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Assessing the Requirements and Viability of Distributed Electric Vehicle Supply

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Abstract. Climate change has been a serious debate topic in almost every country in the world. The need to reduce carbon emission is acknowledged universally irrespective of which side of the climate debate. The development of future electric vehicles will have significant benefits on the environment if this vehicle can be adopted by the general public as the primary mode of transport. However, the existing infrastructure for manufacturing and supporting fossil fuel based vehicles does not fit the operation model of electric vehicle. The industry, supply chain, community and general public need to understand how the new electric vehicle operation system works and what benefits it will bring to them. This paper examines the manufacturing and operational issues of electric vehicles and explores the view of a new global supply chain that will foster design, develop, manufacture and support of electric vehicles. A business plan is proposed to describe the rationale of how to create, deliver, and capture value in terms of economic, social and innovation for supplying electric vehicles to the community.

Keywords. Climate change, Electric vehicles, Operation model, Global supply chain

Introduction

Since Ford Model T was introduced in 1908 as an affordable means of transportation, the number of automobiles has risen to over 1 billion in 2010 [1]. Automobiles today are mostly propelled by an internal combustion engine that is fueled by petrol or diesel [2]. As both of these fuels contribute carbon dioxide to the atmosphere from the burning process, automobiles are blamed to cause climate change and global warming. Climate change brings about significant and lasting effect in the distribution of weather patterns while global warming causes the average temperature of Earth's atmosphere and oceans to increase. Both effects have negative impacts on the ecological, environmental, economic and social factor of the world. Furthermore, rapidly increasing oil prices, concerns on oil dependence, tightening environmental laws and restrictions on greenhouse gas emissions are pushing for alternative power systems for automobiles.

An electric vehicle (EV) is driven by electric motors, it has the advantages that the motor torque generation is fast and accurate, braking energy can be recovered and it does not emit carbon dixode in operation [3]. Since then, research in EV focused n ecological designs [4]. However, although many agreed that one of the main benefits of electric vehicle is its environmental friendliness as compared to the fuel variant of

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vehicle [5], several other studies showed that due to driving style, terrain configuration, meteorological conditions, carbon emission from EV is practically at same level if it was recharged from coal-fired power sources [6], unless it is recharged from cleaner forms of electricity such as hydro and nuclear power. EVs run far more quietly than their combustion-powered counterparts which enhances passenger's health and comfort.

Electric vehicles will have significant benefits on the environment if they are be adopted by the general public as the primary mode of transport. However, electric vehicles are still not commonly used. The existing infrastructure for manufacturing, selling and supporting fossil fuel based vehicles does not fit the operation model of electric vehicle. This paper aims to develop a strategy to revolutionize the supply chain of electric vehicle in the same way as Ford Model T to empower common people with an environmentally friendly means of transportation.

1. Literature Review

The major components for an electric vehicle system are the motor, controller, power supply, charger and drive train [7]. Figure 1 shows a system model for an electric vehicle.

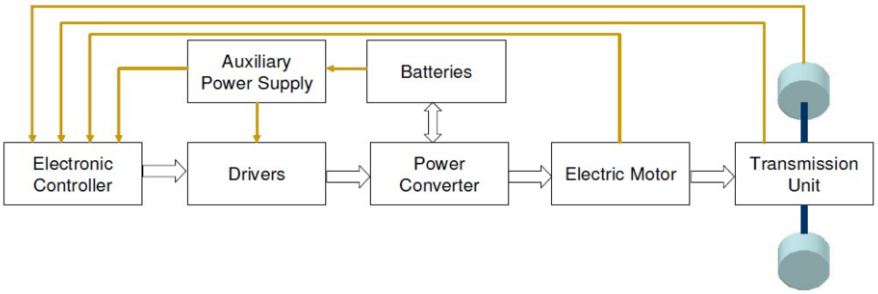

Figure 1. Major components of an electric vehicle.

The control of Electric Vehicle (EV) is complex because its operation varies according to operation parameters and road conditions. Thus, the controller is required to be robust and adaptive with the ability to keep both dynamic and steady state performances. Cheng et al [8] asserts the control of EV is unique and energy efficient.

