

e2o plus – An energy efficient and smart urban mobility solution for India

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Abstract

Demand of customer has been increasing day by day to acquire advanced technologies, performances, quality and cost effective products. The market in India demands on targeting the user groups from vehicle ownership to service mobility. The Ministry of Urban Development in India has announced an upcoming project of developing 100 smart cities focusing on Energy Management, Urban Mobility, Waste Management, Water Management, E-Governance and other Skill Development Centres.

Mahindra Electric known as ME has been pioneering the development of electric vehicles in India and launched several platforms (passenger vehicles, commercial vehicles and fleet) in domestic and export markets. ME successfully launched the e2o plus - the city smart car at an aggressive price point, which provides both individual and fleet owners the flexibility to choose from different variant options. The total project duration for this product was less than 2 years including design, development, verification and validation with the real world usage pattern. Cost effective and frugal engineering forms the basis for the functional development of the e2o plus. Customer insights, typically from an Indian subcontinent point of view was used to determine the features required to increase the desirability of the vehicle.

This paper focuses on the design and the features of e2o plus electric vehicle from the urban mobility and the energy management perspective.

Keywords: Advanced technologies, Smart cities, Urban mobility, Energy Efficiency, e2o plus.

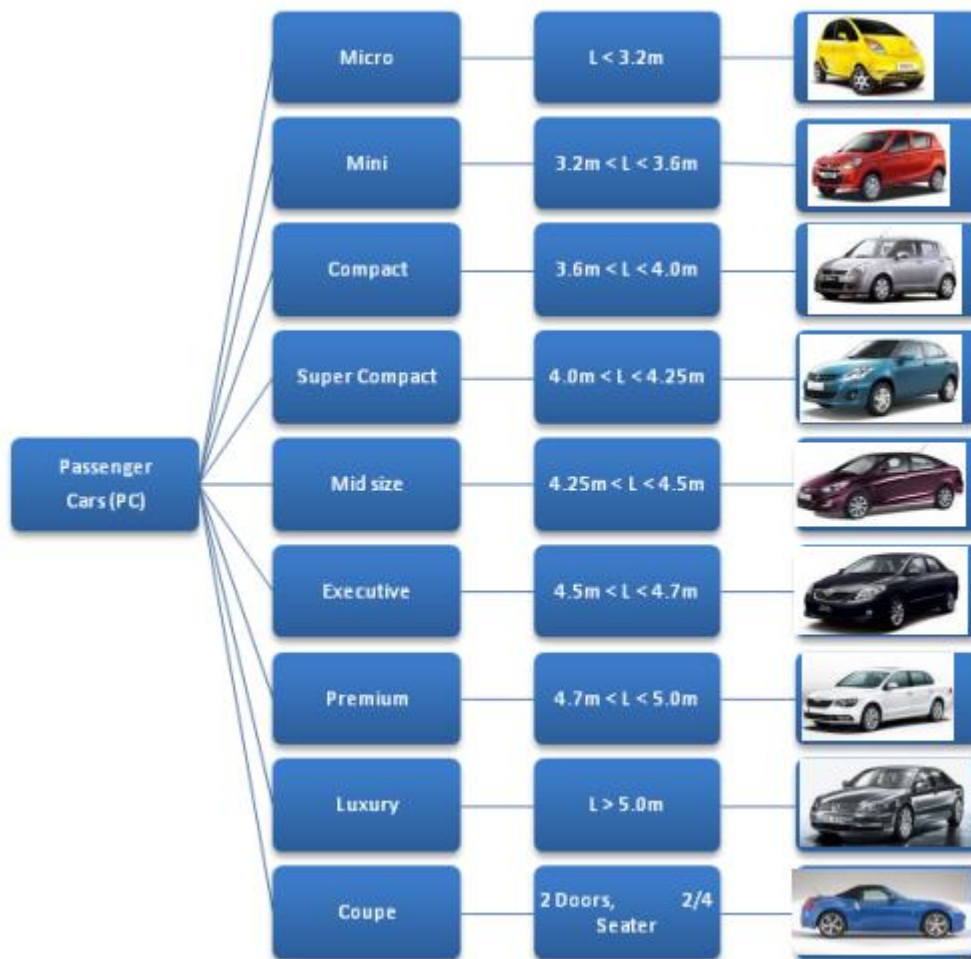
1 Introduction

The Indian car industry is now the seventh largest car manufacturer in the world. The overall Indian automobile industry has grown at a high rate of around 15% (CAGR 2007-12) on the back of a healthy macro-economic growth and overall positive sentiments. As India is a developing economy with relatively

