Designing an Electric Hybrid 'SUV-Sedan' Crossover Vehicle

For Urban India in the Year 2020

Submitted in partial fulfilment of the requirements

of the degree of

Master of Design

by

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Project-II

Designing an Electric Hybrid ‘SUV-Sedan’ Crossover Vehicle For Urban India in the Year 2020

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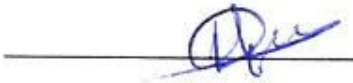
Approval Sheet

This report entitled "Design of electric hybrid SUV-sedan crossover vehicle for Urban India in year 2020" by Tanmay Ohri (roll number 126390005) is approved for the partial fulfilment of the degree of M.Des in Mobility & Vehicle Design

Project Guide

External Examiner



Internal Examiner

Chairman

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I would also thank my classmates and friends for all the necessary inputs and their support throughout the project.

Tanmay Ohri (126390005)
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Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or data has been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Student's signature

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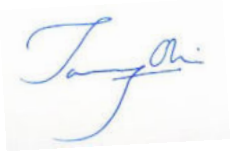

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Introduction

Looking at the current shift in the automotive industry towards the Electric Vehicles this decade is quite accurately being called the 'decade of Electric vehicles'. It is very much possible that by the year 2020 there might be a plethora of electric automobiles well absorbed in the market. There have been many attempts made in this industry to establish the electric vehicle, but none of them succeeded. The current picture of the electric vehicle technology seems very promising, with its advancement in the technology as well as acceptability in the market. This shift towards the electric mobility for future by most of the key players of automotive industry ensures that Electric Mobility is here to stay.

Equally interesting is the Compact SUV segment which has grown substantially and has established itself as a separate CROSSOVER segment. The people in urban areas have special fondness for this SUV-hatchback crossover segment as it provides the experience of an SUV without the hassle attached to its everyday use. The sedan segment on the other hand has also enjoyed a boom with numerous vehicles being launched by almost all the existing automotive brands due to the level of comfort, efficiency and practicality a sedan provides. It is quite needless to highlight the exceptional growth Indian market has seen in the automotive sector over the last few years. With the predicted future growth of auto sector in India, special focus on the demand of this market has to be put.

The project aims at designing an SUV-Sedan Crossover vehicle for India in the year 2020 that runs on an Electric Hybrid drive technology. It deals with exterior design of the vehicle, slightly establishing the electric drive technology being used in it in the year 2020. The idea behind it is to provide the benefits of an SUV vehicle with added experience of a sedan, complete with an efficient electric hybrid drive system for India in the year 2020.

Research

Technical Research

Crossover: By combining the most useful attributes of many vehicle types, the crossover has become the de facto family car, replacing sedans, station wagons, minivans, and traditional SUVs. Its all-wheel drive also makes it popular with people looking to live a more "rugged" lifestyle without compromising on the practicality part in urban environment.

Types of Electric Vehicle (EV) by drive train structure [1] [2]

Parallel hybrid:

In parallel hybrids, the IC engine and the electric motor are both connected to the mechanical transmission and can simultaneously transmit power to drive the wheels, usually through a conventional transmission. Current, commercialized parallel hybrids use a single, small (<20 kW) electric motor and small battery pack as the electric motor is not designed to be the sole source of motive power from launch. Parallel hybrids are also capable of regenerative braking and the internal combustion engine can also act as a generator for supplemental recharging. Parallel hybrids are more efficient than comparable non-hybrid vehicles especially during urban stop-and-go conditions and at times during highway operation where the electric motor is permitted to contribute. Parallel hybrids can be programmed to use the electric motor to substitute for the ICE at lower power demands as well as to substantially increase the power available to a smaller ICE, both of which substantially increase fuel economy compared to a simple ICE vehicle.

Series hybrid:

In series hybrids, only the electric motor drives the drivetrain, and the IC engine turns a generator which in turn powers the electric motor or recharges the batteries. The battery pack can be recharged through regenerative braking or by the IC engine. A battery or super-capacitor pack, or a combination of the two, can be used to store excess charge. Series hybrids usually have a smaller combustion engine but a larger battery pack as compared to parallel hybrids, which makes them more expensive than parallels. This configuration makes series hybrids more efficient in city driving. With an appropriate usage, this type can operate over a substantial distance with its full range of power without engaging the IC engine. And in the other cases, series hybrids can operate without recharging as long as there is liquid fuel in the tank.

Power-split or series-parallel hybrid:

Power-split hybrids have the benefits of a combination of series and parallel characteristics. As a result, they are more efficient overall, because series hybrids tend to be more efficient at lower speeds and parallel tend to be more efficient at high speeds; however, the cost of power-split the hybrid is higher than a pure parallel.

Types by degree of hybridization

Full Hybrids:

Full hybrid, sometimes also called a strong hybrid, is a vehicle that can run on just the engine, just the batteries, or a combination of both. Ford's hybrid system, Toyota's Hybrid Synergy Drive and General Motors/Chrysler's Two-Mode Hybrid technologies are full hybrid systems. The Toyota Prius, Ford Escape Hybrid, and Ford Fusion Hybrid are examples of full hybrids, as these cars can be moved forward on battery power alone. A large, high-capacity battery pack is needed for battery-only operation. These vehicles have a split power path allowing greater flexibility in the drivetrain by interconverting mechanical and electrical power, at some cost in complexity.

Mild Hybrids:

Mild hybrid, is a vehicle that cannot be driven solely on its electric motor, because the electric motor does not have enough power to propel the vehicle on its own. Mild hybrids only include some of the features found in hybrid technology, and usually achieve limited fuel consumption savings, up to 15 percent in urban driving and 8 to 10 percent overall cycle. A mild hybrid is essentially a conventional vehicle with oversize starter motor, allowing the engine to be turned off whenever the car is coasting, braking, or stopped, yet restart quickly and cleanly. The motor is often mounted between the engine and transmission, taking the place of the torque converter, and is used to supply additional propulsion energy when accelerating. Accessories can continue to run on electrical power while the gasoline engine is off, and as in other hybrid designs, the motor is used for regenerative braking to recapture energy. As compared to full hybrids, mild hybrids have smaller batteries and a smaller, weaker motor/generator, which allows manufacturers to reduce cost and weight. Honda's early hybrids including the first generation Insight used this design.

Plug-in Electric Vehicle:

A plug-in electric vehicle (PEV) is any motor vehicle with rechargeable battery packs that can be charged from the electric grid, and the electricity stored on board drives or contributes to drive the wheels for propulsion. Plug-in electric vehicles are also sometimes referred to as grid-enabled vehicles (GEV) and also as electrically chargeable vehicles.

PEV is a subcategory of electric vehicles that includes battery electric vehicles (BEVs), plug-in hybrid vehicles, (PHEVs), and electric vehicle conversions of hybrid electric vehicles and conventional internal combustion engine vehicles. Even though conventional hybrid electric vehicles (HEVs) have a battery that is continually recharged with power from the internal combustion engine and regenerative braking, they cannot be recharged from an off-vehicle electric energy source, and therefore, they do not belong to the category of plug-in electric vehicles

Plug-in hybrids (PHEVs):

A plug-in hybrid electric vehicle (PHEV), also known as a plug-in hybrid, is a hybrid electric vehicle with rechargeable batteries that can be restored to full charge by connecting a plug to an external electric power source. A PHEV shares the characteristics of both a conventional hybrid electric vehicle, having an electric motor and an internal combustion engine; and of an all-electric vehicle, also having a plug to connect to the electrical grid. PHEVs have a much larger all-electric range as compared to conventional gasoline-electric

hybrids, and also eliminate the "range anxiety" associated with all-electric vehicles, because the combustion engine works as a backup when the batteries are depleted.

Examples of Electric Vehicles [2]

Series Hybrid: Chevrolet Volt, Fisker Karma, Renault Kangoo

Parallel Hybrid: Honda's Insight, Civic, and Accord hybrids, Toyota Prius (old)

Series-parallel hybrids: Toyota Prius Plug-in Hybrid

Range Extender - Series Plug-in Hybrid

Why choosing Series Hybrid?

- For making it primarily an Electric Vehicle for substantial distance (eg. more than 50km of pure electric, then extended range by generator driven by ICE). All the efficiency benefits of electric propulsion without a compromised range.
- Having lower or No range anxiety (like parallel hybrids) (unlike other pure EVs like Nissan Leaf). IC engine starts charging the battery after a certain minimum battery limit (e.g.30%)
- Can operate without break as long as there is fuel in the tank (not electric-grid infrastructure dependent)
- Also being a Plug-in Hybrid it can also be charged whenever possible and can be made to work only on electric for reasonably short distances (e.g. 80 km)
- An electric vehicle has a battery size so big that its current degradation of the environment is way more than a hybrid's.
- With technology advancing faster than the infrastructure for electric vehicles and other socio-political/financial challenges, hybrid electric vehicles seem a much achievable future
- A parallel hybrid vehicle may make use of both mechanical and electric drivetrains, adding to more maintenance compared with series hybrid vehicle that uses pure electric drive to the wheels
- The engine is never used to directly power the wheels in series hybrid, and this means it can operate in the most efficient conditions to maximise economy, unlike in parallel hybrids that put varied load on ICE.
- Complex synchronisation is required between motor and engine in parallel hybrid technology

Emissions of such electric vehicles

Take an example of Chevrolet Volt, while operating in all-electric mode the Volt produces no tailpipe emissions. However, the clean air benefit is mostly local because, depending on the source of the electricity used to recharge the batteries, air pollutant emissions are shifted to the location of the electricity generation plants. The amount of carbon dioxide emitted depends on the emission intensity of the power source used to charge the vehicle. When the Volt's battery is depleted and the gasoline-powered engine kicks in, the plug-in emissions are similar to other internal combustion engine vehicles. The amount of total local emissions depends on how much the Volt is driven in all-electric mode and how much in charge-sustaining mode.

CO2 Emission Ratings for Some Leading Vehicles

- Chevrolet Volt: 52.5 CO2 g/km produced in extended-range mode
- A3 Sportback e-Tron 2013: 35 g/km
- Honda Insight Hybrid: 96 g/km
- Toyota Prius Hybrid 1.5ltr auto: 104 g/km,
- Toyota Prius 1.8ltr Plug-in hybrid: 49 g/km, 92 g/km
- Honda CR-V 2WD 1.6L : 119 g/km
- Honda CR-V 4WD 2.2L 149 g/km
- Renault Duster 4x4: 145g/km – 185 g/km
- Mercedes Benz 2013 GLA 4Matic: 151 g/km
- Range Rover Evoque 2.2L 4WD: 149, 169, 174, 199 g/km
- Audi Q3 : 137 g/km to 179 g/km
- VW Tiguan: 176 g/km

Some of the problems with the current Electric (Hybrid) vehicles

- Compromised usable space inside the vehicle
- Less simplicity of the machinery
- Not exceptionally economic if used beyond electric range of the vehicle
- Increased initial cost
- Poor recharging infrastructure in the cities
- Greater charging time
- Higher cost of batteries
- Awareness among the customers
- Issues related to battery waste disposal
- Range anxiety among the users

Some Possible Developments by 2020 [3] [4] [5]

- In the new IDTechEx report, "Range Extenders for Electric Vehicles 2011-2021: Huge sales of hybrid vehicles in the next decade, most will be series hybrids with range extenders. A high proportion of those range extenders will consist of piston and turbine combustion engines designed to purpose, with a generator attached with it
- Worldwide Capacity of Lithium Ion Batteries for Electric Vehicles Will Multiply More than 10-Fold by 2020 - Forecasts Navigant Research (http://www.marketwatch.com/story/worldwide-capacity-of-lithium-ion-batteries-for-electric-vehicles-will-multiply-more-than-10-fold-by-2020-forecasts-navigant-research-2013-05-17)
- ENVIA's battery development has increased the current battery density manifolds, and can cut the costs soon

(http://www.forbes.com/sites/yonicohen/2012/03/21/envias-energy-dense-battery-could-cut-electric-vehicle-costs/)

- Evolving Technology and Market size (awareness)
- ICE rapidly being replaced by second generation Range Extenders consisting of piston engines designed from scratch for fairly constant load in series hybrids.
- Also the third generation micro turbines and fuel cells that work at constant load
- In this decade of the hybrid vehicle, with much more being spent on them than on pure electric vehicles
- The next stage has been to use the newer lithium-ion batteries with greatly simplified piston engines that supply almost steady power and therefore dispense with the complications of a conventional engine designed for hugely varying power demands it no longer encounters because the battery now copes with those. (e.g. At Lotus, DLR, Polaris REX)

Example of Lotus for Range Extender

Now that Chevrolet and Fisker are on-board the series-hybrid love train with the Volt and the Karma, respectively, other companies are taking note. The new Lotus Range Extender is a three-cylinder mono-block motor, meaning the head is inseparable from the block, which lowers weight, reduces production cost, and eliminates a major point of potential failure. [6]

47 HP at 3500 RPM, optimized for running an electrical generator for use in a series-hybrid setup.Can be optimized for only one engine speed, as the electric motors actually deal with the changing power requirements – the gas motor is just there to make power. This is considerably easier than designing and engine that will have good performance and emissions characteristics over all RPM ranges

Studying technical aspects of the benchmark vehicle 'Chevrolet VOLT': [7]

Engine-Electric Drivetrain Architecture

- Front IC engine 1-1.4L petrol turbocharged – 90 HP (67-70 kW)
- Coupled to Front mounted Generator motor – 60 kW
- Floor packed with Li-Po Battery Bed – 28-30 kWh (in 2020)
- Two Electric Drive Motors: Front and Rear – (Max. output 120 kW or 163hp)
- Front electric motor at the front axle under IC engine at the front bonnet
- Rear electric motor at the rear axle
- IC engine under the bonnet coupled with the Generator and Electric Drive Unit
- Battery Bed under the floor, no transmission tunnels – flat floor
- Fuel tank under rear seats
- 3 box sedan-like packaging still provides considerable space in the rear trunk

Operating and driving modes

- Primary traction electric motor/generator, provides good acceleration for driving at lower speeds and regeneration for braking, its maximum output of 111 kW setting the maximum output of the whole system.
- Secondary electric motor/generator, assists the primary electric motor or works as generator capable of producing 54 kW.
- Internal combustion engine of 63 kW power, engaged when the batteries reach the predetermined threshold.
- These units are connected via a planetary gear and electric clutches to provide power output for propulsion in four programmed operating modes:
- **Single motor electric** - The primary motor runs solely on battery power, maximum propulsion power is 111 kW.
- **Dual motor electric** - At higher vehicle speeds the secondary motor engages over the planetary gear such that it reduces the speed of the primary motor. This facilitates higher efficiency and better mileage for the combined system, without increasing the maximum power.
- **Single motor extende**d - The battery reaches its minimum charge which triggers the combustion engine. The engine drives the secondary motor which now works as a generator, via the charging electronics, to keep the minimum battery charge level. The primary motor can still provide its 111 kW for short acceleration, albeit not sustained.
- **Dual motor extended** - The electric motors are used again in dual configuration with increased efficiency at higher speeds. Additionally the gasoline engine contributes propulsion power via the planetary gear. While power is drained from the battery the amount is less than in mode 2 for the same propulsion power, thus extending the range.

Trend Analysis

Favoured vehicles for

'Size Benchmarking':

- Honda CR-V
- Mercedes GLA
- Renault Duster
- VW Tiguan
- Audi Q3
- Range Rover Evoque
- BMW X6
- Ford EcoSport
- Renault Captur
- Kia Sportage

Favoured vehicles for

'Electric Drive Benchmarking':

- Chevrolet VOLT
- Toyota Prius Plug-in Hybrid
- Tesla MODEL X

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User Study

Two categories of users were observed. One set were the SUV users and the second set being the Sedan car users. Almost similar set of questions were asked to all the users. The idea behind this was 'To let the user speak' as much as possible for the best set of answers.

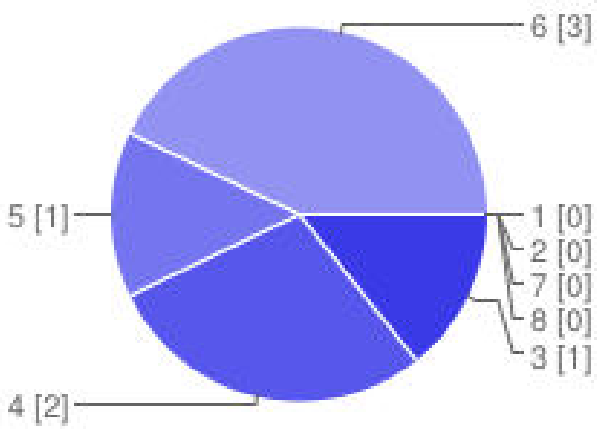
The following is the User study performed with the SUV users –

SUV Users:

Name	*Age*	*Occupation*	*City / Location*	*Your car*
Nikunj Syngal	24	Student	New Delhi	Ford Endeavour
Vijay Jain	52	Self employed	Gurgaon	Mahindra Scorpio
Vikram Sandhu	21	Student	Gurgaon	Toyota Fortuner
Rajiv	51	Business	Delhi	Toyota Innova
Tanuj	27	Professional	Kota	Mahindra Scorpio
Saurabh deswal	21	Student	Gurgaon	Audi Q7
Ramit	21	Student	Gurgaon	Toyota Fortuner

Summary of SUV users' responses:

1. Usually, how many passengers travel in your car?



2. Why do you prefer an SUV?

- Indian roads condition is not so good and car with a low ground clearance is more prone to damages
- I have joint family and have to travel long distances to meet other relatives very frequently. Better ground clearance, good seating capacity, high torque.
- Space. More people can fit in comfortably.
- Comfortable, reliable and supreme versatility.
- Because it is more comfortable than other cars and its ground clearness is more than sedan class cars
- Joint family has the ease to travel at distant parts and driving is comfortable for all other members of the family too.

3. How much distance do you drive in a day on an average? (approx.)

- 10-15 km 200 km
- 80-100 km
- 50-60 km100-120 km
- 30 km
- 175 km

4. What are the things that you like about your car?

- Beer bottle space, cabin space, usb charger, cigarette lighter, cool box
- Its height compared to other cars on the road. Gives a better view. It's good for roads that are full of pot holes. It's spacious. I can easily fit 8 people in it.
- Rugged ,and it can conquer any terrain
- Engine works very well. It has good ground clearing. Easy and sufficient room for leg for the driver and the occupant besides the driver.
- Very comfortable to drive Very powerful Muscular car

- Supreme versatility, multi-utility vehicle, reliability, sporty, striking exterior, comfort driving in city as well as long distances.
- Best car for Indian roads.

5. What are the problems that you face with your SUV?

- Maintenance cost
- Service is costly otherwise no problem
- My head almost touches the top while driving because of my height. More leg room for the seat in-between the driver's and the last row. Mud guards are not installed properly.
- Because it has all-terrain suspension, the ride quality on streets is not good. All the minor terrain features are transmitted to the passengers. The suspension is only good when there are a lot of passengers in the car and/or we're off-roading.
- As I reach speeds of above 110 km/hr. the vehicle seems to be unstable.
- Average and maintenance is costly ,but it's worth
- high running cost for petrol

6. What would you like to change in your SUV?

- The physical appearance. It should be more robust and sturdy.
- Suspension and fuel efficiency
- Nothing
- Interiors are old-fashioned for such a high priced car
- Should be provided with back Mud flaps of the bumper colour only as it gives elegant look to the vehicle. Braking system also needs some attention.
- Reduce the running cost on petrol, large body causing difficulty in parking, need parking sensors.
- Sun roof, lady driver facility

7. List “Top 3” things you want from an SUV?

- Monster looks, efficient performance and good after service
- Power, size, convertible bed
- Power. Space. Good Suspension.
- Ease driving, decent mileage and amazing interiors.
- Ground clearance, Comfortable to drive
- Power 4*4 good interiors
- Easy and more occupancy. Speed and good average for longer distances. Ground clearing in case of rugged terrains.

8. What kind of LOOKS should an SUV have in the future?

- Body should be more strong and more powerful
- very decent mileage with A/C given the size of the vehicle, very good turning radius and ample space
- More sporty and more aerodynamic
- Amazing interiors, sturdy look from exterior, lighting system and stable suspension.

- Muscular looks with good solid lines
- It should look like a modern SUV
- It must have both the present look as well as some additional looks like better light systems, mud guard, and sturdy looking tyres.

9. What kind of FEELINGS do you want from the SUV of the future?

- Intimate feelings as we feel like with a girl
- Comfortable is the first criterion. Then it should have good looks as if we are sitting in a luxurious area with good ambient.
- The looks of a sedan, the utility of an SUV
- Super power of the engine, cosy and comfortable interiors and ease in driving long distances.
- Great and powerful A/C, awesome interiors
- You are driving a luxury

10. Why or why won't you prefer an 'ELECTRIC-HYBRID SUV' car (assuming that in future this technology is well established in India)?

- With an electric hybrid car, we won't be able to control the speed that is being required at National highways and State highways, as it will be driven on slower rate.
- I would prefer it if the electric waste disposal system is well established as well. That is a huge factor to consider.
- I wouldn't prefer electric/hybrid SUV if the running cost of the vehicle is too high. I would prefer it if it help's the environment.
- I won't prefer a hybrid sub ,because I don't want to compromise on power
- Will have to see the reliability and safety advice before switching to such technology.
- Less distance coverage
- I will not prefer because it will not be that good as we prefer now days suv and it will be more costly
- I do not have much idea about the same.

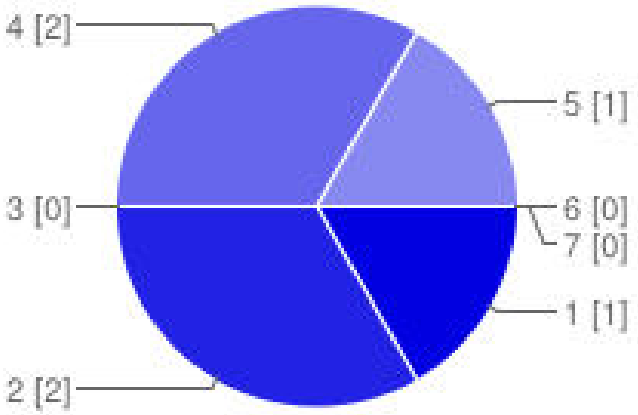
The following is the User study performed with the Sedan car users

Sedan car Users:

Name	*Age*	*Occupation*	*City / Location*	*Your car*
Ishaan Sarin	22	Student	Delhi	Maruti Suzuki SX4 Vxi
Rajesh Ohri	41	Private Service	New Delhi	Maruti Suzuki Swift Dzire Vxi
Alok Kumar	50	Architect	Delhi	Maruti Suzuki SX4
Sarvesh Kr. Pahwa	39	Service, Public Limited Co.	New Delhi	Maruti Suzuki Swift Dzire VDI
Aditi Lakra	21	Student	Gurgaon	Honda Civic
Amrit Lal Sharma	50	Service	Gurgaon	Maruti Suzuki Swift Dzire VDI

Summary of Sedan users' responses:

1. Usually, how many passengers travel in your car?



2. Why did you opt for a Sedan?

- because of comfort and space it offers
- To have a comfortable and nice ride wherever and whenever we want to go.
- Wanted medium segment car which has good looks and features according to my requirement and suits my pocket with good mileage as we Indians are obsessed with "Kitna Deti Hai".
- Boot space, power, comfort, luxury, sporty look, greater leg space in the rear seats.
- because of: comfort luxury mileage(good performance)
- For Multi-purpose usage. Besides city drive, sedan can be used to take a family for one or two weeks of round trips to nearby places.

3. How much distance do you drive in a day on an average? (approx.)

- 40 km approx.
- 100 km
- 60 km
- 80 km (40 km to & fro)
- 30 km+
- 40 km

4. What are the things that you like about your car?

- Driving Comfort Mileage Less Maintenance Ease of Reparability across India Worth for Money
- Has a sporty look, greater ground clearance, huge boot space, driving pleasure, powerful engine, great handling, and fuel efficient, low maintenance cost, neatly fitted interiors, a good music system, and dual airbags.
- Good Looks 2. Mileage 3. Comfort 4. Interiors
- It's very spacious. It's very comfortable. Good interiors, smooth running vehicle
- Spacious, driving comfort, design. The space and the larger than life feel which you get while sitting in the car.

5. What are the problems that you face with your car?

- High turning radius, parking such a massive car is a big problem.
- The car had a problem with the steering wheel. But it soon got sorted.
- Humming Noise in doors - still not resolved besides reporting
- while parking camera sensor should be there
- its low clearance
- Since it is Diesel version, the sound is more. However, less compared to other brands in this segment. 2. Steering mounted audio controls and air bags & ABS should have been made mandatory in all versions. I have middle version so I don't have these facilities.

6. What would you like to change in your car?

- I think I would like to change the steering wheel assembly.
- in the Sedan segment cars, camera should be fitted by the company itself
- just make it a little longer
- increases its ground clearance level Seat should be height adjustable Seat should be more comfortable
- Looks - Sleek or more modern design Interiors

7. Would you prefer bigger cars like Crossover/SUV (e.g. Renault Duster, Ford Eco Sport, Skoda Yeti, Audi Q3 etc.)? Why or why not?

