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Innovation in the midst of uncertainty- A case study of Mahindra Reva Electric Vehicles Private Limited

INTRODUCTION

It was the summer of the year 1989. Chetan Maini, a young graduate student at the Department of Mechanical Engineering, University of Michigan, hit upon the idea of making the most energy efficient car in the world. It all began as a hobby for Chetan, the youngest son of Dr. Sudharshan Maini, the head of the Maini Group in India, when he was in school. The group's first company, Maini Precision Products (MPP) was started in the year 1973. It manufactured 1,500 world-class precision components and assemblies in hydraulics, material handling, automotive and off-highway for customers in Europe, Canada, France, Brazil and Spain.

While in St. Joseph's Boys' High School, Bengaluru, India, Chetan built a remote controlled model car and a go-kart. At the age of 14, he built a 35 cm long electric car that could run at the speed of 30 kilometres (km) per hour. Later, he obtained his Bachelor's degree in Mechanical Engineering from the University of Michigan, the United States, in the year 1992. During the very first year of his college he built a super mileage, solar powered car that would yield 400 km per litre. This car won the first prize in the United States while Chetan was pursuing his Masters in Stanford University in the year 1990. After completing his post-graduation, he joined Amerigon Electric Vehicles Technologies Inc. in the United States. Amerigon which was set up in 1991 by Lon Bell in California, was a pioneer in thermoelectrically heated and cooled seat systems for the automotive industry. Chetan joined Amerigon's electric vehicle project as a project engineer and later got promoted as manager. At Amerigon, Chetan gained knowledge about electric vehicle technology, the fundamentals of cost control, industrial management and marketing strategy.

The year 1991 saw India go through economic reforms and move towards liberalisation, privatisation and globalisation. The economy opened up for foreign countries, thus creating a conducive business environment. The Indian government encouraged the setting up of new industries to encourage global companies entering India. The automobile industry too underwent change with new product launches during this period.

Once, Chetan mentioned, "I used to visit India once a year and started getting a feel of how things are changing – the economy was opening up, pollution was getting crazy, consumerism had picked up and hence I found the idea of a low cost electric car for India very relevant." However, Chetan, who visited India during that period was concerned that if most ambitious Indians dreamt of owning a car, what would happen to the environment? Petrol cars caused more pollution. He felt that the economy and the business environment were ready for the launch of a fuel efficient car for the price conscious Indian. By this time, the parent company

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Maini Group had already made a successful foray into making energy efficient vehicles. Chetan was confident about the expertise he had gained at Amerigon. With this confidence, he launched the electric car in the Indian market.

HISTORY OF ELECTRIC VEHICLES (EV)

The evolution and growth of electric vehicles was inspired by the concept of electro magnetism developed by several European scientists like Volta, Faraday and Tesla. Alessandro G.A. Volta (1745– 1827), an Italian physicist and chemist, was credited with the invention of the first electrical battery. Michael Faraday (1791–1867) was an English scientist who contributed to the fields of electromagnetism and electrochemistry. Nikola Tesla (1856 –1943) was a Serbian American inventor and an electrical engineer. He is best known for his contributions to the design of modern alternating current (AC) electricity supply systems. Thomas Edison could be credited with joining this group as he saw the opportunity for an electric car and his efforts went into making the first nickel iron battery for electric cars. The years after this were probably the most opportune moments for the development of an electric car.

A world exhibition held in Chicago in 1893 featured six types of electric cars. However, these cars were competing with two other types of vehicles, the steam engines and the gasoline Internal Combustion Engines (ICE). This was the period during which several technical and infrastructural innovations took place. Fast charging of batteries was required on a mass scale. For electric cars, grid charging stations were established and there were continuous discussions about further expansion of these capacities (Exhibit 1). It was reported that European countries along with Japan continued the use of electric cars because of shortage of gasoline in Germany. It was also reported that Germans used 3,000 electric vehicles during the Second World War. However, the rate of these infrastructural changes was not good enough to compete with similar changes in gasoline powered automobiles. Various reports released during this period indicate that electric cars lost the race to capture the automobile market.

NEED FOR ELECTRIC VEHICLES (EV)

During the seventies, three important things happened. The Club of Rome released the book *Limits to Growth* by Meadow *et al.* (1972). In their book, the authors highlighted the issue of absolute global limits to future growth due to the use of non-renewable natural resources like gasoline. Second, the western world was hit by an oil embargo by the oil producing nations in the Middle East leading to rationing of oil. The third point of discussion was on nuclear power. From the early seventies, the debate had started across almost all nations in the western world on the potential of renewable resources for other than manufacturing of energy efficient cars.

In the next 50 years, the population of the world is expected to grow up to 10 billion (Exhibit 2) and the number of vehicles to 2.5 billion (Exhibit 3). With the exponential increase in the number of vehicles in the coming years, the gasoline requirement from the automobile industry is expected to be three times more. Needless to say the existing gasoline reserves would be inadequate to cater to the needs of the increased number of vehicles.

Another aspect is that the increase in the number of vehicles would lead to increasing emission levels. If so, what would be the impact of such emissions on the environment? Assuming a linear growth in emissions with the number of vehicles on the roads, our population may not be able to cope with increasing emission levels. Hence, there is need for alternate fuels and alternate cars. EV or Hybrid Electric Vehicles (HEV) could be the solution.

WHAT IS AN EV?

An EV, also known as an electric drive vehicle, is run by electricity from battery operated sources to drive a motor that propels the vehicle, in place of gasoline operated engines (Exhibit 4). An EV is powered by external sources like an electric train, electric aircraft or electric spacecraft, a self-contained battery or a generator to convert battery fuel into electricity.

