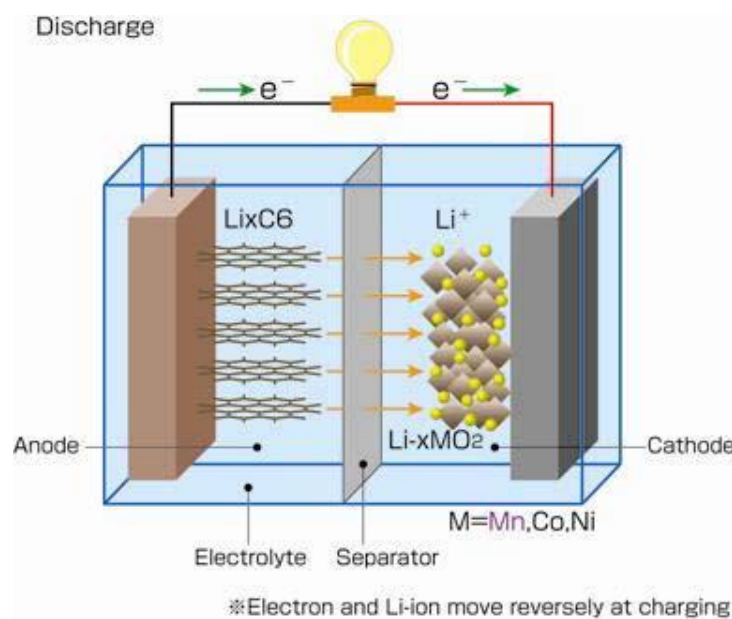


Figure 12: Li-ion Battery Working (pluginindia, n. d)

5.2.2.12 Challenges

If the authorities want to implement the EV in New Zealand, they need to go through the battery system of the EV because current BES is not up to date and require modification. The cost is one of the challenges in this case because if the EV is costly then it will not attract consumer and the same thing will happen when it is not reliable.

5.2.2.13 Durability

Vehicle manufacturers are planning to create lithium-particle batteries with an ensured five-years or 100,000-kilometer driving separation. Profound cycles of lithium-particle battery diminish the battery limit quickly, yet HEVs and EVs will be charged after the battery-put away energy is practically exhausted (Jackey, 2007). What's more, the energy of lithium-particle batteries diminishes in a frosty climate. For utilization of electric vehicles in hilly districts, promote innovation improvement will be important to beat this issue.

5.2.2.14 Safety

Short-circuiting is a threat to any kind of batteries, but in case of lead batteries, the stacks are even high. Lithium battery when short-circuits, high power streams are made and the battery temperature increments to a few hundred degrees inside seconds, heating up the neighboring cells and bringing about a whole battery ignition response. At the point when lithium-particle batteries are inadvertently heated, the concoction structure of the anode and cathode are decimated, and a portion of the lithium particles frame snowflake-molded lithium metal stores called "dendrites," which can make the battery hamper, in the direct outcome imaginable, detonate and burst into flames. Polluting influences in the lithium metal can likewise defile the batteries and cause the development of dendrites (Douglas, 2017).

5.2.2.15 Wireless Charging System

This part of the battery electric system section deals with the wireless charging technology. It is different wireless charging technology is currently in progress or development stage. The commercial market of EV has grown since last few years. The EV require fast and portable charging methods to ensure the effectiveness of EV on the roads of New Zealand. The existing charging methods usually require a high power supply and fixed power stations which limits the mobility of the electric vehicles. The EV require charging within the short time for the long range distance. Inconsistent attachments containers likewise cause extra burden between various EV models (Corey, 2008).

Concerning the remote charging innovations, diverse EV models can share their charging foundation if a similar remote power exchange Wireless Power Transfer (WPT) innovation is received. In the longer term, dynamic street charging innovation will empower clients to charge the EV battery while driving. This realizes much-decreased battery measure, broadened driving extent and lessened vehicle cost, and further invigorate the EV showcase (Lowe, 2010). Far-recorded and close field are the two fundamental classifications for WPT innovations.

These advancements utilize microwave radiation or laser as energy bearer. They are skilled to exchange high control over long separations. Also, the Electromagnetic Charge (EMC) prerequisites are more stringent as the recurrence of operation increments. So the receiving wires ought to be sufficiently extensive to fulfill the power thickness limits, which is illogical for EV WPT applications. Consequently, WPT innovations are mostly utilized in military and space applications, for example, solar power satellite.

In WPT methodology both the electric field and magnetic field are utilized for energy transmission. By utilizing electric-field, power transmission is unaffected by metal obstructions, and furthermore causes bring down Electromagnetic Induction (EMI) than the attractive field partner. The permittivity of air is naturally little, which comes about insufficient coupling capacitance. Rare dielectric materials can improve coupling. In any case, it is still very delicate to the air hole length and relocation of coupling plates.

The magnetic field based WPT advancements have made numerous accomplishments in both short-extend applications. Short-go EV application utilizes sets of ferrite centers to accomplish solid coupling (Corey, 2008). The charging force can exchange many kilowatts, yet the air hole is constrained to a few centimeters and the vehicle development is exceedingly confined.

5.2.2.16 Inductive Power Transfer

This section briefly explains one of the most widely used Wireless Technology. The Inductive power transfer is the method which allows the wireless charging system to the EV. The schematic system diagram is shown below:

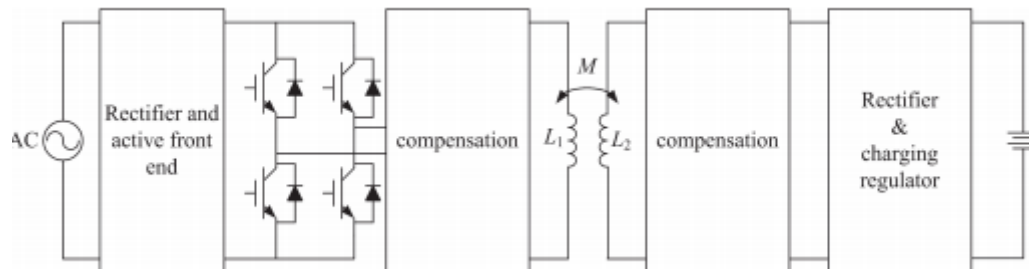


Figure 13: IPT Schematic Diagram (Googleapiscom. 2017)

The inverter is utilized in the system which converts the DC power into the AC current or voltage at high frequency. An inverter converts the DC power into high-frequency AC current or voltage. However, in our design, the BLDC motor is used, so the inverter is not required. The working recurrence fluctuates from many kilohertz to a few megahertz. The key component is a couple of attractively coupled loops. So as to improve the shared inductance, ferrite centers are utilized as a part of one or the two sides of the loops. Litz wires are every now and again used to bring down the parasitic protection and consequently high Q-factor. The loop comprises of many exclusively protected thin conductor stands injured specifically examples to decrease both the skin and vicinity impacts. In any case, for recurrence higher than 1 MHz, wires are less successful and infrequently utilized (Qiu, 2014).

Copper conveyor could be elective arrangements because according to the research copper tubes are more effective. Remuneration capacitances are included both essential and optional sides, either in arrangement or parallel (Ethan, 2017). The reason for compensation systems is to expand the power and reduction in the receptive load of the essential inverter. The arrangement topology is hypothetically ideal because the estimation of essential pay capacitor is free from shared inductance.

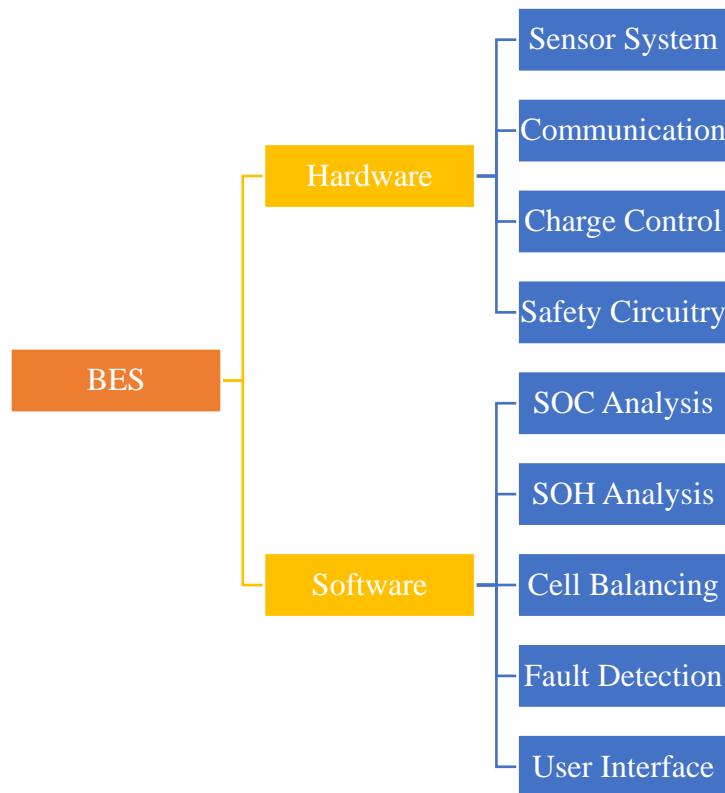
For the arrangement parallel topology, the estimation of essential pay capacitor is autonomous with shared inductance, however, fluctuates with the stack. The parallel compensation is more reasonable when current source trademark at the auxiliary end is required, or a vast essential current is favored. Settled or customizable inactive capacitors are normally utilized as a part of general applications (Qiu, 2014). Dynamic capacitance control is additionally hypothetically achievable utilizing switch-mode control converters, which offer considerably more opportunity for operation (Bangdar, 2015).

For EV application, the load is characterized by the battery's profundity of release and the charging speed, and the common inductance is specifically identified with the relative position between onboard pickup loop and settled transmitting curl. The main issue is both the heap and common inductance are consistently changing because EVs cannot be dependably flawlessly stopped or they are moving amid control exchange. Another issue is that for a specific condition, the heap power and effectiveness cannot accomplish most extreme point in the meantime. In this way, the test for Inductive Power Transfer (IPT) remote charging is the execution of reasonable control techniques, for example, stack coordinating and variable recurrence control to direct the heap control while keeping up high transmission proficiency (Ethan, 2017).

The above mentioned wireless battery charging system is most suitable for the EV in New Zealand. The reason is that wireless charging can allow the consumer to travel long distances and increase the feasibility of electric vehicle. Ministry of Transport must focus on this emerging technology and include it in the Battery Management System to ensure the effective use of this technology.

5.2.2.17 Proposed Battery Electric System for EV

The chart below is the proposed battery electric system for EV. The system consists of different which includes software like SOH & SOC. Some components are related to the hardware of the battery system (Quin, 2016).



5.2.2.18 Hardware

The safety circuit is a vital component in the battery electrical system, and it is in practice since the development of battery system. However, the improvements are essential in the safety circuit due to the installation of numerous sensors within the battery system. For Example, for the prevention of overcharging the alarm sensor and controls are added which also prevent the system from overheating. Battery temperature and current are two major parameters which are measured by the sensors to keep track of battery performance. However, with the advancement in technology, some researchers have proposed that Electrochemical Impedance Spectroscopy (EIS) should be used for the measure of internal impedance in the battery. The major constraint in adopting the EIS is device cost and space. That is why current and voltage of the battery including its temperature must be measured to ensure the effective performance of the battery in real-life.

Information securing and information stockpiling are basic parts for the product in the BES to examine and assemble a database for framework displaying (Jackey, 2007). Charge control is a subsystem representing the charge-release convention. Batteries are frequently charged by the steady present/consistent voltage strategy (CC/CV) and will subsequently need to incorporate a Potentiometer and Galvanometer. The variable resistor might be important to help adjust cells or perform interior protection estimations. Cell adjusting control is as yet a basic outline highlight with the opportunity to get better keeping in mind the end goal to even out the battery pack and proficiently gauge the battery status.

Most subsystems in a BES remain solitary modules, and subsequently, information exchange all through the BES is required. Correspondence through a Bus is a noteworthy approach to exchange information inside the BES. With the advancement of savvy batteries, more information can be gathered to speak with the client and the charger through the microchips fused inside the battery (Erik, 2012). Remote and information transmission procedures are progressively being fused into charging frameworks that encourage correspondence between the battery and the charger.

The above-explained hardware system can allow the Battery electric system to work effectively under various conditions. The performance of the battery will have a positive impact on the overall performance of the car.

5.2.2.19 Software

The software is the center of the Battery electric system. Because it controls all the major operations of the battery system which are either linked to software or hardware. The major operations include the analysis of data and battery state situations. The switch control and monitoring of the battery system also controlled by the software. That is why in the performance of the battery electric system of an electric vehicle the software plays a vital role. The operations of software are not limited because it can control the cell balancing & safety circuit.