EVs have advantages over traditional vehicles utilising combustion engine from the viewpoint of electric and control engineering. According to Sakai and Hori [9], electric motor's performance in torque generation is quick and accurate and therefore allows quicker and more precise control. The output torque is easily comprehensible and motors are small enough to be attached to each wheel. The control can be easily designed and implemented with comparatively low cost.

Tesla Motors, Inc. is a company that designs, manufactures and sells electric cars and electric vehicle powertrain components [10]. The company has positioned itself as a superior luxury vehicle with better acceleration, quieter interior and slick appearance. The manufacturing, sales and support for electric vehicles will require proper establishment of a supply chain so that customers can see themselves involved in the process rigorously [11]. Even though the electric car produced by Tesla is a mainstream form of the electric vehicle only possible at an industry level, the idea revolving Tesla's

innovation in battery swapping stations and replacing batteries within minutes proves to further motivate the feasibility of this product. With the outlook of people exchanging parts of its vehicle on a frequent basis, this leads to further opportunities such as having a supply chain to build an electric vehicle in your own garage.

An effective strategy for distributed manufacturing is modular design [12]. In the computer industry, few large companies used to build and sell only complete and integrated products where the hardware and software from operating system to application programs were wholly designed and build by the computer maker and sold as a complete computer. With modularity, computer companies do not need to build a complete computer to sell it. For example, a desktop computer can be constructed with individual modules, built together and used as a sole product. Companies could push a product to market more quickly by designing, building and selling modules rather than a whole computer. This then outlines various possibilities for the car-making industry where it could be constructed like the computer. Hence, this proposal discusses on the feasibility of a business that constructs an electric car in a garage or workshop which involves various components sourced from local and global suppliers.

2. Market Research

Victorian Department of Transport has committed to conduct trials of electric vehicles in Victoria under the Victorian Transport Plan for a period of five years [13]. These trials are used to provide real-world information on the use of electric vehicles in Victorian conditions, including impact on driver behaviour, refueling patterns and vehicle performance and efficiency. The trials asserts that while commercial and government fleet purchases are particularly important markets for new car sales and particularly for early electric vehicles market, the drivers of the purchasing decision for commercial and government fleet vehicles are likely to be very different from private purchasers.

However, it is not possible to assess consumer willingness to purchase electric vehicles based on revealed purchasing behaviour as there are a small range of electric vehicles available worldwide. It may be possible to approximate who would be likely early market electric vehicles adopters on the basis of who is currently purchasing hybrid vehicles. Hybrid vehicles share a number of key features with electric vehicles, including significantly improved fuel efficiency, a price premium relative to comparable internal combustion vehicle and perceptions of innovativeness of technology.

Moore [14] suggests that there is separation between adopter groups, representing next group's reluctance to adopt the new product in forms that appealed to previous adopters. New technologies that gain liking by early adopters and followed strongly amongst these consumers may encounter difficulties to find mass acceptance or require time to transition from niche to mass-market appeal.

Early adopters of hybrid and electric vehicles are expected to share certain key characteristics. In accordance with Turrentine et al [15], hybrid vehicle purchasers made their purchase decision due to ideological reasons and not mainly to save money and they also paid little attention to fuel costs. Higher fuel economy of the hybrid compared to other vehicles purely remains as a self-satisfaction for their vehicle choice. Kurani and Turrentine [16] found that hybrid vehicle purchasers talked about 'making a commitment': setting an example, being a pioneer, talking to other people about their

car. These consumers were appealed by the new technology, the low emissions, sense of consuming fewer resources and tax incentives such as fuel or carbon taxes.

The remaining issue is the availability of this type of vehicles as a customer's package. Visvikis et al [17] reviewed the potential safety risks of EVs. They concluded that there is still a gap in the type-approval legislation relating to the safety and integrity of the rechargeable energy storage system. Concerns have been expressed about the safety of cyclists and pedestrians (particularly visually impaired people), when crossing the road. Even with an exemption for small series production vehicles that all parts and components are homologated, type approval of EVs is still not guaranteed for the whole vehicle automatically.

3. Technical Analysis

Technical analysis of the manufacturability may be grouped into those pertaining to inputs, throughputs and outputs analysis of the electric vehicle [18].