low GDP per capita, the Indian automobile industry is dominated by 2-Wheelers which comprise of ~77% of the overall market. Passenger vehicles are the 2nd largest segment of the industry with a share of ~15% and commercial and three wheelers comprise of 8% of the market share. In India Passenger Vehicle market is further classified into three segments –

- Passenger Cars (PC)
- Utility Vehicles (UV)
- Vans (Mini Vans - not included in study)

Passenger Cars sub-segment dominates the passenger vehicle market in India with ~70% share. The Passenger Car (PC) segment is categorized into 9 sub-segments primarily based on overall vehicle length as shown in figure



Out of the 9 sub-segments, 3 sub-segments viz. Compact, Mini and Super Compact comprise ~90% of the overall passenger car (PC) market. The largest sub-segment is Compact followed by Mini. The demand for small cars is the highest because of relatively lower per-capita incomes and high traffic density in urban areas. Compact and Mini sub-segments primarily comprise of hatchbacks which are preferred due to relatively low price, high fuel efficiency and easy manoeuvrability.

Today most of the world's population lives in urban cities and the percentage is growing continuously. To make the Smart Cities, the adoption of using efficient energy in a sustainable and environmental friendly is required to improve the quality of life. In India, the market is emerging for electric vehicles in all the segments including 2-wheelers, 3-wheelers, passenger vehicles, fleets and commercial vehicles. Government of India promoting the eco-friendly vehicles under the FAME (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles) scheme offering incentives on electric and hybrid

vehicles. Mahindra Electric developed the e2o plus with high energy efficient and cost effective meeting the needs of customer demands for urban mobility.

2 Comparing the evolution of two EV development programs

It is interesting to compare the evolution of two different EV development programs like BMW i3 and Mahindra e2o plus. The BMW Group started the EV journey with the concept MINI-E in 2009 which was the electrified conversion of the popular Mini Cooper car. This was used for field trials to understand how customers would use an EV.



In 2011, the BMW ActiveE was created as a development vehicle which is based on the BMW 1-series with 4 Door used as a part of Olympic fleet, London 2012. This again was used to understand the usage patterns of its EV Customers.

BMW i3 was the culmination of the project-I that carried the learnings of field trials of Mini-E and the ActiveE which both use lithium-ion batteries.

2.1 EVs in India



The story of Mahindra e2o+ in India had a slightly different character and was more evolutionary in process. There were significant incremental improvements made to arrive at the e2o+. The cars in the line-up are the Reva, the e2o and then the e2o+.

The first Reva model, produced from 2001 to 2007, was a DC motor based car. Its power flowed through a 400 amp motor controller to a DC motor rated at 4.8 kW continuous, with a maximum of 13.1 kW. Power came from eight 6 V, 200 A h, lead-acid batteries located under the front seats and wired in series to create 48 V.

In January 2008, a new model was introduced. It had an AC drive system, which raised the maximum speed to 80 km/h. The power flowed through a 350 Amp motor controller to a 3-phase AC motor rated at 13 kW peak. The battery was however still made of eight 6 V, 200 Ah lead-acid batteries located under the front seats. It had a "boost" switch that gave 40% extra torque for improved acceleration and hill climbing

and increased the top speed to 80 km/h. It weighed 665 kg, including 270 kg batteries. The nominal range was 80 km.

Several new features were added, such as front disc brakes, a collapsible steering column, and a much revised and reinforced chassis that was successfully crash tested at 40 km/h by ARAI in India.

In January 2009, a new model was launched, It was similar to the earlier, but powered by high performance lithium-ion batteries, which reduced the car's curb weight to 565 kg (1,246 lb), offered greater acceleration, reduced charging time to six hours, and extended the nominal range to 120 km

The Mahindra e2O began its journey as NXR M1 class electric concept car unveiled at the 2009 Frankfurt Motor Show. The car's exterior concept was initiated in collaboration with DC Design, and detailed design of production exterior and interior styling was done by the in-house R&D and Styling teams.