EVs first came into existence in the middle of the 19th century, when electricity was among the preferred methods for motor vehicle propulsion, providing a level of comfort and ease of operation that could not be achieved by the gasoline cars of the time. ICE was the dominant propulsion method for motor vehicles for almost 100 years. However, electric power has remained common in modes of transport like trains and smaller vehicles of all types.

Electric vehicles were considered to be not only a transportation machine, but also a new type of vehicle (Chan, 2001). This was a vehicle with a distinct characteristic based on a modern electric propulsion system that had a motor, a power converter and an energy source. It was not just a car, but a necessity in our society, and catered to the need for a clean, energy efficient transportation system. So, it became necessary to understand and study the end user's expectation before designing an EV.

Electric vehicles had three main subsystems - the electric propulsion sub-system, the energy source subsystem and the auxiliary system. Breaking down the product further, there was an electric propulsion system, an electronic controller, a power converter, an electric motor, a mechanical transmission and driving wheels. The second sub-system known as the energy source sub-system had three sub-components - an energy management unit, energy source unit and energy refuelling unit. The energy management unit worked in tandem with the electronic controller to control the regenerative braking system and its energy recovery. It also worked with the re-fuelling unit to monitor and control the refuelling of the energy source. The third sub-system, the auxiliary sub-system, had three components: an auxiliary power supply unit, a power steering unit and a temperature control unit. The auxiliary power supply unit provided the necessary power with different voltage levels for all EV auxiliaries especially for the temperature control and power steering units.

The brakes and accelerator pedals on the car received the input from the driver. The electronic controller transmitted a control signal to switch on or switch off the power devices of the power converter. This monitored and controlled the power flow between the electric motor and the energy source of the electric motor. These mechanisms and engineering concepts allowed the system to control the speed, based on the inputs provided by the driver.

CONFIGURATION OF AN EV

Due to variations in electric propulsion and energy sources there are many possible EV configurations.

Exhibit 5 and 6 show the details of configuration of an electric vehicle.

KEY TECHNOLOGIES OF REVA SUPPORTED BY THE MAINI GROUP

The battery was an integral part of an electric car and was also a critical component - it had to be small and safe. Maini Materials Movement (MMM) stepped in to help out Reva in making the battery chargers for them. This helped Reva cut down on production costs. The other core technology of Reva was the Energy Management System (EMS) which was transferred from Amerigon to The Reva Electric Car Company (RECC) in 1998-99. Since then, EMS underwent tremendous technological changes to achieve superior capabilities (Exhibit 7).

The key components for Reva's body were vacuum formed plastics made by Maini Precision Products (MPP). MPP put up the infrastructure and the machines that built body panels for the Reva. This led to the formation of a new company named Maini Plastics & Composites. The backbone of the Reva was a precision space frame – a complex three dimensional chassis. With its expertise in welding, MMM set up a chassis division and a painting division to service RECC.

As the entire concept of the making of an electric car and its components was new, the suppliers refused to make and deliver even small mechanical components. The Maini group invested heavily in the Pro/Engineer (Pro/E) parametric design software platforms, which was later put into use by Reva. The Maini group provided complete support by handing over the entire factory with all its facilities to the Reva team.

HISTORY OF REVA

In 1956, Sudharshan K. Maini thought of building a small car that would suit Indian conditions. His company, Maini Group, which was incorporated in 1973, supplied high precision automotive components to its clients. MMM, which Sudharshan established in 1984, manufactured electric golf carts, airport vehicles and forklift trucks. Eventually, the Maini Group earned the recognition of manufacturing automotive components and battery operated material-handling equipment and was the first company in India to do so. However, the first Reva car was released in the market only in 2001(Exhibit 8).

Reva was launched when the sales of EV were at an all-time low. Hence, Reva invested in new technologies and a series of innovations. Right from the time of its launch in India, the government, corporates and opinion makers were interested in the concept car Reva. Over the years, Reva won several awards for its innovation as it was the result of a synergy of talent, determination and capability. With the Maini Group well established in India and the emerging middle class seeking mobility in the city with less capital investment, Chetan was confident that India would be a great market for launching the small electric car. A deal was inked in 1994 between the Maini Group of Bengaluru and Amerigon of California to market electric cars in India (Exhibit 9). The first market survey conducted in five Indian cities was very positive and the consumers preferred a two-seater electric car with room for two small children. However, there were concerns about the performance of the car and the charging of batteries.

Based on consumer feedback, the first few cars were made in California. Chetan headed the team from India which worked on building the electric car. About 250 kilograms of materials such as steering racks, suspension brakes, door handles and wiper blades were taken from India to ensure that Indian-made components were used. This ensured supplier connectivity while manufacturing in India and time saving during the testing process. Within a few months, both, the Maini Group and Amerigon had spent over USD 1 million approximately to develop the prototype. At this juncture, funding became an issue in the manufacture of electric cars.

In 1998, the top management of Amerigon discontinued the collaborative work with the Maini Group. This was a setback to Sudharshan because Amerigon had started working on a climate control seat based on the solid state heating and cooling technology. Later, when Lon – founder of Amerigon returned to the company, RECC commenced the designing and manufacturing of compact electric vehicles. The entire production was shifted to India and started work in a shed with 30 employees.