3.1. Input Analysis

Input analysis is mainly concerned with the identification, quantification and evaluation of manufacturing requirements including machinery and materials used. The quality of inputs available in a certain timeframe and cost throughout the life of the project should be properly detailed. If applicable, long-term contracts with potential suppliers should be recorded to cultivate supply sources. In general, the main components for an electric vehicle as shown in Figure 2.

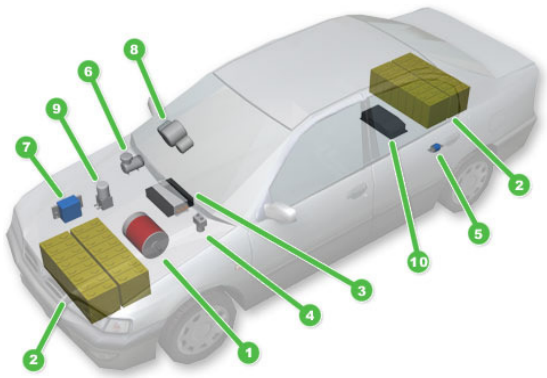

Figure 2. Main components of an EV [19]

Other components that are similarly required for electric cars and common to conventional cars include:

- **Body and main parts**: This includes the bonnet (hood), bump, fascia, fender, grille, pillar, quarter panel, radiator core support, roof rack, spoiler, trim package, trunk, valance, and welded assembly. Additionally, doors and windows are standard as well.

- **Electrical and electronics**: This includes audio or video devices, charging system, electrical supply system, gauges and meters, ignition system, lighting and signaling system, sensors, starting system, switches and wiring harnesses.
- **Interior**: Interior components mainly include floor components and car seats.
- **Powertrain and chassis**: For example braking system; anti-lock braking system (ABS), engine components and parts. As such, a conventional car will require engine oil system, exhaust system, fuel supply system which however is not the case for electric car.
- **Miscellaneous auto parts**: Some parts include air conditioning system (A/C), bearings, hoses, windshield wiper system, air bags, horn and other small parts for a car.

EV purchase prices relative to conventional vehicles are influenced by EV batteries and by final price-point by sellers which will reflect their positioning in each market and business case that establishes each vehicle development program. Given the underdeveloped state of EV manufacturing, it is difficult to characterize maintenance schedules and costs of EVs. EV powertrains are however much simpler than combustion vehicles and have fewer moving parts [20]. Consumable items found in combustion engines (belts, seals, filters, sparkplugs, valves, lubricants, etc.) do not exist in EVs. Meanwhile, maintainable parts that are common to EVs include electronics, cooling fluids and radiators, fans and pump, driveline lubricants, wheel/axle bearings, brake pads and tyres, and air-conditioning systems.

4. Outline of a Business Plan

A business model is required to describe the rationale of how to create, deliver, and capture value in terms of economic, social and innovation for this business.

4.1. Location

Location of the business will be ideal for distribution of products to customers while being close suppliers or port that handles overseas shipping. From statistical information in Victoria [21], it is found that the majority of potential early electric vehicle adopters are located in band east of Melbourne CBD from bayside in the south through to Nillumbik in the north proportion of households that meet early adopter's criteria (Figure 3).

Meanwhile, in order to ensure location of the business should be located near suppliers or the port to ensure ease of obtaining supplies of materials for business operation. Anther factor is to locate business near the customer as the business location works as a showroom while being side-by-side to the assembly site. From the technical analysis, the factory for assembly EVs does not need to be big. A typical industrial site with an area of 1,220 m^2 at the south east suburb of Melbourne only costs $97,700 pa to lease.