Also, online information preparing and examination are required for constantly refreshing and controlling battery capacities. Solid and hearty mechanized information examination is a key factor for progress because the investigation decides state estimation and error identification. This data will be appeared to the user through an easy to use interface with fitting recommendations. The particular elements of the BES programming are talked about beneath.

Assurance of SOC and SOH will be coordinated into a capacity evaluation, which likewise exhibits the life status of the battery and sets as far as possible as indicated by best in class calculations. The target of cell adjusting is to augment battery execution without cheating or over-releasing (Corey, 2008). It inclines to make the SOC levels of cells nearer to each other. The controller will control the charging procedure given an extensive system that relies upon the SOC of every cell.

Therefore, the exact SOC estimation of every cell is fundamental for enhancing the adjusting. Most delicate issues will be found through online information handling. A wise information examination is required with a specific end goal to give battery-blame cautioning and show out-of-resistance conditions (Liam, 2011).

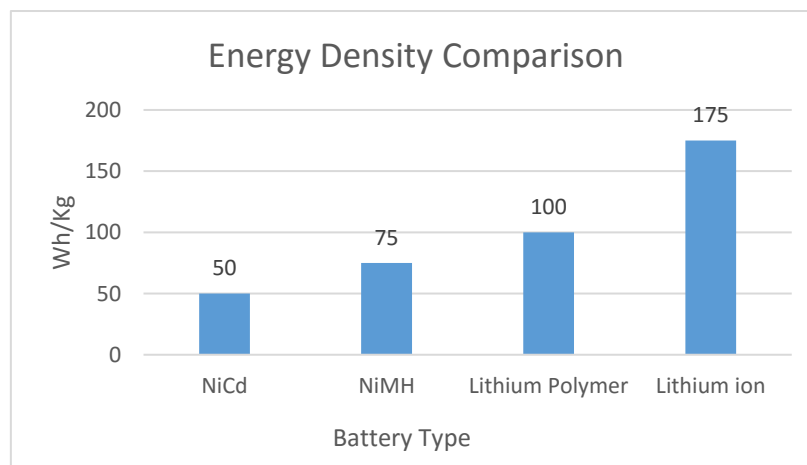
Noteworthy information will be recorded and give the pre-caution condition before the conceivable shortcomings. The UI should show the fundamental data of the BES to the clients. The rest of the range ought to be shown on the dashboard as indicated by the SOC of the battery. Furthermore, anomalous disturbing and substitution proposals are expected to advise the clients as far as the estimation and expectation of the battery.

5.2.2.20 Battery Specifications

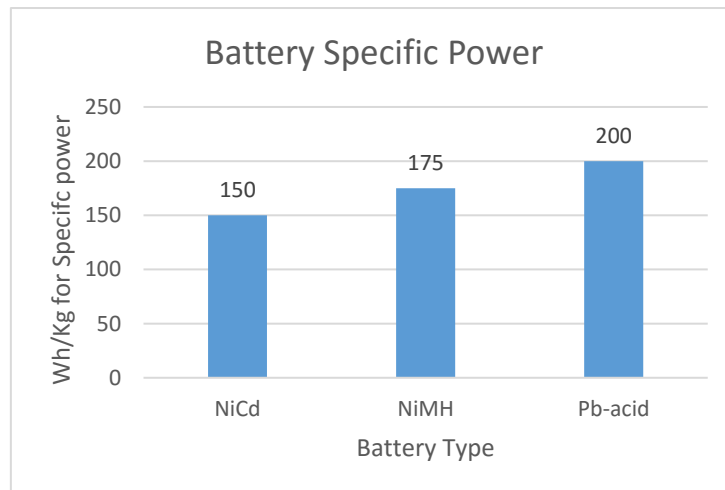
In the electric vehicles, the battery selection is one of the critical decision, and it depends on the energy density of the battery. The ideal battery is the one which stores maximum energy in the cell and has the smallest size which will have a positive impact on the cost and performance of the battery. The most widely used batteries nowadays include Lead-Acid, Nickel-Metal, and Lithium-ion battery. The energy density of each battery is different from each other. There are many factors other than energy thickness that impact the sort of battery chose for use in an electric vehicle. These incorporate cost, life cycle quick or fast charge time and particular power. Another criterion for choosing a battery sort that is firmly identified with energy thickness is a battery's particular energy (Porter, 2016).

Particular energy is critical because it influences the quantity of batteries important in a specific application, and thus the mass or weight of the batteries that a vehicle needs to bear on-barricade to end with a specific electric-just range. It is an essential factor for EVs since it decides their aggregate range, yet not as basic for EVs which convey the lion's share of their energy as a vaporous or fluid fuel (Ethan, 2017).

Rather, for EVs, a battery's particular power turns into the basic parameter in choosing a battery. The graph below reflects the energy densities of different batteries.



The energy demand in case of EV is less as compared to the HEV's because they mostly require two different energy sources. Since hybrids regularly just rely upon the electrical energy put away on-board to give energy to quickening and slope climbing, batteries are looked for that have a high particular power rating and less mass. Particular or Specific power will be control per unit mass, so the capacity of the battery to empower high current draws for brief spans with less weight is the coveted objective for HEVs. The charts beneath compare the particular or specific power between battery sorts. No data was accessible for the lithium batteries as of now.



The battery chargers are just like gas tanks because they provide the required energy to the electric vehicle in order to operate effectively. One critical distinction is that an electric vehicle administrator can completely charge the vehicle overnight, at home, instead of refueling at a fuel station (Porter, 2016). A battery charger is a gadget which changes over the substituting current appropriated by electric utilities to the immediate current expected to revive the battery.

Table 3: Battery Specifications (Porter, 2016)

Battery Type	Power Density W/kg	Life Cycles	Cost (1-10 scale)
Lead-Acid	150	500	1
Litium Ion	230	600	9
Lithium Polymer	350	<600	10
NiMh	150	1500	8

5.2.2.21 Maximum Capacity

The most extreme limit of the battery decides the execution and future existence of the battery. The present technique for estimation is to a great extent in light of the full release test. The online limit is ascertained by:

$$Capacity = \int Idt$$

The above equations reveal that the longer the integration time of the battery the higher the capacity will be. Therefore, the results obtained through this equation indicate the maximum capacity of the battery during the full discharge situation (See Appendix B). The battery will not constantly be released at a consistent release current and won't be drained to the cut-off voltage inevitably. The battery was charged to the full charge, 4.2 V, and quit releasing indiscriminately cut-off voltages. This recreates operation in reality. Along these lines, deciding how to survey the most extreme execution of a battery with halfway release and variation current burdens is a key test. Battery debasement models depend on particular materials, natural conditions, and charge-release cycling (Bangdar, 2015).

Battery status is evaluated while releasing at consistent present and steady temperature. Nonetheless, with regards to the joined variables, the debasement demonstrate in light of the single impact factor is liable to question.

5.2.2.22 Battery Health Assessment

Appraisal of battery safety is a worry for manufacturers. Since battery innovation in EVs is not yet developed, a particular reference or standard should be manufactured given a vast database framework. Notwithstanding limit and energy, more weight components might be joined to assess the well-being status, for example, an expansion in cell protection, a lessening in the genuine limit, and the quantity of charge/release cycles (Mason, 2017).

5.2.2.23 Depth of Discharge in Lithium battery

Depth of Discharge (DoD) is a method that used in order to indicate the state of charge of the battery. The term is utilized to describe how deeply the battery is discharged. In fact, the battery capacity is actually higher than what is rated nominally. In lithium batteries technology there is a correlation between the DoD and the life cycle of the battery.

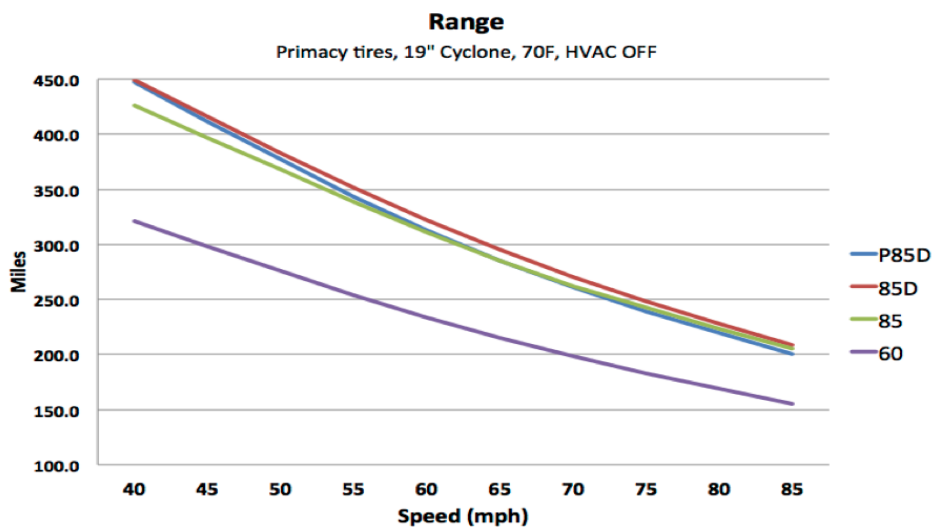
Likewise, the maximum depth of discharge of lithium battery is 80%, and thus if more than that energy is discharge would affect the life cycle of the battery and shorten it. According to (Millner) he states that one of the major issues that associated with the prediction of providence of the life cycle of batteries is the dependence on depth of discharge (2010, p. 2). If the cycle of battery is preformed starting with a fully charged and discharging up to the fixed DoD which is 80%, then the battery gets charged again, then the larger DoD the lower state of charge. Furthermore, the relationship between DoD and SoC is depending on the energy stored status, the SoC percentage point is represented as (0% = empty; 100% = full). On the other hand, the DoD energy stored status is represented as (100% = empty; 0% = full). Nonetheless, SoC usually cannot be measured but it can be predicted from the direct measurement and that is done in two ways which are offline and online. In the offline method, the battery is desired to be fully charged and discharged in constant rate. That method gives an accurate estimation of SoC, however, it costly, protracted, and interrupt the main battery function. On the other hand, online method is recommended by many engineers, due to the fact that this method has five sub-methods to determine SoC indirectly by testing main components in the battery which are: chemical, voltage, current, Kalman filtering, and pressure.

5.2.2.24 Battery Recycling

As the measure of batteries expended increments exponentially, the transfer has turned into a huge issue. Tesla has executed a reusing procedure that reuses more than 60% of a battery's materials. When pack generation volumes increment, this reusing rate will be raised up to 90%. It would be a gigantic misuse of assets if there were no reusing. Tragically, from most producers, the high reusing costs and the intricate transfer process are not worth the exertion of actualizing an environment-friendly reusing technique (Ethan, 2017).

5.2.2.25 Driving Range of EV

The driving range of different electric vehicles is different due to their design specifications and requirement. The driving range of Tesla models is explained in this section. The Tesla cars give the idea of the driving range of three-wheel electric car in real-world. The different Tesla models are compared, and the graph below reflects the range of each model. The major factor which has an impact on the driving range of an EV includes Operating temperature, pressure and age of the battery (Martin, 2004). However, the overall condition of the car has an impact on the battery performance which ultimately has an impact on the driving range of an EV.



As batteries are the center power sources in EVs a, their execution significantly impacts the adaptability of EVs. In this way, makers or manufacturers are looking for achievements in both battery innovation and BES. Chemical composition and reaction in the battery are liable to work & operating conditions, and consequently, the degradation of a battery may fluctuate in various situations. Building up a develop BES is basic for makers who might want to expand the piece of the pie of their items (See Appendix B).

The real constraints associated with the BES were discussed in this paper. They incorporate battery state assessment, demonstrating, and cell adjusting, where in the assessment philosophies of battery status were seen as the pivotal issue. In this way, related work on the SOC, SOH, and SOL of batteries was checked on with correlations. A BES structure was proposed to manage the lacks of BES in both research and business items.

Given past work, particular difficulties confronting BES and their conceivable arrangements were introduced as a strong establishment for future research. Because of changing circumstances in real-world applications, a standard arrangement was not needed. In light of the particular circumstance, distinctive techniques ought to be connected to enhance and advance the execution of BES in future EVs.

5.2.2.26 Factors influence the operation of Lithium-ion battery

5.2.2.26.1 *Battery weight and energy required*

The Lithium battery has earned its position in transport applications based on some advantages. One of these advantages is the ratio of energy to the battery volume or weight. This factor is considering as the energy density and thus how much energy can be stored in 1 litre or kilogram (Koniak & Czerepicki, 2017). Manufacturers have specified that value, which is essential information in order to estimate the suitability in the application that it is going to be utilised in. It is significant to know that the density of energy is differ for the cells alone, and different for finished battery pack that includes the cells. This is occurred by the presence of additional mechanical, electrical and measuring system inside the battery pack. Nonetheless, this information is an essential reference point that would assist the evaluation of how energy affect volume and weight of the vehicle. The density of the battery energy is an essential factor when selecting a battery for given vehicle type. For instance, more than one passenger in cars require small batteries with high capacity, which is limited to the small available space and other restrictions on the weight of the vehicle. On the other hand, in term of single seat EV has more space and the battery size is not important to some extent. However, the overall vehicle weight can be essential factor to certain level, and hence there is limitation of vehicle weight gross restricted by regulations.