CHALLENGES FACED BY REVA

Reva was officially launched in 2001 in New Delhi, the capital of India. Reva went through a series of issues during the launch period. Just before its launch, there was an unexpected blow from the government. The Indian government increased the tax on electric vehicles while reducing the same on petrol vehicles. Consumers were hesitant to adapt to electric car technologies as globally these had not been very popular and Reva as a company was little known in the automotive market. As a benchmark for comparison, Indians preferred high-volume small ICE engine vehicles.

Chetan thought that due to narrow roads and lack of parking spaces, middle class Indians would prefer smaller cars which were easy to navigate in congested cities. Later, he realised that in India, a car was viewed as a status symbol, and the bigger the car, the higher the status accorded to its owner.

Across the globe, battery technology had not evolved with the usage of lead acid variants. The weight of the battery affected the car's range and speed due to which the production department had to compromise on the car's interiors and make it lightweight. Based on consumer feedback, all Reva cars were made air conditioned. In the earlier models, air conditioning had been optional. Consumers faced issues with electric chargers which were later rectified. The company was more reactive than proactive in its components and features as the product was novel in the market and consumers were comparing electric cars with petrol cars. After the new product launch, RECC was more focussed on technology than on creating a strategy about how to reach the consumer by creating awareness among them about eco-friendly cars. In addition to these issues, the lack of a campaign and lack of advertising led to the hampered sales of Reva.

By 2006, people's sentiments in the global scenario had changed for good. Global fuel prices went up and consciousness about emissions related to automobiles increased. The book by Al Gore on "The Planetary Emergency of Global Warming" – *An Inconvenient Truth* created a ruckus in the market and things seemed to be working well for India's electric car Reva. The next generation Reva, developed in 2006, had incorporated many of the features developed in the Next Gen UK car back in 2003, with curved windshields, disc brakes and leather seats. The key new technology AC drive-train, provided higher top speed and better acceleration.

GLOBAL MARKET

A group of entrepreneurs called 'Leader's Quest' visited the production facility of Reva in 2002. Impressed by the plant, they agreed to import Reva in the UK (United Kingdom) under the company name GoinGreen. Reva was launched under the new name G-Wiz. In order to suit the local conditions and standards of the UK, about 134 changes were made in the car. The launch price of G-Wiz in London was about INR 4.2-4.9 lakhs[1] approximately. Ken

[1] 10 lakhs = 1 Million
1 Crore = 10 Million

Livingstone, the then mayor of London, exempted G-Wiz from the congestion charge levied on cars coming into the city centre on weekdays. Free parking and charging were provided in central London. RECC had a remarkable working experience with GoinGreen. It helped them understand the European market and gave a new perspective to the business. Reva sold cars online without a single paper ever being printed. GoinGreen successfully sold 1200 G-Wiz cars over a period of seven years.

In 2007, G-Wiz had to face an unforeseen challenge from the government of the UK. The Department of Transport, UK decided to review the safety regulations of vehicles like G-Wiz. These vehicles fell into the category of quadricycles due to the fact that they were lighter and ran on low speed. In accordance with the same, a crash test was conducted on the vehicle and G-Wiz failed in the test. Photographs of the damaged G-Wiz were flashed across the front pages of the newspapers and other media by the popular magazine Top Gear. As the reports of the crash test had not been positive, the sales of the vehicle dropped. A year later Revai was launched with a more powerful AC drive-train and other safety features leading to increased sales in Europe. The company exported Revai to countries like Spain, Japan, Cyprus, Portugal, Iceland and Norway (Exhibit 10).

GROWTH TRAJECTORY

After the launch of Revai in 2008, future models of NXR and NXG were launched at the Frankfurt motor show in 2009. In a period of two years, over 3,500 cars were sold across the world. Though Reva had the technical expertise to bring out innovative products to the market, the company needed financial support for mass production. As the company was struggling for finance, in 2010, Mahindra & Mahindra (M&M) stepped in and acquired 55.2% of Reva with the promoters holding 31% in Mahindra Reva Electric Vehicles Private Limited.

MAHINDRA GROUP ENTERS

Founded in the year 1945, M&M entered automotive manufacturing in 1947. M&M believed in a business model of creating empowered companies that enjoyed the best of entrepreneurial independence and group wide synergies. It was a USD 16.5 billion multinational group with more than 200,000 employees in over 100 countries across the globe. With a presence in 18 key industries including aerospace, defence, energy, farm equipment, information technology, retail, logistics and automobiles, the company believed in commitment to sustainability.

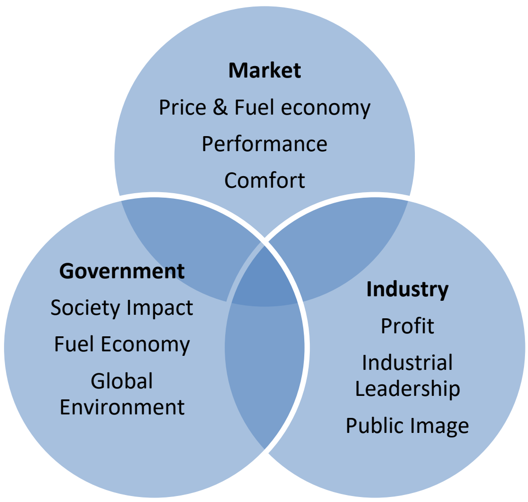
The electric vehicle category was considered by experts to hold a lot of potential as a concept to promote clean air technology. M&M got hold of the better platform on the technological aspects for EV vehicles by acquiring Reva. M&M owns 55.2% equity in Mahindra Reva by a combination of equity purchase from the promoters and a fresh equity infusion of over INR 45 crores into the company (Source: http://www.mahindra.com/news-room/press-release/1294055714). The company bet on alternative fuel development that could give it the cutting edge to compete in a highly competitive global market place.