- Not really, as current car meets my needs
- Definitely. An SUV offers a powerful engine, loads of space and gives you the feel of controlling a beast. Another added advantage to an SUV would be the upper edge it gives is its ability to perform on hilly terrains or rough conditions.
- Yes, I would definitely like to ride a big car like SUV. The thing that attracts me the most is its power.
- Yes but depends on my pocket I would like to own Audi once in my lifetime.
- No, because of economy and performance, Sedan is preferable and it gives an executive look.
- yes because it will offer better clearance level

8. "Top 3" things you want from a SEDAN?

- Loads of space 2. Offers comfort and luxury 3. has an impressive design with a powerful engine
- Enough Luggage Space Driving Comfort even for long drive Fuel Efficiency
- Comfort, mileage-performance, design and looks
- comfort interiors space
- Comfort 2. Mileage 3. More safety features
- Comfortable ride Good average Fuel efficient

9. What kind of LOOKS should a car have in the future?

- More crisp and sharp looks , arrow style.(narrow from front end)
- I would like to have sophisticated and sporty looks for my car.
- high in comfort and design, self-driving cars, eco-friendly, safe cars

- I personal prefer either a sleek and sporty look or a masculine alpha male look to my car.....that would be my future car.
- Colours should be more vibrant
- Sleeker but with enough interior space (an optimized space utilization) Better Interiors with all comforts/accessories required for even long drive

10. Why or why won't you prefer an 'ELECTRIC-HYBRID car' (assuming that in future this technology is well established in India)?

- Yes, will go for it, if it helps reduce petrol usage but without hassle for recharging regularly
- I would prefer an Electric Hybrid car given that it is a well-established technology in future. Because this way I will do my bit in saving the environment.
- If all the facilities like proper charging stations and other necessities are properly available, I will definitely prefer electric hybrid, because it will be pollution free and environment friendly. But the performance level should be high
- I will go for it as it will save Petrol / Diesel
- I will prefer it, as it will be environmentally friendly.
- Electric hybrid car is a good option when it comes to fuel economy however the only apprehensions in purchasing one would be 1. Life span of the car 2. Cost of maintenance 3. Low speed 4. lack of charging facilities available at homes(currently)

Observations from User Study

Arranging the needs of the users according to the number of times they appeared –

SUV users – What they want – Expressed Needs

Needs	Frequency
Power / Speed	6
Comfortable drive / suspension	5
Efficiency (Better Mileage)	5
Comfort	5
Great interiors	5
Big size / Robust / More occupancy	4
Looks - Sporty/Muscular/Sturdy/,Modern	4
Space	3
Easy Driving	3
Luxurious / Good ambience	3
Aerodynamic / Sharp lines	3
SUV utility / Off roading / 4x4	2
High Ground clearance	2
Better Lighting systems	2
Better turning radius	1
After service (Maintenance)	1
Sturdy tyres	1
Miscellaneous (Brakes, mudguard etc)	3

SUV Users – Problems faced

Issues	Frequency
High Running Cost / Poor mileage	4
Maintenance	3
Poor Ride quality / suspension	3
Parking related	1
Less Spacious	1
Old Appearance	1
Mud guard issue	1

SUV Users – Things you like about the car

Features	Frequency
Comfortable / Long distance travel	7
Ground clearance	7
Space / Occupancy	5
Power	5
Rugged / SUV utility / Terrain 4X4	4
Accessories	1
Exterior Looks / Muscular / Sporty	1
Ride Height / View of road	1

SEDAN Users – What They Want – Expressed Needs

Needs	Frequency
Comfort	8
Good Exterior Looks / Sleek / Executive	6
Space	4
Efficiency (Mileage)	4
Safety Features	2
Power	1
Luxury / Good Interiors	1
Eco-friendly	1
Accessories	1
Vibrant Colours	1
Automated driving	1

SEDAN Users – Problems faced

Issues	Frequency
Parking (Cameras etc mandatory)	3
Noise	2
Low Ground Clearance	2
Big Turning Radius	1
Safety features only in select models	1
Increase Length	1
Less Sporty Exterior Looks	1
Low Ride Height	1
Others	2

SEDAN Users – Things you like about the car

Features	Frequency
Driving Comfort / Long trips	10
Space	7
Efficiency (Mileage)	5
Good Looks	5
Good Interiors / Luxury	5
Accessories	3
Power	2
Low Maintenance	2
Handling	1

Problems with Electric Vehicle

Problem felt	Frequency
Lower Speeds / Power	4
High Running Cost	3
Recharging facilities	2
Reliability / Safety issue / Life span of car	2
Low Range	1
Less Knowledge about the technology	1
Electric waste disposal system needed	1

Benefits from Electric Vehicle

Benefits felt	Frequency
Environmental benefits	4
Savings on Fuel/Money	3

Passenger details: Adults/Kids (only for users with 6 passengers in the vehicle) -

SUV User	Distance Covered per day	Passengers Details	Frequency	Note
Nikunj Syngal	15 km	4 Adults + 2 Kids	Very low	SUV only when more than 4 passengers travelling
Vikram Sandhu	60 km	6 Adults	5 days in a week (High)	SUV shared by 6 friends daily for commute
Tanuj	100 km	4 Adults + 2 Kids	Low	All 6 happen to travel together very rarely

Insights from User Research

Categorizing User Needs as:

VITAL: ESSENTIAL: DESIRABLE (Cumulative chart)

NEEDS	FREQUENCY OF OCCURANCE
Driving Comfort / Long trips	10 (Most Vital)
Space	7
Ground clearance	7
Power / Speed	6
Good Exterior Looks (Sleek, Executive, Muscular, Sporty)	6
Efficiency (Better Mileage)	5
Good Interiors / Luxury / Ambience	5
Comfortable drive / suspension	5
Environmental benefits	4
SUV utility / Terrain - 4X4	4
Big size / Robust / More Occupancy	4
Ease of Parking	3
Easy Driving	3
Aerodynamic / Sharp lines	3
Low Maintenance Cost	3
Safety Features	2
Better Lighting systems	2
High Ride Height	1
Small Turning Radius	1
Increased Range of Electric Vehicle	1 (Least Needed)

Customer Profile

Knowing the Primary Customer:

- Age group: 28 – 38 years
- Young Professional: Self-employed/Multinational firm/Small Business owner/Defence Services officer
- Vehicle buying capacity: 13 - 17 lacs
- Possibly living on the outskirts of the main city – Medium to Big (3 BHK flat)
- Medium size family – members 4 to 6 (1 to 2 Kids in the family)
- Person with old family members (Comfortable ride and egress/ingress height)
- Demanding sufficient storage for household shopping
- One who needs safe and compact vehicle for one/two small children and their needs
- Covers long distance each day to and from work
- Daily travel distance – 80-120 km
- SUV enthusiast
- Wishes for SUV feel without hassle of huge size of the vehicle
- In need of a vehicle apt for his/her status, comfortable as well as economical
- Person having less time for vehicle maintenance – carefree
- Person with knowledge of trends and technology at Global level
- Driving preferences: Mostly urban roads + Mild soft off-roading
- Person with hobbies like travelling, outdoor celebrations with family & friend get-togethers
- A person who wants to define his/her status in the society: Status Symbol
- Inclined towards Electric Vehicle technology
- Sensitive to Environmental issues
- Smart user who keeps track of his/her commute & money spent on fuel
- Looking for a new vehicle as Primary car to replace older Hatchback/older sedan
- Not a first time buyer
- Brand conscious shopper, particular tastes in style and fashion
- Tech savvy person – Wants to keep pace with the technology & show it proudly
- Person who finds time for Fun activities with family beyond work – Picnic, trips, weekend outings

Scenario: Year 2020

Picturing the scenario in the year 2020, when our vehicle is going to be used. The aim is to visualize various aspects involved in the satisfactory usage of such a vehicle in those conditions at a given time in future.

Infrastructure & Govt. regulatory:

- Very high cost of Petrol/Diesel/CNG
- Electric Vehicles being given subsidy by Govt. in Metropolitans /Major Urban cities
- Quick electric charging units installed next to the road at parking spots
- Higher investments in Renewable sources of energy for electricity generation
- Very stringent emission norms and fuel efficiency rules
- Increased consumer awareness and knowledge about the technical aspects
- Attractive insurance and accidental cover, and loan schemes

Technology Related:

- Advancement in battery technology providing high density batteries up to 400 Wh/kg (Current being approx.. 80 - 120 Wh/kg)
- Cost of batteries reduced with better manufacturing technology in practice at that time
- Current full battery charging times: 8 hrs @ 120V, 4 hrs @ 240 V
- High density quick charge storage batteries reduce charging time to: 4 hrs @ 120 V, 2 hrs @ 240 V
- With 240 V supply available at Office/Household/Parking spots/Rental charging stations, 2 hours can be managed
- Quick Boost Charging facilities available (Not recommended for daily charging of batteries otherwise batteries will get degraded)
- Quick Charging time: 30 minutes which provides up to 80% of battery energy
- Quick Charging facilities available at Mall parking, Electric stations, offices, hospitals etc.

The Vehicle:

- An SUV-Sedan Cross vehicle with 6 seating capacity
- With pure electric range of about 400 km on normal driving
- Li-ion battery pack of 110 kWh capacity
- Two electric motors of 65 kW (Rear) and 65 kW (Front) producing peak vehicle power of 120 kW (160 BHP)
- On board Range Extender 3 cylinder 600 cc petrol engine optimised for best efficiency at fixed RPM range coupled to Electric generator for recharging batteries

Usage scene 1:

- Vehicle kept on overnight charging: 100% battery
- Would last 200 km on pure electric on normal road conditions
- Road journey included home to office travel which was covered within the battery range

Usage scene 2:

- Vehicle battery 100% charged overnight
- Mild off roading trip that involves smooth City roads at the start, with uneven, bad roads in the outskirts beyond the highway
- With Battery running out, IC Range extender engine kicks in automatically and now the vehicle runs on the electricity being produced by consuming gasoline
- Good availability of Diesel/Petrol in the regions outside well established city
- On spotting a charging station the vehicle can be given a quick boost charge
- On spotting a regular gasoline station, vehicle can be filled in with fuel
- Vehicle returns home and put to slow overnight charge

Usage scene 3:

- Vehicle not put to overnight charge, Current battery status: 50% battery left
- The vehicle is run on pure electric in the city roads for the available charge
- After the threshold is reached the Range extender IC engine kicks in to generate electricity
- Upon reaching the destination (office etc.) the vehicle is put to charge.
- Battery charges to 100% before you start the journey again.

Extrapolations of Vehicle Specifications for the Year 2020

Studying an existing benchmark vehicle for growth trend:

Benchmark for technical considerations: **Honda CR-V (4WD AT)**

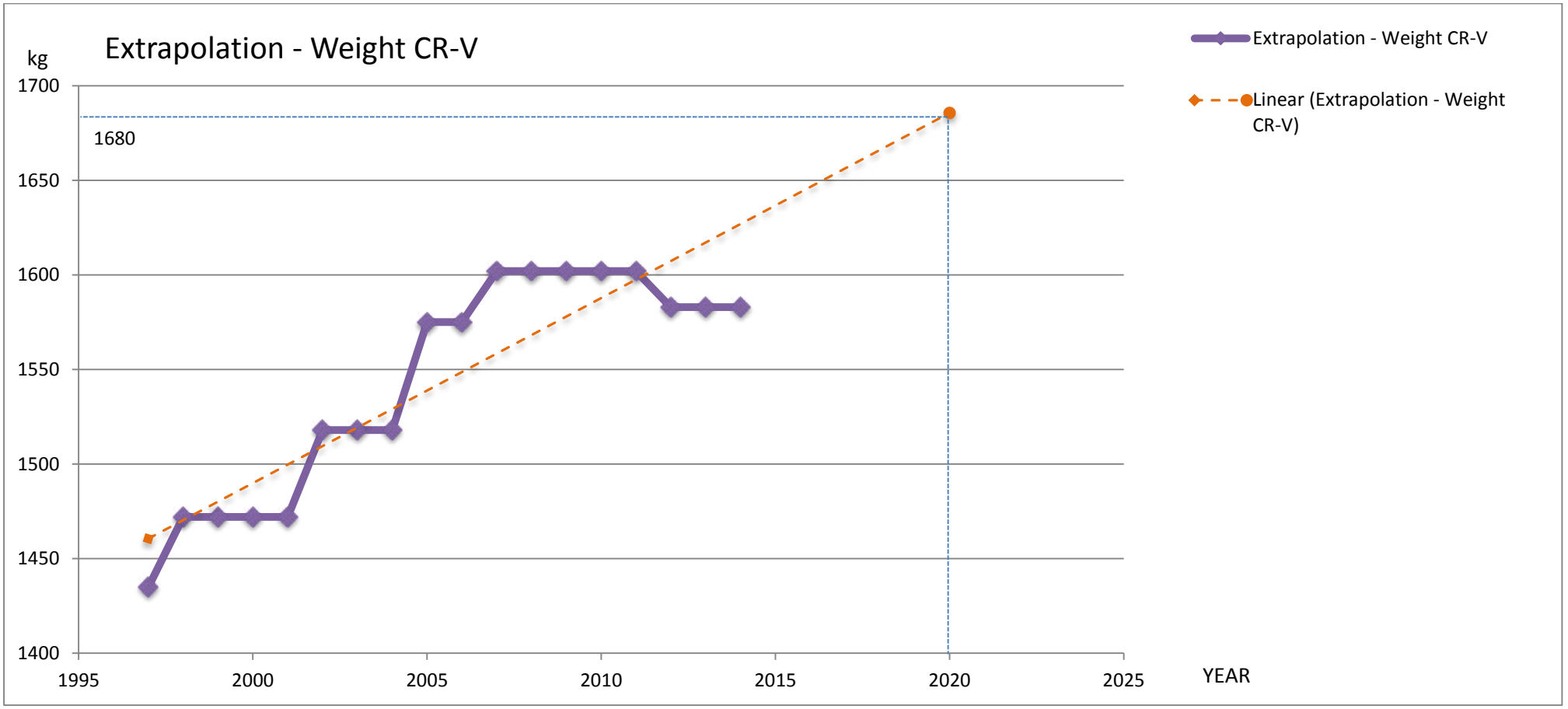
Data collected for Honda CR-V for the production years: [8] [9]

Kerb weight (kg), Mileage (mpg/ km per L), Engine Power (BHP)

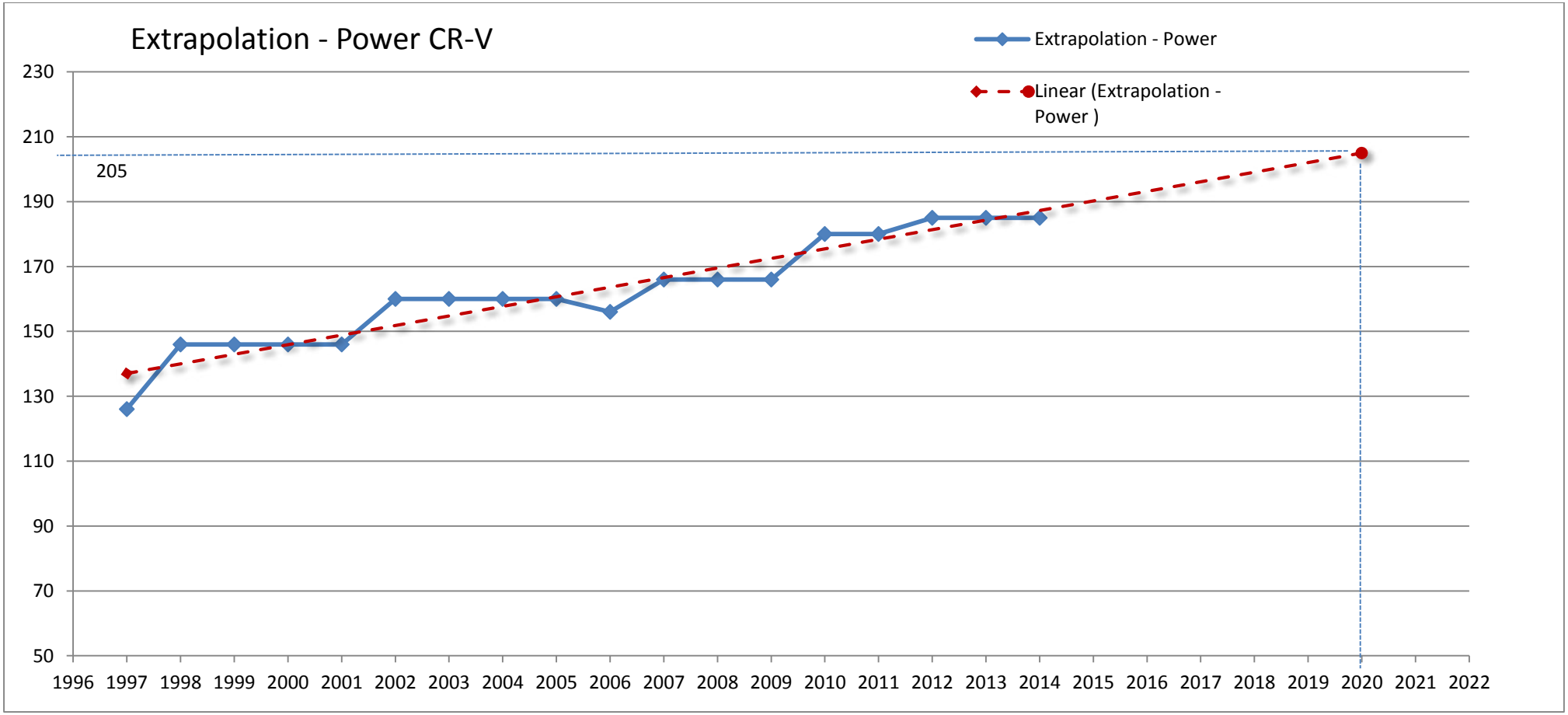
Year / CR-V Model	Weight lb (kg)	Mileage mpg-US (km per Litre)	Power (BHP)
2014	3490 (1583)	22 – 30 (9.35 – 12.75)	185
2012, 2013 EX AWD	3490 (1583)	22 – 30 (9.35 – 12.75)	185
2011 EX 4WD AT	3534 (1602)	21 – 27 (8.92 – 11.47)	180
2010 EX 4WD AT	3532 (1602)	21 – 27 (8.92 – 11.47)	180
2009 EX 4WD AT	3532 (1602)	20 – 26 (8.5 – 11.05)	166
2008 EX 4WD AT	3532 (1602)	20 – 26 (8.5 – 11.05)	166
2007 EX 4WD AT	3532 (1602)	22 – 28 (9.35 – 11.9)	166
2006 EX 4WD AT	3472 (1575)	21 – 26 (8.92 – 11.05)	156
2005 EX 4WD AT	3472 (1575)	21 – 26 (8.92 – 11.05)	160
2002, 2003, 2004 EX 4WD AT	3347 (1518)	21 – 25 (8.92 – 10.62)	160
2000, 2001 EX 4WD AT	3245 (1472)	22 – 25 (9.35 – 10.62)	146
1998, 1999 EX 4WD AT	3245 (1472)	22 – 25 (9.35 – 10.62)	146
1997 Base M	3164 (1435)	22 – 25 (9.35 – 10.62)	126

Source URL:
autos.msn.com/research/vip/overview.aspx?year=2000&make=Honda&model=CR-V

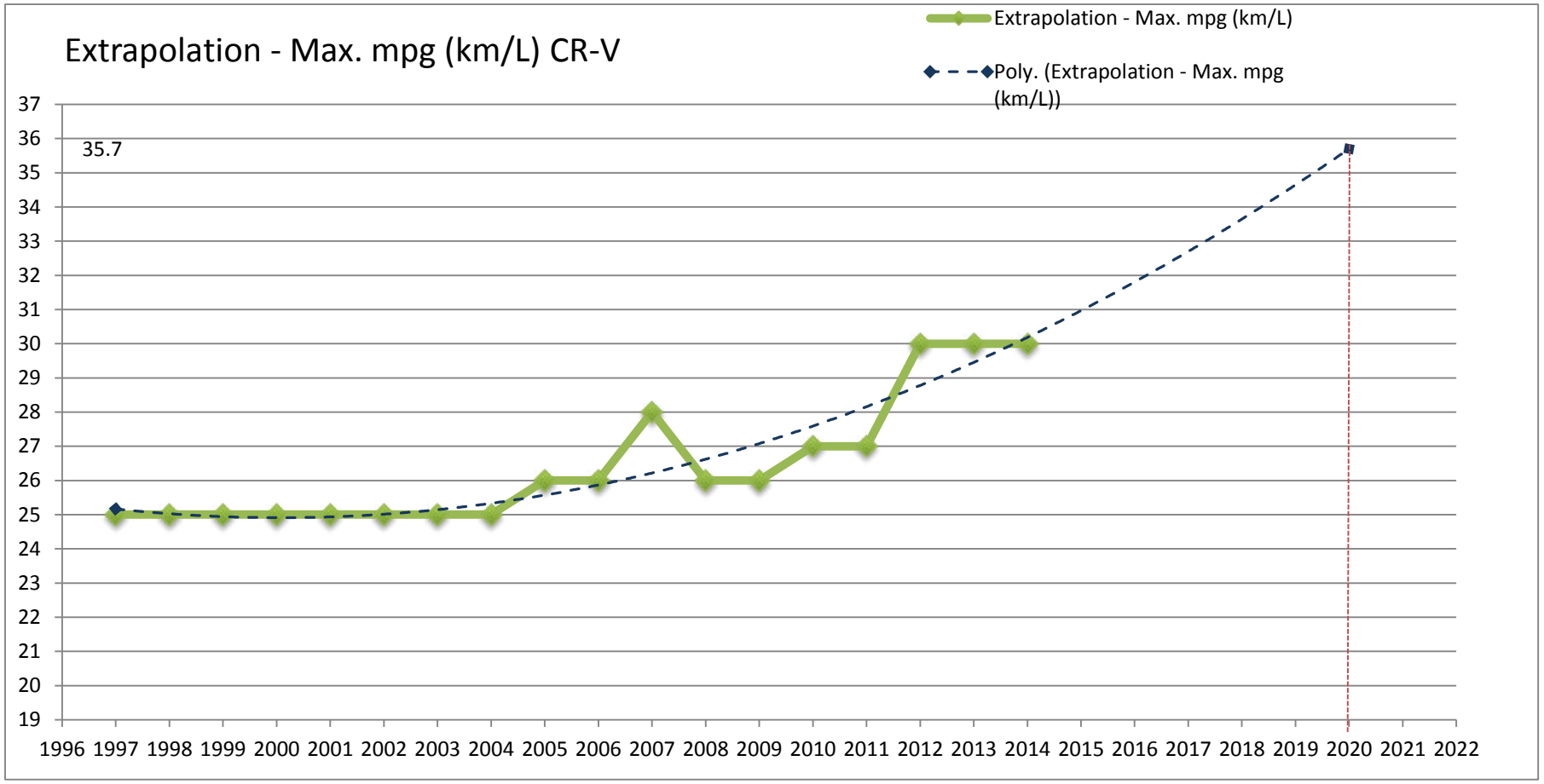
Simple Weight Extrapolation of CR-V for 2020



Simple Power Extrapolation of CR-V for 2020



Simple Mileage Extrapolation of CR-V for 2020



For CR-V in 2020, it is hence predicted by this extrapolation of Power, Weight and Mileage that:

Power: 205 BHP

Mileage: 35.7 mpg (15.18 km/L)

Approx. weight: 1680 kg

Electric vehicle benchmark's Weight (Chevrolet VOLT): 1720kg

Calculations for the New Vehicle

Weight Calculations of the New Vehicle

Studying reduction in weight with downsizing of the vehicle:

Car / Weight(kg)	Downsized model / Weight (kg)	Weight Reduction (%)
Tata indigo – 1155kg	Tata indigo CS – 1065kg	7.8%
Hyundai accent viva – 1090kg	Hyundai Accent – 1039kg	4.6%
Suzuki Dzire VXI 2011 (4160 mm) – 1025kg	Suzuki Dzire VXI 2013 (3995mm) – 970kg	5.5%
Chevrolet Optra Magnum Max 1.6 (2009-2011) – 1230kg	Chevrolet Optra SRV – 1230kg	0%

Considering 6% weight reduction by downsizing the length by 170mm - as an average

Quantifying – Advantage of Weight Reduction in the New Vehicle in 2020

- Reduced weight of: IC Engine, gearbox, mechanical transmission
- CR-V length downsized: (Approx. 6% lighter in weight for 170mm decrease in length Example Swift Dzire)
- Use of Weight saving materials: 25-30% lesser weight in 2020
- Range extender engine: Small Aluminium block - 3 cylinder 600cc engine coupled with electric Generator - 120kg (for comparison - 85kg 600 cc Nano engine)
- Addition of weight of Battery and Induction Motors

Calculating approximate weight of the new electric vehicle in 2020

- ✓ (Approximate weights)
- ✓ CR-V current weight: 3529 lbs = 1600 kg
- ✓ Weight of 67kW Induction motor = 106 kg
- ✓ Weight of new 100 L (400 km range) battery pack = 260 kg
- ✓ Weight of 600cc Range Extender engine = 100kg
- ✓ Transmission weight = 70 kg
- ✓ Weight of 2.4L IC engine = 300kg
- ✓ Assumed weight reduction: 25 – 30 % (Due to usage of High-strength steel, Aluminium, magnesium, carbon-fibre parts)