5.2.2.26.2 *Thermal behaviour of lithium-ion*

The active enhancement of electric vehicle and hybrid has been accompanied by leaps in the technology of batteries as applied in order to store energy. Thermal behaviour and heat control are essential issues in lithium battery, which is susceptible to the effect of temperature. Temperature above 50°C and lower than -10°C would result lower longevity of the battery or lower the charging efficiency (Sato, 2001). Hence, lithium battery can withstand and perform well in a maximum 45°C.

5.2.2.27 Operating characteristics and function of EV battery

The main function of battery in electric vehicle is storing energy for the operation of the vehicle. In fact, the operation of EV is similar to ICE car, nevertheless, in pure EV must operate in accordance with battery SoC in mind. Likewise, the ICE requires to be refuelled periodically. The primary difference is the limitation of the capacity of energy stored and recharge time. The functions of the battery they are as follows:

1. The power acceptance (acceptance of recharging time)
2. Energy acceptance (sufficient capacity of energy)
3. Depth of discharge
4. Acceptable power output
5. High reliability
6. Capability to communicate with controlling system and user interface
7. Reliability of safety system

Meanwhile, the battery needs perform the above functions efficiently and safely. As referred to one of battery manufacturer Boston Power “Safety is the most important criterion for electric car batteries” as cited in (Schafer, 2011).

5.2.2.28 Battery cooling and heating

As mentioned above the thermal management system is an essential factor in the overall battery as well as EV performance. Hence, lithium battery conversion would provide cooling or heating actions based on the battery pack condition. The main goal of this system is to ;

- The cause of runaway be battery overheating state.
- Ensure that cells in battery are working in the most efficient temperature.
- Crating an isothermal battery pack, which temperature is even from cell to cell, and hence that will minimize the imbalance charge over a cycle.

Meanwhile, cooling and heating system must be operated whither the vehicle is moving or held stationary. First, heating the pack is important during the cold days, and that will be when EV first starts till the cells get warmed discharge phase (moving). In our case, that would be less important due to the mild winter in New Zealand. On the other hand, the cooling method that will be used in our case is air cooled or liquid cooling. Liquid cooling needs an extra level of integration of external parts, so, that may not be achievable in most EV. Therefore, in this case, the absorbed effective method is air cooling. Thus, the battery packs are placed in the bottom of the EV and they are exposed to the air while the EV is moving.

5.2.3 Electric Vehicle Design

In this section, the electric vehicle complete design is discussed. The design of the electric vehicle is crucial part because the goal is to develop the electric vehicle which is feasible and reliable in the environment and other conditions of New Zealand. The vehicle design which is proposed in this section is single seat three-wheel electric vehicle. The reason to choose three-wheel design was to make the design compact to make the car lightweight and increase the overall performance of the car (Erik, 2012). The fundamental reason for existing is to build up a vehicle that has comparable driving attributes to a typical car. Plan and manufacture of the single seat three-wheel EV concentrate on building up a basic, lightweight and effortlessly worked vehicle. During the designing of the EV, the ease of manufacturing, safety, and reliability are kept in mind (Bangdar, 2015).

Examinations are directed on every single real part to upgrade the quality and unbending nature, enhance vehicle execution, and to diminish multifaceted nature and to assemble costs. This combined with suitable research, to make another undercarriage and suspension framework that has enhanced execution and highlights. The major parts which were analyzed in this section include Suspension system, Chassis, braking system, Steering system, Motor, Controller and Batteries, and body of the EV (Douglas, 2017). Calculations are performed to determine the engine power and various other specifications of the single seat electric vehicle. This section does not include the battery system of the car because it was discussed previously in BES section. Every segment should be displayed legitimately all together to avoid wrong conclusions.

Meanwhile, in this project many researches and study on real existing EV should be taken into account. For a clarification and understanding purposes few visits were made for Tesla company in Auckland. A meeting was held on 24th of September 2017 with one of Tesla Company crew, few general questions were raised about EV in general. Other meetings were held on 26th of September 2017 and 6th of October, all major components were discussed and an arranged time was set for test drive and experience the performance of Model S sedan. As a result, that experiment was useful in order to have a clearer picture about EVs.

5.2.3.1 Electric Vehicle Specifications

Table 1 reflects the design specifications on which the single seat three-wheel EV design is based. The maximum speed limit for this EV is 90 km/hr which is sufficient for the short range distances and on the roads of the New Zealand.

Table 4: single seat three-wheel EV Design Specifications

Specifications	Value
Engine unit	66 – 80 hp
Top speed	90 km/h
Wheels size	205/40R17
Driving System	Front wheel self-contained motor.
Braking System	Mechanical drum brake to the all wheels.
Steering System	Mechanical power steering
Chassis	Gentile steel (15-30mm)

5.2.3.2 Suspension System

The suspension is one of the most important components of any vehicle. In this section, the design specification of the rear and front axle of the electric car is discussed. The calculation is performed according to the requirement of the single seat three-wheel electric Vehicle (Li, 2013).

5.2.3.3 Body/chassis strength, rigidity and crash resistance

The days have long past, thankfully, when stress engineers regarded aircraft as hollow cylinders with beams stuck out of the side and cars as something simpler. Modern predictions of chassis body behavior and virtually every aspect of car design rely ultimately on complex computer packages. Nevertheless, a basic understanding of the behavior of beams and hollow cylinders does give an insight into body chassis design. Bending would be caused by the weight of the vehicle, particularly when coming down after driving over a bump and the torsion from cornering. The weight of the vehicle will cause stresses to mount in the tube and will also cause it to deflect. The torsion will likewise result in shear stresses and will cause the tube to twist. Assuming an even weight distribution, the maximum bending stress σ ($N.mm^{-2}$). will be given by the formula:

$$\sigma = \frac{wL^4r_0}{8I}$$

Where:

w is the uniform weight/length ($N.mm^{-1}$)

L is the length (mm)

r_0 is the radius (mm) and I is the second moment of area (mm^4).

I will be given by:

$$I = \pi \frac{r_0^4 - r_i^4}{4}$$

And the maximum deflection δ (mm) in the middle of the beam will be given by

$$\delta = \frac{5wL^4}{384EI}$$

Where:

E is Young's modulus ($N.mm^{-2}$).

Similarly, the shear stress in the cylinder wall q ($N.mm^{-2}$). is given by

$$q = \frac{Tr_0}{J}$$

Where:

T is the applied torque ($N.mm$)

J is the polar second moment of area (mm^4), which will be given by:

$$J = \pi \frac{r_0^4 - r_1^4}{2}$$

The angle of twist θ (radians) is given by

$$\theta = \frac{TL}{GJ}$$

Where:

G is the rigidity modulus ($N \cdot mm^{-2}$).

Certain clear conclusions can be drawn from these equations. To minimize stress due to both bending and torsion both I and J must be kept as large as possible. For a given mass of material, the further it is spread from the center of the tube, the larger will be both I and J , thus reducing stresses, deflection and twist.

5.2.3.4 Driving resistance

The driving resistance is represented as F_D which describes the physical resistance between the vehicle tires and the ground. There are many factors that influence the driving resistance they are acceleration F_a , rolling F_r , aerodynamic F_{ae} , and slope of road resistance F_s . In order to calculate the driving resistance, the following expression can be utilised:

$$F_D = F_r + F_{ae} + F_a + F_s$$

Another primary type resistance is the weight of the vehicle as well as the road slope as shown in figure14 below, where there is another expression can be utilised it is as follows:

$$F_D = m * g * f * \cos\beta + \frac{\delta}{2} * A * C_w * V^2 + m * a + m * g * \sin\beta$$

Where:

m = the mass of the vehicle

g = the gravity

f =rolling friction

$\cos\beta$ =the road slope or angle

δ = density of the air

A=size of the frontal area

C_w=drag coefficient of the vehicle

V= velocity of the vehicle

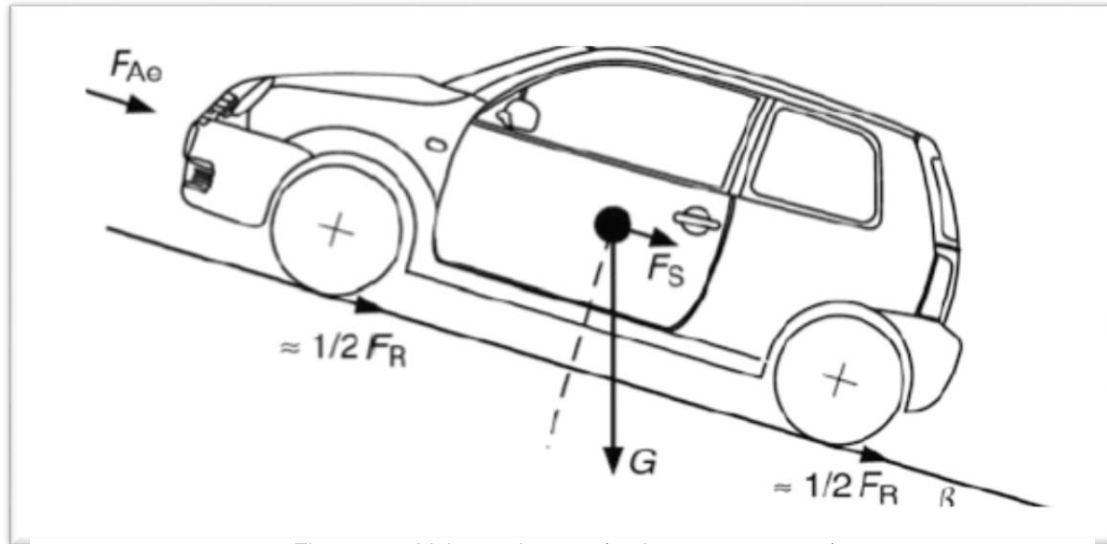


Figure 14: driving resistance (springernature, 2017)

5.2.3.5 Motor, Controller and Batteries

In this design, the driving system is based on Brushless DC motor, battery units, and controller. The motor is to be connected to differential then transfer the rotational power to two front wheels, hence, in our design gear is not required. Due to the fact that the maximum speed is limited to 90 km per hour, thus, the speed can be regulated by the controller in accordance to acceleration pedal. Likewise, the controller job in this case is to regulate the amount of energy that is supplied by battery units in order to deliver to the motor. The controller is positioned between the two front wheels due to the limited space available in the EV design. The battery units are placed in the bottom of the EV under the passenger seat with safety standards consideration.

5.2.3.6 3D Model

The Solidworks is utilized to develop the 3D model of the EV axle. The complete suspension system of the EV consists of different components which include axle, hub, spring and different joints to ensure the effective working of the suspension system. The figure 15 below reflects the 3D model of the suspension system which was designed for single seat three-wheel electric vehicle. The body and frame of our EV will be manufactured within Wintec workplace, and thus other secondary components will be purchased.

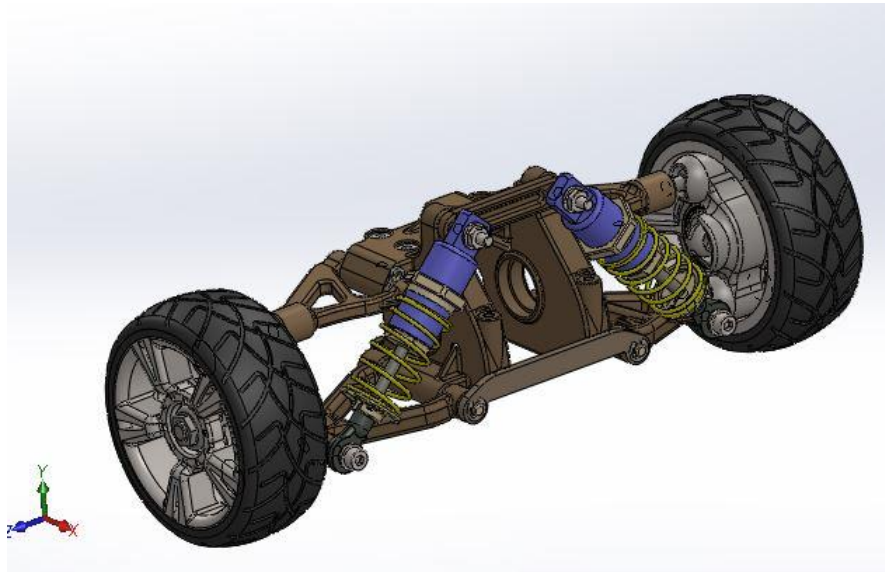
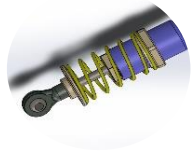


Figure 15: Suspension System of EV (Ytimgcom, n. d)

The suspension system shown above is the ideal design but it can be changed for the ease of manufacturing and to make the design reliable. Figure 16 shows the different components which were developed to complete design the suspension system. This suspension system is best suitable for the roads of New Zealand (Miller, 2013).