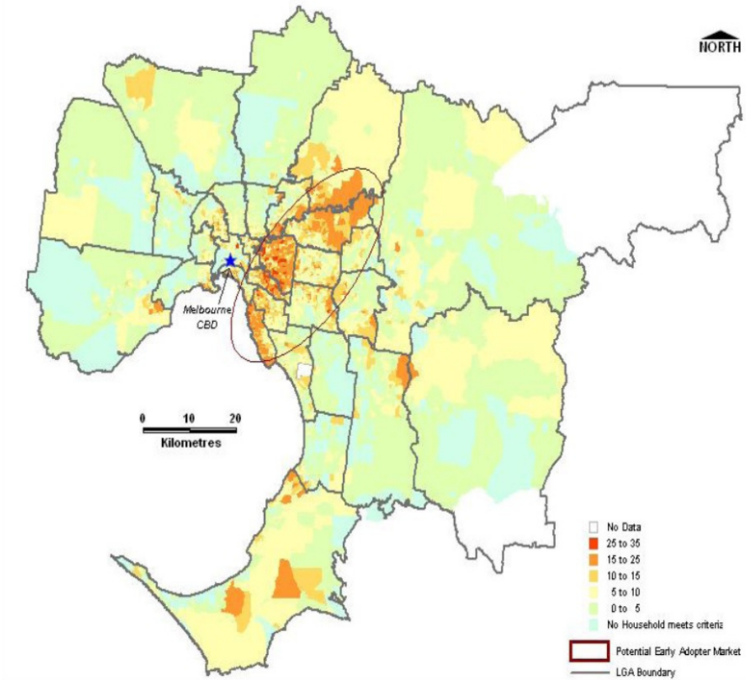

Figure 3. Households meeting electric vehicle early adopter criteria [22].

4.2. Nature of Business

This business aims to provide its customer a cheaper and more economical alternative to purchase electric vehicle where components are sourced locally and overseas, assembled and build-to-order. As this business requires an extensive logistics and supply chain, it will adopt two different business models that are inter-related to look at delivering the seven basic components as mentioned. The two business models are direct sales and 'bricks and clicks' model.

Direct sales model is to market and sell products directly to consumer without the need to go through dealership. The benefits of doing so are firstly, lower the cost render to buyers when they purchase their components or service directly from us. By having the buyers to deal with the factory directly, there is no worry of getting a different price at a different store, which might be the case when going through a dealer that could vary its price for the same component. This one-price-anywhere concept will boost the confidence of consumer on our components, products and service by giving the same treatment and pricing statewide. As this business is fairly new in the country, increasing the confidence of potential consumers should be not overlooked.

The 'bricks and clicks' model is to integrate both offline (bricks) and online (clicks) presences. This way allows the customer to order products either online or physically in one of the stores. Also, prior to any purchase, this allows them to learn about the products thoroughly from home or visit the store to physically try on the products. Online marketing features components features, specifications, pricing, and pictures to allow potential consumers to learn about the products and services available, or at least have access to information from home to build up the interest.

With two models, the products and services are made available for access by consumers as well as providing contact information and nearest store location. By having a simplistic yet detailed approach towards the business would garner positive response and interest from potential consumers on the new innovation of this project.

4.3. Components sourcing and assembly

There are different methods to source components. Initially, components can be sourced from either locally or globally depending by the price and ease of accessibility factor. An ideal profit margin has to be there for any possibility of success of the business. Three models are proposed:

- Medium: Four seater 4 door.
- Small: Two seater 2 door
- Large: Five seater expandable to seven

Parts are sourced and stocked according to these models. The nature of the business provides service to assemble the electric vehicle once the order is made as the electric vehicles are built-to-order.

Assembly of components is handled by a local factory. There will also be on-site inspection and service available for customers within a range of services that could be done at the customer's location.

4.4. EVs in Operation

In the future, the possibility of setting up charging station and battery swapping infrastructure for customers can be established when enough electric vehicles are running on the roads. Battery charging and Battery swapping are two completely different approaches and will require further work [23]. For battery charging service, although many battery system manufacturers try to reduce the charging time, the minimum time for a full charge EV is still in the range of an hour. For battery swapping, it is clear that users are not confident to exchange their batteries with others with unknown history. A different type of battery hire and exchange service system needs to be created.

4.5. Distribution

As a start-up business, the business only plans to provide its products locally. As a means of distribution, customer can pick up the products at the business location or the final product can be sent on land at the customer's cost. The estimate supply lead time is approximately 20 days for the parts to arrive. However, certain parts will be ordered in bulk and therefore require zero lead time as it is stored in the factory. The assembly process will take up to three days which however could be reduced with multiple orders, if they are built together. This will give a total delivery time approximately three weeks from sourcing to delivery to customer.