Calculated approximate weight for the new vehicle (Based on CR-V + Chevrolet Volt):

- ➢ (Current CR-V weight) + (Weight of two Motors) + (Weight of batteries) + (Weight of Range Extender engine 600cc with electric generator) – (25% less weight with lighter materials) – (Removal of Transmission) – (Removal of IC engine) – (Reduced weight due to Shorter length)
- ➢ 1600 kg + (105 kg + 105 kg) + (260 kg) + (120 kg) – (25% of 1600 kg) – (70 kg) – (300 kg) – (200 kg)
- ➢ = 1220 kg Kerb Vehicle weight (extrapolated for 2020)

Power Requirement of the new vehicle

For 1680 kg Honda CR-V vehicle, Power required (extrapolated for year 2020) = 210 BHP (From extrapolation graph data)

Hence, for 1220 kg vehicle power required = 160 BHP (rounded off)

For producing Maximum output of 160 BHP with Two Induction Motors:

160 BHP = 117.7 kW

Considering ~ 120 kW,

Two Induction Motors of 65 kW each weighing = 105 kg each

Development in Battery Technology

- It is claimed that there is at least on an average 5% IMPROVEMENT in the battery density every year so far. This pace has been consistent but not sufficient. It's safe to assume this 5% growth till 2020. [4]
  Current battery Chevrolet Volt = 16.5 kWh
  With 5% growth on 16.5kWh every year till 2020 gives = 22.1 kWh in 2020

- Battery technology research giant company ENVIA claims to have almost developed currently a battery technology quite similar to the existing with improvements that provide 2 Times more Energy Density in the current batteries. They are under the process of finding its way to the market with a manufacturer.
  - 2x battery density [5]

  Source: http://www.forbes.com/sites/yonicohen/2012/03/21/envias-energy-dense-battery-could-cut-electric-vehicle-costs/2/

- Another technology and huge investment market consultant giant 'NAVIGANT' has published a report for the benefit of automotive companies which are eyeing huge investments in electric vehicle technology. The report predicts affirmatively about a TEN Times more Energy Density in batteries by 2020 compared to today.
  Which implies : 10x battery density [4]

  Source: http://www.marketwatch.com/story/worldwide-capacity-of-lithium-ion-batteries-for-electric-vehicles-will-multiply-more-than-10-fold-by-2020-forecasts-navigant-research-2013-05-17
  Source:http://www.iea.org/topics/transport/electricvehiclesinitiative/EVI_GEO_2013_FullReport.pdf

- All eyes are on the 'Metal-Air' (e.g. Aluminium – Oxygen) batteries that are a burning topic in the world right now as far as

most advanced and recent battery technologies is concerned. We can take a wise guess from the above mentioned reports as to how much improvement in the battery density can be made till 2020 with fair amount of belief. [3]

- **Hence, considering "5x Improvement in today's battery density by 2020"**

Battery Extrapolation

Chevrolet VOLT's battery pack today:

Energy: 16.5 kWh

Weight: 197 kg

Volume: 100 L (3.5 cubic feet) that lasts approx. 40miles

- ✓ With 5% growth on 16.5kWh every year till 2020 gives = 22.1 kWh in 2020
- ✓ Let's take the assumed **5x growth** in battery density in 2020, it gives:
  = **110.5 kWh battery energy in same volume of battery (100 L)**
- ✓ Volt's current energy density (Wh/kg): = 16.5kWh/197kg = 16500 Wh/197 kg = 83.75 Wh/kg
- ✓ Considering 5-times increase in energy density in 2020, expected energy density of the battery: = 83.75 x 5 = **418.75 Wh/kg**

Now we can either:

- Keep the same battery volume with better energy storage = 110.5 kWh
- Or we can have the smaller size/ Volume of the battery with lesser kWh rating for saving in space
- Or we can also have an Energy (kWh) and Volume configuration for a cheaper battery.

Battery and the Range of the Electric Vehicle

Chevrolet VOLT's 111kW with 16.5 kWh battery lasts approx. 40 miles. **Considering 5x Battery Density growth by 2020:**

110.5 kWh battery pack and 418.75 Wh/kg energy density

- ➢ Now, if 111 kW with 16.5 kWh battery pack gives = 40 miles (i.e. Chevrolet Volt's Motor and battery in normal usage)
- ➢ 111 kW with 110.5 kWh battery pack will give = 268 miles (431 km) (With x5 Battery Density as predicted with previous calculations for year 2020)

Hence, the new 120 kW (New Motor Power requirement) with 110.5 kWh battery pack would give

= 247.9 miles

= 398.9 km

= ~400 km approx.

So a 100 L battery with x5 times increased battery density (110.5 kWh) running 120 kW motors would last for approx. 400 km in our vehicle.

Hence we get for our battery specification: 400 Km – 100 L battery – 260 kg

Range Extender engine

Taking a small Aluminium block - 3 cylinder 600cc engine coupled with electric Generator – weighing about 120kg

(For comparison - Nano engine is 85kg - 600 cc)

Considering this Range Extender Engine with FUEL TANK capacity of: 20 L (Current Standards: 35-50 L hatchbacks, 60L Sedans)

Range Extender IC engine

600 cc 3 cylinder IC engine with lightweight construction of aluminium and optimized efficiency for set RPM range coupled to an Electric Generator to produce electricity

Considering overall Extra range available due to Range Extender system: 300 km Minimum

Design Brief

Vehicle and Packaging

The vehicle should be a futuristic Electric Hybrid Crossover which would satisfy the user with its decent Sports Utility and equally high ride-comfort levels of a comfortable Sedan. The vehicle should accommodate 6 people with 4 Adults + 2 Children seating capacity. There has to be no compromise on the comfort and space within the vehicle as it is meant for long distance driving. The Ground-clearance of the vehicle should be best in its class for satisfactory mild off-roading needs of the user. Vehicle should boast of enough power and torque for its young customer to feel alive and must take full advantage of it Electric drive to deliver high efficiency and cost savings, keeping the environment clean. The vehicle's exterior looks should be sleek and elegant yet sporty and muscular.

Vehicle Specifications

- Max. Kerb weight of vehicle: 1220 kg
- Tyre size: 235/55 R18 [10]
- Electric Drive: Front axle Electric motor – 65 kW, Rear Axle motor – 65 kW
- Combined Max. Power of two 65 kW Motors: 120 kW (160 BHP)
- Transmission: Electric transmission, Series hybrid
- Range Extender engine with electric generator: 3 cylinder, 600 cc Aluminium lightweight IC engine optimized for a small rpm range, coupled with 50 kW Electric generator
- Range Extender engine – generator weight: 120 kg
- Fuel tank capacity: 20 L
- Battery: 110.5 kWh battery weighing approx. 260kg and 100 L in volume
- Electric Range of vehicle: 400 km +- approx. on pure electric
- Estimated extended range with IC engine range extender: about 300 km
- No. of seats: 6 (4 Adults + 2 Kids)
- Max. Vehicle speed: 220 km/h

Aesthetic

The vehicle needs to possess sporty character with a hint of muscularity. There should be elegance, sleekness and appeal in its looks. The SUV-ness of the vehicle should get enhanced with an element of robustness in it. The vehicle shouldn.t be bulky but should have presence on the road. The sharpness of its aerodynamic exterior should clearly portray its agility. The vehicle is not meant to be fast, but sporty and active. And the amalgamation of such an exterior with equally young and comfortable interior would complete the experience. It's a rugged & active SUV with the elegance and sharpness of a sedan.

Packaging Exploration

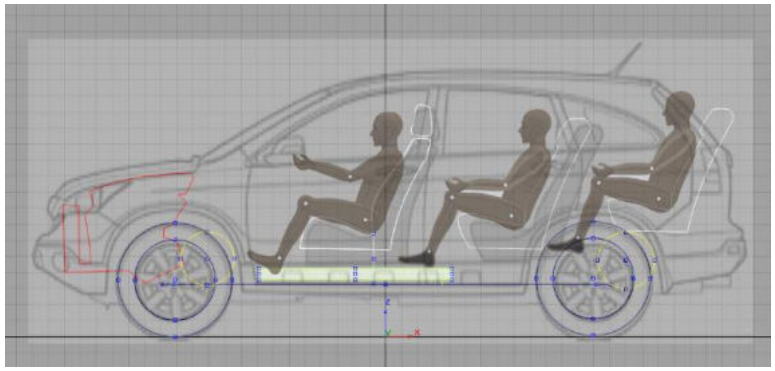
Seating Layouts [11]

For seating 6 passengers very comfortably, for long distance travel as well as mild off-roading. Mostly the passengers aren't all adults as found out from user research.

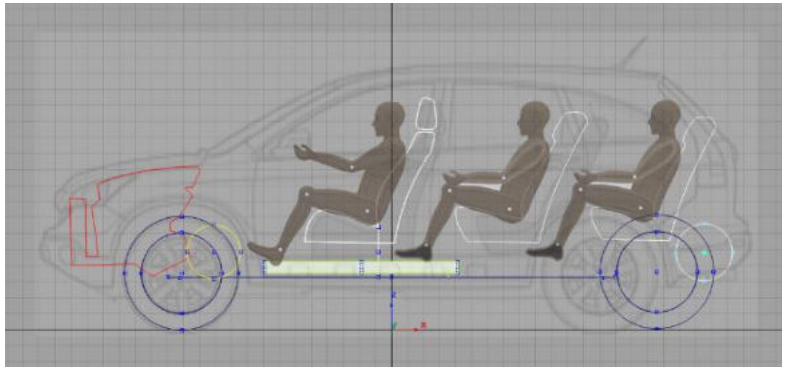
Exploring 3 row Seating arrangement with an underlay of Honda CR-V's silhouette for size estimation. Layout explorations needs to take care of engine, motors & battery placement as well as the ground clearance and dimensions of the vehicle. Layout has to ensure sufficient space, and room around the passenger for the comfort levels expected.

3 row explorations:

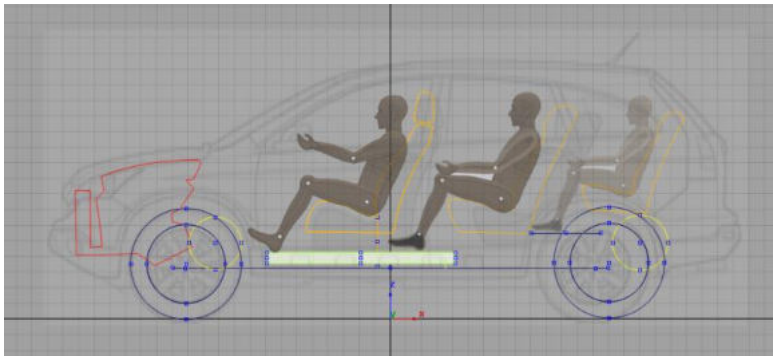
Layout - A



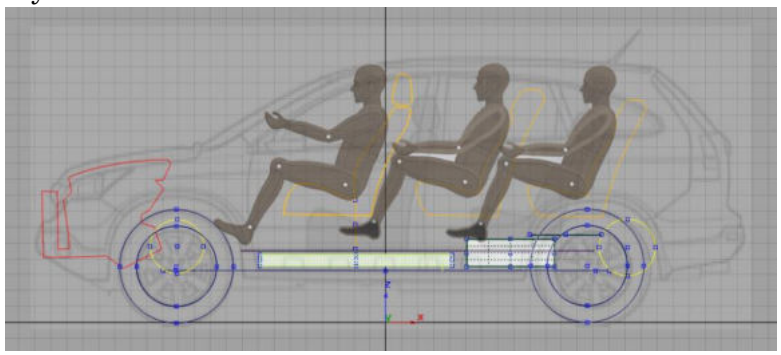
Layout - B



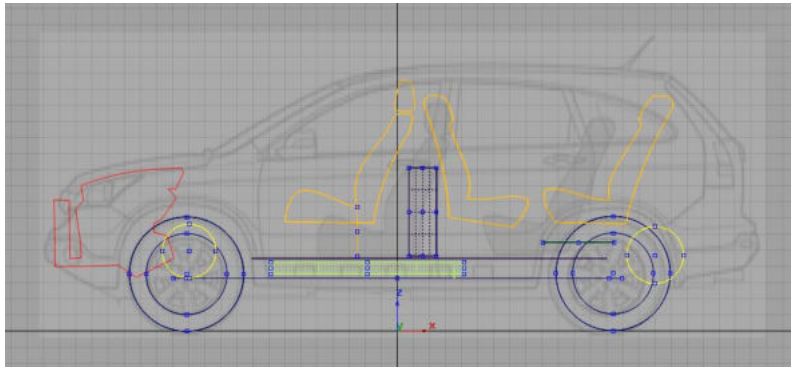
Layout - C



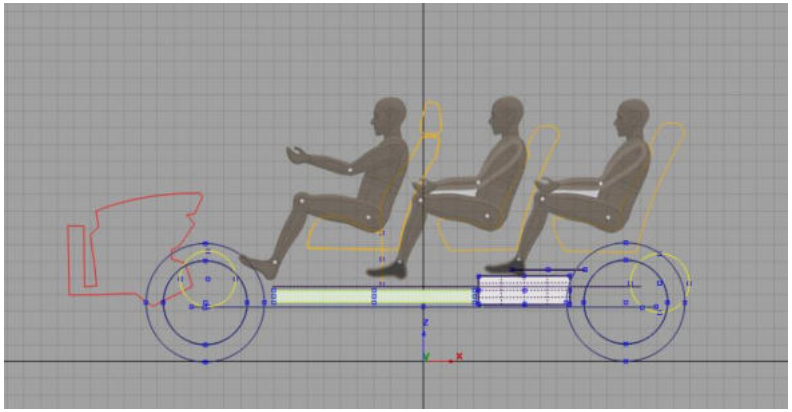
Layout - D



Layout – E



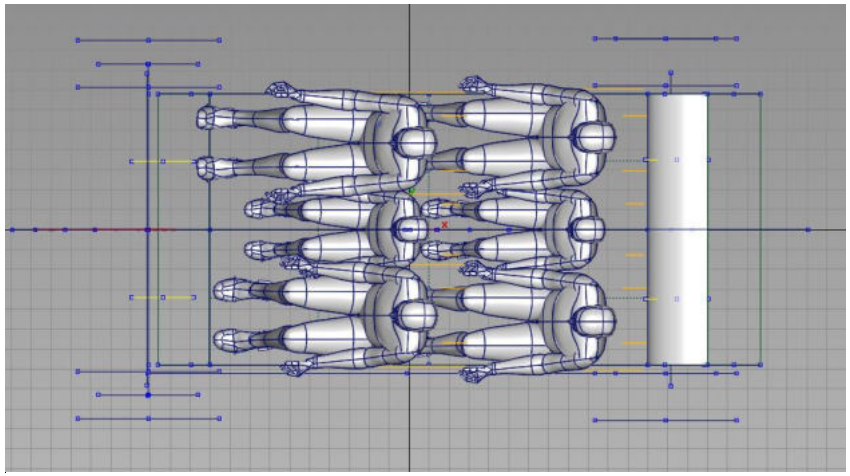
Layout - F

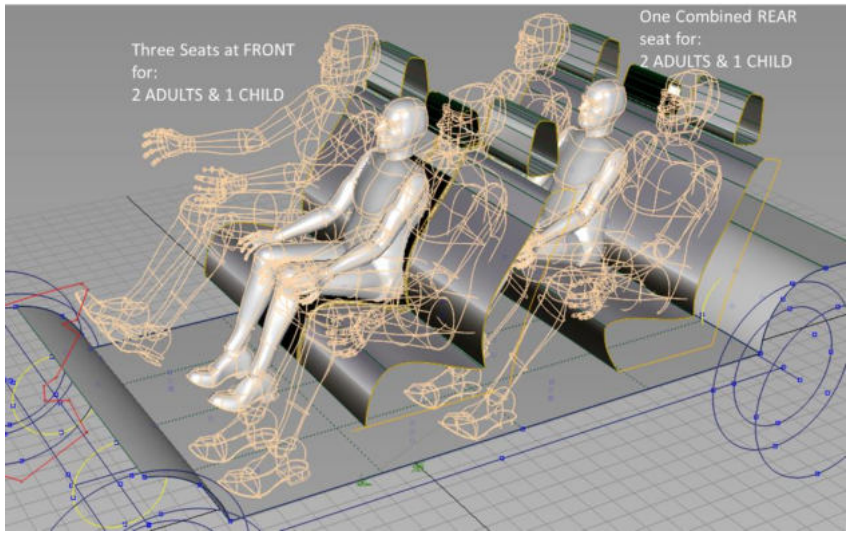


The user study concluded that the number of seats need to be only 6 with 4 Adults + 2 Child seats comfortably situated.

A different approach with only 2 rows of seating was thought of while setting seating layout in the car. The new idea seats 2 Adults + 1 Child comfortably in the front row and similarly 2 Adults + 1 Child couch seating at the rear seats. As the electric car needs far lesser controls (gear levers, clutch etc.) the space in the middle of two conventional seats in the front row can be utilized.

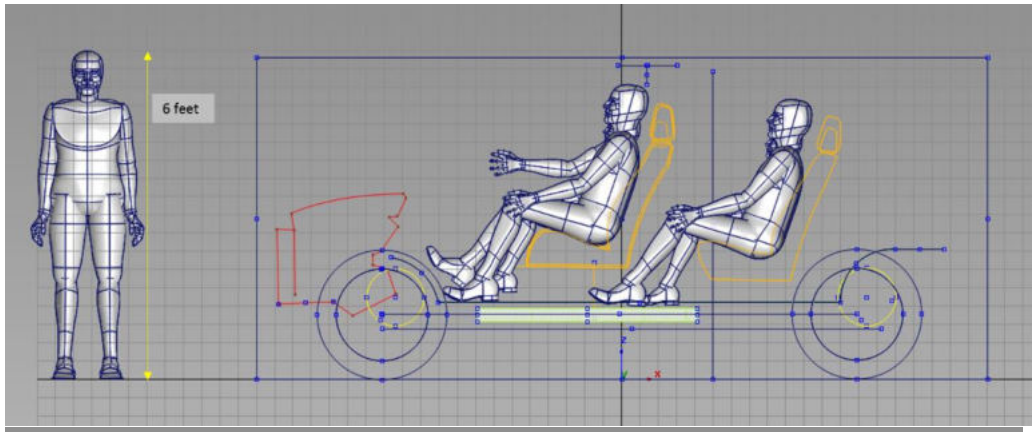
New 2 - row seating layout:

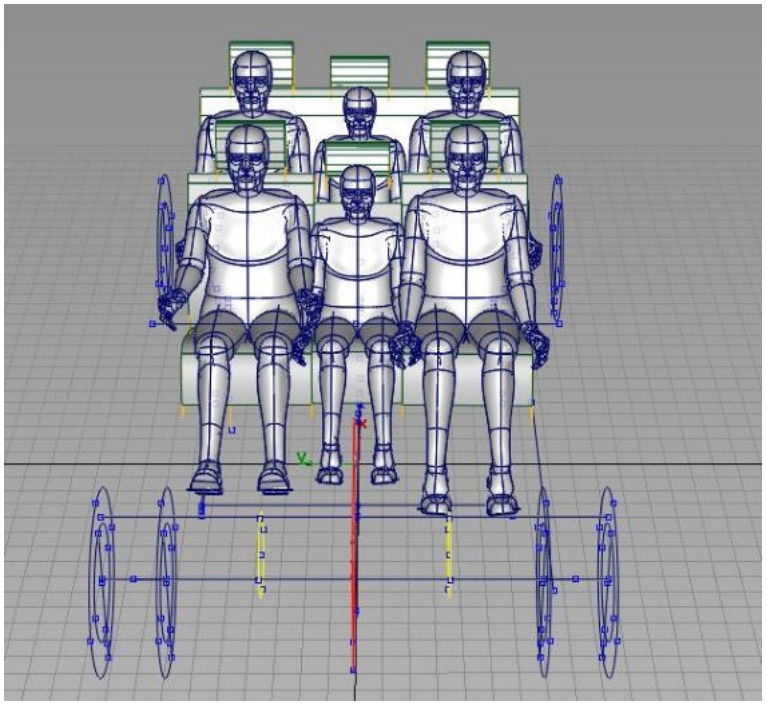


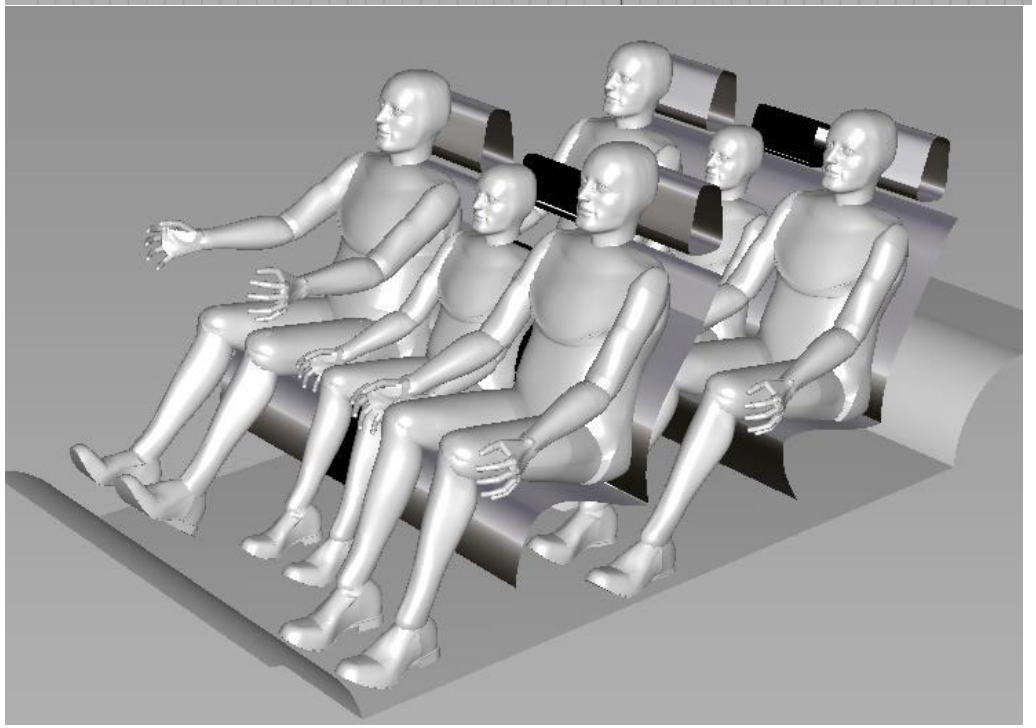


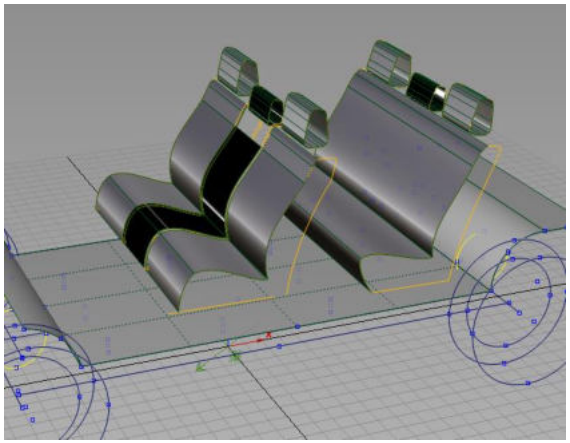
Though it is being called as 'Child seats' in the middle, the width of 350mm of that seat can easily fit a grown adult with very little compromise on the comfort part. [11]

The final seating arrangement is as shown:

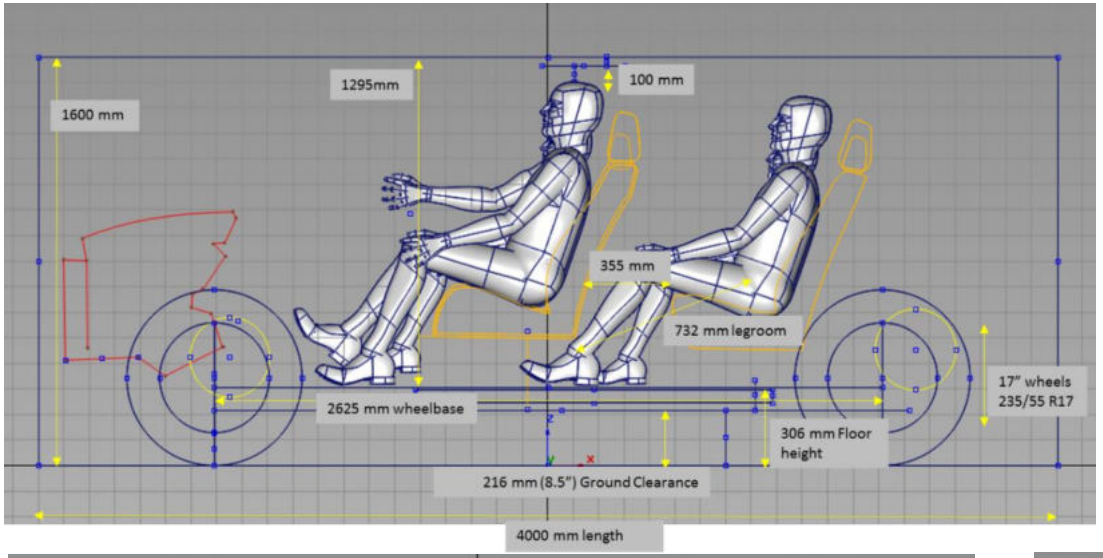




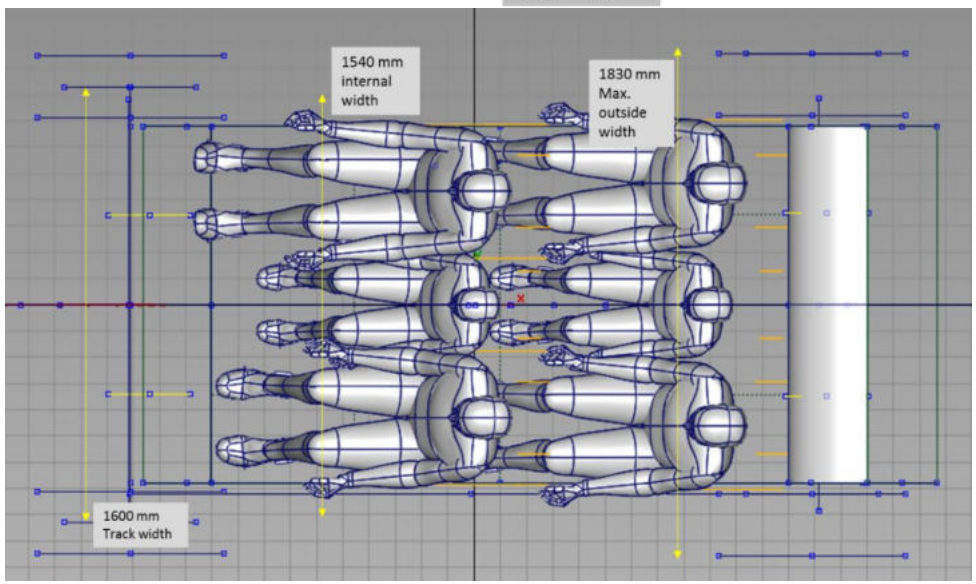


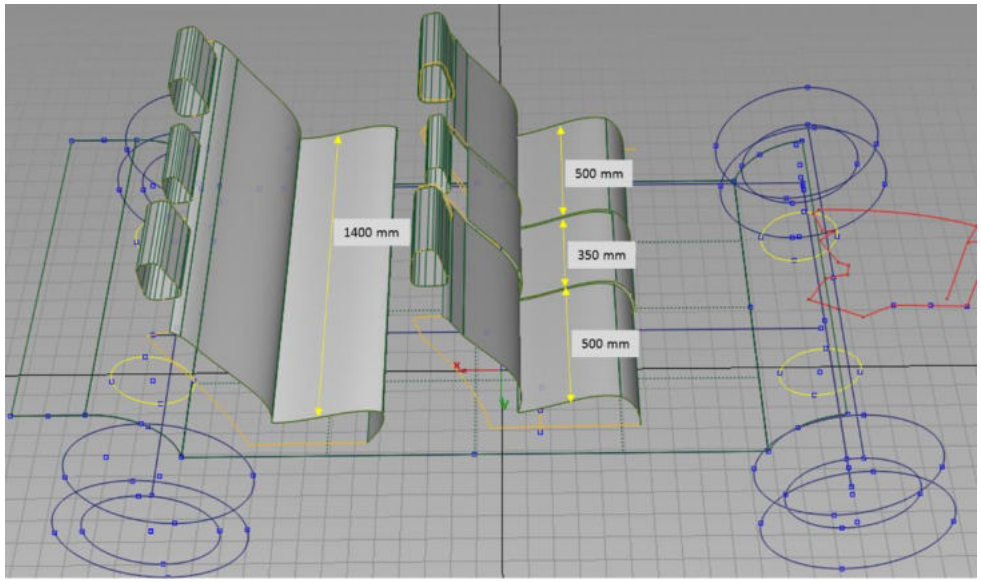


Dimensions



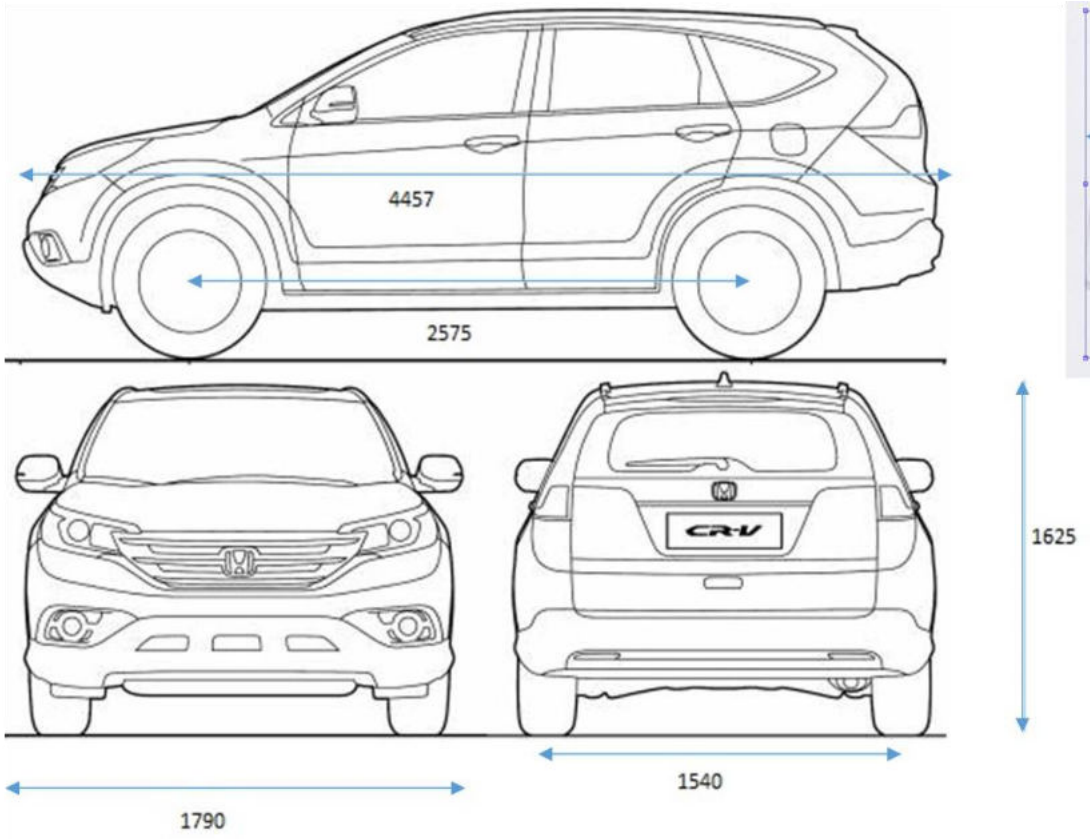
The overall dimensions are as shown in the diagrams. The dimensions of the seats are the average dimensions used for car seats worldwide which have been further experimented with using adult males of various sizes. The idea is to reduce the waste width of the seat and maximizing efficient seating to get the least interior width of the vehicle.

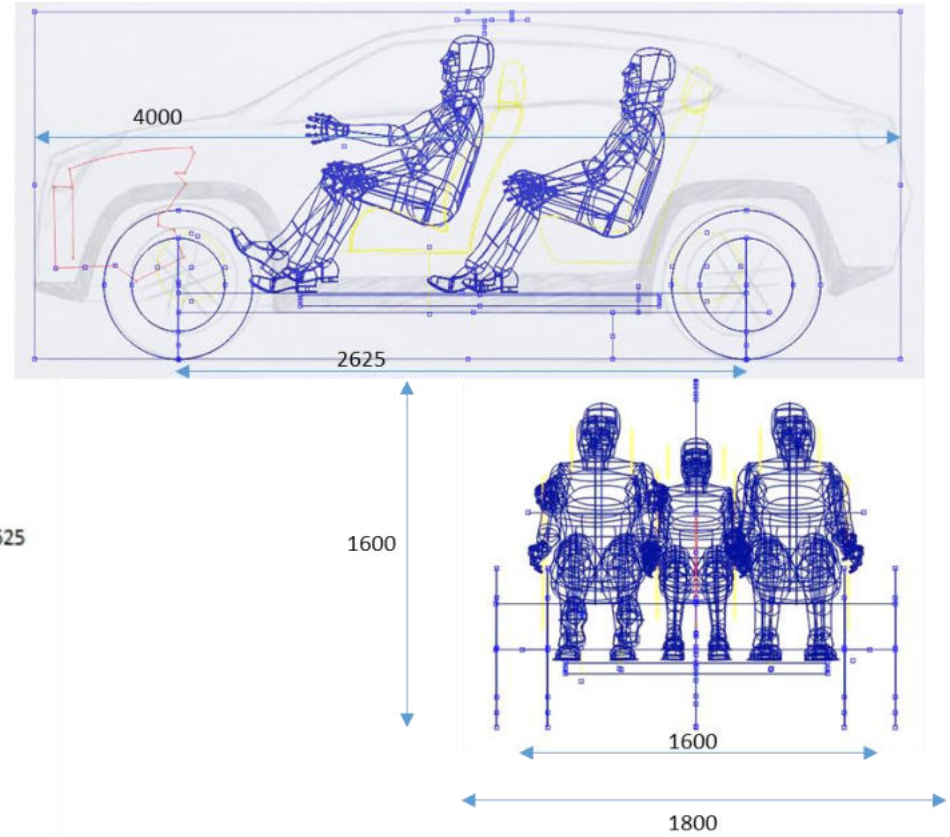




Comparison of Dimensions

Comparing dimensions of the 2013 Honda CR-V (benchmark) with the dimensions of our vehicle. On the left we have Honda CR-V and on the right we have our dimensions.





Design Keywords

Following are the keywords derived for the aesthetic explorations of the vehicle

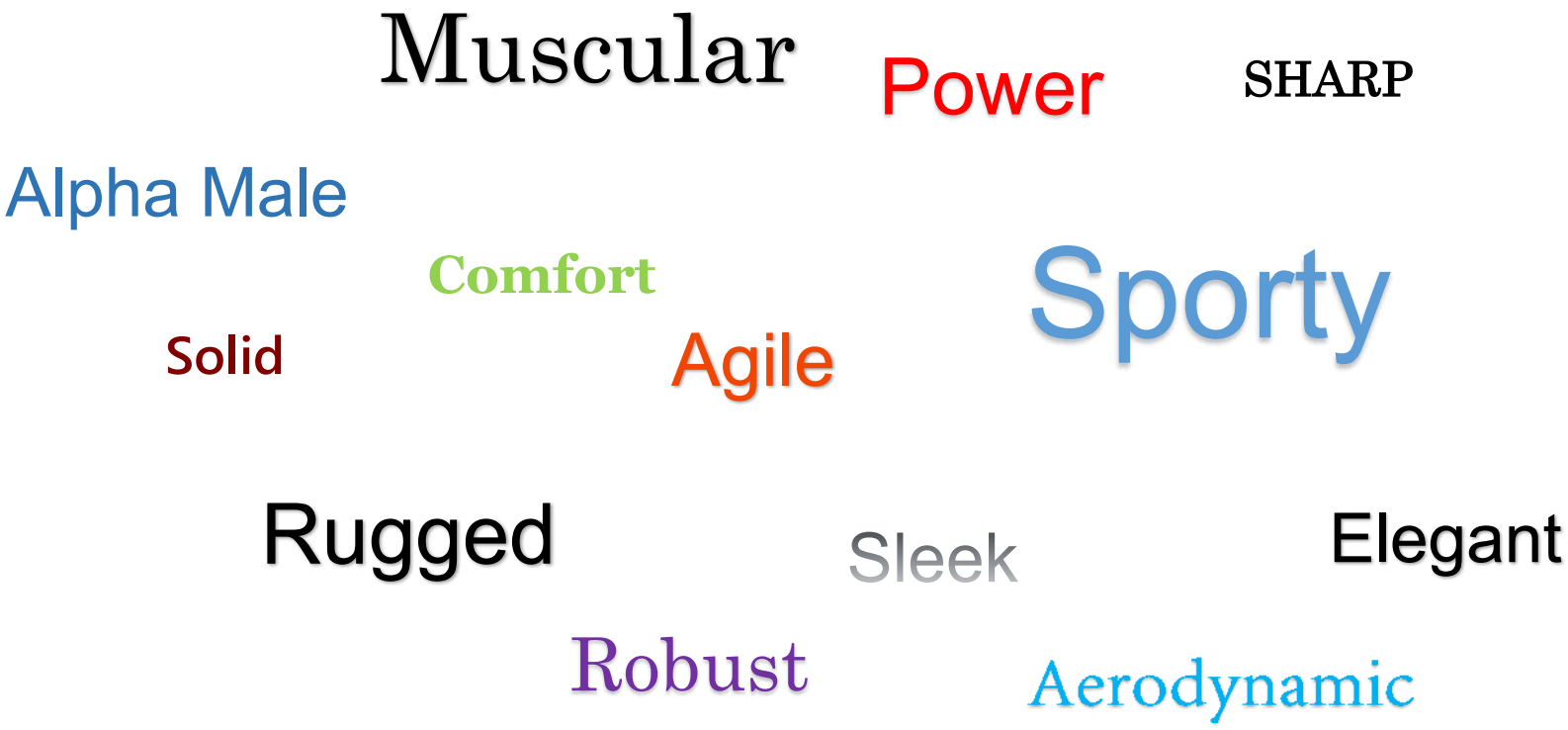


Image Board

The following two keywords were selected for the expression to be given to the vehicle:

SPORTY

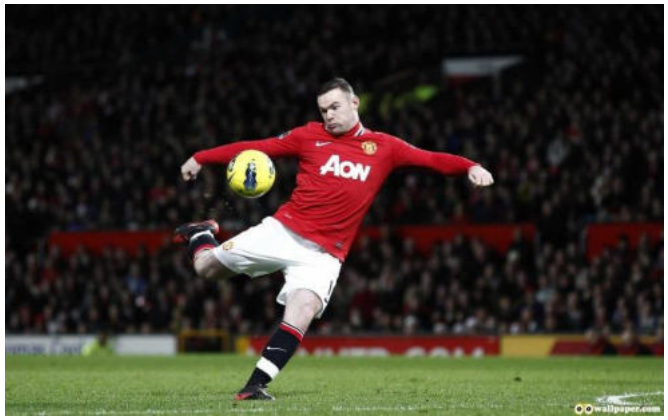






Image source: Internet

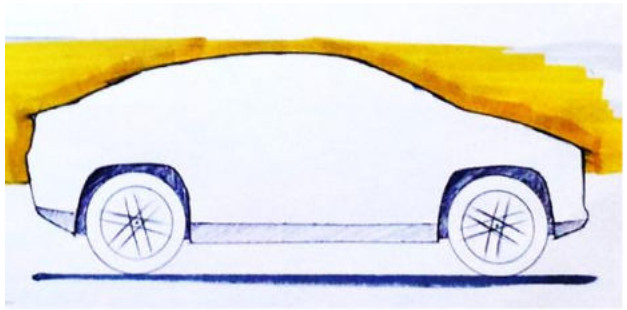
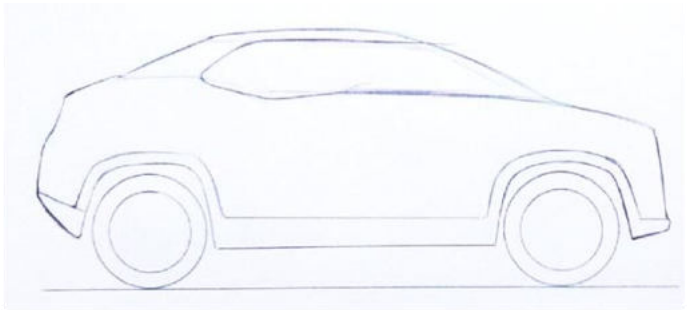
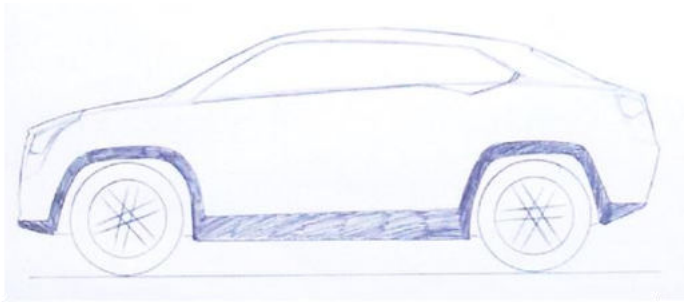
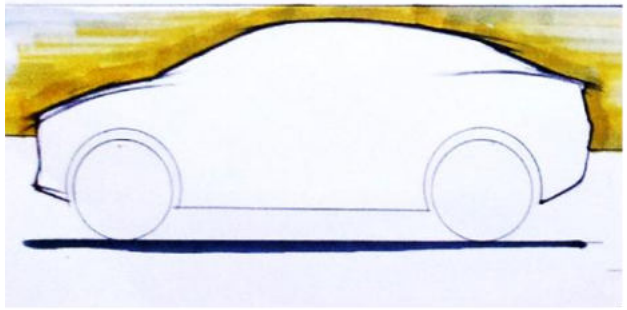
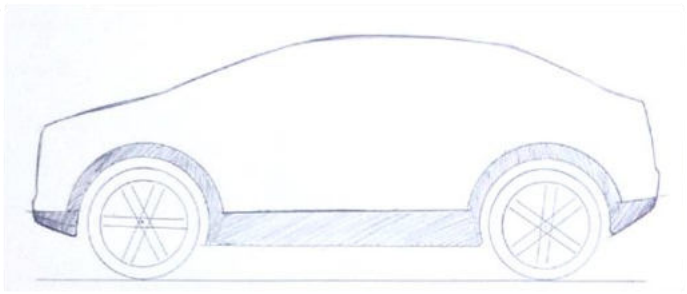
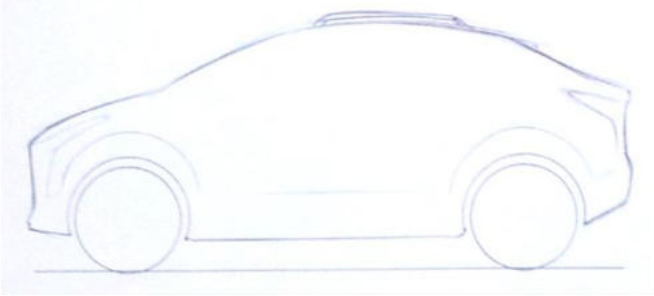
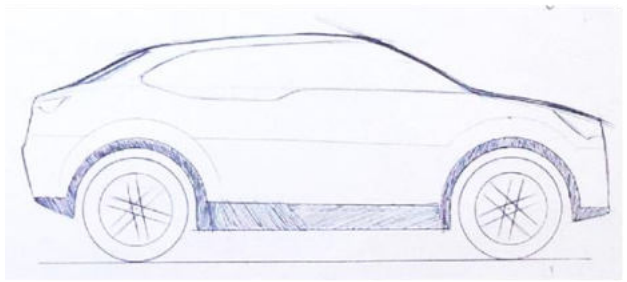
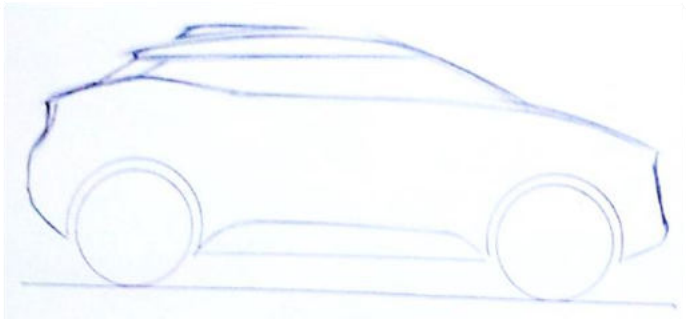
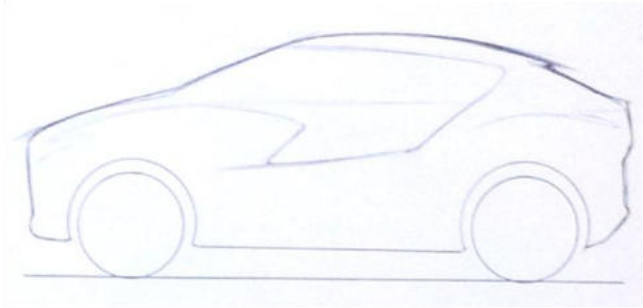
Image Board