Under the new management, Mahindra Reva launched Mahindra e2o (previously Reva NXR) – an urban electric car hatchback in 2013. The car was priced at USD 11,000 and got a 29% subsidy from the Government of India during its launch. The subsidy was later withdrawn. The car was priced at USD 11000. e2o has ~16% lower CO_2 emissions that petrol, ~33% lower than diesel even after accounting for emissions from electricity generation system in India. (Source: http://www.cseindia.org/userfiles/cngfuture_pdf.pdf)

At the time of launch, there was no central government subsidy available for electric vehicles in India. However, the State Government of Delhi provided subsidy to vehicles registered to owners residing in Delhi State. In November 2010, the Government of India, through the Ministry of New and Renewable Energy (MNRE), announced a subsidy of INR 950 million for electric vehicles. The subsidy provided benefits of up to 20% on the ex-factory price with a maximum benefit of INR 100,000 on electric cars. This scheme ended on March 31, 2012. Effective April 1, 2015, the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme was brought in by the Government of India.

A new plant with an annual production capacity of 30,000 vehicles in Bengaluru was set up. It was considered to be the largest operational example of a plant specifically dedicated to the assembly of battery electric vehicles. Mahindra e2o added new features of telematics and mobility solutions in alliance with the telecom major Vodafone.

For a technologically sound product like Reva e2o, in order to become commercially successful, three supporting pillars were required. These pillars, namely, markets, government and industry would play complementing roles. Each of the components would operate with a different goal, but with cooperation and commitment, the chances of success would be higher.



Factors like fuel economy, performance and global environment worked in the favour of the e2o. If the government had provided subsidies to the buyers with the support of the industry to produce innovative electric vehicles, the markets would have definitely reacted, with more consumers switching to eco-friendly vehicles.

FUTURE ROAD MAP OF REVA

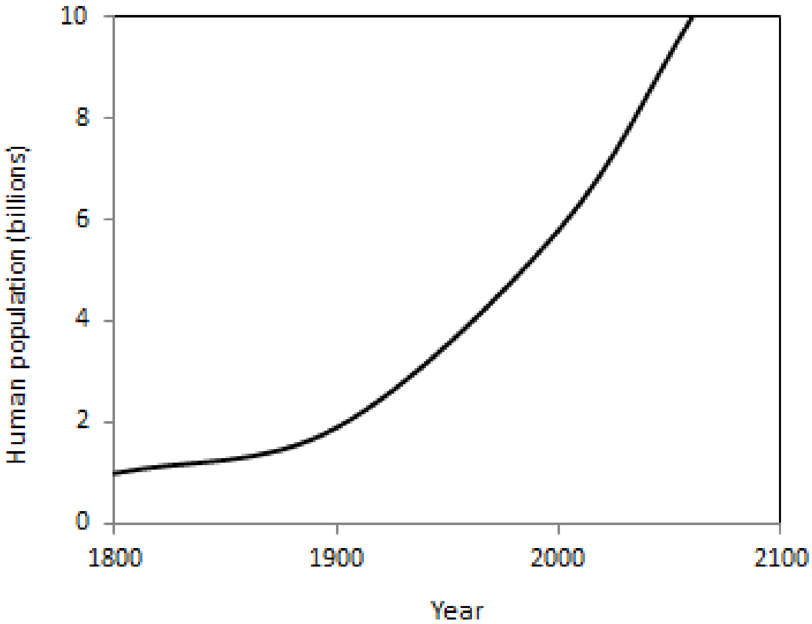
According to industry experts and environmentalists, EVs as a concept had a bright future as consumers became more environment conscious. They preferred to drive eco-friendly cars. To help drive the vehicle for a longer distance on a single charge, battery companies invested heavily in research and development to manufacture less expensive batteries. Huge infrastructural requirements of fast charging stations were required as the sales of electric vehicles increased. Mahindra Reva as a company would benefit more in the event of competition picking up in this space. The company looked at introducing battery operated vehicles for various companies' fleet vehicles which plied within the city. With increasing demand within the country for oil and its increasing prices, electric vehicles would be the best solution forward for India.

Exhibit 1

Comparison of BEV, HEV and FCEVs			
Type of EVs	**Battery EVs**	**Hybrid EVs**	**Fuel Cell EVs**
Propulsion	Electric Motor Drive	Electric Motor Drive ICE	Electric Motor Drive
Energy System	Battery Ultra capacitor	Battery Ultra capacitor ICE Generating Unit	Fuel cells
Energy Source and Infrastructure	Electric Grid Charging facilities	Gasoline Station Electric Grid Charging facilities	Hydrogen Methanol or Gasoline Ethanol
Characteristics	Zero Emission Independence on Oil 100-200 KM Range High Initial Cost Commercially available	Very low Emission Dependence on Oil Very long Range Complex Commercially available	Ultra-low Emission Independence on Oil High Energy Efficiency Very High Cost Under Development (2001)
Major Issues	Battery management High Performance Propulsion Charging facilities	Managing Dual Energy Sources Dependence on Driving Cycle Battery Cycle and management	Fuel Cell Cost Fuel Processor Fuelling System

Source: C.C. Chan, State of the Art of Electric and Hybrid Vehicle, Proceedings of IEEE, Vol 90, No 2, pp247-275.