4.6. Costing and Selling Price

This business assembles cars in a small workshop. The personnel will be qualified staff with relevant knowledge in electric vehicle assembly process (Table 1). As such, the

business will require engineers and technician to be in charge of the technical process while front desk staff is also required to handle the business side in terms of customer query and ordering process.

Table 1. Costing plan

Miscellaneous Cost	Cost per month	Description
Rent	$ 8,100	97,700 per annum
Labour	$41,000	Includes staffing of 5 qualified mechanics, 3 frontdesk/management staff and reward to entrepreneur of this business.
Marketing	$ 1,000	Web hosting and other marketing fees
Utilities	$ 500	General expenses
Total	**$50,600**	

Assuming that total miscellaneous cost is shared among 5 cars (estimated orders per month). The cost of the small assembly shop can be apportioned to the production quantity. By adding the component and car body costs, and with a 30% profit margin, the selling price of a EV can be sold at the factory price in Table 2.

Table 2. Factory selling price

Models	Cost (Main Components)	Cost (Car Body)	Total Miscellaneous Cost	Total Cost	Selling Price (30% on top of Total Cost)
A	2800	2650	3535	8985	11680.5
B	2800	5300	3535	11635	15125.5
C	2800	7950	3535	14285	18570.5

4.7. Legal and administrative

This investigation focuses on the viability of supply chain. The legislation issue is an engineering issue that is outside the scope of this study. Hence, the business system considered here assumes availability of a type approval for a family of EVs.

Other legal and administrative issues include choice of the form of business organisation, registration and clearances and approvals from diverse authorities. The electric vehicle manufactured by the business will require a 'Vehicle Sales Licence' that allows buying, selling and auctioning vehicles other that motor cycles, caravans or campervans in the country [23]. Registration of vehicle is also required with Vicroads to ensure it meets necessary safety and environmental standards [24].

5. Risk Assessment

The risks in this business can be assessed from the supplies. Suppliers have the choice to exercise bargaining power on participants in an industry by raising prices or reducing the quality of purchased goods and services. Powerful suppliers may earn more of the value by charging higher prices, limiting quality of services or shifting costs to industry participants.

The business relies on the components supplied by suppliers that are based locally and globally. The business model works on having the electric cars to be built-to-order where it can be considered to be 'just-in-time' for the components to arrive as they are needed and when there are orders. Any unexpected delay or unreliability from the supplier can cause a major upset in the process of delivering final product to the

customer within the promised time. This can further lead to losing confidence from the customers and potentially lose out any form of market share.

The rivalry among existing competitors may take on many forms such as price discounting, new product introductions, advertising campaigns, and service improvements. High level of rivalry limits the profitability of an industry. The degree of which rivalry drives down an industry's profit potential depends on the intensity with which companies compete and the basis on which they compete.

The above risks need to be mitigated. The company needs to prepare for any unreliable suppliers that could be the ones to provide main components for the electric vehicle. It is also dangerous for the company to be complacent with the current products available especially facing with a diverse market for electric vehicles, not to mention to compete with conventional cars. Therefore, the company should aim at building up its reputation through the products and services it provides to be a class on its own, even if selling a cheaper product as compared to the other alternative products available, thus able to put the company head-to-head with the competitors.

6. Conclusion

Due to the design characteristics of electric vehicles, it is possible to harness the power of an effective global supply chain to manufacture the vehicles at a location close to the customers. Modularity as practiced in the computer industry has shown prospects of building an integrated product from individual modules. By integrating modular design, electric car can be built from different modules that are grouped by mechanical, data and power interface.

A feasibility study was carried out to know whether a sizeable market for the proposed product exists, what would be the investment requirements and how to go about to establish that idea. The market analysis indicates the location of potential early adopters within Victoria which provides a good indicator of where the business should be located. The technical analysis was also about to identify the required components of the electric vehicle. A business plan was then constructed to define the business of electric vehicle. The components required to build an electric vehicle was also identified, leading to selection of suppliers for parts and material required. Three products were proposed categorised as 2-door, 4-door and family size variants to provide a variety of products to market. The pricing is found to be reasonable compared to traditional fossil fuel powered vehicles.

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