RUGGED

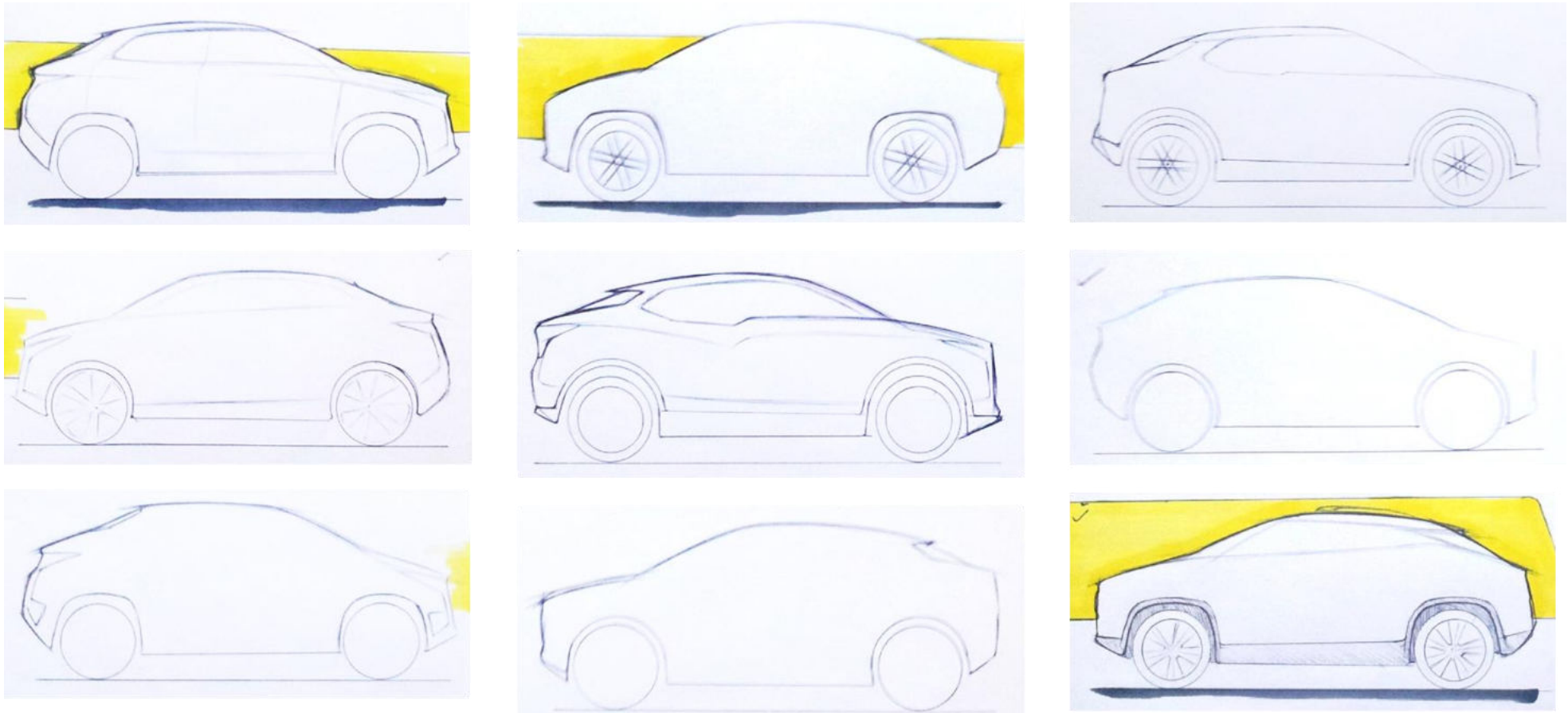
Image source: Internet

Ideations

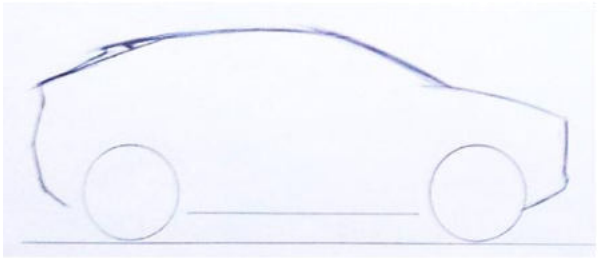
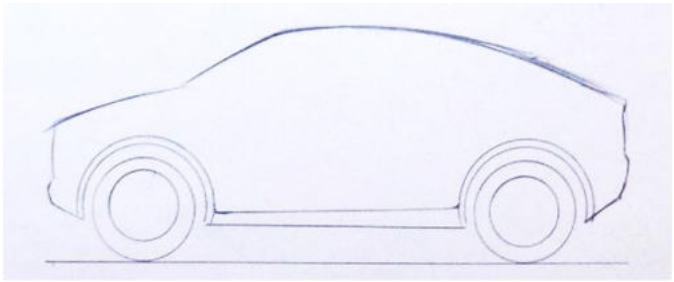
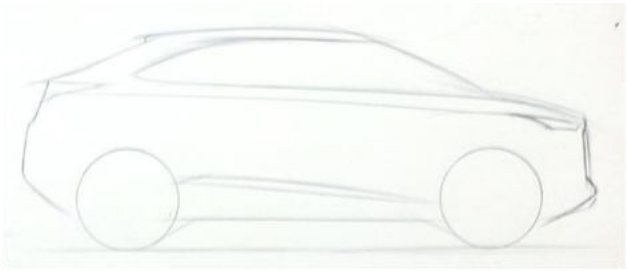
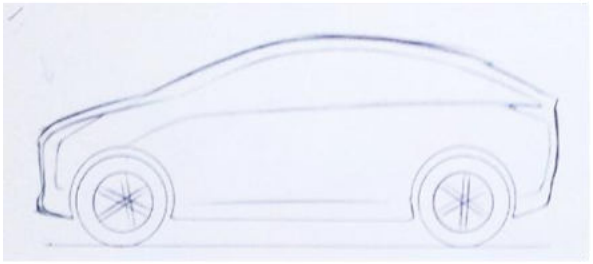
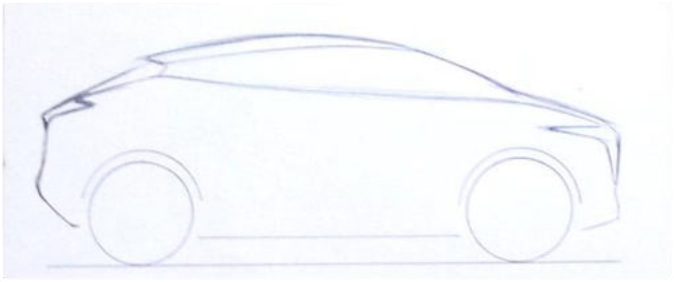
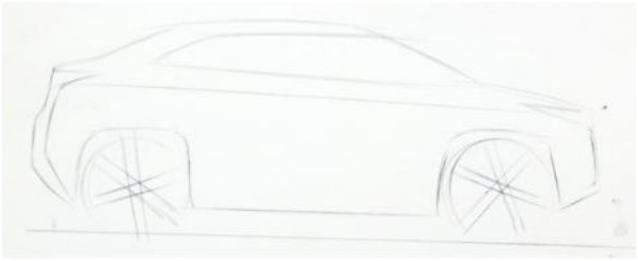
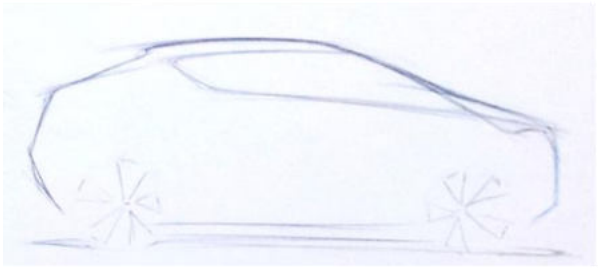
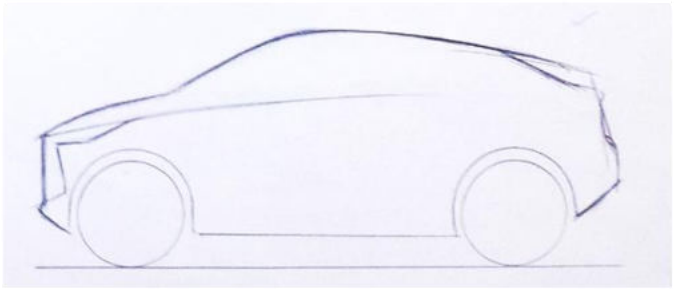
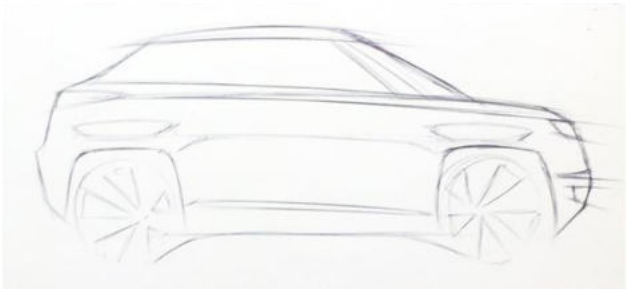
Silhouette Explorations 1

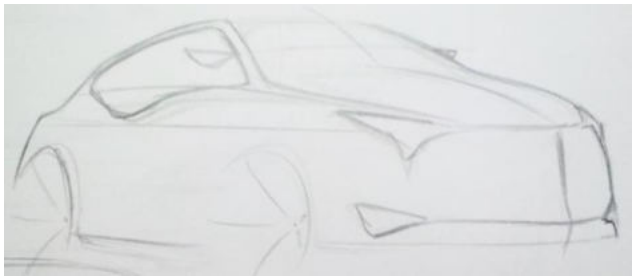
Silhouette Explorations 2

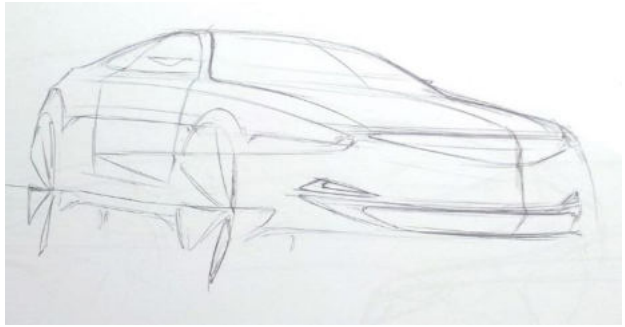
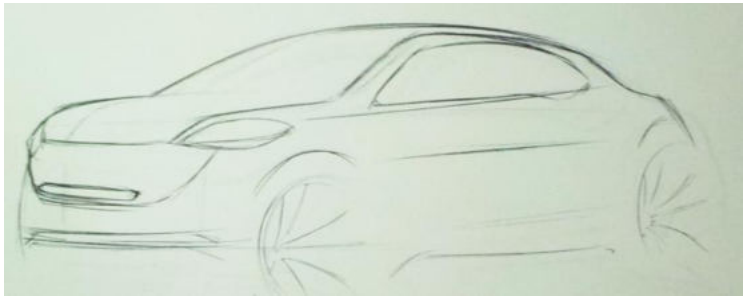


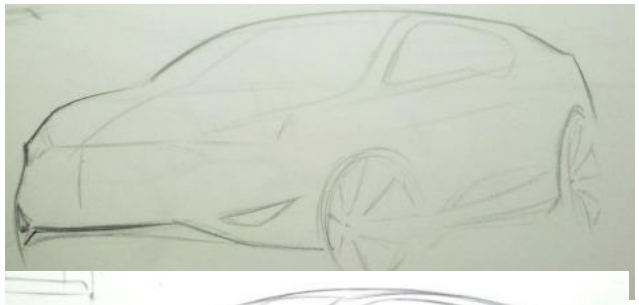
Silhouette Explorations 3

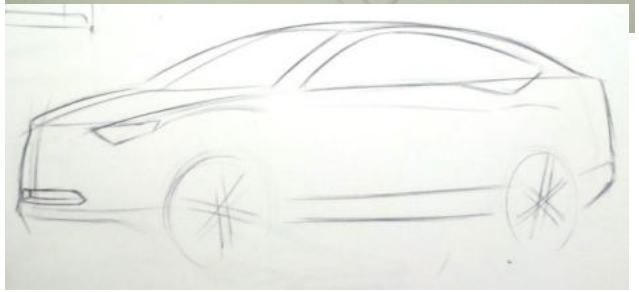










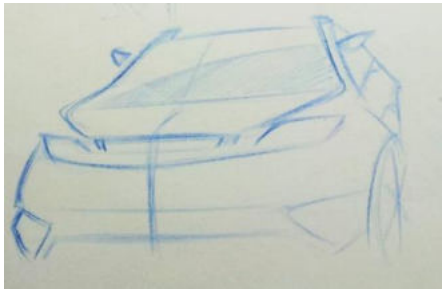
Initial Vehicle Explorations

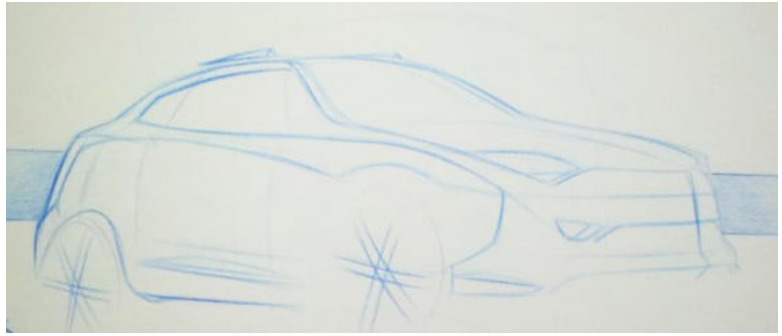



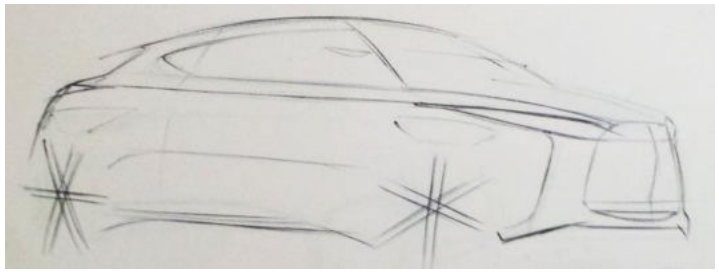
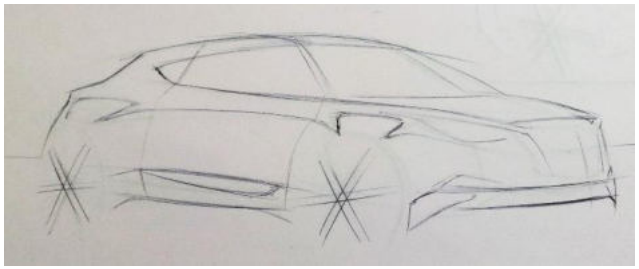
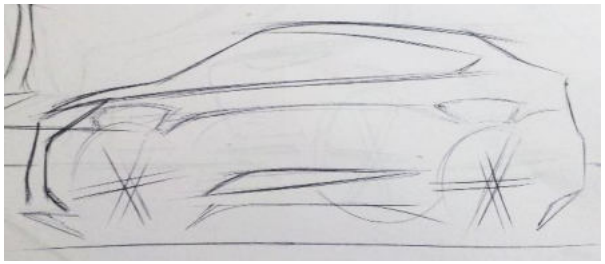
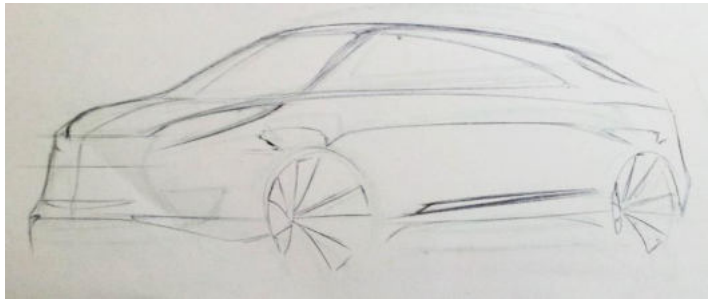
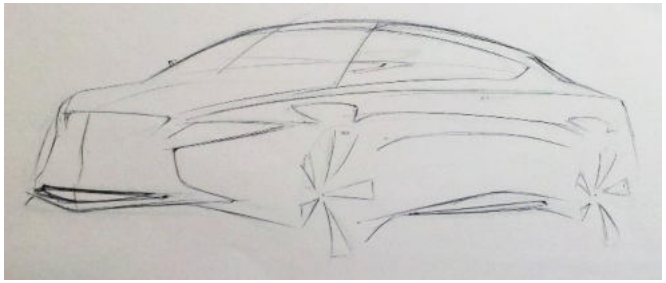


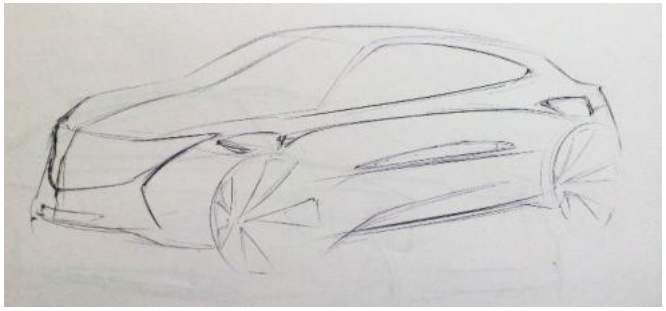
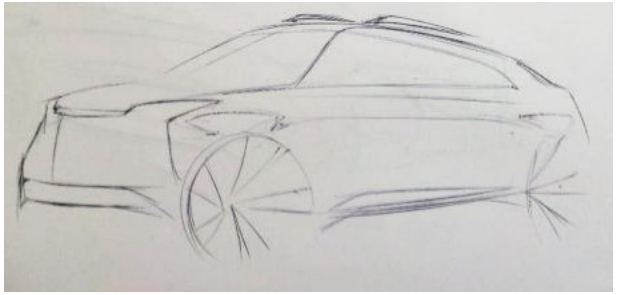



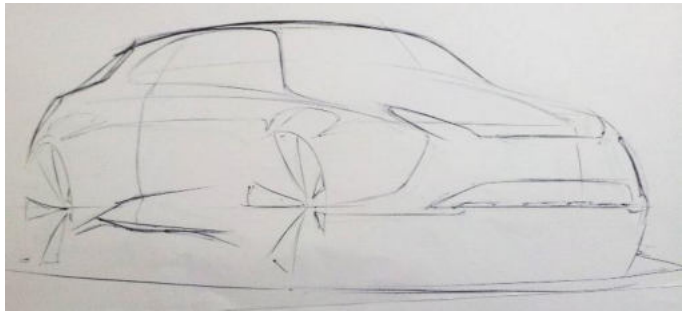


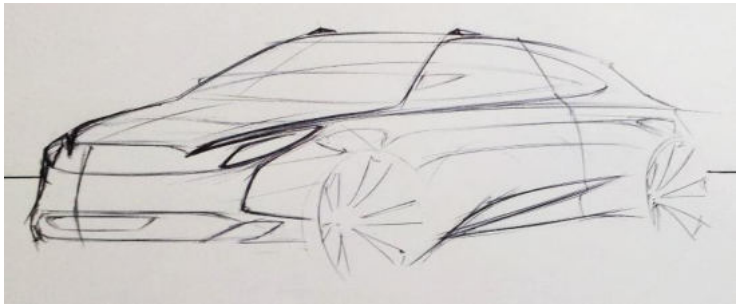
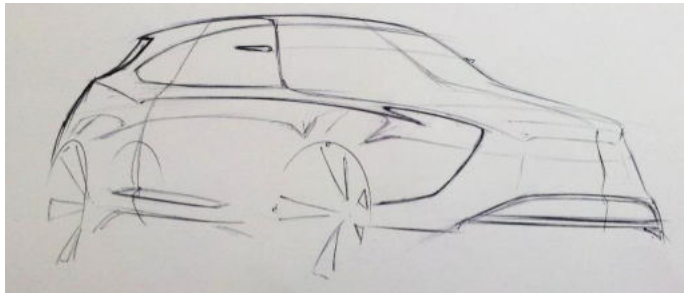


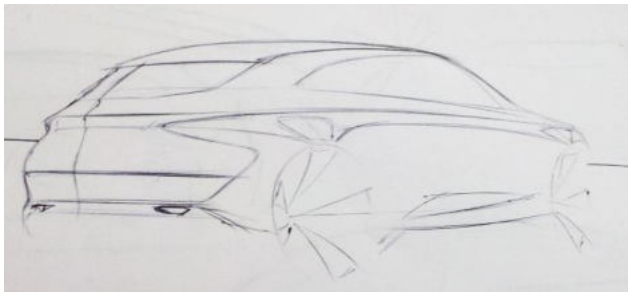
Concept Ideations

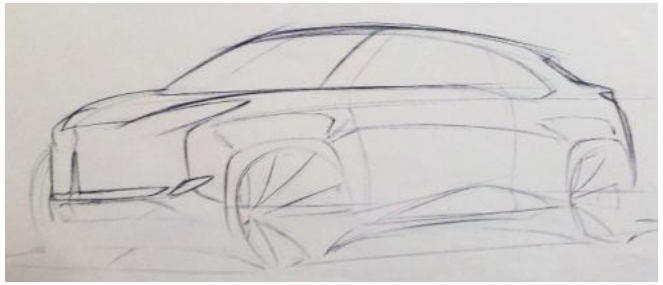
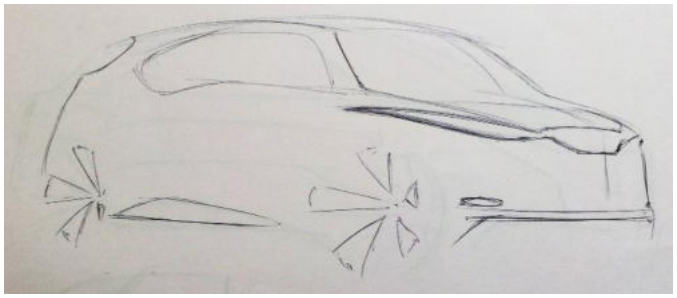
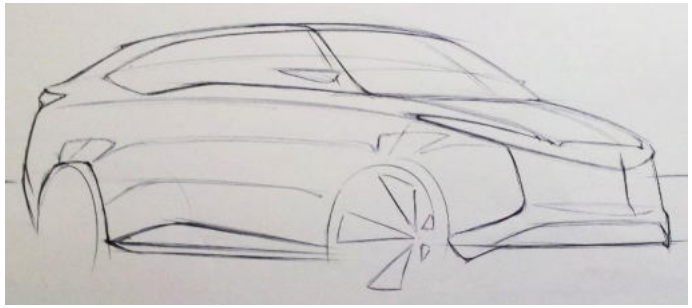
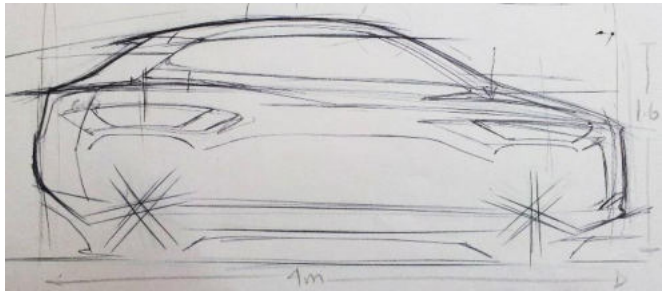








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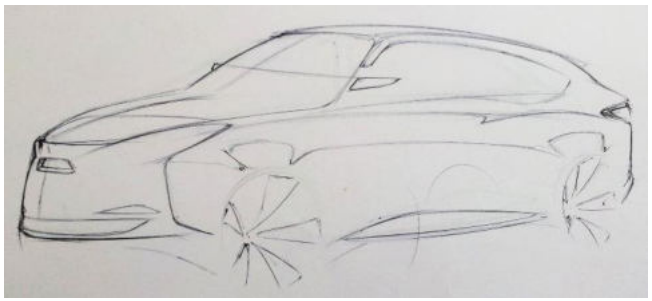
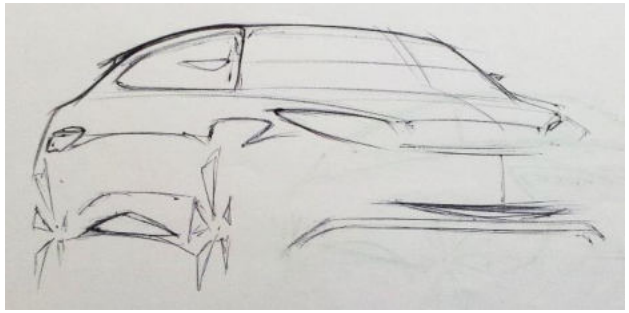
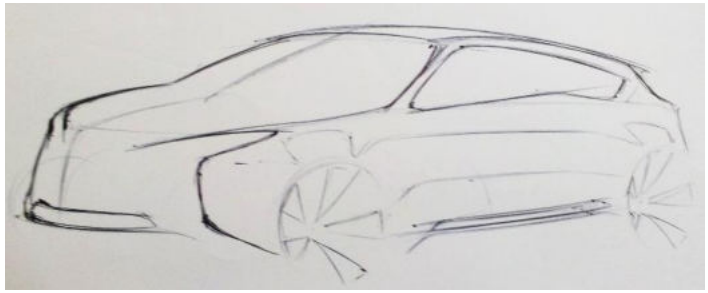
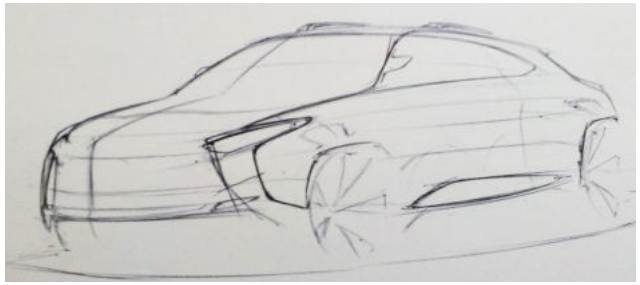
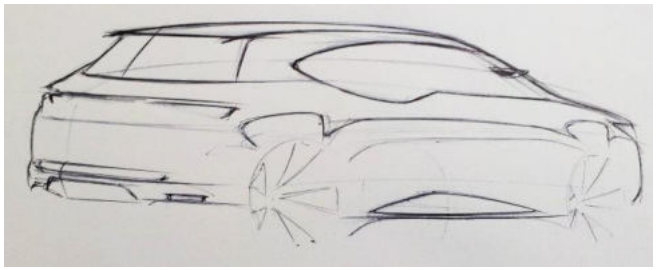
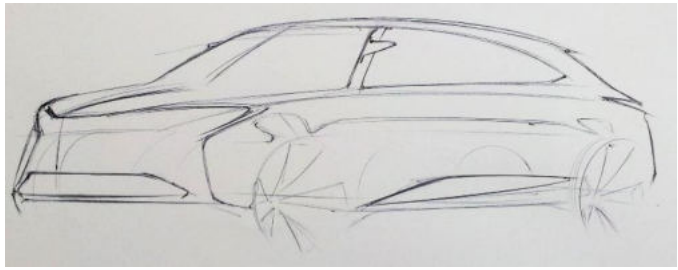
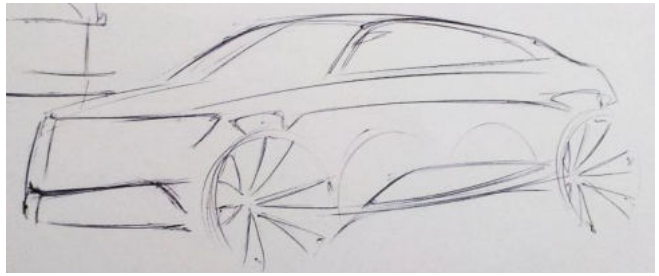
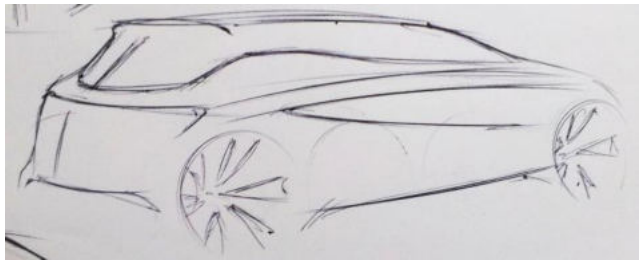
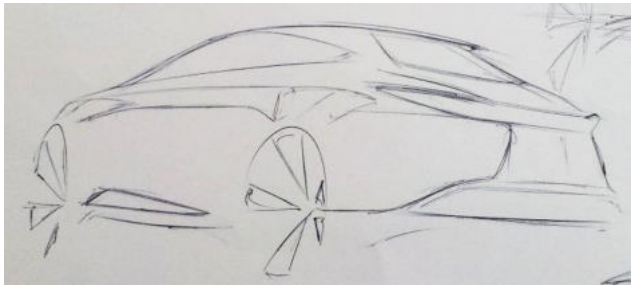