Exhibit 2
Growth of Human population



Source : C.C. Chan, State of the Art of Electric and Hybrid Vehicle, Proceedings of IEEE, Vol 90, No 2, pp 247-275.

Exhibit 3
Growth of population and Vehicles

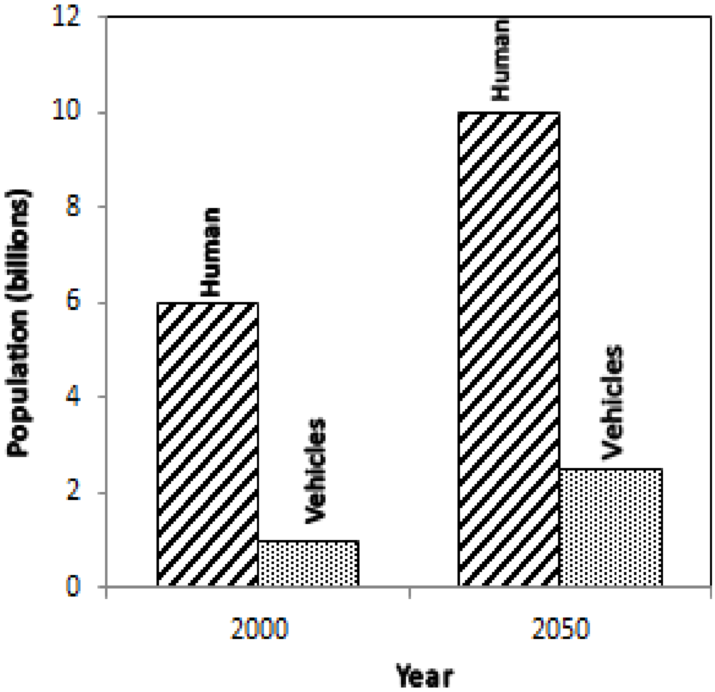
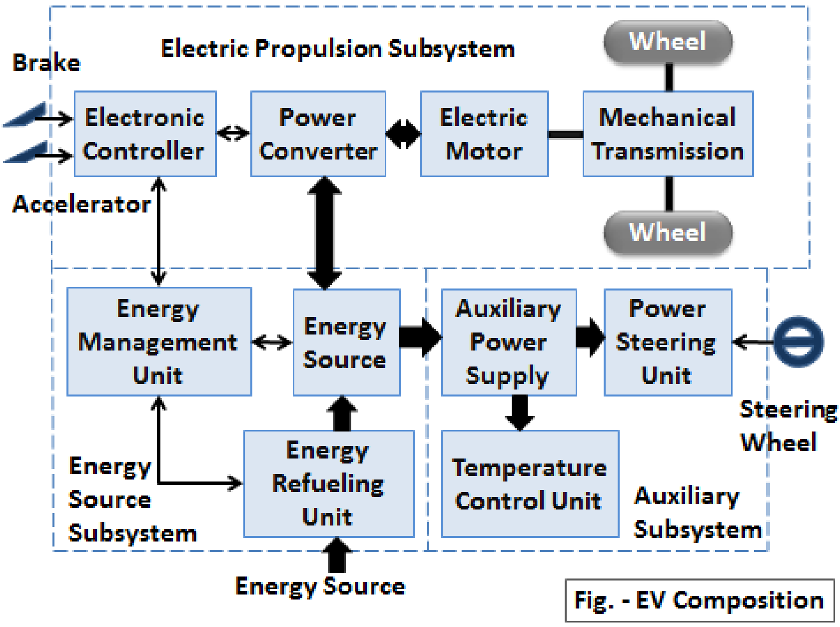


Fig.1. Growth of population and vehicles

Source: C.C. Chan, State of the Art of Electric and Hybrid Vehicle, Proceedings of IEEE, Vol 90, No 2, pp 247-275

Exhibit 4



Source: C.C. Chan, State of the Art of Electric and Hybrid Vehicle, Proceedings of IEEE, Vol 90, No 2, pp247-275.