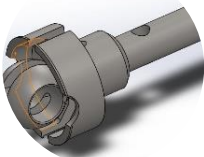
Some of the components are shown below: These models are made in the Solidworks. Each component is designed using the factor of safety because safety is the most important for the electric vehicle. Mechanical components play an important role, and the designing of the entire suspension system is critical. The Shock and Spring assembly is the most important part of this suspension system because it bears the most load and shocks during operation of EV.



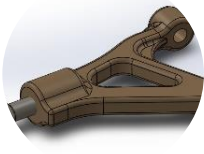
Shock & Spring Assembly



Shock Body



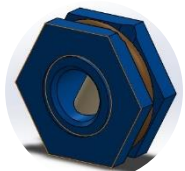
Front Axle Assembly



Upper Arm Assembly



Tyre & Rim Assembly



Hexagonal Hub Assembly

Figure 16: EV components (Ytingcom, n. d)

5.2.3.6 Wheels & Tire

The wheel is the vital segment, which interacts with the street or road. The back wheel is driving wheels, but in case of our design, the front wheels are the driving wheel. The material utilized for the wheel is elastic tube tire and gentle steel edge (Morgan, 2017). There are different functions which the wheel perform that include support to the weight of the vehicle and withstanding the brake stresses. It also absorbs the cushioning effect and shocks which are produced due to the bumps in the road.

In the ordinary car, the rear wheels are used transmit power, but in this case, the front transmits power because it is the three-wheel electric vehicle (Li, 2013). However, there are some requirements which must be fulfilled in designing the effective and high-quality wheel for the EV. These requirements include strength, equilibrium both dynamically and statistically, lightweight and feasible to operate in case of emergency. The tires of the Electric vehicle have their requirement which includes the ability to absorb the shocks, should possess uniform wear to prevent the phenomenon of skidding. To consume less power and allow the vehicle to move smoothly, they must possess the rolling resistance. The pattern design configuration must be with the end goal that the tire may not slip much on wet streets. The tire elastic must have a high coefficient of erosion. The noise of the tire depends on its threading pattern and to reduce the noise the threading pattern must be high quality and effective.

There are two types of tires which can be utilized but in this design, the tubeless tires are preferred. The reason is safety and efficiency of tubeless tires. Customary plans of pneumatic tires required a different internal tube which could fail for various reasons, for example, inaccurate tire fit, rubbing between the tire divider and inward tube creating abundance warm, or a cut (Rodgers, 2017). The tire and the edge of the wheel shape an impermeable seal, with the valve being specifically mounted on edge. On the off chance that a tubeless tire gets a little cut, air escapes just through the opening, prompting a delicate collapse.

5.2.3.7 Steering System

The principle capacity of steering system or guiding framework is to change over the rotational movement of directing wheel into the precise relocation of front wheels. The steering framework. Should likewise keep up the straight-ahead movement of the vehicle while the experiences most gaps and street knocks and should work with least exertion. The steering mechanism which was selected for the single seat three-wheel electric car design was Ackerman steering mechanism.

The function of the steering system is to turn the vehicle according to the instruction of the driver and to control the wear of the tires. Most of the tires get wear and tear because of the poor performance of the steering system. That is why it is important to maintain the steering system in good condition. However, the primary function of the steering is to transfer the rotary motion into the angular displacement during the operation of the electric vehicle (Chon, 2007). The power steering systems are now utilized which ease the effort of the driver. The other functions of the steering system include the directional stability, self-righting effect, and must act as shock absorber.

Vehicle steering relies on guiding framework, suspension framework, and tires. A smooth execution of controlling framework ought to have the following prerequisite. The front wheel should move without horizontal slide while arranging bends. The tires must have great flexibility so that on bends, these may take after a curve of more prominent sweep than the firm tires. The wheels should naturally come to a straight position in the wake of arranging the curve (Dyson, 2017). While going straight, the wheel must keep up the impartial position. The framework must be irreversible to a specific degree with the goal that base front-wheel stuns are transmitted to the driver's hand.

5.2.3.8 Ackerman Steering Mechanism

To achieve true rolling for a three-wheeled vehicle moving on a curved track, the lines drawn through each of the three wheel axes must intersect at the instantaneous center. The actual position the instantaneous center constantly changes due to the alternation of the front wheel angular positions to correct the steered vehicle's path. Since rear wheel is fixed and dragged but the front wheels axes are independent of each other, the instantaneous centers lies somewhere along an imaginary extended line drawn through the axis of the rear axle.

The Ackermann principle is based on the two front steered wheels being pivoted at the ends of an axle-beam. The original Ackermann linkage has parallel set track-rod-arms, so that both steered wheels' swivel at equal angles. Consequently, the intersecting projection lines do not meet at one point. If both front wheels are free to follow their own natural paths, they would converge and eventually cross each other. Since the vehicle moves along a single mean path, both wheel tracks conflict continuously with each other causing tire slip and tread scrub. Subsequent modified linkage uses inclined track-rod arms so that the inner wheel swivels about its king-pin slightly more than the outer wheel. Hence the lines drawn through the stub-axes converge at a single point somewhere along the rear-axle projection.

At the point when track bar is moved to one side amid the left turn. It pushes at just about a correct edge against the correct controlling knuckle arm. The left end of the track pole, however not just moves to one side yet additionally swings forward as appeared in the figure 17 below, so the left wheel is turned an extra sum (Morgan, 2017). In this manner, the edge of the internal wheel with bar hub is more noteworthy than that of the external wheel. Likewise, when a correct turn is influenced, the correct wheel to will be turned an extra sum over that which the left wheel turns.

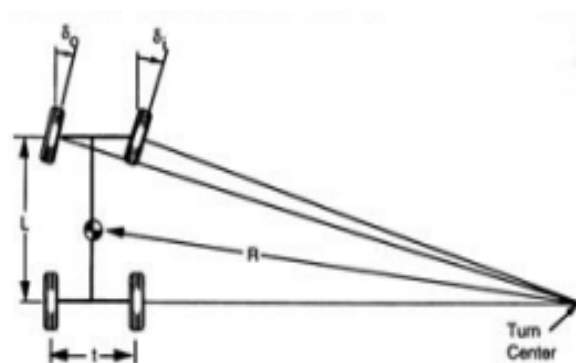


Figure 17: Ackerman Steering Geometry (Morgan, 2017)

5.2.3.9 3D Model of Steering

Figure 18 below reflects the 3D model of the Ackerman steering system along with the roper steering. The system works on the principle of rack and pinion gear system.



Figure 18: Ackerman Steering Model (Ytingcom, n. d)

The chart below reflects the major components of the steering system which were modeled using the SolidWorks software.



Figure 19: steering components (Ytingcom, n. d)

5.2.3.10 Chassis or Frame of EV

The chassis needs to be fabricated whereas the other components are purchased and collected using the chassis as the foundation. To ensure stability a tubular steel sub frame will be used. The SSEV requires fabrication with a 3 millimeter (3 mm) aluminum sheet into an aluminum box for the chassis spine and to hold the lithium batteries. The bending of the aluminum into a long rectangular shape will be kept as simple as possible. Simplicity is essential for the maximization of rigidity and enhances low weight of the SSEV; the more the aluminum sheet is manipulated, the less strength from rigidity will be available. Using the aluminum box as a support for the lithium batteries at the center of the car is an extra precaution to protect the batteries from impact. The disadvantage is that no high loads can be placed on the aluminum box, but this can be fixed by preparing sub-frames. The sub-frames will allow the loads to be distributed in a more balanced method. The sub-frames are also fabricated. They are fabricated from tubular steel. A good, lightweight, easy-for-construction material is aluminum. Aluminum is durable, non-flexible with a good stiffness. The chassis can be thought of as a folded aluminum box with the purpose of carrying all the loads (Mason, 2011a; Taranovich, 2011a). A good, lightweight, easy-for-construction material is aluminum. Aluminum is durable, non-flexible with a good stiffness. The chassis can be thought of as a folded aluminum box with the purpose of carrying all the loads (Mason, 2011a; Taranovich, 2011a).

It is the principal structure. This needs to help the different parts, and also the body of the vehicle. The gathered vehicle without a body is called as the undercarriage. The material is utilized for Chassis Gentile steel (15-30mm). It is the structure to outfit underpins for transmission framework, the body, and different units. It keeps the connection between the other related parts with a specific end goal to play out their ordinary capacities and opportunity from the strain (Shubham, 2014).

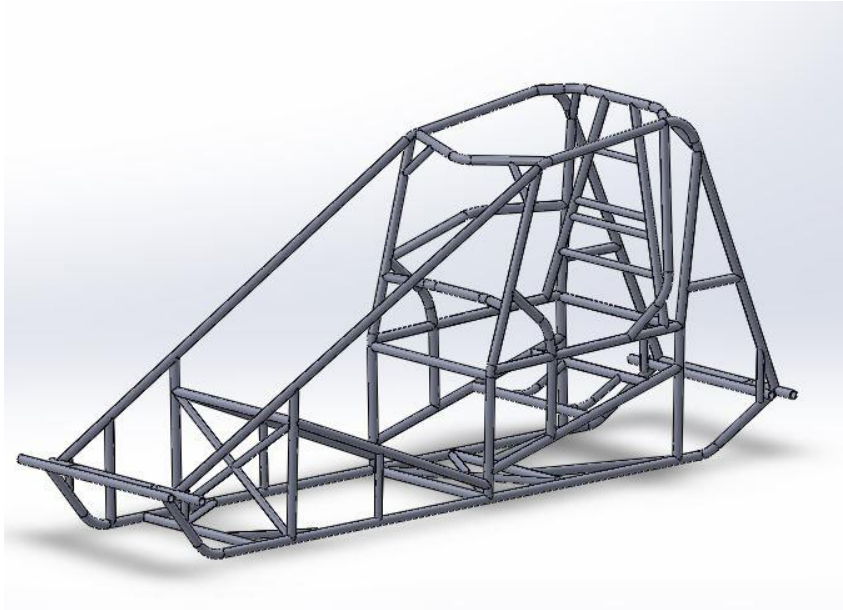


Figure 20: Frame of single Seat EV (Ytingcom, n. d)

5.2.3.11 Braking System

The Braking framework comprises of a strong circle, 6mm thick, coupled specifically to the hub utilizing a center and bolted over the hub by a grub screw and a key as appeared in Figure 21. A two-cylinder Brake Caliper is incited by a standard 250cc cruiser raise brake pressure driven ace barrel. This acquaints erosion with the brake circle accordingly instigating braking. The circle brake is a great deal like the brakes on a bike. Bike brakes have a caliper, which presses the brake cushions against the wheel. In a circle brake, the brake cushions crush the rotor rather than the wheel, and the power is transmitted using pressurized water rather than through a link. Grinding between the cushions and the circle backs the plate off (Rao, 2017).

The disc brakes are not used for the single seat three-wheel electric vehicle because the speed limit of the electric vehicle is just 90 km/hr which can be controlled through hydraulic drum brake system. Therefore, the brake system which will be used for this project consists of the hydraulic drum brake system, and it is lightweight but effective as compared to the conventional car brakes. The braking system is similar to the scooter brakes, but the major difference is that the brakes are applied on all three wheels of the vehicle to ensure the safety of the consumer. Figure 21 below shows hydraulic drum brake (Shubham, 2014). In our design, drum brakes are ideal, because it is light in weight and all three wheels have drum brakes as well as they will work simultaneously.



Figure 21: Brake System(Knott, n. d)

Hydraulic brake is the slowing mechanisms that utilize a cylinder at the hand lever called the "ace" cylinder. The cylinder pushes brake liquid through fixed brake tubing to another arrangement of cylinders at the caliper called the "slave" cylinders. The slave cylinders push the cushions to the rotor. Since the water-powered liquid does not pack or flex, pressure driven frameworks are viewed as higher execution than mechanical frameworks (Shubham, 2014).

5.2.3.12 The body of the EV

The body of the electric vehicle is reverse tricycle base for single seat. The ideal design for this project is reverse trike body of the electric vehicle. There are several reasons to select the reverse trike body design which includes the compact design, reliability, stability, and durability. The batteries of the car are on the back, but due to the non-existence of the petrol section, the design is suitable for electric vehicles. A switch trike is essentially a vehicle having two wheels in the front and one on raise side. Most autos have the motor driving the back to hagggle guiding to the front ones. Some are an eco-accommodating human-fueled vehicle with an exacerbated electric drive framework, and some are controlled by I.C. Motors.