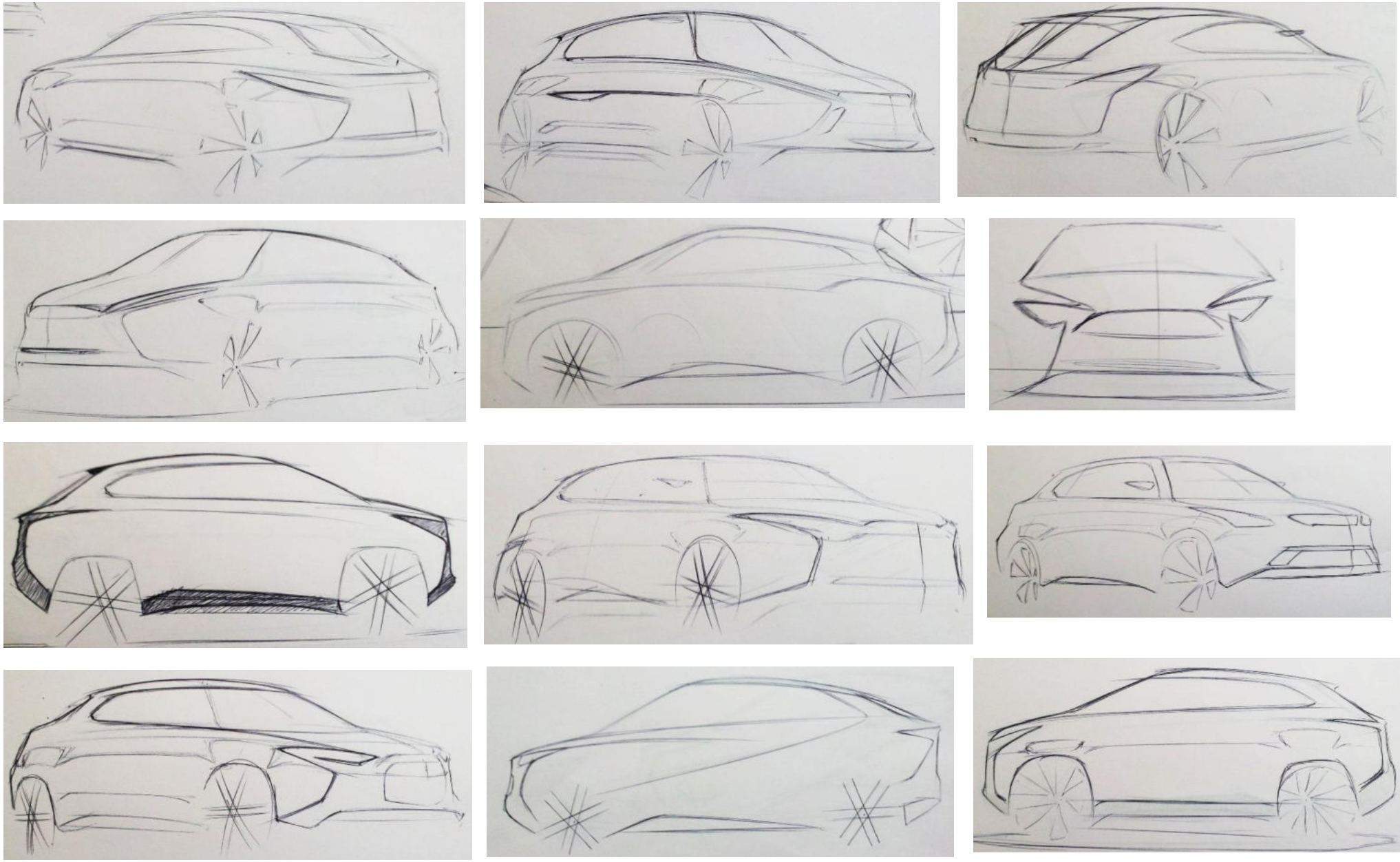


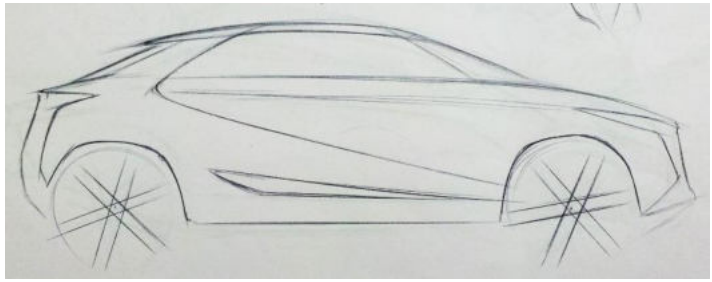
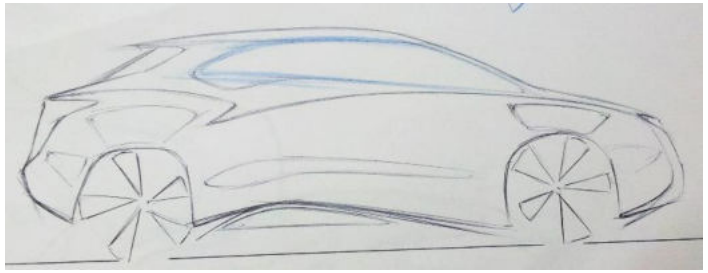
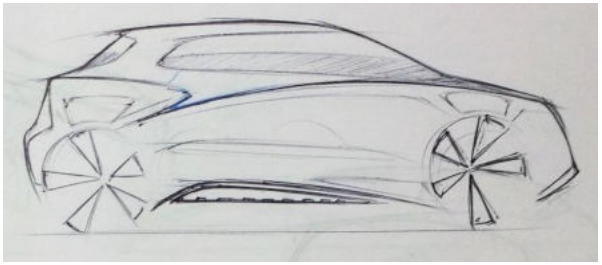
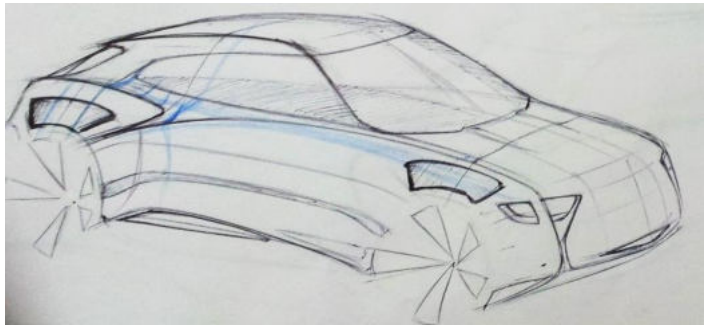





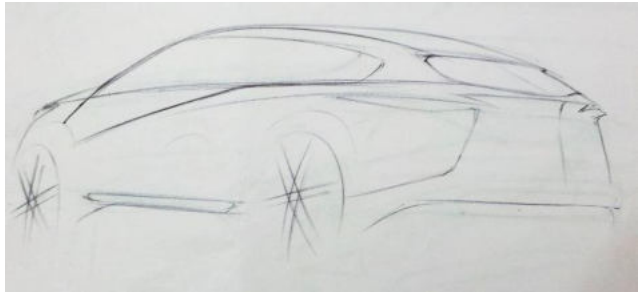


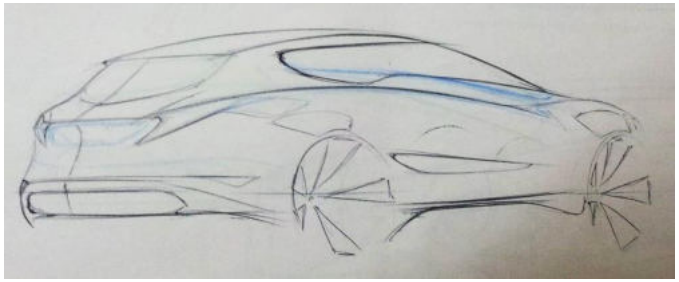
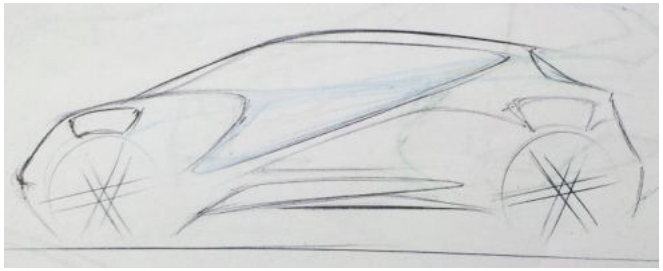
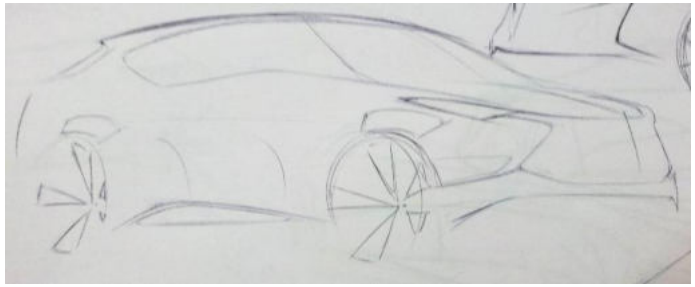
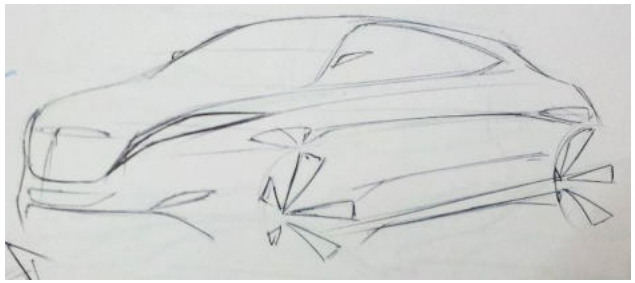
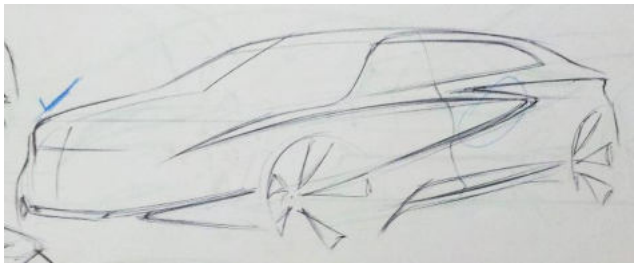