Exhibit 5
Classification of HEVs

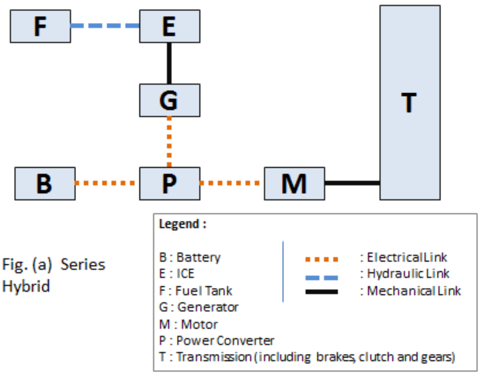


Fig. (a) Series Hybrid

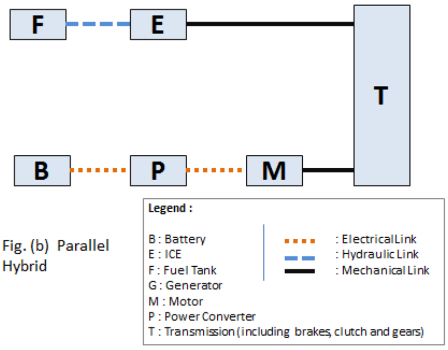


Fig. (b) Parallel Hybrid

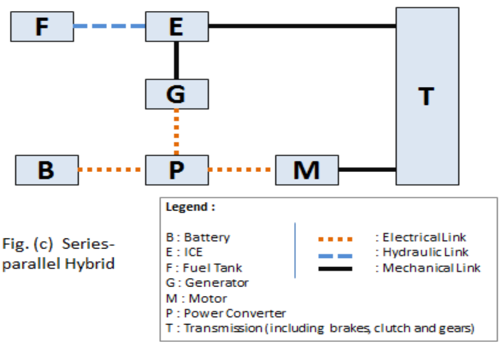


Fig. (c) Series-parallel Hybrid

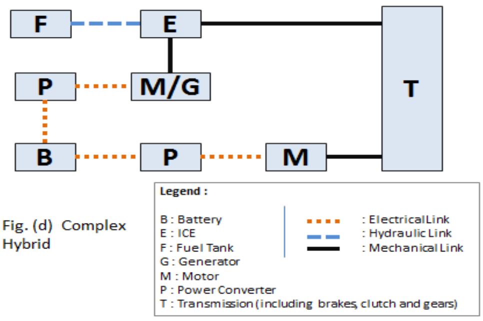


Fig. (d) Complex Hybrid

(**Source:** C.C. Chan, State of the Art of Electric and Hybrid Vehicle, Proceedings of IEEE, Vol 90, No 2, pp247-275)

Exhibit 5 shows the four classifications of an HEV. This is essential to understand the technological changes that are happening in the EVs.

Fig (a) is an example of a series hybrid system.

Figure (b) is a series parallel hybrid system.

Figure (c) is a parallel hybrid system.

Figure (d) is a complex hybrid system.

Exhibit 6
Classification of HEVs

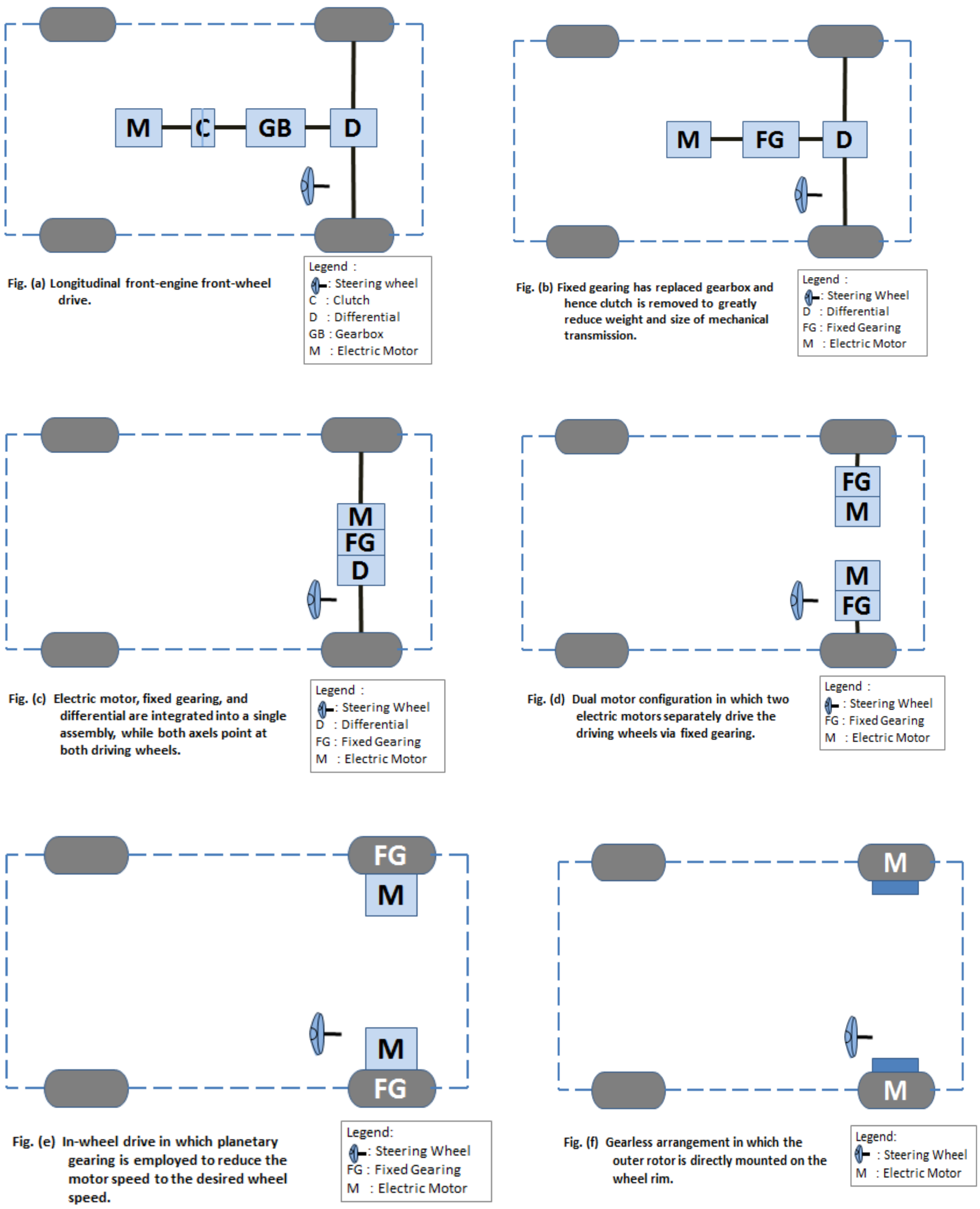


Fig. (a) Longitudinal front-engine front-wheel drive.

Fig. (b) Fixed gearing has replaced gearbox and hence clutch is removed to greatly reduce weight and size of mechanical transmission.