A Reverse Trike has the upsides of both the kind of vehicle that is autos and bicycles. On the off chance that we influence these vehicles to incline toward corners it makes it a flawless, virtual single track vehicle and despite the fact that having three-wheels it can be driven like a bike, and the third additional wheel gives the vehicle more footing to influence it safe to even at high speeds (Ron, 2001).

On the one side when we consider the non-inclining vehicle, they are steady similar to an auto and are best at low speed and in movement conditions, however, need to battle with divergent power at fast amid cornering (Oke, 2012). Considering an inclining reverse trike they are great at high speeds and checks the radial power by their inclining activity yet are unpleasant in the movement and at low speeds as the driver needs to put their foot down to help the vehicle. Figure 22 below reflects the reverse trike body of the EV car designed in Solidworks.

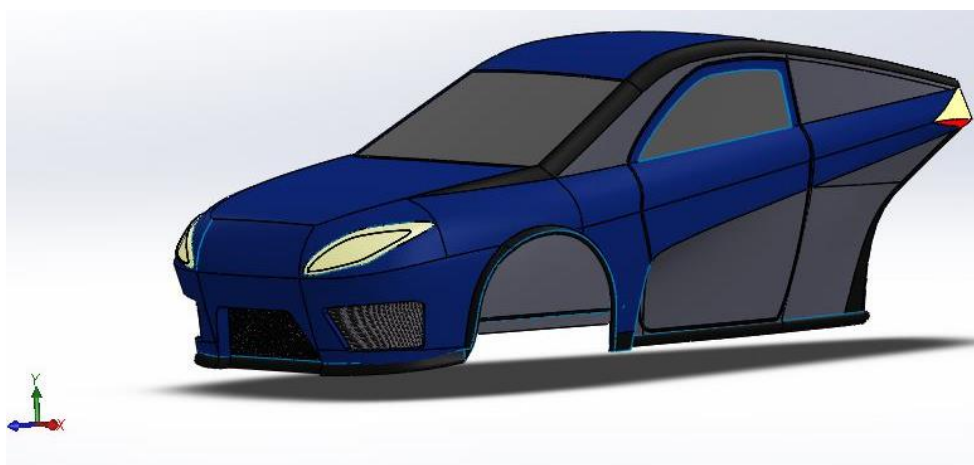


Figure 22: Three-Wheel EV Body (Ytimgcom, n. d)

As a model to assess the execution of inclining reverse trike, we have chosen a three-wheeled inclining vehicle. The designed vehicle has three-wheels that all slender together with the vehicle body. The single back drive wheel has an electric BLDC engine to drive the vehicle (Shubham, 2014). The setup is picked since it streamlined the back body and drive prepare plan. This implied that expected to be fabricated the casing to coordinate the required vehicle subsystems. Figure 23 below reflects the proposed prototype of the single seat three-wheel electric vehicle.

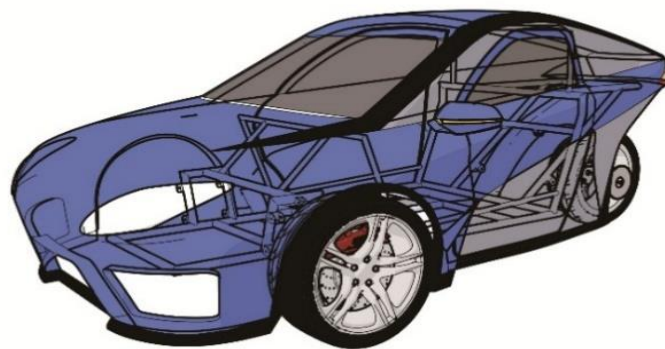


Figure 23: single seat three-Wheel Electric Vehicle Design (Ytingcom, n. d)

5.3 Resources

5.3.1 Tools, materials and skills

The following list of the tools, materials and skill set is not all inclusive, as no doubt during the building of the SSWEV other items will be needed. The following list does show the basic tools and materials needed and those with the highest cost. The skill set is addressed in terms of hiring a professional electrician as well as Wintec's experts, in order to avoid electrocution or fire hazards.

- Soldering; soldering tools
- Mill (or access to metal shop for outsourcing)
- Power board \geq 3 ounces (oz.) copper; heavy copper clad isomer, PCB (poly chlorinated byphenyls)
- Drill with angle attachment
- Pneumatic riveter
- Drill Press
- Press to bend chassis aluminum box (holds batteries)
- Motor control for motor and a mounted inboard.
- Materials: for the motor and mounted inboard (Ganhaar, 2013)
 - 1/4" x 3/4" x 12" C110 copper bar
 - Two 3/16" x 3/4" x 10" C110 copper bars
 - 3/4" x 1.5" x 8" aluminum bar
 - 3/8" x 8" x 11" aluminum plate
 - 3/16" x 3/4" x 8" steel bar
 - Two 1/16" x 3/4" x 8" unclad FR4 used in making PCB
 - 1/16" x 6" x 8" unclad FR4 board
 - 5/16" drill bit (or 3/8" drill bit if you need slope)
 - 1/8" drill bit
 - 3/16" drill bit (Must allow a #6 screw to fit through)
 - Aluminum 1.2 m x 3 m x 3 mm sheet for chassis box and its lid
 - Aluminum or polymer sheet to reinforce the chassis box
 - Pressed aluminum sheet for floor box
 - Chassis (aluminum 0.6*900*900mm)
 - smaller rivnuts and screws (6 to 8 mm)
 - Lithium cells 45 CALB 128 Ah fits into the plan as is
 - 12 V ignition switch
 - Gates GT3 (toothed drive belt) 30 mm wide
 - Steel square tube, hollow (25 mm x 1.6 mm)
 - Pressed aluminum sheet

5.3.2 Costs

In this section, an estimation of cost for the main parts of EV are gathered. The first main part cost is the battery units, high cost of lithium batteries for vehicle is a concern. As per the latest assessments accessible for batteries for vehicle utilize, the cost of a lithium battery is four to eight times that of lead battery and one to four times that of NiMH (Liam, 2011). Other secondary parts of the EV are not included such as equipment, tools, joining parts etc. In fact, Wintec workplace and facilities will carry on to build the EV. The table below illustrate parts and cost estimation;

Table 5: Project budget items and cost estimate

Component	Type	Cost (NZ\$)
Body	Aluminum stucco (0.6*900*900mm)	56.92 per sheet
Frame	Gentile steel (15-30mm)	100.52
Battery	Lithium ion (128V, 80Ah, 10-13KW)	7,168
Motor	Brushless DC	1500
Controller	BLDC motor controller	1170
Brakes	Hydraulic drum(Dexter “10*2-1/4 in)	120.45
Tires & wheels	205/40R17	183.65 per piece
Steering	Electric power steering rack	249
Suspension	Shock absorbers & steering wheel	197.30
Seat	Bucket seat	199.95
	Total	10,944. 79

5.3.3 Goals

Targeted goals for the SSWEV project are listed below.

- The system voltage target is 100 V
- Top speed 85 to 90 km/h
- Acceleration goal is to reach 80 km/h from 0 in 12 to 15 seconds.
- Calculations for the range of the vehicle will set a 112.5-km goal when the SSWEV is at full performance level.
- Road tests will verify range and evaluate performance
- Road tests will measure power consumption the expectation based on size and capacity is expected to be approximately 250+ Wh/mile
- Overall EV weight 650 to 800 kg
- One gear 300 Nm torque 1:3 ratio
- Operate motors and controllers at 100 V corresponding with 45 lithium cells that are connected in-series (Holmes, 2011)
- Total battery set-up weight: limited to 100 kg

5.3.4 Safety features

- Bulkheads also known in this project were added to the chassis aluminum box to add strength. The lining with ply (or more aluminum) is necessary to avoid buckling of that length of the box that runs along the spine of the chassis. An impact or load shifting during acceleration and deceleration causes buckling. The stability of the seat is also increased because the reinforced aluminum box allows for strengthened mounting points. The seat and the motors are both more stable with more mounting points in strong, durable materials that are not likely to buckle.
- Personal safety: Wear gloves when working; remember to be extra careful when dealing with electrical voltages; take time to do things right; hire an electrician; One builder of an EV by converting a Volkswagen bug highly recommended covering wrenches by wrapping them with electrical tape as close the top as possible

6.0 Conclusions and Recommendations

The single seat three-wheel electric vehicle design is proposed in this report which is modelled in SolidWorks. This report includes the wireless charging stations and battery electric system for the single seat electric vehicle. The battery electric system proposed for this specific car composed of hardware and software components to ensure the efficiency of the system. The primary goal in developing the battery electric system of the EV was to ensure that it has long driving range. The current EV are struggling to achieve the long driving range. The primary issue faced during the developed of BES was the integration of Wireless Charging technology with the current EV BES. The design selected for the EV is Reverse-trike. The unique features include the shifting of the centre of mass of the more extensive position.

This design provides more stability and traction to the vehicle as the weight shift is towards the front wheels of the car. The limitation in this design of the EV includes the body shape because it is not the conventional body of the car. Therefore, the manufacturers have to develop the technique to make the shape aerodynamic to reduce the drag force on the car. The overall design and battery electric system of the car proposed in this research project are suitable for the road and legal standard of New Zealand and have the potential to overcome the issues related to the development of current electric vehicles. The recommendations in the design of the EV are listed below:


- The body of the car should be made more aerodynamic than non-aerodynamic shape to reduce drag.
- In order to achieve long driving, range the efficient wireless charging system should be installed.
- To reduce the capital cost of single seat EV the material selection during manufacturing must be lightweight and durable.
- The power steering is recommended in the future design of the EV to reduce the effort in its operation.
- The battery management system should be refined for the proper efficiency and utilization of the power during operation.

7.0 Students Declaration

7.1 Bakelka, Omar

I have not copied any part of this report from any other person's work, except as correctly referenced. Collaboration: No other person has written any part of this report for me.

Student Name: **Bakelka, Omar**

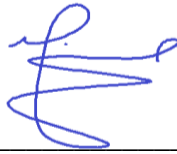
Student declaration of the above: _____ 

Date 04 / 12 / 2017

7.2 Alghamdi, Majed

I have not copied any part of this report from any other person's work, except as correctly referenced. Collaboration: No other person has written any part of this report for me.

Student Name: **Alghamdi, Majed**




Student declaration of the above: _____

Date 04 / 12 / 2017

7.3 Alqahtani, Saeed

I have not copied any part of this report from any other person's work, except as correctly referenced. Collaboration: No other person has written any part of this report for me.

Student Name: **Alqahtani, Saeed**

Student declaration of the above:  _____

Date 04 / 12 / 2017

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9.0 Glossary

Acronym/Term	Meanings
Alternating Current	An electric current that turns around bearing at normal interims. Electric auto engines are the majority of the new breed being of AC sort.
Battery	Power is stockpiling medium that nourishes electric current to the engine. More established EVs utilized NiMH batteries.
Charging	'Refilling' an electric auto's battery with power. The time a battery takes to charge relies upon the extent of the battery in kWh and the measure of electric current being provided.
Direct Current	Electric auto with DC engines for the most part being more affordable to purchase and more straightforward to use on an electric auto.
Electric vehicle	Any vehicle that utilizations electric engines, either in full or to a limited extent, as the impetus. This incorporates unadulterated electrics, crossovers, expanded range electric vehicles and hydrogen energy unit vehicles.
Hours Power	A unit that is utilized to quantify the energy of motors and engines. One unit of strength is equivalent to the power expected to lift 550 pounds one foot in one moment.
Hybrid	An auto that incorporates a little battery and an electric engine to improve the effectiveness of the motor. The battery's charge is kept up by the ICE motor - it cannot be charged by connecting to an electrical supply.
Internal Combustion Engine	A motor controlled through the consumption of non-renewable energy sources. The term 'ICE' regularly utilized as shorthand for any vehicle fueled by an interior burning motor, regardless of whether oil or diesel or some other combustible medium.
Lithium-Ion Battery	These are the present standard in electric vehicle batteries, offering great vitality thickness, power, and quick charging capacity. The life of a lithium Ion battery is evaluated to be the same as the life of the auto.
NiMH Battery	A sort of battery utilized as a part of some more established electric vehicles, offering preferable vitality thickness over lead corrosive yet not as much as lithium particle.
Plug in Hybrid Electric Vehicle	A kind of auto that is designed like a normal half-breed, yet with a greater lithium particle battery pack that can be energized by connecting to a standard power supply. Unadulterated electric driving is expanded over a standard half, and a half before the ICE starts up to help control the wheels.
Plugged-in Places	An NZ government plot that gives financing to particular districts to kick-begin the utilization of electric vehicles locally and tests charging foundation.
Pure Electric	A vehicle controlled exclusively by electric engines utilizing power gave by onboard batteries. The batteries are charged utilizing power from the national network.
Range	The separation you can go on unadulterated electric power before the battery requires a revive.
Range Anxiety	A term used to portray the dread of coming up short on the battery while driving an unadulterated electric auto. Genuine records propose run tension is not as regular as thought, and trials demonstrate that nervousness subsides after some time as drivers turn out to be more OK with their autos' real range capacity.