Range, speed, safety and interior specifications were made along the lines of a new generation of battery electric vehicles. The Mahindra e2o, passed all safety tests in 2013 when it was crash tested in Spain.

The Mahindra e2o had features like the REVive battery charging system. Through the telematics remote access to the car's on-board Energy Management System, the company's support centre could individually determine the battery condition and allow access to a small reserve charge. Mahindra e2o was manufactured through processes that do not pollute all the way from the design stage in India's first Platinum certified automobile plant. The facility itself is naturally lit and ventilated, uses LED lights, recycles, gets 35 percent of its power from solar panels. Much like a modern-day smartphone, the Mahindra e2o had functions that can be powered remotely. Remote diagnostics through telematics monitored the e2o on a daily basis giving instant diagnosis of any existing or impending problems. A smartphone app provided information of the car's state of charge, and even sent a reminder for its various functions. One could remotely lock and unlock the car, start and stop charging, turn the car on and off, switch the air conditioning on and off and even set a schedule using the smartphone app.

There were other ingenious technologies that have been incorporated in the e2o such as Sun2Car, and Regenerative braking system that further boosts the car's range. The Sun2Car, for instance, allows people to charge the e2o using solar energy while it's parked.

The car has a lithium-ion battery pack that takes five hours for a full charge, and with a weight of 830 kg (1,830 lb). The e2o was one of the more advanced cars on Indian roads, with smartphone-controlled features, GPS navigation system and a dashboard-mounted touchscreen, keyless entry, start/stop button, and regenerative braking.

3 e2o plus

e2o plus – the “City Smart” is a 4 door hatchback all electric vehicle. The name e2o stands for energy to oxygen and Plus promising zero emission, low running cost and energy efficient. Four variants P2, P4, P6 and P8 has been launched in India on October 2016.

The Mahindra e2o+ with 4 variants with Range up to 140 km. It is positioned as a smart city car with the following differentiating features: Regenerative Braking, Instant Torque, REVive emergency recharge, Small turning radius, Hill Assist, etc.

Low running costs is one of the major features of the car with a cost of just 0.7 Rupees/km. (16.5 units of electricity consumed @ Rupees 6/unit, at a range of 140 km for P8 variant).

Improved remote diagnostics, progress reports, information about charging points are the other attractive features.



Variant	P2	P4	P6	P8
Body pack	Hatch back			
Seating capacity	4			
Drive Type	RHD			
Power Train	48V		72V	
Battery Power	11kWh		16kWh	
Range	110Km		140Km	
Standardised Consumption	88Wh/km		99Wh/km	
REVive	5Km		10Km	

Following are detailed specifications of the e2o+:

Variant	P2/P4/P6	P8
Body Type		
Body Type	Hatchback	Hatchback
Seating Capacity	4	4
Battery		
Capacity	210 Ah	210 Ah
Technology	Lithium Ion	Lithium Ion
No. of Module	16	23
No. of Cells	48	69
On-board power	11 kWhr	16 kWhr
Battery Weight	84 kg	121 kg
Gear Box		
Type	Direct Drive	Direct Drive
No. of Forward Modes	2	2
Gear Ratios	10.83:1	8.64:1
Motor		
Construction	3 Phase AC Induction Motors	3 Phase AC Induction Motors(P2 Long Core)
Power	19KW @ 3500 rpm	30 kW @ 3500 rpm
Torque	70Nm @ 1000 rpm	91Nm @ 2000 rpm
Controller	600 Amp	550 Amp
Dimensions		
Overall Length	3590 mm	3590 mm
Overall Width	1575 mm	1575 mm
Overall Height	1585 mm	1585 mm
Ground Clearance*	170 mm	170 mm
Wheel Base	2258 mm	2258 mm
Track	1312 mm	1312 mm
Boot Space	135 ltrs	135 ltrs
Weight		
Unladen Kerb Weight	937 kg/932 kg/940 kg	990 kg
Gross Weight	1257 kg/1252 kg/1260 kg	1310 kg
Brakes		
Front	Disc	Disc
Rear	Drum	Drum
Parking Brake	Manual	Manual