Fig. (c) Electric motor, fixed gearing, and differential are integrated into a single assembly, while both axels point at both driving wheels.

Fig. (d) Dual motor configuration in which two electric motors separately drive the driving wheels via fixed gearing.

Fig. (e) In-wheel drive in which planetary gearing is employed to reduce the motor speed to the desired wheel speed.

Fig. (f) Gearless arrangement in which the outer rotor is directly mounted on the wheel rim.

Source: C.C. Chan, State of the Art of Electric and Hybrid Vehicle, Proceedings of IEEE, Vol 90, No 2, pp247- 275

Exhibit 6 shows the different configurations of electric vehicles.

Figure A shows the first alternative which is a direct extension of internal combustion engine vehicles. The different components are an electric motor (M), a gearbox (GB), a clutch (C) and a differential (D) by incorporating both gearbox and clutch. The driver can shift the gear ratios and hence can provide different torque at different speeds.

Figure B shows an arrangement of electric motor, fixed gearing and a differential. We note that this configuration is not suitable for an ICEV as the engine by itself without clutch and gearbox cannot offer different torque at different speed.

Figure C shows a different configuration which is most commonly adopted by modern electric vehicles. In this concept, similar to the transverse front-engine front-wheel drive of the existing ICEV, the electric motor, fixed gearing and differential are integrated into a single assembly both at axle points at both driving wheels.

Figure D shows a dual motor configuration in which two electric motors separately drive the driving wheels with via fixed gearing. In this setting, other than the mechanical means, we need the differential mechanism. In an EV, this can be provided by two electric motors working at two different speeds. Depending on whether the driver is turning the EV towards the left or the right, the electric controller changes the speed accordingly.

The configuration E shows the fixed planetary gearing system which is used to reduce the motor speed to the desired wheel speed. It should be noted that the planetary gearing is favoured in this arrangement as it offers the advantage of high speed reduction ratio of the gears as well as inline arrangement of input and output shafts.

Figure F shows the gearless arrangement in which the outer rotor of the motor is directly mounted on the wheel rim. This configuration completely abandons any mechanical gearing and the in-wheel drive can be accomplished by having a low speed outer rotor electric motor inside a wheel. Hence the speed control of the motor is equivalent to the control of the wheel speed and also the speed of the vehicle.

The above six configurations demonstrate the size and application of different types of EVs. We are moving from configuration A which was a direct extension of the ICEV to configuration F which is under technology demonstration or small scale production. The selection of an EV configuration is an important decision to be taken before the EV is launched. The major criteria for this selection are based on compactness, performance, weight and cost.

Exhibit 7
Original Technical Specifications of REVA

1	Type	Two door hatchback
2	Payload	Two adults plus two children (227 kg)
3	City driving range	80 km
4	Top Speed	65km per hour
5	Charge Time	80% 2.5 hours, 100% in 6 hours
6	Battery	48 V , 200 amp-hrs, EV tubular loaded acid batteries
7	Operating Cost	INR 0.40 per km
8	Length	2638 mm
9	Width	1324 mm
10	Height	1510 mm
11	Ground Clearance	150 mm
12	Minimum turning radius	3505 mm
13	Wheel Base	1710 m
14	Curb Weight	670 kg/without battery 400 kgs
15	Body Panel material	High Impact ABS vacuum formed panels
16	Frame Type	Welded tubular steel space frame
17	Suspension	Mcpherson Strut [front] Solid axle with coil over springs[rear]
18	Motor	High torque [70Nm] separately excited DC motor 5 KW continuous , 13 KW peak
19	Controller	Microprocessor based with regenerative breaking
20	Charger	220 V, 2.2KW, high frequency switch mode type

Maini, D. S. (July, 2013). *Reva EV, India's Gift to the World.* Random House India.

Exhibit 8
Chronology of Events

1994 Reva Electric Car Company (RECC) was founded by Chetan Maini, as a joint venture between the Maini Group of Bengaluru and Amerigon Electric Vehicle Technologies (AEVT Inc.) of the USA. RECC joined with several automotive experts to develop components for Reva. Curtis Instruments Inc. of USA developed a Motor Controller specifically for the car. The car had a high-tech power pack for which Tudor India Limited supplied customized Prestolite batteries. The charger for Reva was developed by Modular Power Systems of USA (a division of TDI Power). Later, RECC started manufacturing the charger themselves through a technical collaboration agreement between MPS and the Maini Group.

2004 GoinGreen of the UK entered into an agreement with RECC to import REVA cars and market them under the G-Wiz moniker.

2006 Reva received an additional investment of $20 million from Draper Fisher Jurveston and Global Environment Fund (GEF).

2008 A revamped Reva model was launched by name Revai. The company started production of a Lithium-ion variant called the Reva L-ion in 2009.

2009 At Frankfurt Motor Show, Reva presented its future models Reva NXR and Reva NXG. During the event Reva and General Motors India declared a technical collaboration to develop affordable EV for the Indian market. As a result of this General Motors India announced an electric version of their hatchback in the New Delhi Auto Expo 2010: named e-Spark, Reva was to provide battery technology.

2010 India's largest sports utility vehicles and tractor maker Mahindra & Mahindra bought a 55.2% controlling stake in Reva. Following the deal, the company was renamed Mahindra Reva Electric Vehicles Private Limited. Mahindra’s president of automotive business, Pawan Goenka, became the new company’s chairman. As a result of the ownership change General Motors pulled out of the tie-up with Mahindra Reva that was to produce the e-spark.