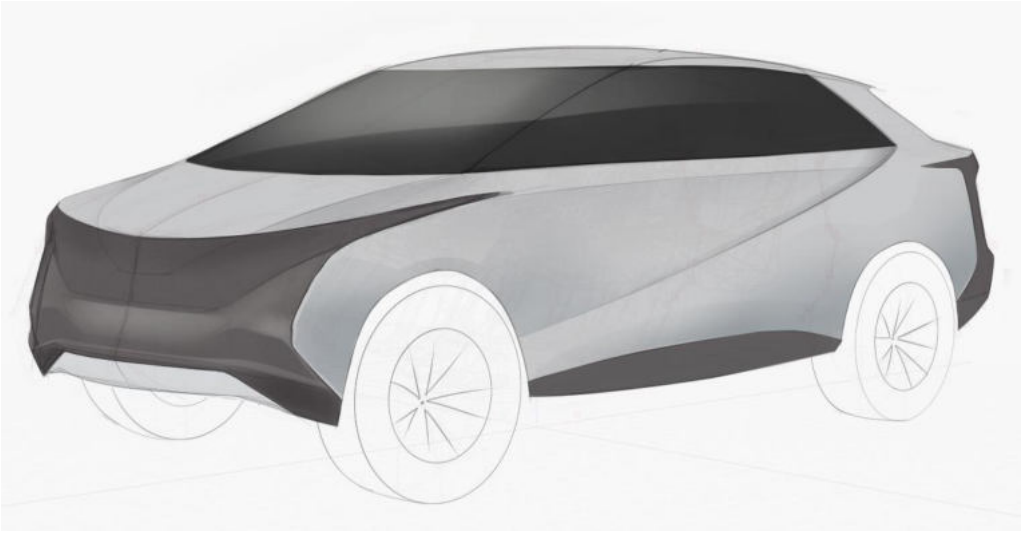





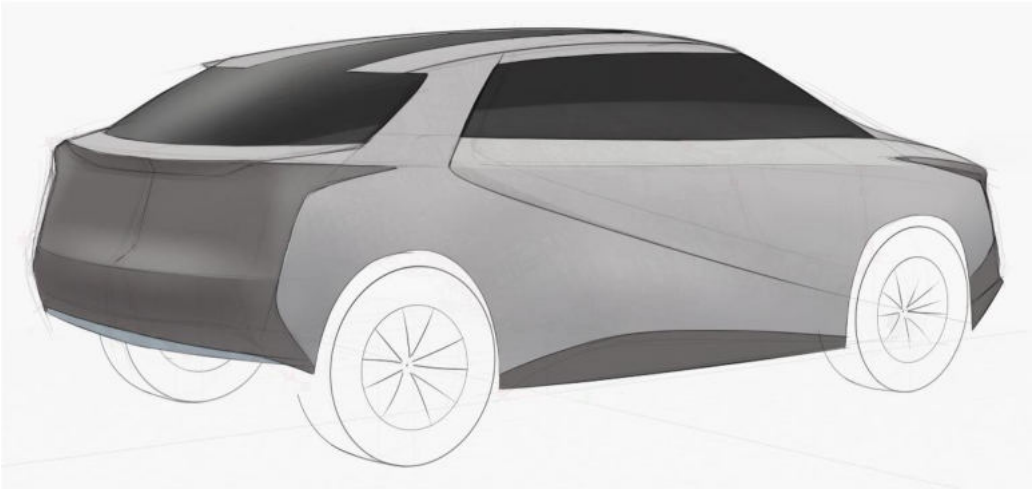


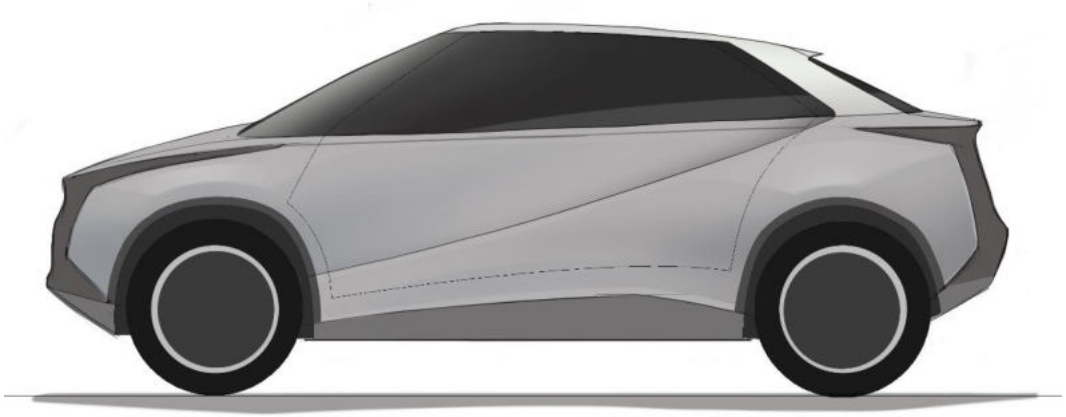






Concepts – Shortlisted Sketches

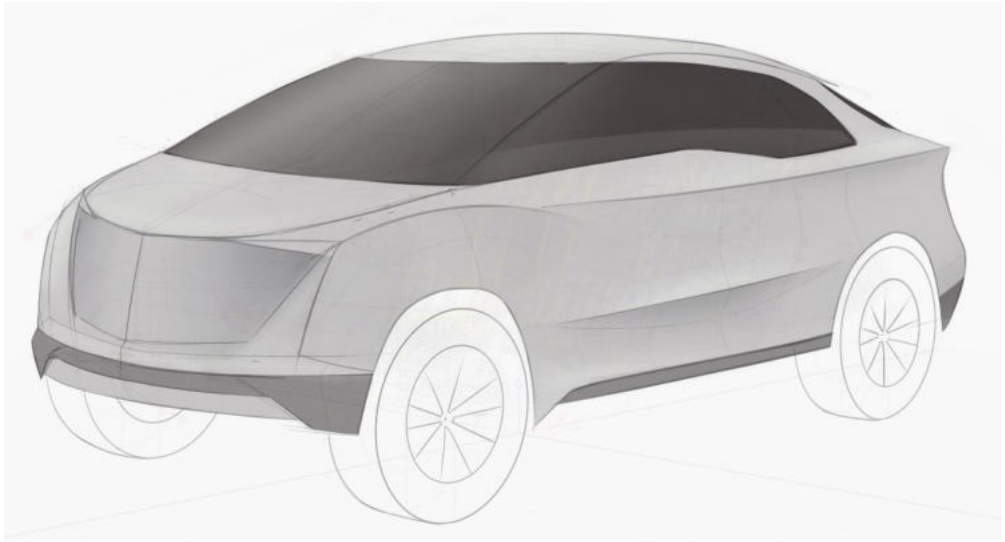
Concept 1

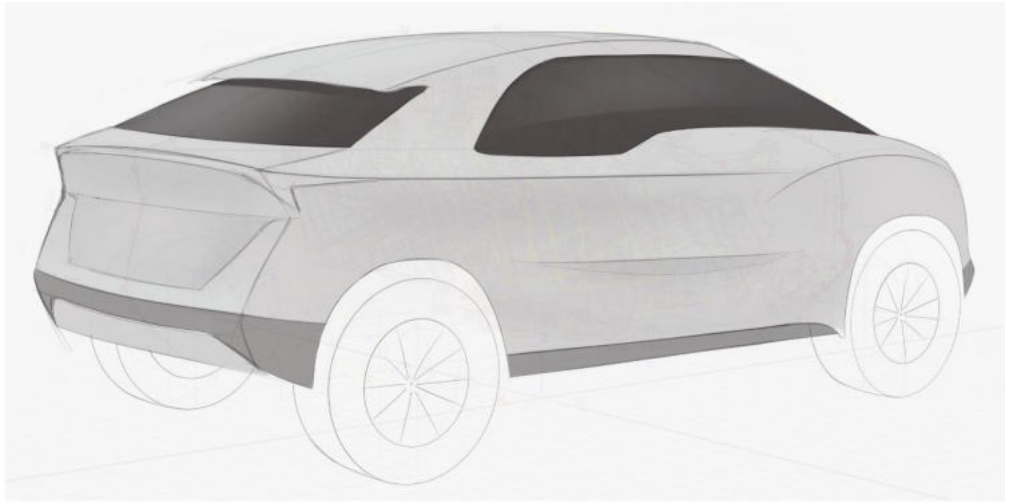


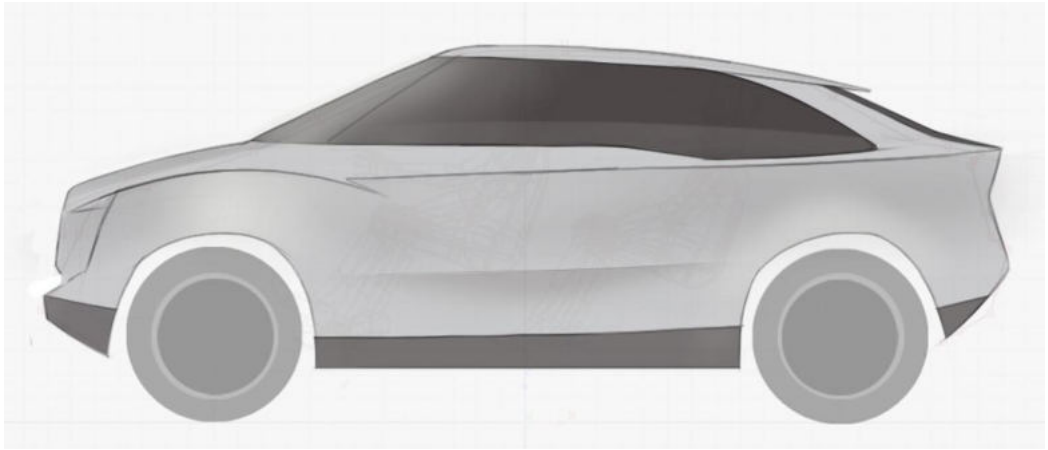




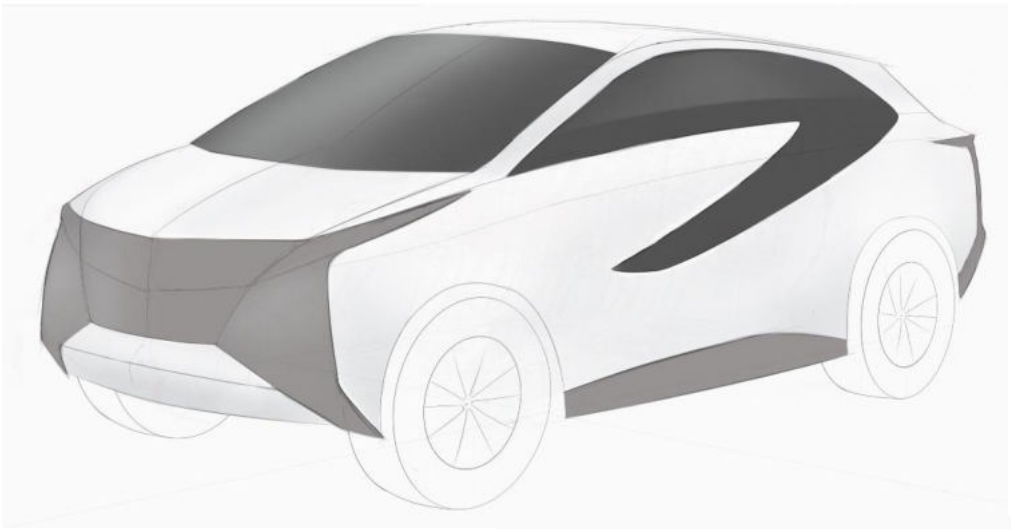
Concept 2

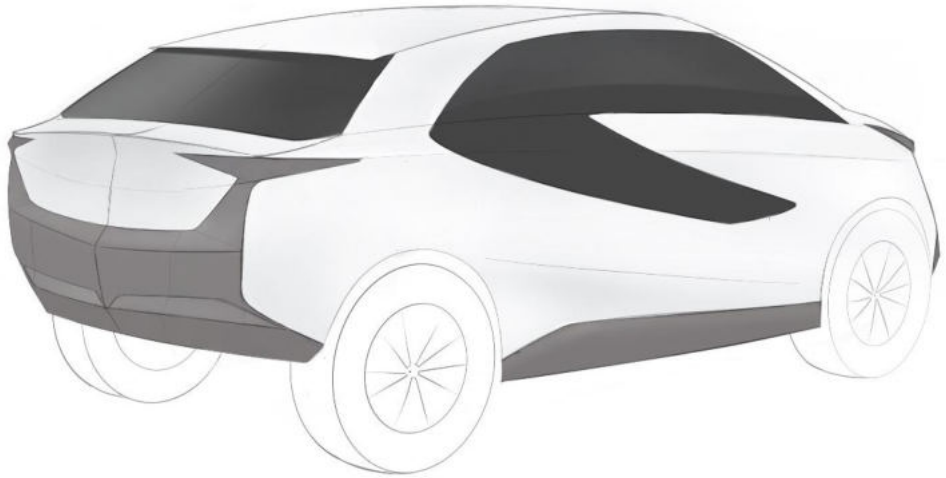


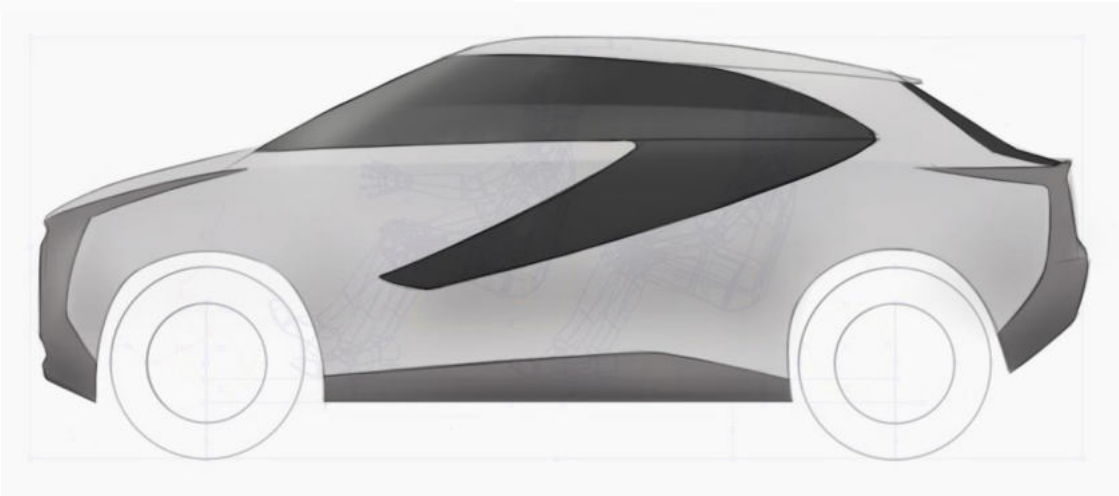




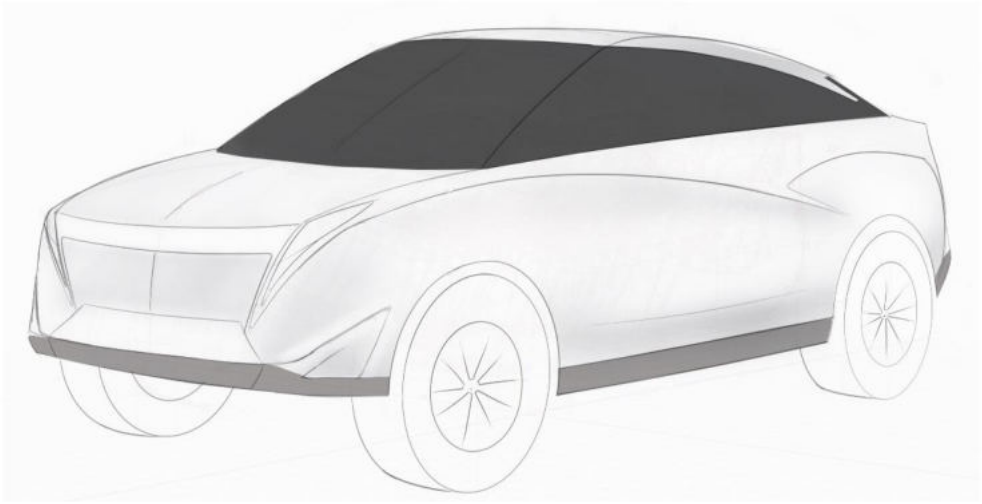
Concept 3

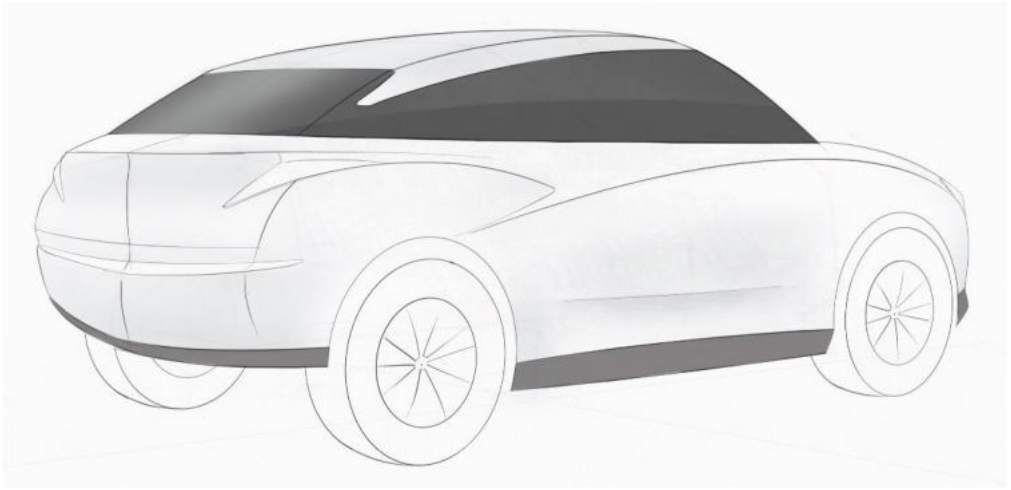


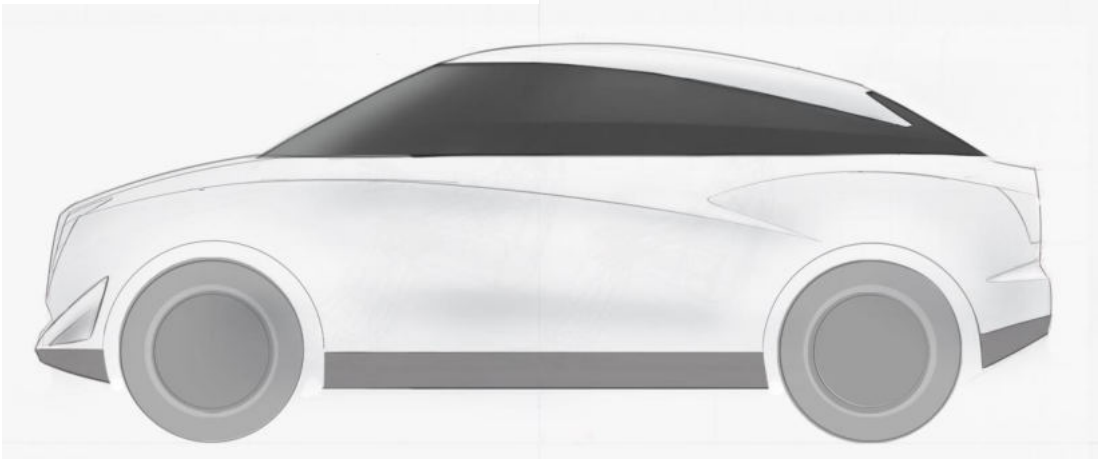




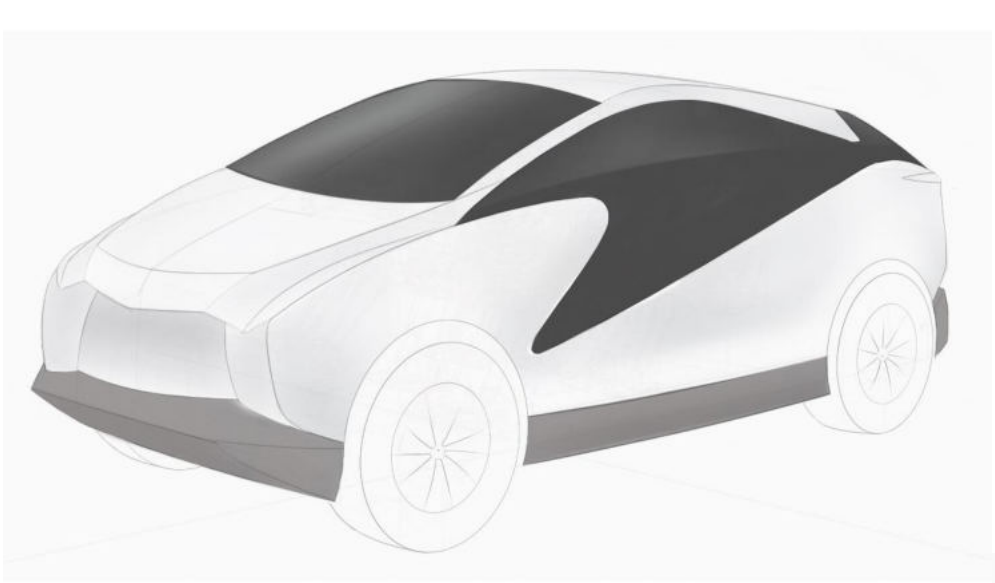
Concept 4

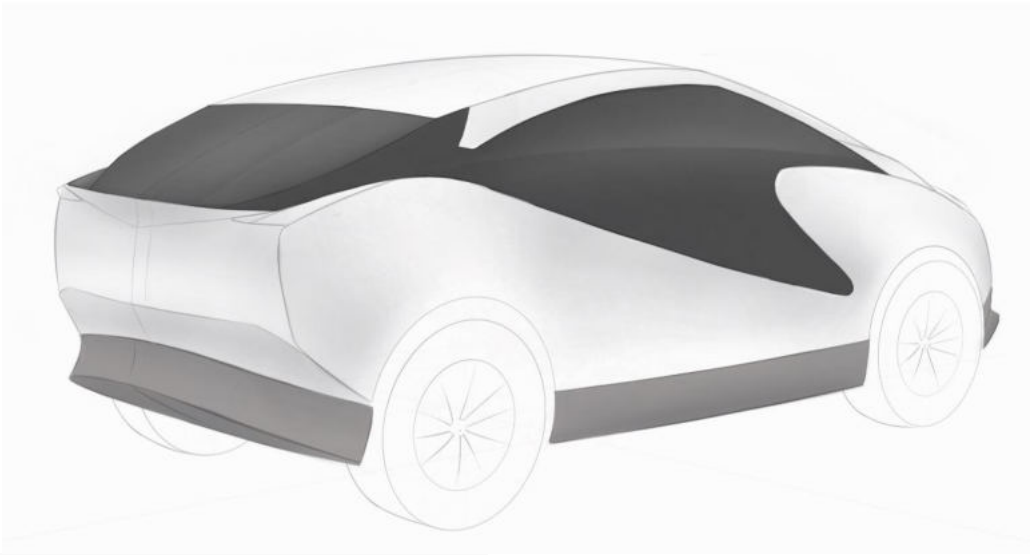


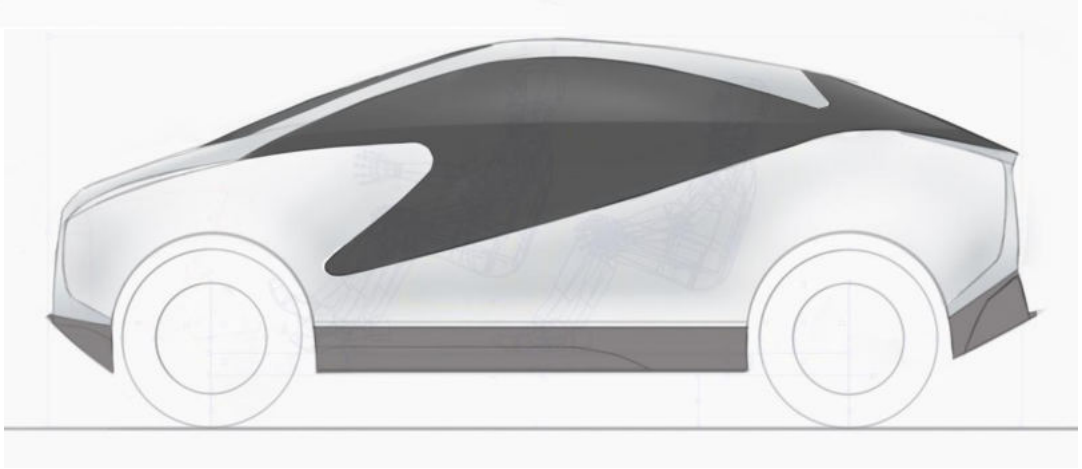




Concept 5





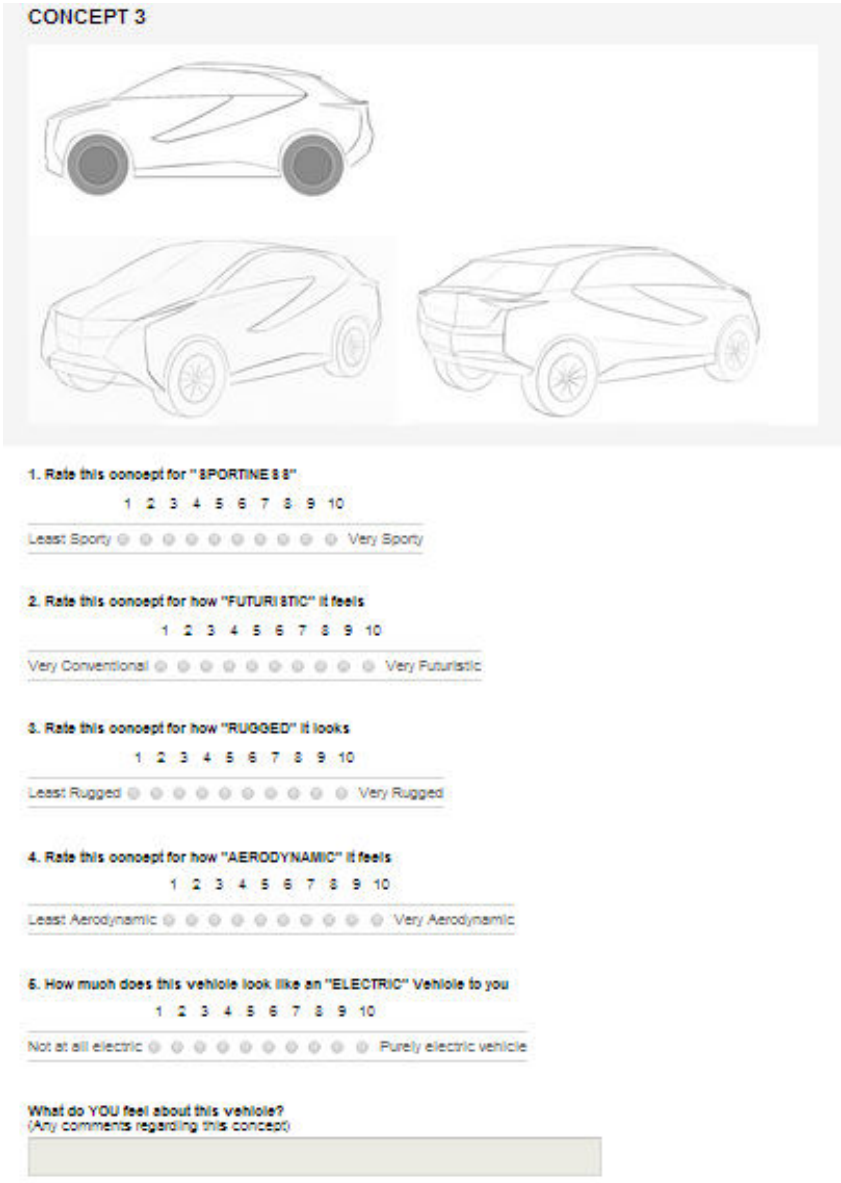


Evaluation of Concepts

All the concepts are rated on a scale from 1 to 10 for each of the following characters:

- Futuristic
- Conventional
- Sporty
- Muscular / rugged
- Aerodynamic

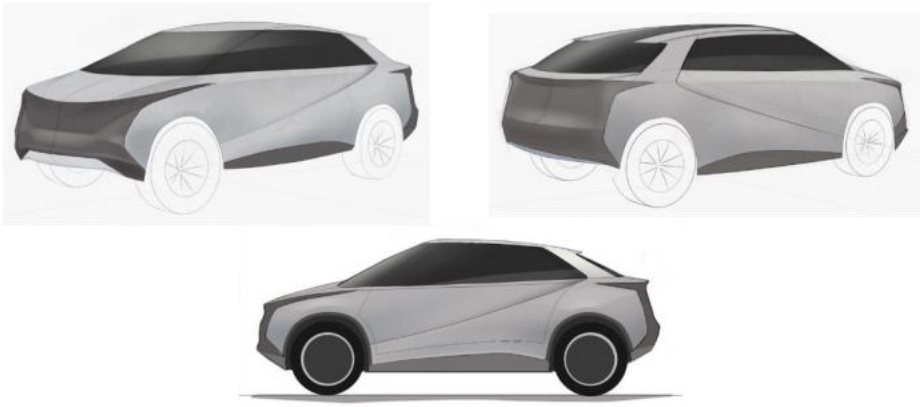
An online questionnaire survey was undertaken for evaluating every Concept against the Design keywords mentioned above:



User Response

Concept 1 Scores

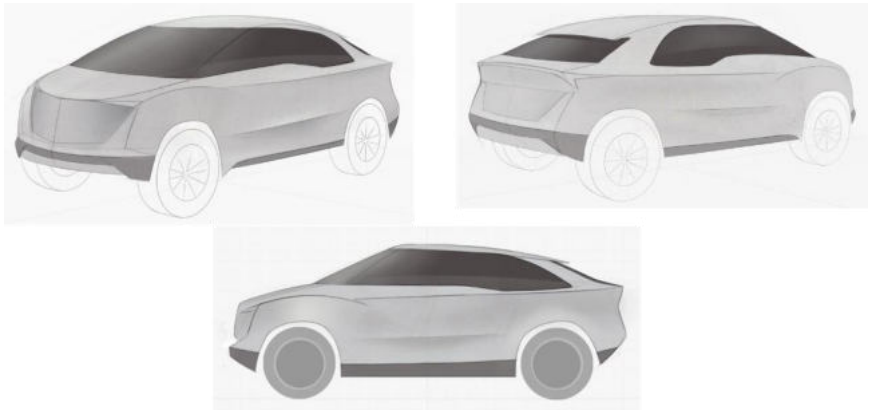
- Sporty: 7
- Futuristic: 4, 7
- Rugged: 5
- Aerodynamic: 6
- Electric: 7



Key comments: Angular shape– raised rear adds to sportiness, Profile has good stance, Very sporty but graphics might make car feel smaller rugged rear, immensely sporty front, Bit too tall and uninteresting from quarter view

Concept 2 Scores

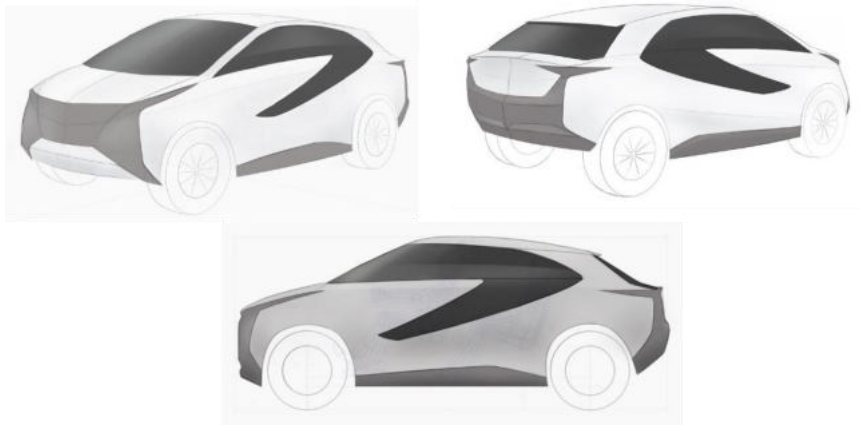
- Sporty: 5
- Futuristic: 5
- Rugged: 6
- Aerodynamic: 6
- Electric: 6



Key comments: Quarter views more interesting than side, Looks heavy, can handle rough terrains may be, Electric feel front the front grill

Concept 3 Scores

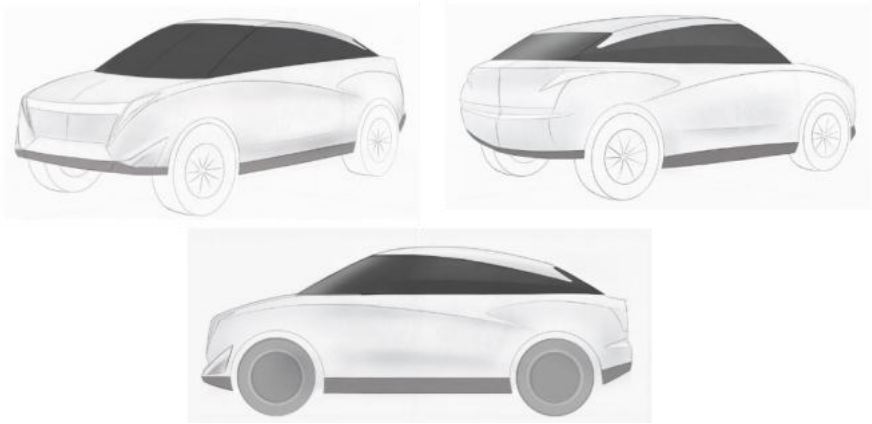
- Sporty: 7
- Futuristic: 8
- Rugged: 7
- Aerodynamic: 7
- Electric: 8



Key comments: Futuristic, Increased windows area looks better, Love the raw edgy character on it, A bit too triangular lights

Concept 4 Scores

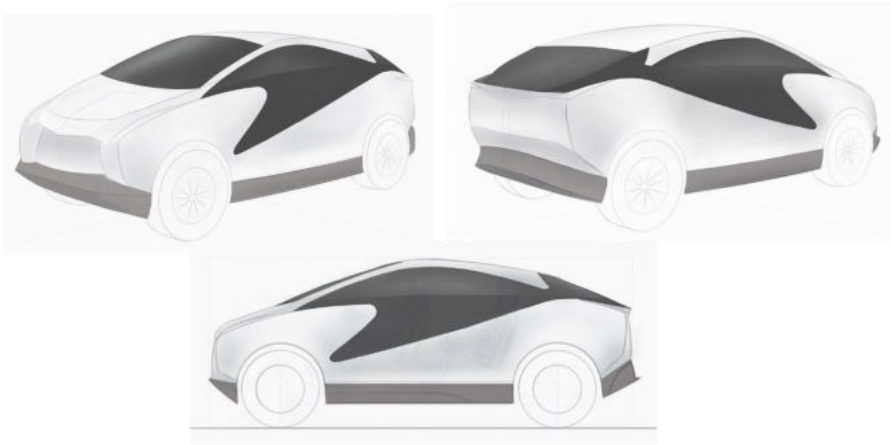
- Sporty: 5
- Futuristic: 4
- Rugged: 4
- Aerodynamic: 7
- Electric: 6



Key comments: Nice flowing lines, gives feeling of coupe, Rugged and muscular, Classy, Lovely rear view and side profile

Concept 5 Scores

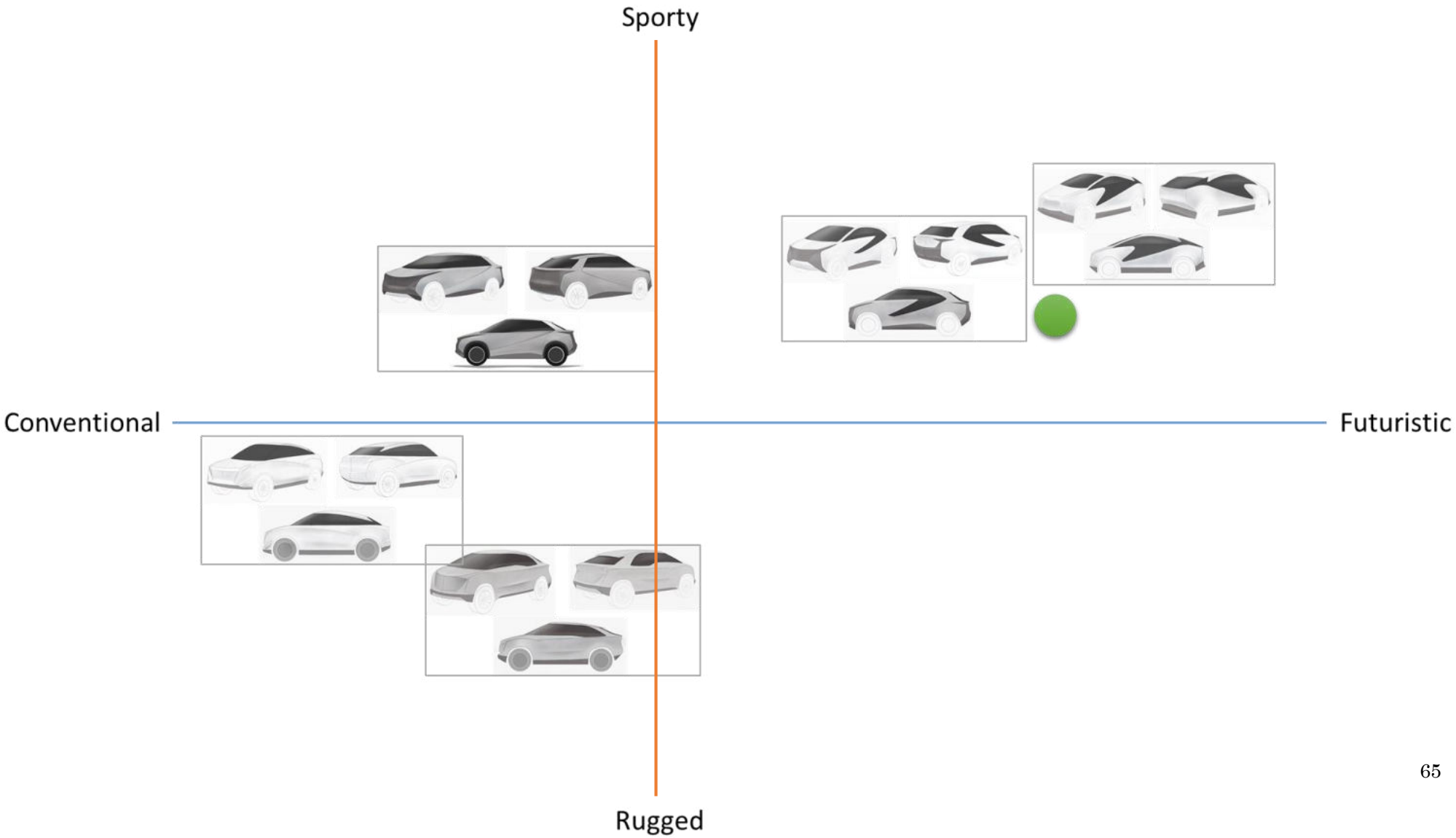
- Sporty: 7
- Futuristic: 8, 9
- Rugged: 6, 8
- Aerodynamic: 7
- Electric: 9



Key comments: One of the freshest design, Looks very sporty but side doesn't go very well with the form, Justifies all the Keywords mentioned, Very interesting profile and front, Rear is also never seen before in any car yet

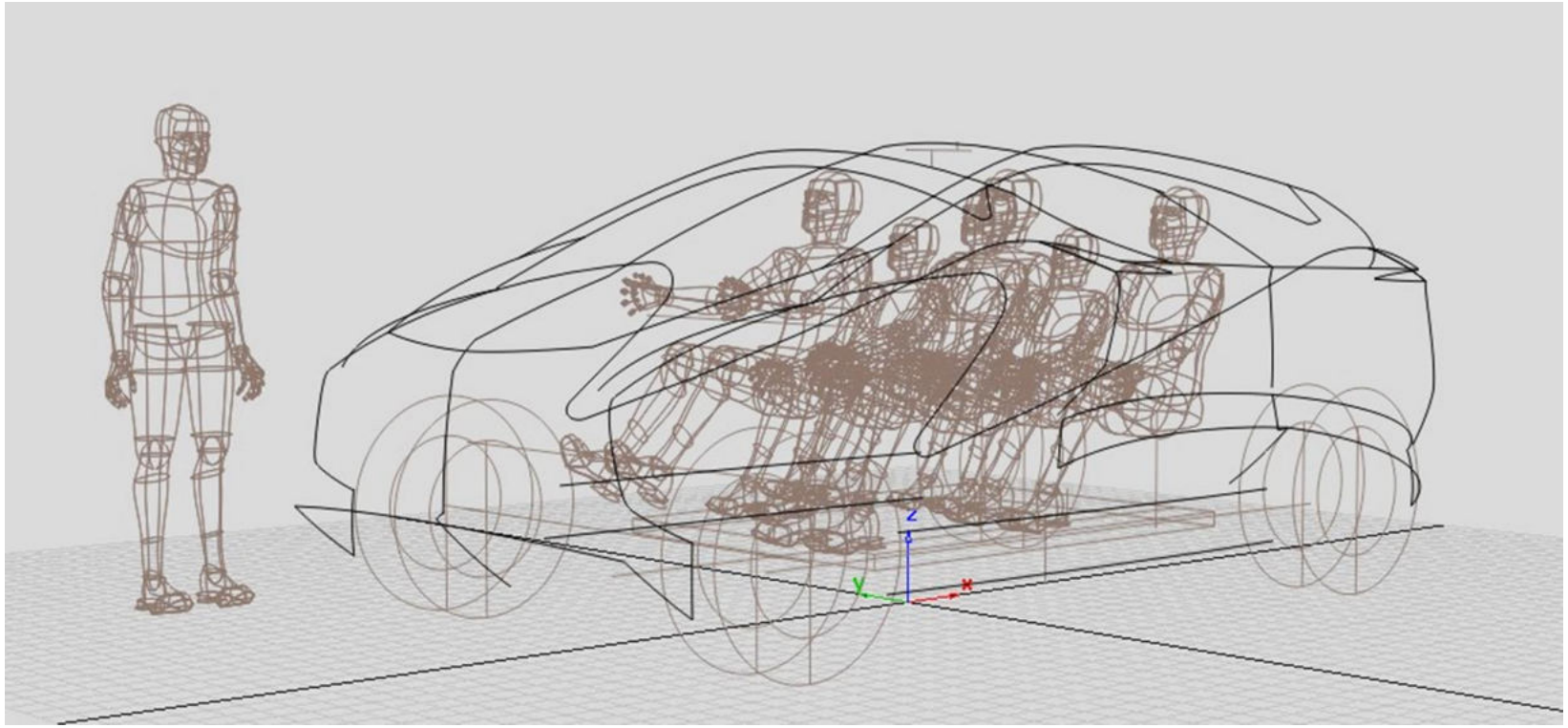
Quadrant

This is the placement of the 5 concept directions on a Design Quadrant based on the keywords opted for the design. This plotting on this graph is approximately done by referring the numbers from the concept evaluation from users.