Variant	P2/P4/P6	P8
Steering		
Assisted	Electric	Electric
Turning Radius	4.35	4.35
No. of Steering Wheel turns	4 turns	4 turns
Suspension		
Front	Mac Pherson Strut Type Independent Suspension With Coaxial Spring.	Mac Pherson Strut Type Independent Suspension With Coaxial Spring.
Rear	Twin Pivot Trailing Arm With Coaxial Spring Damper	Twin Pivot Trailing Arm With Coaxial Spring Damper
Tyre		
Wheel Rim Size	14"	14"
Tyre Dimension	165/60/R14 - 79T	165/60/R14 - 79T
Spare Wheel	155/70/R13 - 75T	155/70/R13 - 75T
Range		
Driving Range	110 km	140 km
Standardised Consumption	88 WH	99 WH
Revive	5 km	10 km
Charging @ 30 Degree Celsius		
3 KW single Phase 16 Amp Charger	6 hrs	9 hrs
10 KW 3 Phase 32 Amp Charger	1 hr 15 mins (95%)	90 mins(95%)
Performance		
Gradability	10 deg	10.5 deg
Top Speed	80 kmph	85 kmph
0-40 KMPH	6.3 sec	5.2 sec
0-60 KMPH	14.1 sec	9.5 sec
Warranty		
Car	3 years/60000 km**	3 years/60000 km**
Battery	3 years/60000 km**	3 years/60000 km**

3.1 Features

Smart technologies are integrated for the control and convenience. e2o Plus comes with an app to monitor the vehicle information and control through mobile apps. Regenerative braking technology helps in the urban mobility to utilize the kinetic energy into electric energy while braking process and the energy used to extend the driving range. Also the patented REVive technology is included and shall be activated when the state of charge below the defined threshold and the conditions are met.

4 Smart Urban Mobility Projects

4.1 Global Scenario

Governments are playing a key role across the globe in facilitating greater adoption of electric mobility through use of the following five main levers of public policy to influence the early adoption of EVs 1) Demand incentives 2) Supply side incentives for promoting manufacturing 3) Power and Charging Infrastructure 4) Research & Development incentives 5) Imposition of stringent fuel efficiency norms.

Different nations follow different strategies for promoting electric mobility. While United States has been primarily focusing on both demand and supply side incentives, with Government directly subsidizing private incentives, Japan and France have been focusing on supporting charging infrastructure. Whereas, China has a very comprehensive and large scale program for adoption of e-mobility with large investments.

4.2 Scenario in India

Government of India jointly with the industry prepared a strategic road map for the automotive industry covering every aspects of its growth ranging from broad direction on fiscal policies, emissions, safety and globalisation in terms of technical standards, enhancing competitiveness, skill development, Research and Development, Validation, etc. The Department of Heavy Industry (DHI) seeks to achieve its vision by providing necessary support and funding the research, design, development and demonstration projects and also spearheading the electric mobility initiative in the country. In addition, the Department of Science and Technology (DST) has a funding scheme for all industries, including automotive industry.

In order to finalize the National Electric Mobility Mission Plan, the DHI in collaboration with the Industry formed a focus group members and established the road map, objectives, and targets to be achieved by year 2020. This is fully incorporated in the National Electric Mobility Mission Plan 2020 (NEMMP 2020) which is the basis for guiding all the future schemes, policies and other interventions of the government for electric mobility.

In this context, the Government of India is promoting the cities and forming the Smart Cities by developing the infrastructure and creating Industrial Corridors between big metropolitan cities in India. This includes the development of Smart City Program with eight critical pillars like Smart Governance, Smart Energy, Smart Environment, Smart Transportation, Smart IT, Smart Communications, Smart Buildings and Smart Health Hospitals

5 Conclusion

Both global and local trends are strongly influencing mobility and transport solutions for the future. Hence the need for developing Smart cities with Smart electro mobility solutions are required to happen in parallel. Mahindra e2o Plus is an example of how smart mobility is being designed and integrated simultaneously with evolving smart cities in India. As cities in India continue to evolve so will mobility and the electric vehicles. It is important for EV designers to be aware of the ever changing eco-systems for electric vehicles and quickly adapt the designs to seamlessly integrate the optimum solution keeping features, cost and customer expectations in mind.

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