Regenerative Braking	A vitality recuperation framework utilized as a part of most electric vehicles that can help charge the battery while the auto is backing off. Normally, the electric engine goes about as the generator so that power can stream both courses amongst it and the battery.
Revolution per Minute	The quantity of times the pole of an electric engine turns through 360 degrees in a single moment.
Reverse Trike	A switch or reverse trike is essentially a vehicle having two wheels in the front and one on raise side
Torque	The curving power that causes pivot. On account of autos, torque governs and is the main consideration in an auto's accelerative capacity – with liberal torque, the auto's throttle reaction is significantly more honed.

10.0 Abbreviations

AC Alternating Current	Alternating Current
AS	Ackerman Steering
BES	Battery Electric System
BMS	Battery Management System
C	Centigrade
CO ₂	Carbon dioxide
DC Direct Current	Direct Current
DOF	Degree of Freedom
ETS	Emission Trading System
EV	Electric Vehicle
hp horsepower	horsepower
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
kg	Kilo gram
Li-Ion	Lithium-Ion Battery
IEC	International Electro-technical Commission
m	meter
MoE	Ministry of Environment
MoT	Ministry of Transportation
mm	millimeter
NZ	New Zealand
NZTA	New Zealand Transport Agency
OECD	Organization for Economic Cooperation and Development
PHEV	Plug-in Hybrid Electric Vehicle
RCD	Residual Current Device
SRP	Seating Reference Point
SOH	The State of Health
SOC	The State of Charge
SAE	Society of Automotive Engineer
V	Volt
W	Watt
Wh	Watt-hour
ICV	Infantry Carrier Vehicle

11.0 Appendices

Appendix A

- J1634 SAE Standard

Electric Vehicle Energy Consumption and Range Test Procedure

Standard: **J1634_200210** Issued: 2002-10-25

HISTORICAL Access the latest revision: [J1634_201707](#)

Issuing: **Light Duty Vehicle Performance And Economy Measure Committee**
[Committee Information](#)

Publisher: SAE International

Pages: 13

Scope: This SAE Recommended Practice establishes uniform procedures for testing electric battery-powered vehicles which are capable of being operated on public and private roads. The procedure addresses electric vehicles (EVs) only. It is the intent of this document to provide standard tests which will allow for determination of energy consumption and range based on the Federal Emission Test Procedure using the Urban Dynamometer Driving Schedule (UDDS) and the Highway Fuel Economy Driving Schedule (HFEDS). Realistic alternatives should be allowed for new technology. Evaluations are based on the total vehicle system's performance. Dynamometer test procedures are specified in this document in order to minimize the test-to-test variations inherent with track testing, and to adhere to standard industry practice for energy consumption and range testing.

- J1773 SAE Standard

SAE Electric Vehicle Inductively Coupled Charging

Standard: **J1773_200905** Reaffirmed: 2009-05-28

HISTORICAL Access the latest revision: [J1773_201406](#)

Issuing: **Hybrid - Ev Committee**
[Committee Information](#)

Publisher: SAE International

Pages: 35

Scope: This SAE Recommended Practice establishes the minimum interface compatibility requirements for electric vehicle (EV) inductively coupled charging for North America. This part of the specification is applicable to manually connected inductive charging for Levels 1 and 2 power transfer. Requirements for Level 3 compatibility are contained in Appendix B. Recommended software interface messaging requirements are contained in Appendix A. This type of inductively coupled charging is generally intended for transferring power at frequencies significantly higher than power line frequencies. This part of the specification is not applicable to inductive coupling schemes that employ automatic connection methods or that are intended for transferring power at power line frequencies. in the charge coupler). The charge controller signals the charger to stop charging when it determines that the batteries are completely charged or a fault is detected during the charging process. The following steps correspond with the diagram in Figure 1, and describe the closed-loop charging system.

- J1402 SAE Standard

Automotive Air Brake Hose and Hose Assemblies

Standard: [▶ J1402_196804](#) Revised: 1968-04-01

HISTORICAL Access the latest revision: [J1402_201710](#)

Issuing: [▶ Hydraulic Hose And Hose Fittings Committee](#)

[↳ Committee Information](#)

Publisher: SAE International

Pages: 3

Scope: This recommended practice covers minimum requirements for air brake hose assemblies made from reinforced elastomeric hose and suitable fittings for use in automotive air brake systems including flexible connections from frame to axle, tractor to trailer, trailer to trailer and other unshielded air lines with air pressures up to 1 MPa, that are exposed to potential pull or impact. This hose is not to be used where temperatures, external or internal, fall outside the range of -40 °C to +100 °C.

- J1270 SAE Standard:

Measurement of Passenger Car, Light Truck, and Highway Truck and Bus Tire Rolling Resistance

Standard: [▶ J1270_200609](#) Revised: 2006-09-19

HISTORICAL Access the latest revision: [J1270_201710](#)

Issuing: [▶ Highway Tire Committee](#)

[↳ Committee Information](#)

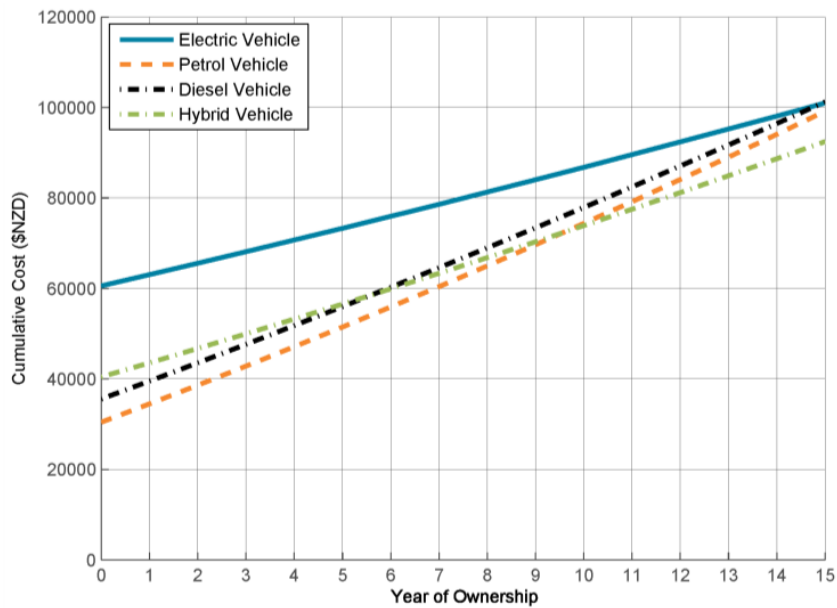
Publisher: SAE International

Pages: 8

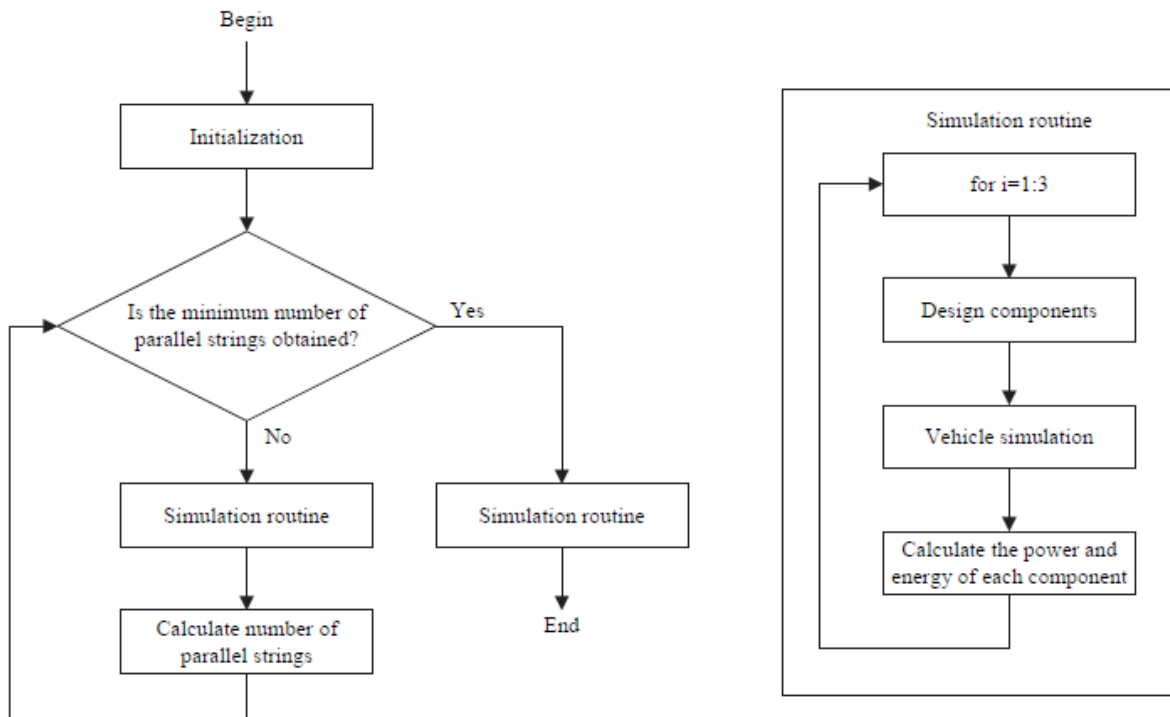
Scope: Basic Methods--The force, torque, and power methods of measurement are all in common use and should yield the same test results. Effects of steering, traction, surface texture, and non-steady-state tire operations are excluded from the recommended practice because they are still in the research stage. Force Method--The chief advantage of the force method is that the only parasitic losses in the measurement are tire spindle bearing losses and aerodynamic losses associated with rotation of the tire and its wheel. The main disadvantage of this method is that the spindle force measured can contain a severe error caused by load misalignment and load-spindle force interaction ("crosstalk"). Elimination or compensation of these effects is necessary. A minor disadvantage is that the loaded radius of the tire must be measured in order to convert spindle force to rolling resistance. Torque Method--The torque method has the advantage that the measurement is direct: rolling resistance is the net torque divided by the test wheel radius.