2011 GoinGreen, the UK's exclusive importer of G-Wiz, announced that it was no longer stocking the model (although it would order them on a 4-6-week lead time when requested by customers).

http://en.wikipedia.org/wiki/REVA. (n.d.). Retrieved November 12, 2015, from http://en.wikipedia.org.

Exhibit 9
Memorandum of Understanding between Amerigon of US and Maini Group of India

0.1 Amerigon is a vehicle design, systems engineering, and component supplier to the world automotive industry. Principal emphasis is on development and production preparation of an exceptional electric vehicle suitable for final fabrication and sale in India. Amerigon has produced four generations of electric vehicles that incorporate the best design, system integration, and proprietary components available in the world. The results are incorporated in the design of a durable, low cost vehicle with superior performance, manufacturability, and appeal to the rapidly growing Indian middle class.

0.2 Maini is a diverse group of manufacturing companies based in Bengaluru, India. Founded 21 years ago, Maini is acknowledged as an innovator in its fields. The Maini Group is managed by technocrats and is primarily engaged in the manufacture of high-precision automotive components and assemblies for original equipment customers both in India and overseas. Customers include Bosch in Europe and General Motors in the United States. Maini also manufactures electrically powered material-handling equipment and has developed Chets, India's first electric vehicle which is ideal for touring large factories. Chets has been approved and is subsidized by the Government of India.

0.3 Metropolitan areas of India and the rest of Asia are grappling with the immense problems of increasing fossil fuel consumption and air pollution. The need to solve these critical and rapidly growing problems have been recognized by all city corporations, local and federal Governments, and by a raft of international monitoring agencies. The problem is compounded by rapidly growing population and standard of living. These factors create an enormous demand for personal use vehicles, thus exacerbating already acute problems. India itself has the fastest growing middle class in the world, with substantial buying power. As an example, in the city of Bengaluru alone, the number of vehicles is growing by more than 200 every day. About the only long-term solution inside, and one which has unanimously been deemed as effective by development and environment agencies, is the introduction of the electric-powered town car.

1.0 Amerigon and Maini intend to collaborate jointly and on a long-term basis, both technically and financially, to develop, manufacture, and market electric vehicles primarily for requirements in India and other Asian nations. Amerigon and Maini both fully recognized the untapped potential and vast promise of India and other Asian nations immediately and over the long-term for electric vehicles. Essentially, compared with conventional vehicles, the EVs need to be produced in modest quantities, and at low prices, with corresponding affordable tooling and manufacturing costs, yet reflect the highest level of available technologies in design and function. Given these requirements, the Amerigon-Maini collaboration ideally matches and complements the capabilities of each entity.

1.1 Amerigon can supply proprietary critical and sophisticated components and subsystems developed and manufactured in the US. Amerigon is also recognized as one of the world's best EV designers and system integrators. Maini offers the experience and expertise of a highly regarded experienced manufacturer possessing very affordable labour, unique facilities, and the ability to cost-effectively assemble and manufacture EVs in limited quantities. It has the capacity to both directly produce and readily procure precision and other components within India in accordance with Amerigon's specifications. By combing the existing strengths and existing superior resources available in the United States and India, the result is a cost-effective and efficient collaboration ideally suited to meet the needs of the Indian market.

1.2 Apart from the all-round feasibility and complementing factors of the Amerigon-Maini match, the result also affords a partnership whereby Amerigon can place into use its developed technologies and Maini can capitalize on its manufacturing expertise and its respected position in Indian industry. By doing so, Amerigon will establish ready, long term markets, for its sophisticated high technology components and Maini will manufacture and sell to the Indian and Asian markets highly desirable, world competitive EVs.

2.0 Amerigon and Maini will enter a long-term resource collaboration and integration partnership, each pooling its strengths.

2.1 Maini will develop and manufacture components, according to a program developed by Amerigon, and provide highly skilled affordable labour and expertise, as well as the physical facilities for manufacture of EVs in India. Maini will also provide all local inputs including Market Research Data, vehicle requirements in India, and testing and marketing. If required, Maini will provide technical manpower at Amerigon to develop the capability to work the Amerigon's and other US companies' components and subsystems.

2.2 Amerigon will provide vehicle design and prototypes, appropriate highly sophisticated and high-tech components, and in cooperation with Maini, 10 to 15 production prototypes and initially 100 vehicle kits for assembly in India. Amerigon will also source as required, low cost tooling for initial vehicle kits.

2.3 Amerigon will continue exporting kits, with Maini providing assembly facilities, staffing, and those components which can be readily cost-effectively manufactured in India.

3.0 The actual workings of this unique and promising partnership will be discussed in detail, commencing soon after the acceptance of this Memorandum of Understanding.

Maini, D. S. (July, 2013). *Reva EV, India's Gift to the World.* Random House India.

Exhibit 10
Comparison Chart of Reva with top cars in the world

Brand	Model	Range (miles)	Mileage (miles/gallon)	Price (USD)
Ford	Electric	76	105	29,170
BMW	i3	81	124	43,350
Chevy	Spark EV	83	119	25,170
Volkswagen	e-Golf	83	116	35,450
Nissan	Leaf	84	114	29,010
Mercedes	B-Class Electric	87	84	41,450
Fiat	500e	87	116	32,300
Kia	Soul EV	93	120	33,700
Tesla	Model S	270	240	85,000
Mahindra Reva	e2o	75	5.84**	15,670

**miles/kWh

Source: "CO2 baseline database for the Indian Power Sector, Jan 2012" published by Central Electricity Authority, Ministry of Power, Government of India