Selected Concept

Concept 5 was chosen after the evaluation of all the concept directions. Wireframe model of the concept for setting up accurate dimensions was made as shown below. The dimensions and proportions of the vehicle were freezed beforehand during the technical layout development.

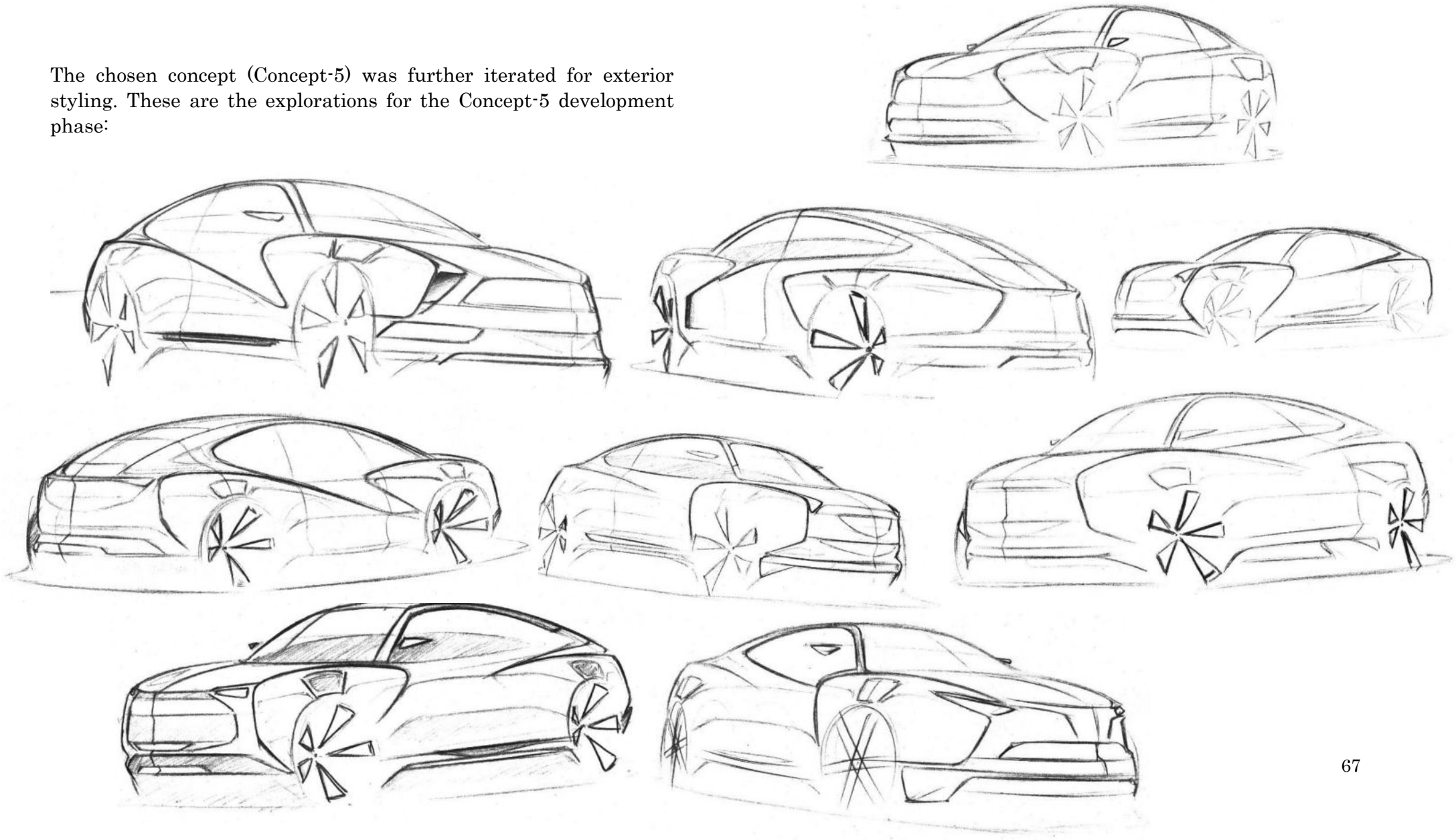


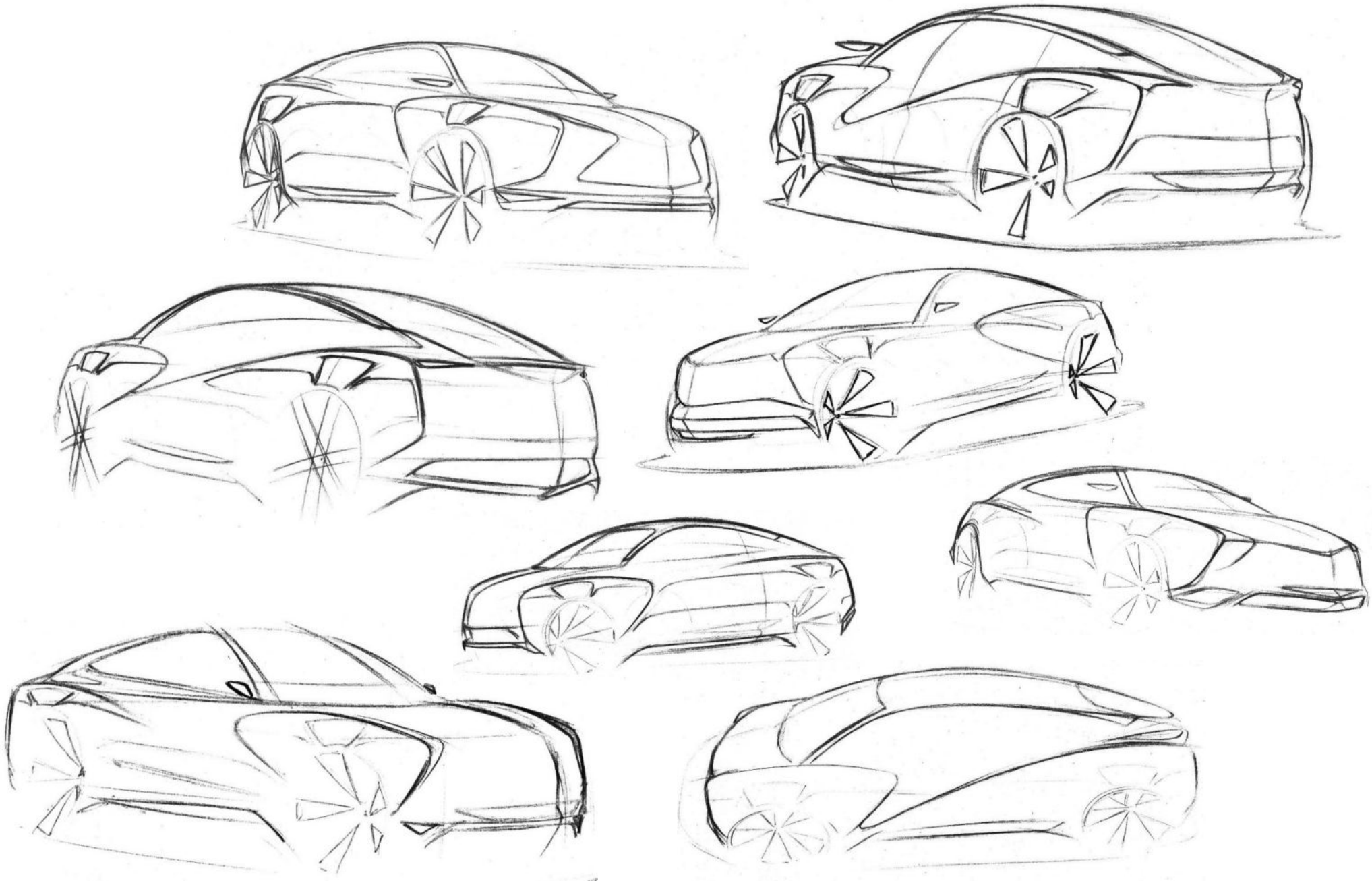
3D modelling

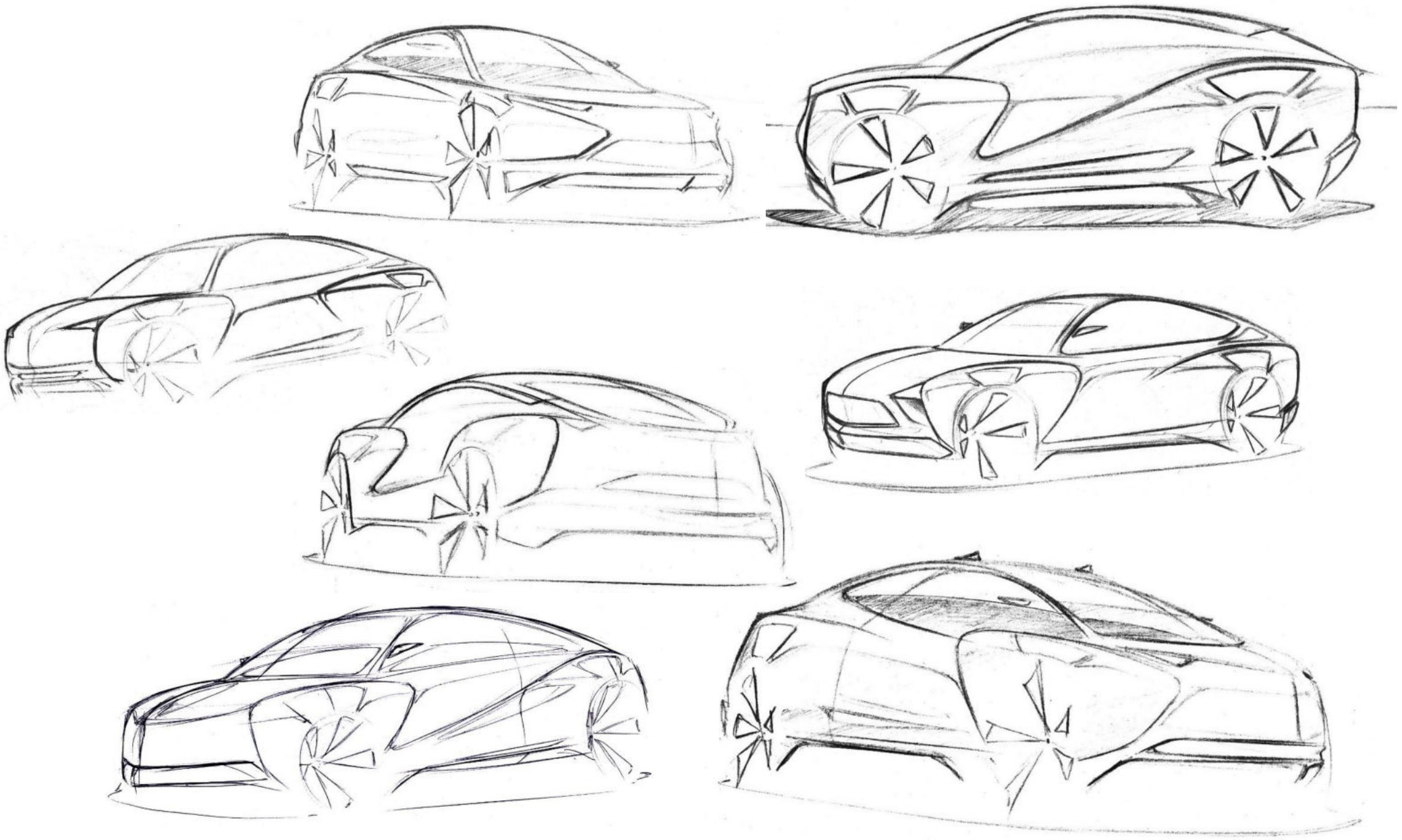
Wireframe model (showing the passengers with the model of the car)

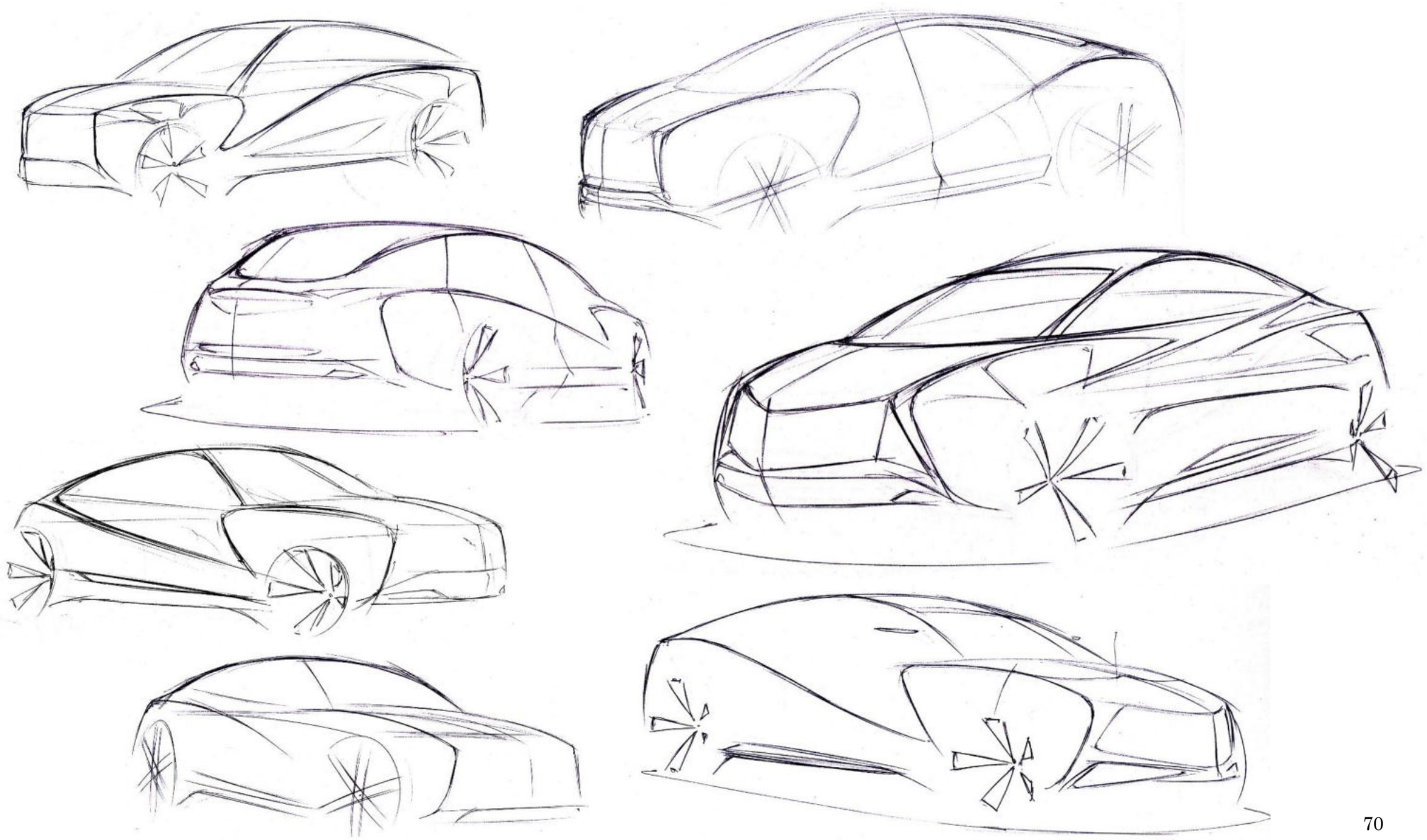
Concept Development

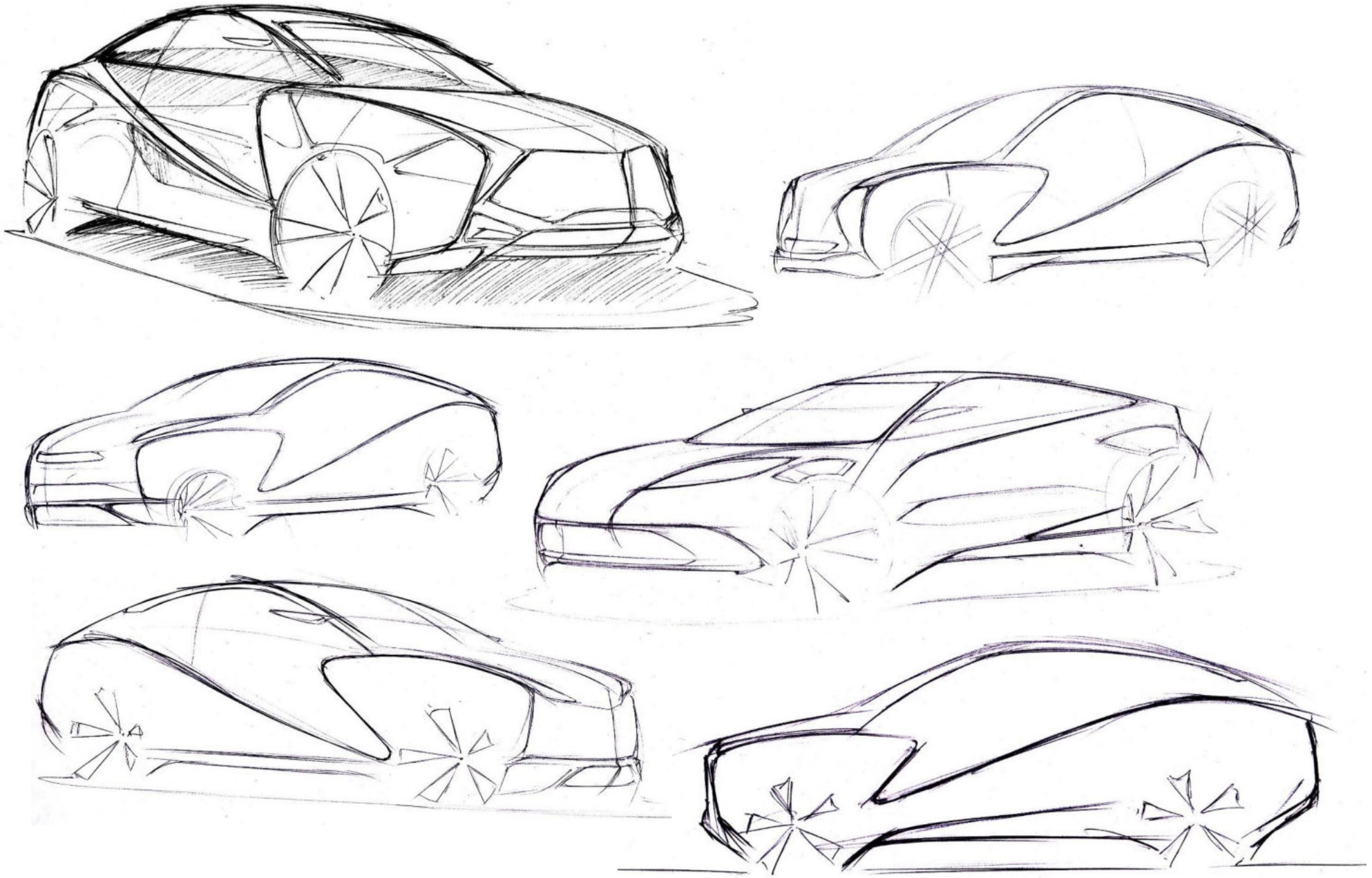
The chosen concept (Concept-5) was further iterated for exterior styling. These are the explorations for the Concept-5 development phase:







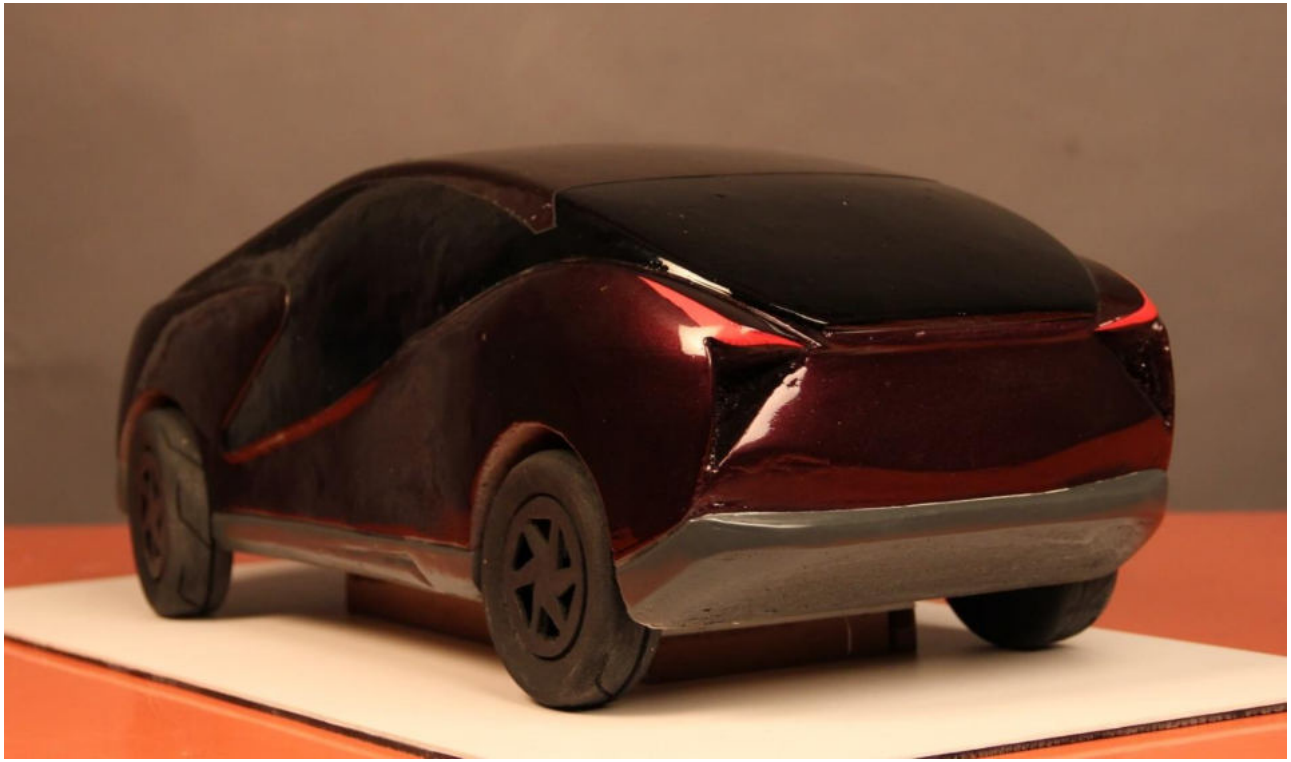




Key Sketch

Final Model

This is the 1:8 model of my SUV-Sedan Crossover car for Urban India in 2020



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