Appendix B

- Cumulative cost of Different Vehicles



- Sizing of BES



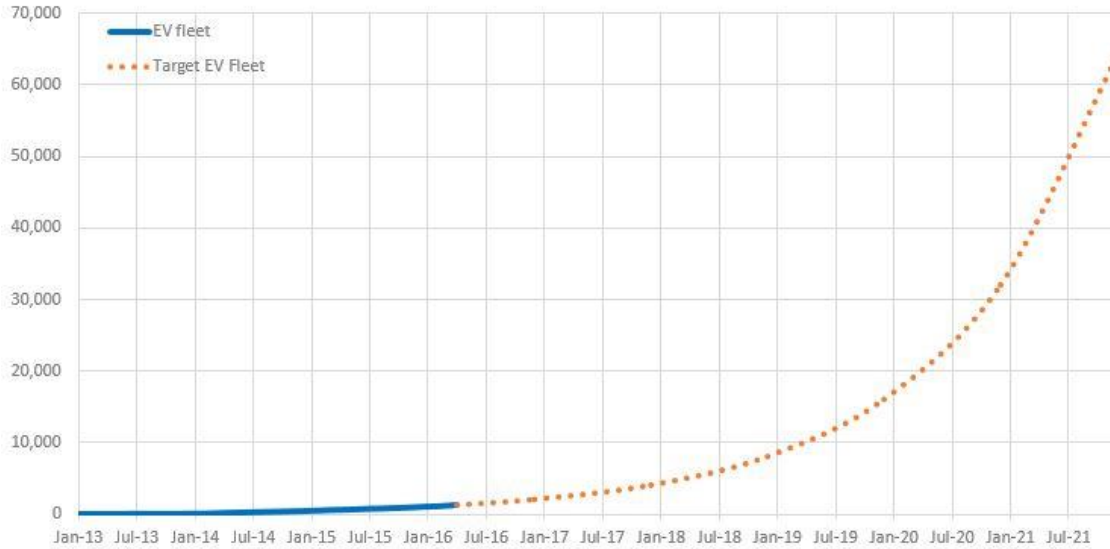
Appendix C

- EV Statistics in New Zealand

Electric Vehicle Fleet & Govt Target

Source: Ministry of Transport

transportblog
co.nz

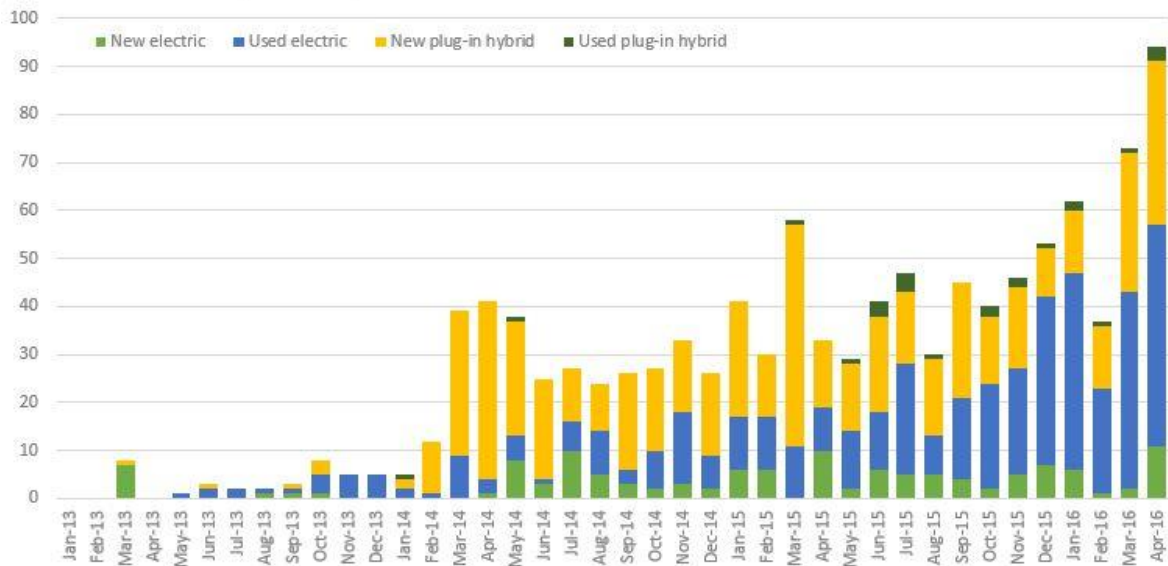


- Vehicle Registration Statistics

Electric Vehicle New Registrations

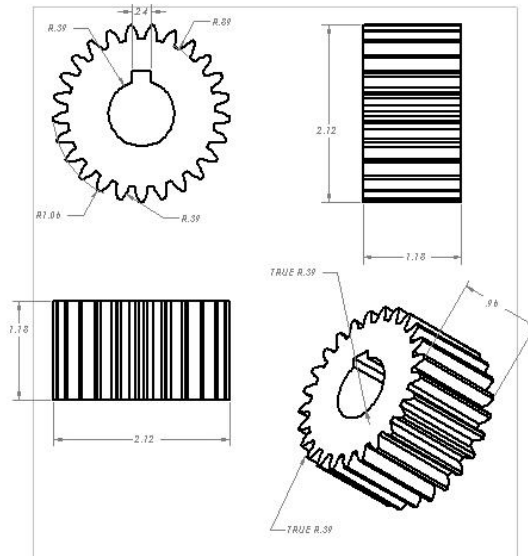
Source: Ministry of Transport

transportblog
co.nz

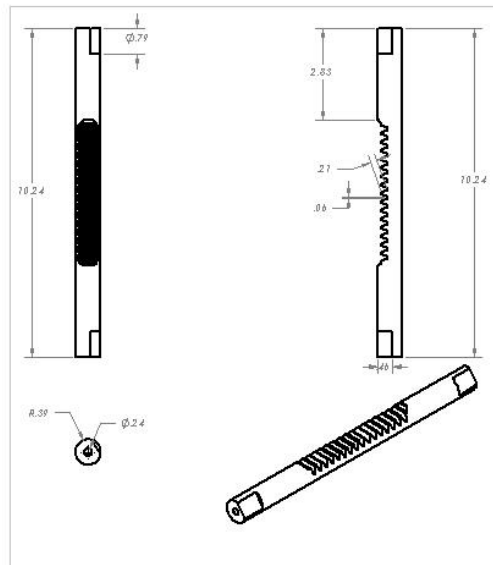


Appendix D

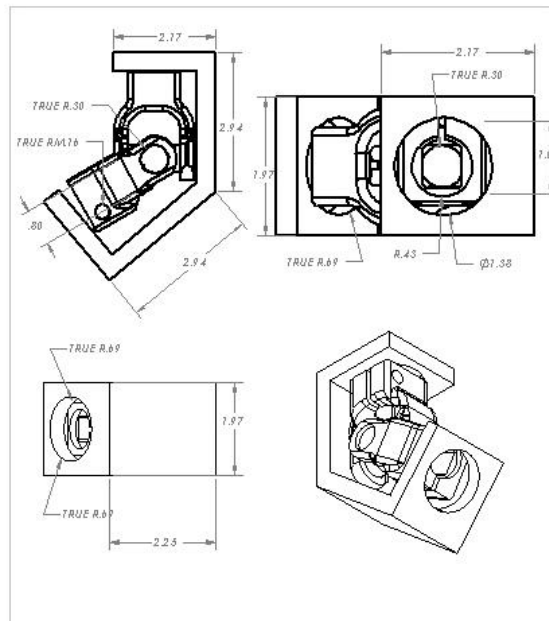
- Pinion Gear Drawing



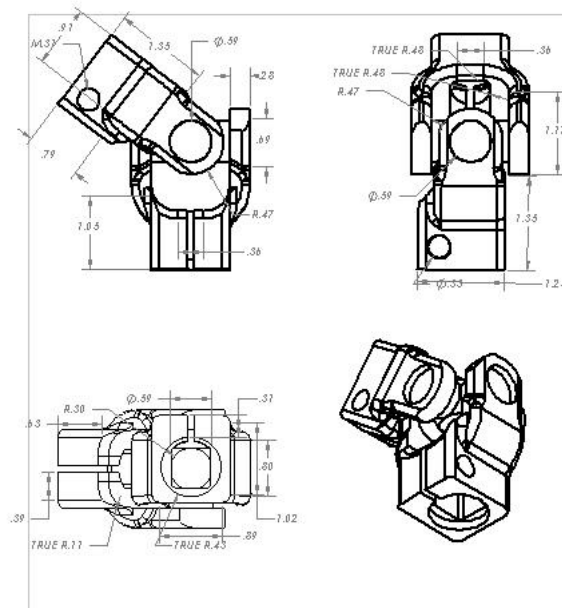
- Rack Drawing



- Steering Joint Drawing

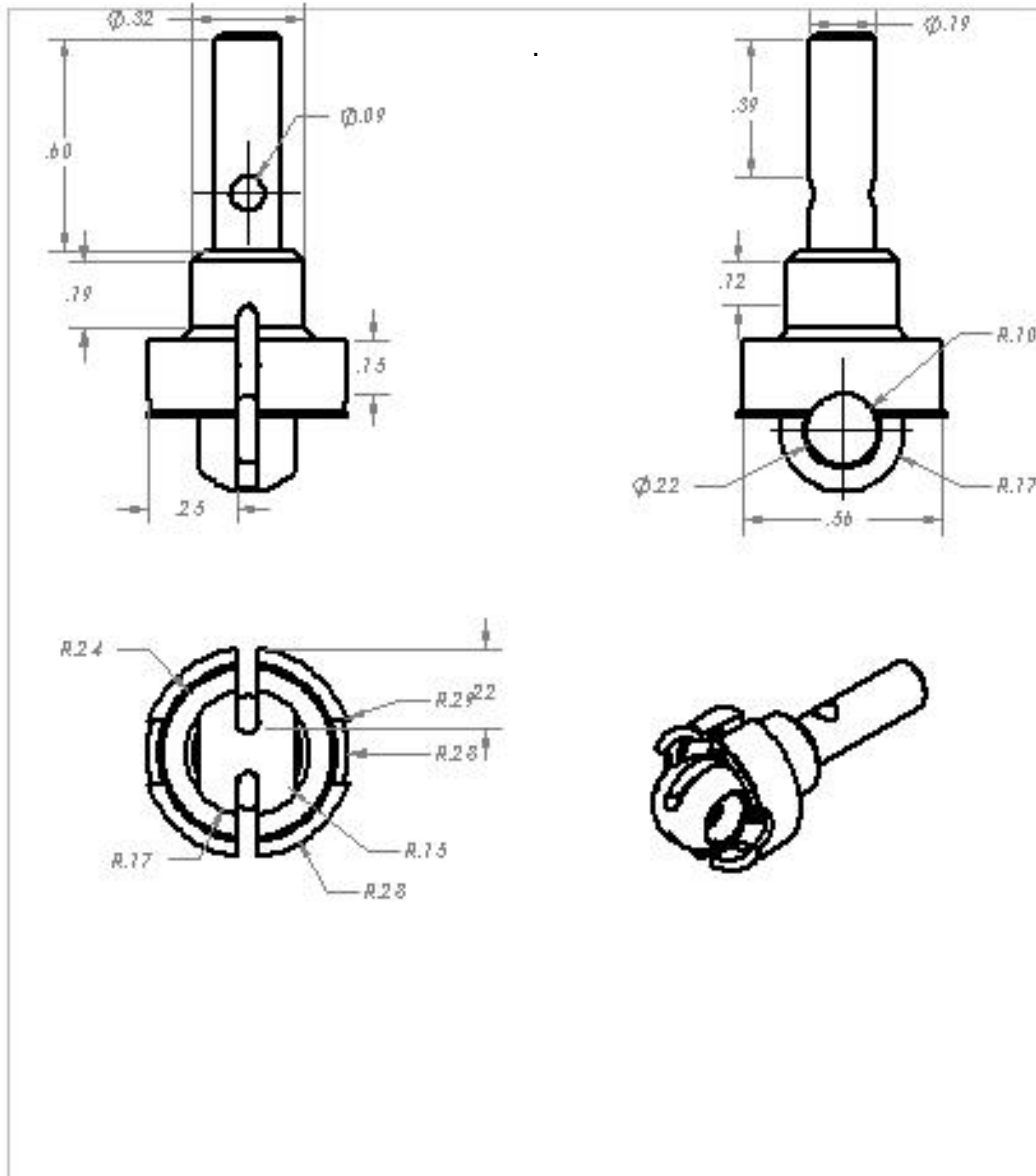


- Universal Joint Drawing

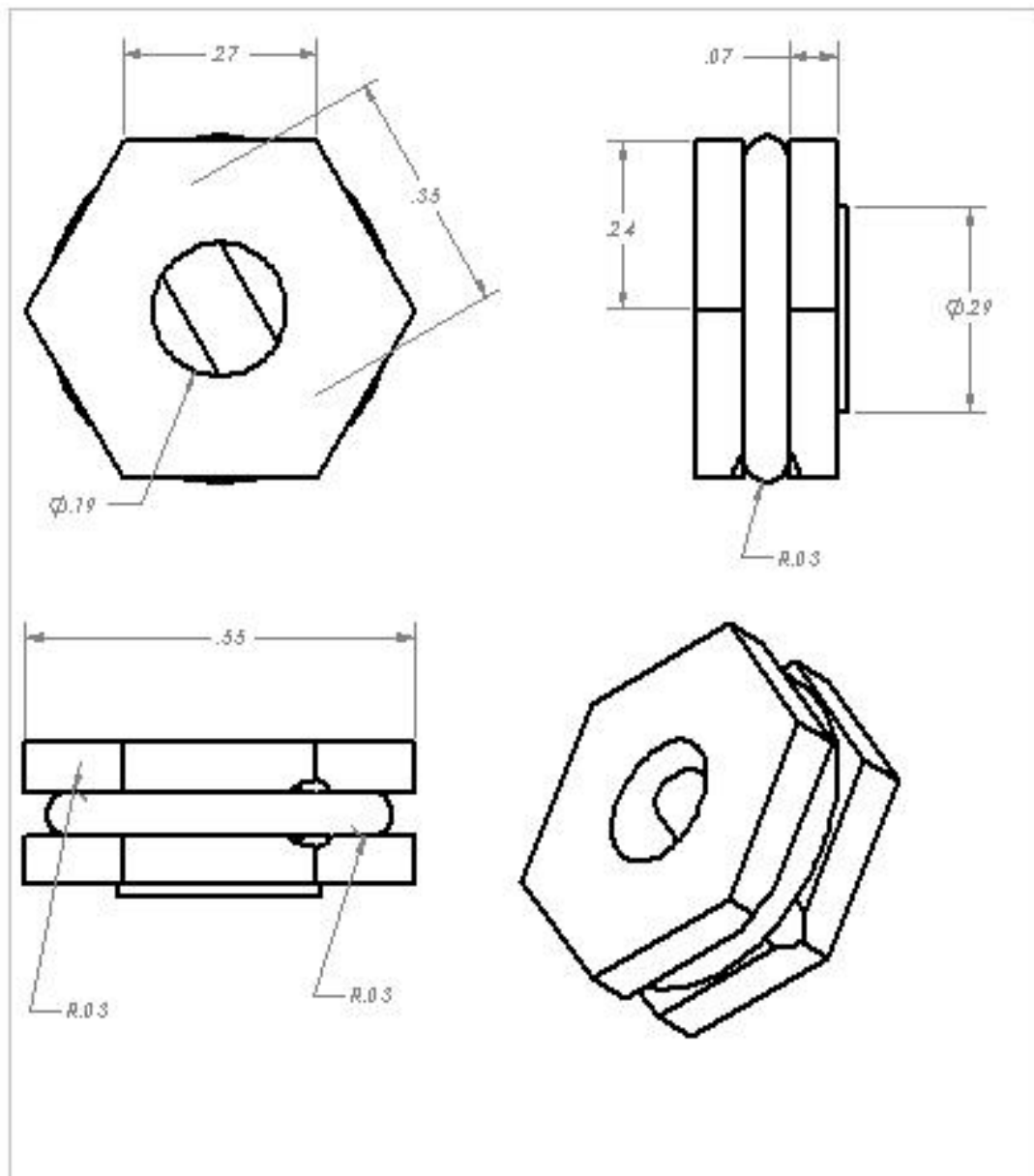


Appendix E

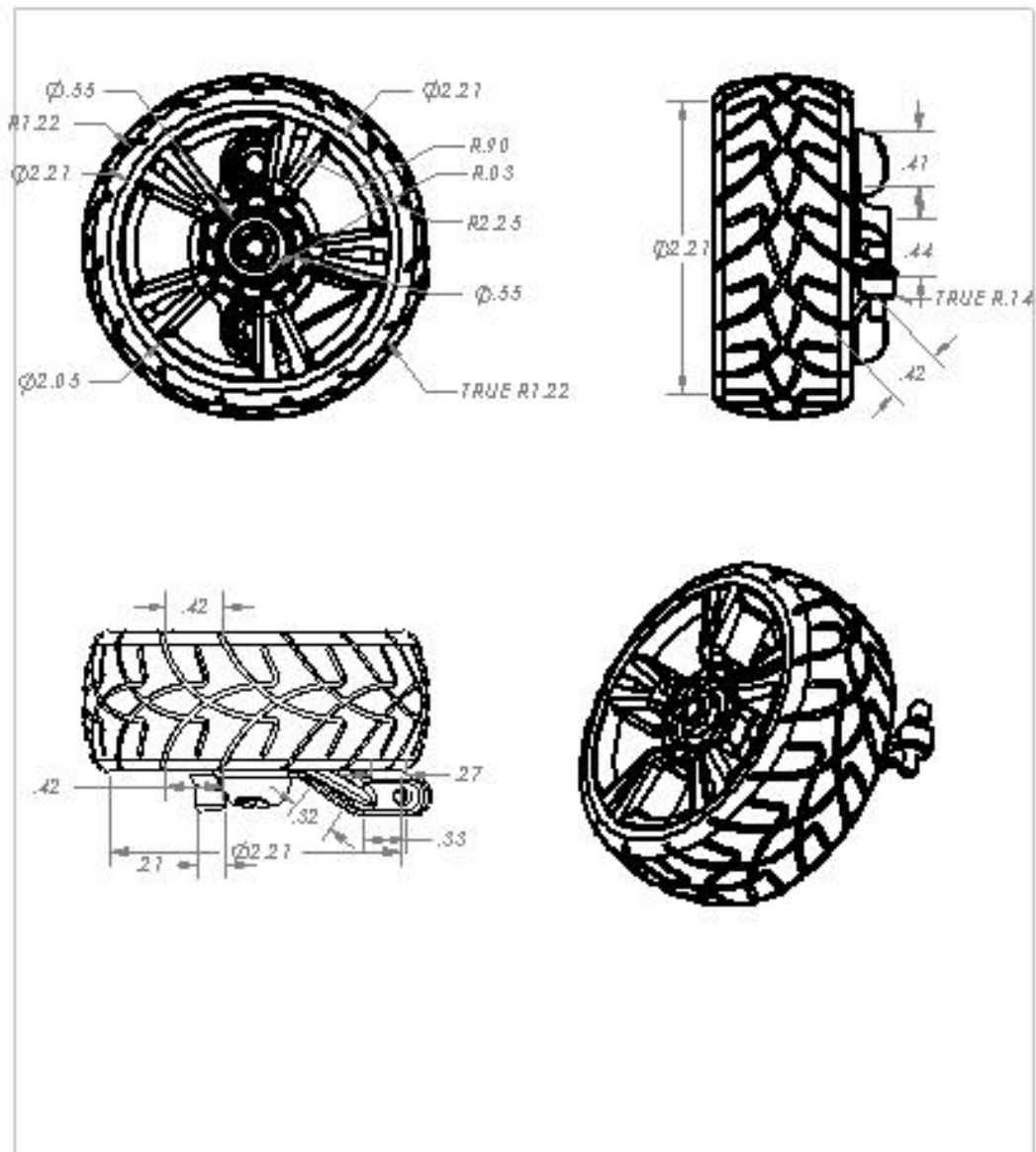
- Front Axel Drawing



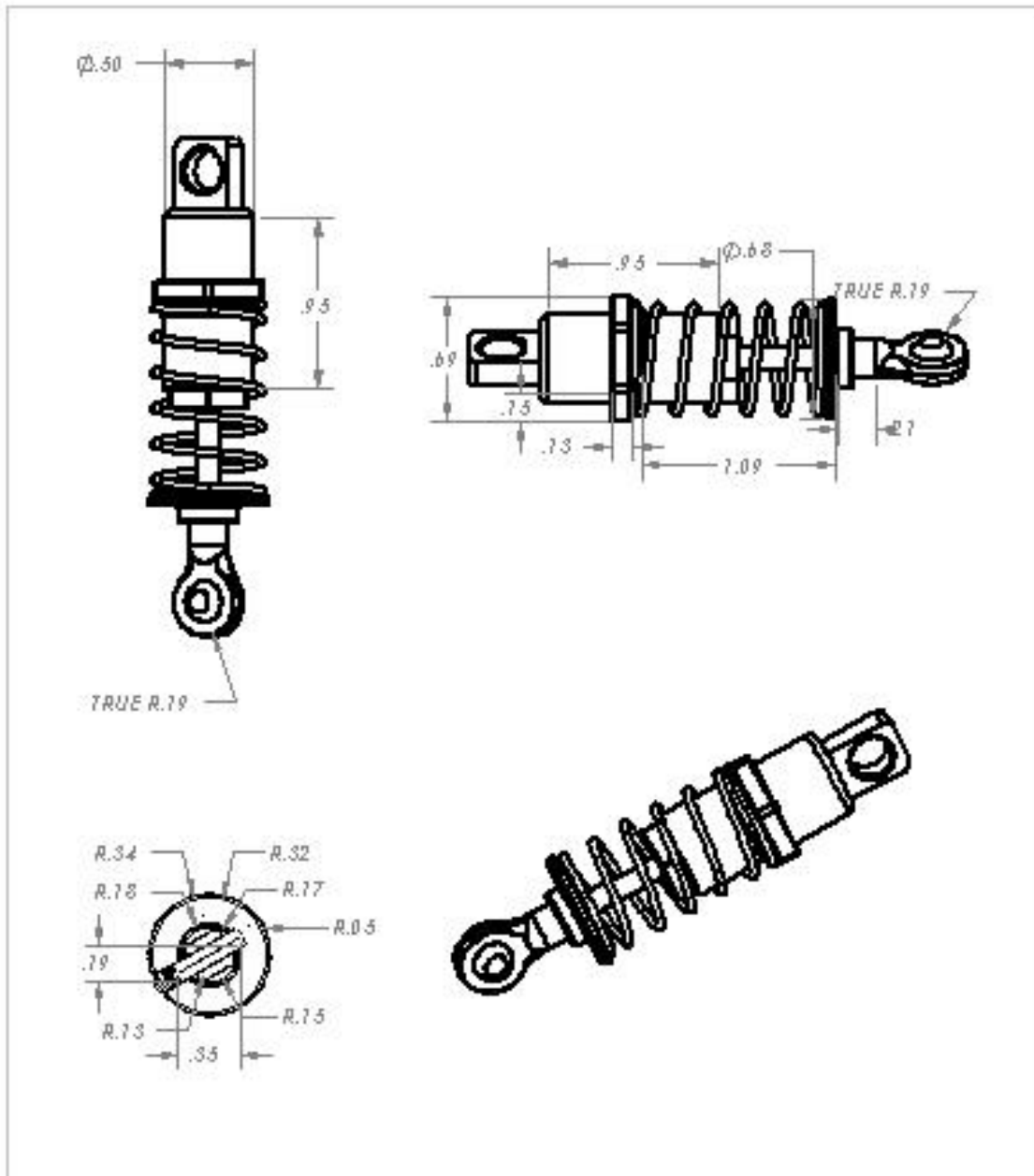
- Hub Drawing



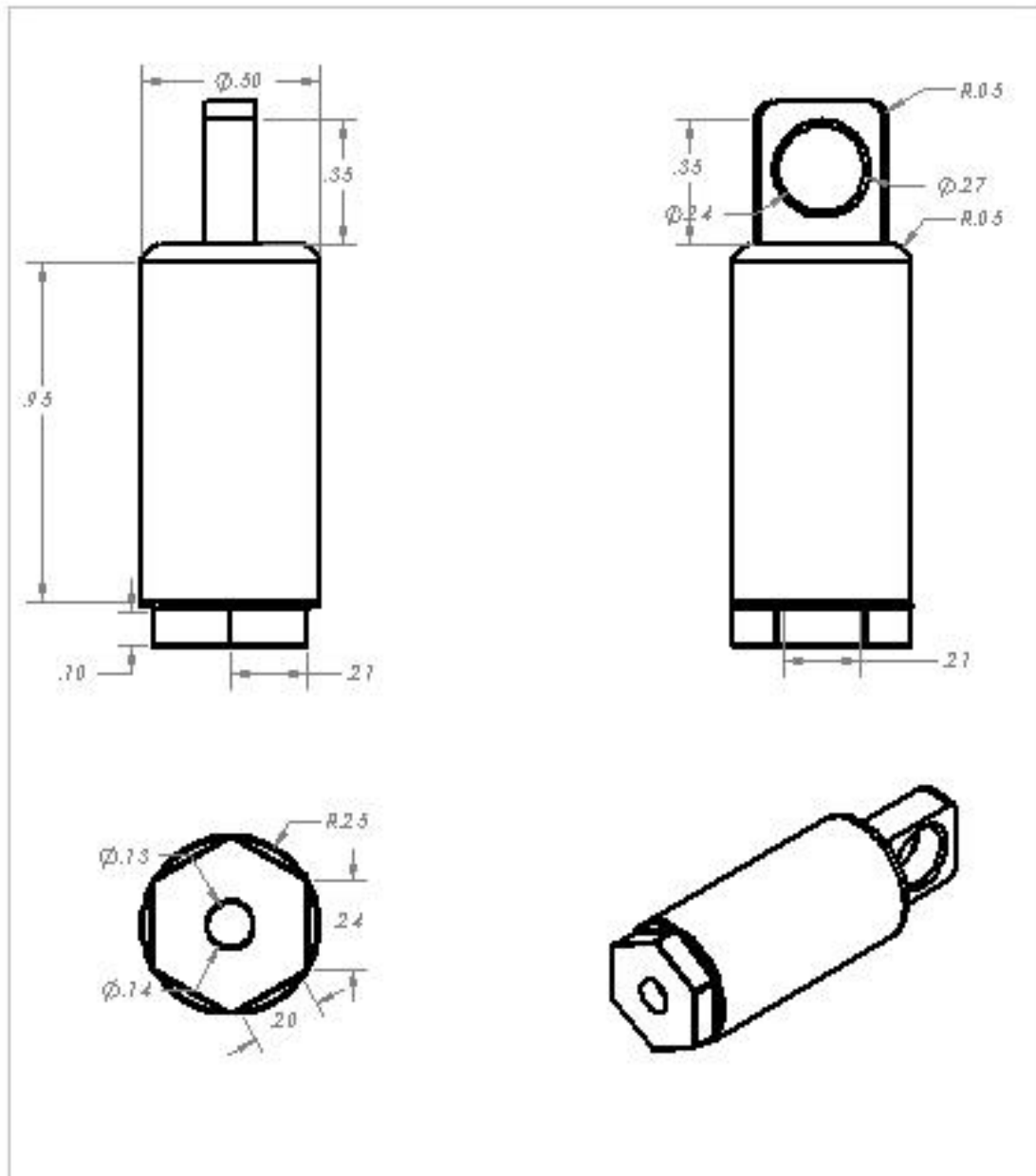
- Wheel Drawing



- Shock Absorber Drawing



- Shock Body Drawing



- Upper Arm Drawing

